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Systematics and Taxonomy: Follow-up

Report with Evidence

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CONTENTS

Oral Evidence

Written Evidence

NOTE: References in the text of the report are as follows:
(Q) refers to a question in oral evidence
(p) refers to a page of written evidence

ABSTRACT

Systematic biology is at the heart of our understanding of the natural world.

In this time of climate change, understanding the connection between the natural world and human well-being—understanding the value and dynamic of "ecosystem services"—has a vital importance more widely recognised than ever before. "Ecosystem services" is a concept which has developed an importance in recent years to the point where it now sets the context of the current debate on environment sustainability. Simply defined, ecosystem services are "the benefits we derive from natural ecosystems".

This is our third inquiry into systematics and taxonomy. We reported in 1992, under the chairmanship of Lord Dainton, with a follow-up inquiry in 2001–02 under the chairmanship of Baroness Walmsley. We chose to embark on this inquiry now because of the environmental imperatives increasingly manifest in our daily lives. We have asked two questions in particular: whether systematic biology in the UK is in a fit state to generate the essential taxonomic information required to understand ecosystem services and whether the UK has the skills available to understand and predict the impact of climate change on biodiversity.

We have concluded that the state of systematics and taxonomy in the UK, both in terms of the professional taxonomic community and volunteers, is unsatisfactory—in some areas, such as mycology, to the point of crisis—and that more needs to be done to ensure the future health of the discipline. We propose, for example, that there should be more effective and regular dialogue between the users and producers of taxonomy on the priorities for developing UK systematic biology, and we emphasise the importance of stimulating recruitment and also of taking steps to fire the imagination of school children by creative incorporation of environmental and biodiversity issues into school curricula.

The study of systematic biology, in common with other areas of science, has been transformed by technological innovation. Of particular importance are the development of molecular taxonomy and the potential of web-based taxonomy. We have no doubt that the benefits to be reaped from technological innovation are enormous. We are aware however that they need to be harnessed with discrimination and we call on the Research Councils and the taxonomic institutions to respond to this challenge.

Although we received clear evidence from the taxonomic community of a widespread concern about the state of the discipline, that concern appears to be largely unheard by the Government and by the Research Councils. We find this worrying. We believe that part of the problem is the fragmentation within Government of responsibility for systematic biology. We therefore recommend that the Department for Innovation, Universities and Skills be designated as the lead department and that that department should exercise the leadership without which we fear that the downward slide of UK taxonomy is set to continue.

Systematics and Taxonomy: Follow-up

CHAPTER 1: INTRODUCTION

BOX 1

Definitions

Taxonomy is the scientific discipline of describing, delimiting and naming organisms, both living and fossil, and *systematics* is the process of organising taxonomic information about organisms into a logical classification that provides the framework for all comparative studies. In this report systematics and taxonomy are referred to collectively as *systematic biology*.

Importance of systematic biology

1.1. Two hundred and fifty years ago, Carl Linnaeus (1707–1778) introduced the system for scientific names which is used today. Since then, taxonomists have described and named about 1.78 million species of animals, plants and micro-organisms. The total number of species on Earth is unknown but, according to the Millennium Ecosystem Assessment, probably lies between 5 million and 30 million.[1] Systematic biology is the tool by which these components of biodiversity are identified, named and enumerated, and by which their relationships are described.

1.2. The evidence we received emphasised the central importance of systematic biology to our understanding of the natural world. The Wellcome Trust describes it as "fundamental to the understanding of biodiversity and the ways that biodiversity may be changing, particularly in the context of climate change and global health threats" (p 321). The Joint Nature Conservation Committee (JNCC) refers to systematics as "an essential tool that underpins biodiversity conservation by providing a logical classification and framework for describing and studying living organisms" (p 146), and the United Kingdom Biodiversity Research Advisory Group (UK BRAG) and the Global Biodiversity Sub-Committee (GBSC) of the UK Global Environmental Change Committee (UK GECC) describe taxonomy as "a necessary underpinning for biodiversity conservation and sustainable use, ecosystem services and climate change in the UK and globally" (p 311).

Previous reports

1.3. This inquiry follows two previous reports by this Committee.

1.4. Our first inquiry, under the chairmanship of Lord Dainton, was prompted by concern for the state of systematic biology research in the United Kingdom. The Committee's report, *Systematic Biology Research*, was published in 1992,[2] following which several short-term measures to stimulate systematic biology

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1 See www.maweb.org

2 House of Lords Science and Technology Committee, First Report, Session 1991–92, *Systematic Biology Research* (HL Paper 22).

were introduced, such as the Natural Environment Research Council (NERC) Taxonomy Initiative (1994–1998) and the Wellcome Trust Biodiversity Initiative (1993–2002).[3] Both Initiatives are regarded as having been successful and their contribution is still felt today. Professor Georgina Mace, Director of the Centre for Population Biology at the NERC Collaborative Centre, for example, told us that one of the reasons why NERC had been able to fund a number of grants relating to the expertise base in taxonomy was that "many of those taxonomists trained as a result of the Taxonomy Initiative in the 1990s are now embedded within research groups" (Q 54).

1.5. A decade after the original inquiry we became aware of continuing problems in systematic biology and a second inquiry, under the chairmanship of Baroness Walmsley, was launched in 2001. The purpose of the inquiry was (a) to establish whether systematic biology in the UK was in decline and if so why, (b) to clarify whether it mattered if systematic biology were in decline and, in particular, what impact a decline would have on biodiversity conservation, and (c) to identify what action, if any, was required. The Committee's report, *What on Earth? The Threat to the Science Underpinning Conservation*, was published in 2002.

1.6. The response to the recommendations made in the 2002 report has been mixed. There have been some successes. For example, the Committee recommended that the Biotechnology and Biological Sciences Research Council (BBSRC) should reconsider its decision not to award academic analogue status to the Royal Botanic Garden Edinburgh (RBG Edinburgh) and Royal Botanic Gardens, Kew (RBG Kew) (Recommendation 1.5). Academic analogue status has now been awarded to both institutions. The Committee also recommended that the systematic biology community should increase efforts to demonstrate the relevance and importance of systematic biology (Recommendation 1.6). As a result, an annual systematics debate series was inaugurated by the Linnean Society, and the Linnean Society and the Systematics Association, together with the BBSRC, launched a new funding scheme (Collaborative Scheme for Systematics Research—CoSyst) for systematics projects, which is now in its third year.

1.7. Other recommendations were not taken forward. For example, the Higher Education Funding Council for England (HEFCE) did not explore ways in which to support systematic biology, as they do with other minority disciplines (Recommendation 1.4), and the Department for the Environment, Food and Rural Affairs (Defra) did not establish a co-ordinating body (Recommendation 1.8). In view of the Government's generally disappointing response, many of the issues addressed by our 2002 report are revisited in this second follow-up inquiry.

Our current inquiry

1.8. The Government's new focus on environmental sustainability and increasing awareness of the impact of climate change on biodiversity have made it

[3] The UK Systematics Forum was also established to provide a focus for systematic biology science, but was wound down in 2001. See House of Lords Science and Technology Committee, 3rd Report. Session 2001–02, *What on Earth? The Threat to the Science Underpinning Conservation* (HL Paper 118), paras 2.7, 2.8, 3.6 and 3.7.

timely for the Committee to return again to the issue of systematic biology; and, in particular, to consider:

(a) whether systematic biology in the UK is in a fit state to generate the essential taxonomic information required by the emergence of the concept of ecosystem services (see Box 2 below), and

(b) whether the UK has the skills available to be able to understand and predict the impact of climate change on biodiversity,

whilst continuing to meet the ongoing needs of biodiversity conservation and also the broader needs of taxonomy as a discipline which underpins all aspects of biology. In considering these questions, we have borne in mind the historical importance of the UK within the global taxonomic community as a result of the collections held in the UK (for example, The Natural History Museum (NHM), RBG Kew, RGB Edinburgh and the Zoological Society of London).

BOX 2

The ecosystem services concept

Ecosystem Services are the benefits we derive from natural ecosystems. These benefits may be derived from supporting services such as primary production by green plants (upon which virtually all life depends), from regulating services such as atmospheric gas regulation or pollination, from provisioning services such as access to wood for fuel, fibres and food products, and from cultural services such as the recreational and spiritual value of natural ecosystems. This powerful concept has sharpened awareness of the direct relationship between the provision of ecosystem services and continued human well-being (ref. *Millennium Ecosystem Assessment*),[4] and was assimilated into the rationale behind sustainability with astonishing rapidity.

1.9. This is not just a UK issue. Broad concern over the state of taxonomy internationally led the parties to the Convention on Biological Diversity (CBD) to acknowledge the existence of a "taxonomic impediment" to implementation of the CBD, referring to the shortage of taxonomic expertise, taxonomic collections, field guides and other identification aids, as well as to the difficulty in accessing existing taxonomic information. In response to this "taxonomic impediment", in 2002 the parties to the CBD launched a programme of work under the Global Taxonomy Initiative.[5]

1.10. Like every scientific discipline, systematic biology is changing rapidly. New analytical and computational methods are constantly under development and there was a sense in our 2002 report that some of the novel approaches explored in a preliminary way during that inquiry might transform (and strengthen) the discipline. As part of our current inquiry, we have looked again at some of the technological developments within systematic biology in order to assess progress after six years and to consider their potential for the systematic biologist and for the discipline as a whole.

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4 See footnote 1 above.

5 *Guide to the Global Taxonomy Initiative*, 2008, CBD Technical Series No 30, 105pp. Published by the Secretariat of the Convention on Biology Diversity. See http://www.cbd.int/gti/

Acknowledgements

1.11. The membership of the Select Committee is set out in Appendix 1, and our call for evidence, published in December 2007, in Appendix 3. Those who submitted written and oral evidence are listed in Appendix 2. We would like to thank all of our witnesses, as well as those who submitted articles and other materials in the course of the inquiry.

1.12. We launched this inquiry with a seminar, held in the Darwin Centre at The NHM, in February 2008. During the course of the day we had the pleasure of touring some of The NHM collections. A note of the seminar is given in Appendix 4. We are very grateful to The NHM for hosting the event and to the speakers who participated in it.

1.13. Finally, our Specialist Adviser for this inquiry was Professor Geoffrey Boxshall FRS, Merit Researcher at The NHM. We are grateful to him for his expertise and guidance throughout the inquiry. However, the conclusions we draw and the recommendations we make are ours alone.

CHAPTER 2: THE ROLE OF SYSTEMATIC BIOLOGY IN THE DELIVERY OF POLICIES

Range of policy areas involving systematic biology

2.1. Systematic biology describes a set of skills which are fundamental to a range of policies, the successful implementation of which is critical to our long-term quality of life. In this chapter we set out a number of examples which demonstrate the importance of systematic biology in the delivery of national and international policies.

Conservation of biodiversity in a global context

2.2. The Government promotes the sustainable use and conservation of biodiversity through its continuing commitment to the Convention on Biological Diversity (CBD) signed at the Earth Summit in 1992. Under the headline of environmental sustainability the UK has a broad cascade of international obligations and commitments that are implemented at national and regional levels. These include:

- Government Target—Halting biodiversity loss by 2010
- EU Habitats Directive
- Global Strategy for Plant Conservation
- EU Water Framework Directive
- Convention on Trade in Endangered Species (CITES)
- Ballast Water Convention (the International Convention for the Control and Management of Ships' Ballast Water and Sediment)
- Convention on the Protection of the Marine Environment of the North-East Atlantic (OSPAR)
- EU Marine Strategy Directive.

2.3. In 2004, as a response to the CBD Global Strategy for Plant Conservation endorsed in 2002, the UK Government launched their Plant Diversity Challenge (PDC) which "sets out the framework for plant and fungus conservation throughout the UK" (p 285). In a 2007 assessment of progress towards meeting targets within the PDC,[6] a meeting of stakeholders made a number of recommendations, including the following: (a) to focus research on improving understanding of the importance of UK plant and fungal species in a European context, specifically highlighting the need, amongst other things, for a UK fungal checklist; and (b) to develop and deliver an action plan to address the need for plant and fungal skills and expertise in the UK In the view of the PDC Steering Group, the lack of basic checklists of the species of fungi and plants that occur in the UK currently makes it "impossible to create meaningful Red Data Lists,[7] Biodiversity Action Plans and protected species lists" (p 286).

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6 *Plant Diversity Challenge: 3 years—16 targets—one challenge, Progress in the UK towards the Global Strategy for Plant Conservation* (PDC2).

7 Also known as the International Union for the Conservation of Nature and Natural Resources (IUCN) Red Lists which evaluate the extinction risk of thousands of species and sub-species.

Conservation of UK biodiversity

2.4. The availability of taxonomic expertise and the tools created by taxonomists underpin conservation policy in the UK; and Defra, which has responsibility for conservation, is a key user of the outputs of systematic biology research (p 49). Selection of Sites of Special Scientific Interest in Great Britain and Areas of Special Scientific Interest in Northern Ireland and also the implementation of species recovery and action programmes under the UK Biodiversity Action Plans are the key mechanisms for the delivery of UK conservation policy and "the accurate identification of species" is "fundamental" to the effectiveness of those mechanisms (p 146). Systematic biology also enables the UK to discharge its obligation under the EU Habitats Directive to report on the conservation status of UK species of European importance (p 146).

Protection against invasive alien species

2.5. Increasing international concern over invasive alien species had led to initiatives such as the establishment in 1997 of the Global Invasive Species Programme, an international partnership dedicated to tackling the global threat of invasive species; and, in 2004, as a party to the International Maritime Organization, the UK adopted the Ballast Water Convention as a measure to limit the spread of marine alien species. According to the Royal Horticultural Society (RHS), taxonomists are in the front line of research on alien species by providing identifications of newly introduced species (p 297).

Responding to climate change

2.6. The Government has recently renewed its commitment to the Millennium Development Goals, one of which is to ensure environmental sustainability, including a significant reduction in the rate of biodiversity loss by 2010.[8] Achieving this goal will depend on being able to document and measure the impact of climate change on biodiversity. For example, Professor Rick Battarbee of the Environmental Change Research Centre at University College London described a new system of freshwater biological indicators that was being developed with EU funding to monitor impacts of climate change: "assessing the ecological status of surface waters using biological indicators (diatoms, phytoplankton, aquatic macro-invertebrates and aquatic plants) is central to the EU Water Framework Directive, and the need for taxonomic skills is growing …" (p 117).

Capacity building

2.7. The Department for International Development (DFID) promotes responsible environmental management and is investing in building in-country capacity through research.[9] Systematic biology is especially important in biodiversity-rich developing countries because it is the underpinning science upon which biodiversity conservation is based. The UK has an obligation under the CBD to promote access and benefit-sharing with regard to biodiversity.

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8 See www.un.org/millenniumgoals/

9 See www.dfid.gov.uk

Adapting to ecosystem services analysis

2.8. As a result of the rapid emergence of the ecosystem services concept (see Box 2 above), there has been a shift in research focus to ecosystem functioning. Professor Mace told us that "much of the science that is prioritised in NERC's new strategy deals with the biological effects of climate change and the ecosystem services …". This has placed a greater emphasis on micro-organisms, soil arthropods, marine invertebrates and fungi because of the pivotal role these organisms play in the large scale flow of energy through complex ecosystems.[10] "It is quite clear," Professor Mace said, "that there will be new kinds of information that we need on the taxonomy particularly of micro-organisms that play a significant role in … ecosystem processes" (Q 72).

Policing global trade in endangered species

2.9. Implementation of the Government commitment to the Convention on Trade in Endangered Species (CITES) is dependent on accurate identifications. For example, some corals, some timbers, some orchid species are protected, but others are not—taxonomic expertise is routinely called upon in policing the global trade in many natural products. According to UK BRAG, "without taxonomic expertise, enforcement [of CITES] would be impossible" (p 315).

Promoting public engagement in environmental issues

2.10. Membership of biodiversity-based organisations such as the Royal Society for the Protection of Birds (RSPB) and the RHS is impressively strong in the UK (Q 316). Innovative public engagement in issues such as biodiversity and environmental sustainability is supported by the Department for Culture, Media and Sport (DCMS) through the exhibitions and events at The NHM and through the regional museums (for example, the Horniman Museum in London, The Manchester Museum and the Oxford University Museum of Natural History) supported by the Museum Libraries and Archives' Renaissance in the Regions programme (p 48).

Identification of emerging diseases and disease surveillance

2.11. International trade, international travel and climate change are changing the dynamics of diseases of humans and of domesticated species, and are altering the distribution patterns of disease vectors (Q 218). Public concern about the spread of infectious diseases is high, especially during periods when diseases such as Bluetongue and avian influenza feature in the national news. As we noted in our 2002 report,[11] it is crucial that taxonomic expertise is maintained to enable the development of robust transferable tools for the identification of emerging diseases and for disease surveillance (see also The Wellcome Trust p 321).

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[10] See Millennium Ecosystem Assessment at www.maweb.org

[11] House of Lords Science and Technology Committee, First Report, Session 1991–92, *Systematic Biology Research* (HL Paper 22), p 18.

Taxonomic skills in the private sector

2.12. Taxonomic skills are also used in the private sector. For example, Professor Richard Gornall, President of the Botanical Society of the British Isles (BSBI), referred to ecological consultants who require properly qualified staff with taxonomic identification skills for making statutory environmental assessments on behalf of local authorities and commercial companies (Q 175). Such skills are also important in assessing the significance of habitat loss caused by new developments.

Conclusion

2.13. **Measuring progress towards halting the decline in biodiversity is a key international obligation which cannot be achieved without baseline knowledge of biodiversity. Creating baselines and monitoring change is dependent upon the availability of taxonomic expertise across the range of living organisms.**

2.14. **Systematic biology underpins our understanding of the natural world. A decline in taxonomy and systematics in the UK would directly and indirectly impact on the Government's ability to deliver across a wide range of policy goals.**

CHAPTER 3: HEALTH OF THE DISCIPLINE IN THE UK: PROFESSIONAL TAXONOMISTS, VOLUNTEERS AND RECRUITMENT

Taxonomists in the UK: general picture

3.1. There has been no comprehensive assessment of the numbers of taxonomists in the UK for more than 10 years. Dr Sandra Knapp, Botanical Secretary of the Linnean Society, told us that "in response to the Dainton inquiry [published in 1992] there was a UK Systematics Forum which set out to compile data about how many systematists there were, but it was a largely voluntary exercise"—and Australia was the only place where good data had been compiled (Q 132). Precise data for the UK are generally restricted to a particular sector, such as algal or fungal taxonomy. In view of this, **we recommend that a study should be commissioned by NERC to ascertain the current number of taxonomists in the UK and also trends in the number of taxonomists in the UK.**

3.2. Despite the absence of general data, the majority of submissions to the inquiry testified to a general picture of decline, particularly in UK universities.

UK university sector

3.3. The health of systematic biology in the UK university sector was variously characterised:

(i) "almost extinct in universities" (BSBI p 85)

(ii) "continued decline in university sector" (RBG Edinburgh p 9)

(iii) "Professional expertise in universities and other organisations appears to have continued to decline severely over recent decades" (Buglife p 223)

(iv) [of mycology] "it has declined catastrophically", "there are no, effectively, no fungal systematists … employed in UK universities" (European Mycological Association p 243)

(v) "There are no lichen taxonomists left in British universities" (British Lichen Society) (p 208)

(vi) "paucity of university systematists" (Biosciences Federation p 196)

(vii) "near-elimination of taxonomists from the university sector in the UK" (Systematics Association p 112).

Wider science community

3.4. In the wider science community, systematic biology was similarly characterised:

(i) "declining population of professional systematists", [traditional systematics in the UK] is "dwindling in relation to the needs of its users" (JNCC p 147)

(ii) "whole set of skills and expertise to maintain the international standards for identification is disappearing rapidly from the UK" (Research Councils UK p 39)

(iii) "there is a lack of taxonomical expertise that is accessible to government, conservationists and education establishments" (Plantlife International p 289)

(iv) "Ecological consultants … are really struggling for properly qualified people with taxonomic identification skills" (Professor Richard Gornall, President of the BSBI) (Q 175)

(v) "[A 2002 study of UK insect taxonomists] … shows a clear decline in numbers of both amateur and professional taxonomists, and our own difficulties … confirm that the decline is continuing" (Royal Entomological Society p 294)

(vi) "the number of active prokaryotic taxonomists in UK institutions is declining" (Society for General Microbiology p 305)

(vii) "Numbers … [of algal taxonomists] … have declined markedly over the last 20 years" (British Phycological Society p 218).

3.5. In our 2002 report, using CAB International[12] (CABI) as an example, we noted that it had "drastically reduced" the number of PhD grade taxonomists that it employed.[13] The fall in numbers has continued. The following statistics demonstrate the decline and ultimately the extinction of taxonomy in CABI:

TABLE 1

Taxonomists employed by CAB International 1992–2008[14]

	1992	2002	2008	2011 projected
Bacteriology	1	0	0	0
Entomology/arachnology	12	0	0	0
Mycology	15	7	3	0
Nematology/parasitology	6	1	1	0

Taxonomists in the UK: age profile

3.6. Added to this general picture of decline, there is a demographic issue. Survey data on ages of taxonomists are lacking for the UK as a whole but partial data and narrative evidence confirm that the population of professional taxonomists is ageing. At the National Museums Liverpool "all but one of the senior curatorial staff are in their fifties and most are close to retirement" (p 277). The deep-sea research group at the National Oceanographic Centre Southampton includes five taxonomic experts, three of whom are already retired and one is only a few years from retirement (p 46). At the Plymouth

12 Formerly the Commonwealth Agricultural Bureaux.

13 House of Lords Science and Technology Committee, First Report, Session 1991–92, *Systematic Biology Research* (HL Paper 22), para 3.14.

14 Written evidence, p 226.

Marine Laboratory the skilled marine invertebrate taxonomists "are already in retirement, or close to it" (p 46). Dr John Waland Ismay, Chairman of the Dipterists Forum, observed that most fly experts are retired or near retirement and have no replacement in training (p 320). The National Museum of Wales has 16 trained taxonomists, the majority over 40 (p 282). A similar picture exists in the voluntary sector. For example two members of the Hertfordshire Natural History Society's recorders' group are in their 30s, the majority are over 50, a few are in their late 60s and a couple over 70, with "no sign of younger members coming through" (p 257).

3.7. While some organisations, such as the Sir Alister Hardy Foundation for Ocean Science, are maintaining a spread of ages in their staff of taxonomists by careful succession planning (p 46), it appears that in general the average age of taxonomists in the UK is increasing. Across the range of different types of research organisation, taxonomic experts are retiring and are not being replaced.

Sectors in crisis

3.8. Mycology or fungal taxonomy, already highlighted as a problem area in our 2002 report, has continued to decline and the situation in the UK has become so grave as to be generally recognised as a crisis. The severity of this situation was referred to by a number of witnesses, including: the RBG Kew (p 14 ff), the RHS (p 296), CABI (p 224), UK BRAG (p 316), Plantlife International (p 289) and the European Mycological Association (p 243). Dr Richard Fortey, President of the Geological Society, said that "on the mycological side, the number of macro fungal taxonomists in this country has dwindled to the fingers of one hand or maybe less" (Q 234).

3.9. Dr Jim Munford, Programme Director of the National Biodiversity Network (NBN) Trust, observed that for some groups of freshwater organisms such as rotifers, and soil invertebrates such as collembolans, there was no taxonomic activity in UK (Q 215). The need to secure taxonomic expertise on marine organisms and foster capacity was highlighted on a European scale by the European Platform for Biodiversity Research Strategy;[15] and, overall, there is low taxonomic capacity in the UK in algae (British Phycological Society, pp 220–21), in a whole range of insect groups (Q 215), other soil arthropods, marine invertebrates and microbes, some families of flowering and non-flowering plants, as well as in fungi (National Museum Wales p 283; RBG Edinburgh pp 9–10). Freshwater taxonomic expertise has also been lost through the closure by NERC of the Freshwater Biological Association River Laboratory in Dorset.[16]

Classification of taxonomic activity

3.10. Taxonomic activity covers three key tasks: description, identification and phylogeny. "Identification" is described by the Linnean Society as "working out what an organism is", "description" is "working out the limits of species, genera and higher groups" and "phylogeny" is "working out how organisms are evolutionarily related" (p 90). They need to be considered separately because "each has a different dynamic and each is in a different state in

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15 Recommendations of the meeting of the European Platform for Biodiversity Research Strategy held under the Portuguese Presidency of the EU, November 2007.

16 See http://www.nerc.ac.uk/press/releases/2006/cehdecision.asp. Press release dated 13 March 2006.

terms of support and health" (p 90). Dr Knapp of the Linnean Society explained that "phylogenetics in part gets funded by research councils; descriptive taxonomy is funded by the great taxonomic institutions of the country and identification gets funded by the Darwin Initiative, a bit by Defra and the user community" (Q 160).

3.11. Description supports both identification and phylogeny by generating the names of the organisms and formally characterising them. These characteristics are used to provide the tools necessary for ecologists and conservationists to identify the organisms they work with. These tools range from traditional field guides and keys, to more technology based tools. Morphology and molecular-based phylogenetic studies (see Box 3 below) remain founded on descriptive taxonomy and the need for accurate identification and the deposition of type or voucher specimens in museums remains central to the discipline.

Descriptive taxonomy

3.12. Descriptive taxonomy enables us to discern the units of biodiversity, so the delimitation of a species is essentially an hypothesis about the distribution of variation in nature. The basic task of describing and naming the organisms on Earth is far from complete and even in the UK new species are regularly found and described, especially marine and soil invertebrates, fungi and microbes. Building a comprehensive inventory of the national fauna and flora is fundamental—an essential tool underpinning policy on conservation and the sustainable use of biodiversity.

3.13. Descriptive taxonomy is described by the Linnean Society as "the most at risk sector" of systematic biology not only in terms of our ability to describe new species and document the biodiversity of ecosystems, but also in refining and even diagnosing the species we already know (p 90). In general, there is a declining population of professionals involved in descriptive taxonomy and even in major institutions, such as The NHM, a smaller proportion of resource is expended on descriptive taxonomy than at the time of the last inquiry. Dr Nic Lughadha, Head of Policy and Science Co-ordination at RBG Kew, commented that "people who nowadays call themselves taxonomists are spending a smaller proportion of their time doing descriptive taxonomy". She continued: "we are investing in the collections' maintenance at the expense of descriptive taxonomy. The balance is out of kilter and it needs further resources invested in the system in order to rebalance so that we can have an appropriate balance of collateral development and maintenance" (Q 7).

3.14. This change in UK contribution to descriptive taxonomy is reflected in various metrics. For example, the UK now ranks only tenth in its contribution to descriptive taxonomy measured using a sample of over 10,000 species of animals described since 2001 (see Table 2 below). (It should be noted that these data are presented here in raw form as an indication only. There are a number of factors which could be applied as a way of scaling them to make them more informative: for example, by size of population of each country, by the stage of development of the educational system, by historical factors or by number of indigenous species. We have not applied these or other factors on this occasion since the general indication provided by the raw data makes our point sufficiently well.)

TABLE 2

Relative national ranking of output in descriptive taxonomy based on numbers of new marine species and on numbers of new animal species described in the e-journal *Zootaxa*

Marine species: described 2002–2003*	***Zootaxa*: described 2001–2007****	**Overall ranking: combined data**
1 USA	1 USA	1 USA
2 Australia	2 Brazil	2 Brazil
3 Japan	3 PR China	3 Australia
4 Germany	4 Australia	4 PR China
5 France	5 Germany	5 Germany
6 Russia	6 Argentina	6 Japan
7 Spain	**7 United Kingdom**	7 France
8 United Kingdom	8 France	8 Russia
9 The Netherlands	9 Mexico	9 Spain
10 Brazil	10 Japan	**10 United Kingdom**

* Data from P Bouchet, *The Magnitude of Marine Biodiversity* (2002), in C Duarte (Editor), *The Exploration of Marine Biodiversity, Scientific and Technological Challenges*, Fundación BBVA, Bilbao.

** Data from www.mapress.com/zootaxa

3.15. Another metric is the percentage of UK-based authors publishing papers in systematic biology journals. The Linnean Society (p 91) noted a drop of five percentage points (from 17 per cent to 12 per cent) in the number of UK-based authors publishing in their three peer-reviewed journals over the period 2001 to 2007. Similarly, but over the 50-year period from 1958 to present, the British Lichen Society noted a decline from over 90 per cent to under 10 per cent of British-based articles in their journal *The Lichenologist* (p 210).

Identification

3.16. Accurate and repeatable identification is essential for monitoring change through time and is a fundamental tool for detecting the effects of environmental change on the Earth's biodiversity (p 91). This is a complex sector and it is difficult to generalise about the national capacity for species identification because identification skills are widely but unevenly spread. There is a strong professional identification sector which includes the Environment Agency, the conservation agencies, Defra laboratories such as the Centre for Environment, Fisheries and Aquaculture Science and the Central Science Laboratories, non-governmental organisations such as the Sir Alister Hardy Foundation for Ocean Science, as well as the major taxonomic institutions, universities and commercial consultancies. There is also a robust voluntary sector, consisting of charities, associations and the many volunteers working for Local Record Centres.

3.17. In several key groups, for example birds, butterflies and some families of flowering plants, reliable identification guides are available and identification skills are strongly developed through the volunteer community, with highly organised support from organisations such as the RSPB, the British Trust for

Ornithology, the BSBI and the RHS. There is no shortage of identification skills in such groups (Q 199).

3.18. However, in some groups (including those highlighted in paragraphs 3.8 and 3.9 above) identification skills are in short supply. We are concerned that the shortage of identification skills in these areas may compromise the capability in the UK for monitoring biodiversity change and implementing policy.

Phylogenetic systematics

3.19. Of the three main tasks, phylogeny appears to be in the best health. In addition to the major institutions, there are active research groups investigating aspects of phylogeny in several UK universities and phylogenetic methods are central to expanding fields such as comparative genomics and metagenomics. The availability of Research Council funding for phylogenetics, for comparative genomics and for methodological advances has contributed to the viability of this area. It is increasingly being understood that each level in a hierarchical classification is of value for conservation (p 146). Phylogenetic studies group together at higher levels related species that share common ancestors and many biological properties; and then, as the JNCC explained, "these shared properties can be used predictively to investigate how related species can best be conserved" (p 146).

Supply and demand

3.20. There are many users but few producers of taxonomy. Defra describes itself as "a user of the outputs of systematics and taxonomy" (Q 100) and NERC describes itself in similar terms (p 37). Most organisations involved in making identifications are also users of basic taxonomic information, as are the teams of researchers involved in phylogeny. There are few producers—descriptive taxonomists—to meet this demand and this is, as we have noted, the area of systematic biology identified as being most at risk. In the recent past, taxonomic expertise was spread more widely through the universities, but the decline of taxonomy in the university sector has changed the dynamics of supply and demand. Major producers of new taxonomic research, such as RBG Kew, have indicated that they do not have sufficient taxonomists to cover all the areas for which expertise is being requested (pp 14ff). The NHM has reduced the proportion of resource expended on descriptive taxonomy as the science undertaken there has become more diverse (p 2).

3.21. **The Committee believes that the major taxonomic institutions alone will not be able to meet demand for taxonomy. It is therefore, in our view, critically important that there should be more effective and regular dialogue between the users and the producers of taxonomy on the priorities for developing UK systematic biology. Such dialogue should be facilitated by the Research Councils.** The users of taxonomy are very important to the long-term survival of the science but no truly dynamic science can exist led only by its users because, as Dr Knapp reminded us, "users do not lead developments in science" (Q 135). This dialogue should take place within the context of developing a roadmap, an issue to which we turn in the next chapter (see paragraph 4.4).

Importance of the voluntary sector

3.22. The UK is extremely fortunate in having a large corps of citizen biologists who are actively engaged in biodiversity issues. Most biological recording in the UK is run by volunteers (Q 220). We received a range of evidence demonstrating the value of their contribution. For example, Dr Nic Lughadha of RBG Kew referred to the interaction between professionals and amateurs in mycology as "essential" and as a "very productive and close relationship" (Q 36). Professor Richard Lane, Director of Science at The NHM, described the relationship as "pretty intimate", and acknowledged that amateurs were often "extraordinarily knowledgeable" and would on occasions be used as "the authority" (Q 36).

3.23. As we have already observed, major organisations, such as the RSPB, the British Trust for Ornithology, the BSBI and the RHS, provide an impressive reservoir of expertise, particularly in species identification for "charismatic" groups of organisms like birds and flowering plants. Voluntary sector engagement has remained strong in such groups although, for example, a smaller percentage of members of the BSBI is made up of professionals now so there has been "a drift towards a preponderance of … volunteer recorders (Q 199). But, as Professor Battarbee told us, in other important indicator groups, like freshwater diatoms, a once-thriving volunteer community has all but vanished "as experienced professionals have retired or gifted amateurs have slipped away and not been replaced" by a new generation (Q 179).

3.24. Mrs Margaret Hodge, Minister for Culture, Creative Industries and Tourism at the DCMS, told us that "every Government department is trying to grow the volunteering capacity" in all areas of community activity and noted as relevant to our inquiry the large voluntary membership of the RSPB (Q 316). **We welcome the Government's commitment to promoting voluntary action. The work of the volunteer community is crucial to the vitality of systematic biology. But the voluntary effort is patchy, tending against non-charismatic organisms and in favour of the charismatic. We urge the Government, with the assistance of the taxonomic institutions, to show more leadership in this matter and to take steps to promote voluntary action, giving particular attention to those sectors which cover the less charismatic species.**

Recruitment

3.25. Given the evidence we received about the health of some areas of systematic biology, it is perhaps not surprising that some organisations have experienced difficulty in recruiting taxonomists. The NBN Trust, for example, said "that there are increasing difficulties recruiting … professional staff proficient in species identification across a broad range of groups by, for example, ecological consultancies and local authorities" (p 143). **In view of the Committee's concern that demand for taxonomic skills will exceed supply, stimulating the recruitment of new researchers and new volunteers is vitally important.**

Inspiring a new generation

3.26. Systematic biology needs to promote whole organism biology since the "static (if not declining)" population of scientists with this expertise is the "single biggest barrier to delivering research priorities in taxonomy and

systematics" (Linnean Society, p 90). It must also stimulate wider public engagement in order to increase the flow of young volunteers into local recording schemes and, for some, into systematics as a career path. Professor Fortey referred to each species having a biography that is intrinsically interesting (Q 226): telling the biographical stories of species is at the core of such highly successful television series as Sir David Attenborough's *Life on Earth*. Taxonomy represents the starting point for a species: once a new species is described and named the process of building that biography can begin.

3.27. It is self-evident to us that for systematic biology to engage the public, in particular young people, those involved in the discipline need to devise powerful messages about the value of the discipline. One approach may be to stress the importance of role models. Professor Philip Esler, Chief Executive of the Arts and Humanities Research Council (AHRC), said that his research council had funded a project on John Walker, an early geologist in Edinburgh (Q 90). A topical example would be Charles Darwin whose bicentenary is in 2009. Darwin was an expert taxonomist who described numerous new genera and species, created an important reference collection now housed at The NHM, and devoted eight years to writing two large taxonomic monographs on barnacles. These volumes are still used by specialists today. The difficulty he experienced in distinguishing between species of barnacles further focused his attention on variation within and between species and helped focus his ideas on evolution.

Taxonomy in schools and the importance of field studies

3.28. Biology in schools strongly emphasises human biology while concerns over safety issues have led to a reduction in field study trips. We believe that it is critically important that school children of all ages, starting with those in primary school, should be taught about the natural world and given opportunities to enjoy it first hand. **In order to promote awareness of environmental sustainability as an over-arching issue, we consider that, as a matter of high priority, a greater component of biodiversity-related topics, including taxonomy, should be included school curricula. Field study trips and other practical exercises, which have served to introduce generations of children to the diversity of living organisms, should be encouraged as a means of engaging and stimulating young people (as future volunteers) to become involved in biological recording.**

Regional museums and reference collections

3.29. Regional and national museums have a vital role in inspiring young people to become interested in environmental issues such as biodiversity, conservation and sustainability. The vitality of the local and regional museum sector is providing novel outreach opportunities that foster engagement with new audiences (Q 314). Regional museums and reference collections are also an archive providing essential reference and voucher collections for biological recording. These are important both for the validation of biological records and for the local training of new generations of naturalist specialists (pp 145 and 326). **We welcome the Government's acknowledgement of the importance of the Renaissance in the Regions programme in providing additional resources for regional museums** (Q 310 and p

48). **At the same time, we urge the Government, through the appropriate funding agencies, to ensure continuity of funding to sustain curation, taxonomic work and outreach in the regional museums.** We note that the importance of continuity of funding to university museums was a matter which was raised in a report by the House of Commons Culture, Media and Sport Committee in June 2007.[17] The Commons Committee referred in particular to "how precarious university museums' funding was". We note also, that in their response, published in October 2007, the Government said: "DCMS officials are working closely with officials at the Department for Innovation, Universities and Skills to ensure that the value of university museums is properly appreciated and adequately funded by HEFCE and the institutions they fund. We will, of course, continue to work closely with the museums sector to secure optimal levels of funding beyond 2009."[18]

Training

3.30. There are several UK Masters courses in systematic biology and taxonomy, some involving partnerships between universities and research institutes, such as the University of Edinburgh and RBG Edinburgh, and Imperial College and The NHM. Masters courses are typically broadly based and produce a pool of new postgraduates each year trained in the basics of systematic biology. There is a substantial number of PhD projects based in the UK that "tick the box" for having at least some component of taxonomy, but only in a minority of these is the primary focus on descriptive or revisionary taxonomy (Q 26). At this higher level of the PhD or post-doctoral fellowship, it appears from the evidence of Dr Alastair Culham of the Centre for Plant Diversity and Systematics at the University of Reading that it is common for qualified taxonomists to leave the UK because career paths are much stronger abroad (Q 192).

3.31. Lord Rooker, Minister for Sustainable Food and Farming at Defra, and Mrs Hodge, Minister at the DCMS, were not in favour of central planning but where there were skills shortages they encouraged employers to express their demands and engage in dialogue with Department for Innovation, Universities and Skills (DIUS) and HEFCE (QQ 305–306). Mrs Hodge commended the Department for Children, Schools and Families and the museums for encouraging and bringing alive to young people the exciting and challenging prospect of a career in science be it taxonomy or elsewhere, and saw it as a responsibility shared with DIUS (and the Research Councils) and users (Q 305).

Mentoring for volunteers

3.32. Professional taxonomists have long engaged with the voluntary sector in a training-mentoring role and, crucially, they have provided quality assurance. For example, Professor Mary Gibby, Director of Science at the RBG Edinburgh, referred to the support given to "the amateur community" by professional taxonomists through the specialist societies (Q 35). Such

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[17] House of Commons Culture, Media and Sport Committee, Sixth Report, Session 2006–07, C*aring for our collections* (HC 176), para 65.

[18] Government response to the Culture, Media and Sport Select Committee Report on *Caring for our collections*, Session 2006–07, Cm 7233.

arrangements have largely been *ad hoc*, often generated by personal contacts with scientists. We fear however that this role will come under increased pressure given the shrinking pool of whole organism, taxon-based expertise in the UK. We recognise the value and importance of this mentoring and support. **We recommend that steps should be taken, for example by the establishment of a periodic event, to foster personal networking between professional and voluntary taxonomists, the NBN, and other stakeholders.**

CHAPTER 4: TOOLS AND TECHNOLOGY FOR THE TWENTY-FIRST CENTURY

Opportunities

4.1. According to The NHM, "responses to the biodiversity crisis and to the challenge of climate change require a transformation in the nature and volume of taxonomy …" (p 1). The science of taxonomy is expanding rapidly: new species of plants, animals and microbes are being described daily, new and more powerful analytical and computational methods are constantly under development, and ever-growing amounts of biodiversity informatics data are becoming accessible through the web. The incorporation of new technologies, such as high throughput DNA sequencing and automated digital data-gathering, will be critical to the development of taxonomy.[19] The Committee heard of the exciting opportunities and challenges for systematic biology in the twenty-first century as it develops to meet the need for a more profound understanding of the diversity of life and of the impact of environmental change on that diversity. UK scientists are playing a leading role in developing the vision of taxonomy for the future.

4.2. Taxonomy is a global enterprise. Its core strength has traditionally been in Europe, North America and Japan, but the balance is changing and the emergence of nations such as Australia, Brazil and China as major contributors serves to emphasise this international dimension. UK national initiatives and the importance of UK resources, such as reference and type collections, are increasingly framed in this wider international context (p 93). The credibility of UK scientists engaged in realising the vision for the future of taxonomy depends in part upon the UK maintaining involvement in major international initiatives, like the Global Biodiversity Information Facility (GBIF) and the Biodiversity Heritage Library (BHL).

Digitisation of collections and the Internet

4.3. The magnitude of the challenge facing taxonomists as they seek to document biodiversity on a global scale indicates that there will have to be substantial, even radical, changes in how taxonomy is conducted. At our inquiry seminar (see Appendix 4 and also pp 39 and 94), Professor Charles Godfray, Hope Professor of Entomology at Oxford University, described progress towards a web-based taxonomy in the CATE project—Creating a Taxonomic E-science—funded by NERC under their e-science programme. **We have no doubt that the Internet will play a crucial role in the evolution of taxonomy and it is clear that further pilot studies in web-based taxonomy involving a wider range of types of organisms should be undertaken urgently by the research community.**

4.4. Essential components of this Internet-based taxonomy will include:

(i) Internet-based descriptive taxonomy (alpha e-taxonomy);

(ii) a clearing house mechanism for biodiversity information (for example, the GBIF);

(iii) access to digital images of specimens;

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19 *Taxonomy in Europe in the 21st Century* (Report prepared for the Board of Directors of EDIT).

(iv) access to specimen-based and collection-based information;

(v) on-line access to libraries of taxonomic publications (for example, the BHL);

(vi) databanks of molecular sequence data (for example, GenBank).

All of these components exist already, although some are only small-scale pilots. **We believe that a roadmap for the delivery of Internet-based taxonomy should be developed. Furthermore, we encourage the taxonomic community to come together to take the lead in its development since, in our view, it will only be effective if it emerges from the community. The process of developing this roadmap should be funded jointly by the BBSRC and NERC as a high strategic priority.**

4.5. There is no "quick technological fix" for the "taxonomic impediment" (see paragraph 1 above) and the web alone cannot necessarily accelerate the taxonomic enterprise greatly (p 13). Implementation of the roadmap will require long-term commitment by the major UK taxonomic institutions and it will require them to exercise a level of leadership commensurate with the scale and importance of their collections and their expertise in research, curation and informatics. It will, we anticipate, also require substantial additional funding, from Government and other sources.

4.6. The Committee welcomes the progress of the Linnean Collection digitisation project with its 17,000 images of plants and 27,000 images of insects already available on the web (p 93) and we welcome the success of RBG Kew in obtaining substantial funding from charitable trusts, such as the Andrew W Mellon Foundation, to support digitisation projects for African and Latin American plants (p 20). However, the lack of core funding and the consequent reliance on external charitable sources have resulted in the major UK taxonomic institutions being slow in making collections data available over the Internet. When asked whether UK taxonomists were keeping up with the rest of world in terms of digitisation, the response of Professor Stephen Hopper, Director of RBG Kew, was discouraging: "by no means, way behind" (Q 22 and p 20). Notwithstanding the scale of their collections, **the Committee finds the rate of progress by the UK taxonomic institutions in digitising and making collections information available to be disappointingly low. Unless a more strategic view is taken of how they can contribute to the development of the field of biodiversity informatics, there is a significant risk of damage to the international reputation of major institutions such as The NHM** (Q 91).

4.7. More broadly, GBIF suggested that the current rate of data digitisation and dissemination in the UK "hampers the progress of systematics and taxonomy not only in the United Kingdom, but worldwide" (p 251). Given their global scale and historical significance, UK taxonomic collections carry a responsibility to share access to the biodiversity information they house with the country of origin. In the light of the importance of halting biodiversity loss in progressing towards environmental sustainability (one of the Millennium Development Goals), the Committee considers that DFID should take a much stronger interest in promoting benefit-sharing with developing countries through funding digitisation projects.

4.8. **The Committee recommends that those UK taxonomic institutions with major biological collections should develop strategic plans for making biodiversity informatics more readily accessible to users through the Internet, and that DFID should fund selected digitisation projects that focus on the biodiversity conservation and sustainability needs of developing countries.**

4.9. The Research Councils, particularly BBSRC, have played an important role in supporting pilot studies and proof of concept studies in the area of biodiversity informatics (Q 76). Beyond these innovative technological aspects, digitisation of major collections has been viewed as the responsibility of the institutions themselves (Q 91). **The Committee, however, recognises that certain kinds of big research questions relating to large-scale biodiversity patterns in space and time can only be addressed using large-scale data. UK researchers addressing such questions should be able to apply for Research Council funding to create large-scale aggregated datasets.**

Barcoding

4.10. Barcoding, the use of a short standard sequence of DNA to identify individual organisms, has been available as a technique since the 1990s. In theory, organisms or fragments of organisms can be identified by comparison to a reference database of barcode sequences. The power of the technique is that it allows accurate identification of previously unidentifiable stages such as larvae, seedlings, and the fungal mycelium. However, the technique is absolutely dependent upon the availability of a searchable databank of reference sequences from accurately identified voucher specimens. Barcoding is a tool of value in addressing many different questions. In the UK there is substantial barcoding effort currently involved with diagnostics—that is, with identification. However, it is apparent that UK research on barcoding has slipped behind progress made elsewhere (pp 18 and 312) and the Wellcome Trust refers to an "apparent lack of collaboration between different barcoding initiatives which makes for significant confusion" (p 322).

4.11. The evidence we received focused on plant pathogenic fungi, where barcoding effort comes from at least four teams (the Central Science Laboratory (CSL), the Scottish Crops Research Institute, Forest Research and the University of Reading). The CSL is a lead partner in an EU project to barcode statutory plant health pests and diseases (p 56). The development of barcoding technology represents an unprecedented opportunity to tackle the "taxonomic impediment" in mycology but these efforts require close co-ordination (p 270).

4.12. **The Committee is concerned about lack of co-ordination of barcoding effort nationally and about the potential for duplication of effort. The efficiency of barcoding as a diagnostic technique increases in proportion to the number of different species barcodes available for comparison. In the case of plant pathogenic fungi, we recommend that UK BRAG addresses the task of how best to co-ordinate barcoding effort across the UK.**

DNA-based taxonomy and the morphological approach

4.13. Metagenomics, the study of genetic material recovered directly from environmental samples rather than cloned material, and barcoding are immensely powerful techniques for exploring and understanding biodiversity. The European Distributed Institute of Taxonomy (EDIT) Consortium recognises that "there is a danger that DNA-based taxonomies will de-couple from morphologically-derived taxa" (p 236).

BOX 3

Definitions

In taxonomic studies the two most commonly used types of information about organisms are *molecular* and *morphological*. Today, *molecular information* is usually DNA sequence data and forms the basis of metagenomics techniques and barcoding. In contrast, *morphological information* is based on external and internal anatomy and is often referred to as traditional or classical taxonomy. In any study, these data types can be used separately or can be combined.

Despite the power of molecular taxonomy "it is important that molecular approach develops alongside the classical [morphological] approach" (p 43). There is considerable concern about the risk of growing "sectoral separation" between professional taxonomists using molecular approaches and the conservation and volunteer communities who require the translation of taxonomic outputs into tailored products such as field guides and keys.

4.14. **The Committee recommends that NERC supports research into developing an effective, functioning interface between rapid taxonomic techniques such as metagenomics and traditional morphological taxonomy.**

Keys and handbooks

4.15. Accurate identification of species is fundamental to conservation in the UK (p 143) and the work of the voluntary sector in particular is heavily dependent on identification tools produced by taxonomists. Handbooks, identification keys and field guides are noted as highly important in the *United Kingdom Taxonomic Needs Assessment*.[20] However, many species groups have never been covered by an identification guide and many existing guides are out of date due to nomenclatural changes, and to the influx of invasive species (p 313).

4.16. The production of identification keys and field guides is critical, especially in an environment of increasing numbers of invasive alien species, but in many groups of organisms—about half of all UK insects for example—no field guides are available for the UK (Q 215). There are several established and prestigious series, such as the Synopses of the British Fauna, the Royal Entomological Society handbooks and the Freshwater Biological Association keys, but the production of new guides is slow. The limiting factor is not the funding or marketing of the handbooks but the availability of taxon specialists willing to produce handbooks (pp 90, 294 and 313). We return to this issue in next chapter.

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[20] A Taylor, *United Kingdom Taxonomic Needs Assessment*. Natural History Museum/Defra 23/02/2006.

Research collections

4.17. The three taxonomic tasks of description, identification and phylogeny are supported by key resources, in particular by research collections. The largest national collections, such as those housed at The NHM and RBG Kew, continue to be world-class resources and new developments, such as the Darwin Centre and the Millennium Seed Bank, are world-leading facilities.

4.18. Regional and university museums represent an important archive providing essential reference material for teaching and housing voucher collections for reference by local recorders. Professor Mace indicated why these collections were valued: "taxonomists, zoologists and botanists, as part of their training need to have access to the specimens themselves"—there was, she said "absolutely no replacement for the real object" (Q 63). These collections are important both for validation of biological records and for training both scientists and new generations of naturalist specialists.

4.19. Smaller collections are vulnerable and their future appears insecure. In the case of plant collections, of 602 herbaria present in Britain in 1945, 97 have been destroyed or cannot be traced, 230 have been transferred to existing institutions, the whereabouts of 106 are currently unknown, leaving 169 extant (preliminary data from survey by the BSBI, p 88). Adrian Norris, a retired Senior Curator of Natural Sciences at Leeds City Museums, commented that "the development of Regional Museum HUBS and the extra funding from the DCMS has made some difference," but urged that this funding be allocated so that museums can "fund strategic taxonomic tasks by employing trained taxonomists, as well as funding the proper storage of their collections" (p 284). Continued support from Government for regional and university museums, through programmes such as the Renaissance in the Regions programme, is essential.

National Biodiversity Network (NBN)

4.20. The UK's Biological Records Centre (now hosted by the NERC Centre for Ecology and Hydrology at Wallingford) and many Local Record Centres are connected virtually by the NBN. The NBN provides access to over 27 million species distribution records from 229 different datasets—"the majority of these derive from voluntary recording organisations or from local record centres"—and it makes analytical tools available through its portal, the NBN Gateway (p 146). The NBN functions as a facilitating body and its funding, which is made up from payments from its member organisations, is described as "very fragile" because it is dependent upon individual priorities set by its members (Q 217). The Committee recognises the pivotal role played by the NBN in making datasets available electronically and in facilitating access to a wide range of users.

4.21. The Committee welcomes the establishment by Defra of the Fund for Innovation in Local Biodiversity Recording. This fund, administered by Natural England, will make £181,000 available during the year 2008–09 for building capacity in Local Record Centres and to increase the geographical scope, quantity and quality of biological information served through the NBN (p 54 and Q 318).

4.22. **In view of the continuing success of the NBN in accessing and serving data, and its importance in engaging with and empowering the large voluntary sector involved in biological recording nationally, the**

Committee urges Defra to assist the NBN in moving towards a less fragile funding model.

CHAPTER 5: FUNDING

Diversity of funding sources

5.1. Taxonomic research in the UK is dependent upon "a plurality of funding sources" (Q 81): core research at RBG Kew is funded by Defra, at The NHM by DCMS, at RBG Edinburgh by the Scottish Executive, and at the National Museum Wales by the Welsh Assembly Government. As well as funding RBG Kew, Defra states that where the development or implementation of policy requires input of systematic or taxonomic expertise, this will be factored into the contract (p 51) and research is also carried out at Defra laboratories such as CSL and the Centre for Environment, Fisheries and Agriculture Science (CEFAS) (p 50). Some aspects of taxonomy research are funded by Research Councils (but see paragraphs 5.4 to 5.6 below). The Wellcome Trust funds research into aspects of systematic biology relevant to its mission (p 321) and a number of other organisations, the RHS (p 298 and Q 175) for example, support a small amount of targeted research.

5.2. The BBSRC Collaborative Scheme for Systematics Research (CoSyst) is managed by the Linnean Society and the Systematics Association (p 40). This scheme is funded by the BBSRC at £75,000 a year for 3 years (£225,000 in total) and supports developing collaborations between systematists and non-systematists that will lead to full Research Council proposals. Early indications are positive (Q 82) and we encourage those involved to review the scheme in due course with a view to continuing and expanding it. (We note the comment of the Linnean Society that the entire three-year funding is equivalent to only a single average BBSRC standard grant (p 92).)

5.3. The Linnean Society and the Systematics Association together operate the Systematics Research Fund—a scheme for providing small grants for work in taxonomy. The total funding for 2007–08 was £72,000: £36,000 (provided by the Linnean Society (£20,000), the Systematics Association (£6,000), the Bentham-Moxon Trust (£5,000) and NERC (£5,000)) (p 92). The sum of money involved is small but this is a welcome demonstration of improved cohesion within the community.

Funding by NERC

5.4. The evidence we received about the willingness of the Research Councils to fund taxonomy was confused. According to NERC, it "is not primarily concerned with systematics and taxonomy *per se*, focusing instead on using the information", a position confirmed in oral evidence: "taxonomy that is funded is directly related to another research project and only that" (Q 53). NERC subsequently clarified their answer: they "do not fund alpha taxonomy *in vacuo*" but they do fund it and other systematics and taxonomy research "where it is required to address important scientific questions" (p 78). But then Professor Alan Thorpe, Chief Executive of NERC, agreed in response to questioning that NERC would not discriminate against taxonomy and that it was incorrect to say NERC did not fund taxonomy *per se* (Q 254).

5.5. One consequence of these mixed signals appears to be that applicants feel the need to "hide" or "disguise" the taxonomic component of their research grant applications (QQ 180 and 230). Dr Fortey, for example, said that bodies like NERC "do not hand out money for grant proposals that are primarily taxonomically aimed"; and speaking from his own experience, he said: "the grants that I have been successful in getting have got taxonomy in them hidden away or rather cunningly concealed under a scientific hypothesis" (Q 230). While this concealment might result in some taxonomy being funded, we find it difficult to see how NERC can gain an accurate picture of the importance of taxonomy in underpinning biodiversity and climate change studies.

5.6. **The approach of NERC to funding taxonomy appears confused. We are very concerned that the mixed signals perceived within the taxonomic community are detrimental to the transparency which should characterise scientific discourse. We invite NERC to make a clear statement setting out its approach to the funding of taxonomy.**

Production of identification keys and field guides

5.7. We have already referred to the importance of identification keys and field guides (paragraphs 4.15 and 4.16 above). Although their production is critical (p 313), it is the non-availability of taxon specialists willing to produce guides that is the limiting factor (see paragraph 4.16 above). In addition to the general decrease in numbers of available specialists, it seems likely to us that the "effective invisibility" of such works in the Research Assessment Exercise process (see paragraphs 6.10 to 6.14 below) is a significant factor in the lack of willingness to generate new identification guides amongst those remaining specialists.

5.8. **We recommend the establishment of a new process for commissioning the production of identification keys and field guides, involving joint actions between users setting priorities, funders supporting fixed-term appointments, host institutions providing access to collections and literature resources, and established series publishers producing the volumes. We also recommend that UK BRAG should explore the options for commissioning the production of new and updated identification guides for the UK fauna and flora.**

CABI fungi collection

5.9. The RBG Kew has taken on responsibility for curation of the CABI collection of fungi in order to ensure that this important collection remains secure and accessible to researchers (p 22 and Q 14). This is a valuable scientific asset which is held nationally but is of global scientific significance. RBG Kew has requested Defra to provide additional funding of £750,000 for housing and curating the collection (Q 303). Lord Rooker indicated that there was an issue concerning the departmental responsibility for funding of CABI and stated that there was "very little likelihood of funding" by Defra (QQ 303–304).

5.10. **Whilst we understand that there are always many pressures on Government funds, we are concerned about the future of the CABI fungal reference collection given its significance to the stability of fungal systematics. Its loss would deepen the crisis in fungal**

taxonomy. **We urge the Government to acknowledge this significance and to take steps to secure the CABI fungal reference collection into the future.**

CHAPTER 6: GOVERNMENT AWARENESS

Overview

6.1. Systematic biology is notable for the way in which effort, resources and responsibilities are spread across Government departments, between the universities, museums and botanic gardens, and through the voluntary biological recording sector. This spread reinforces our view of systematic biology as a basic infrastructural discipline underpinning the delivery of a broad raft of policies, but during this inquiry we have become aware of an astonishing lack of awareness in Government, both of the importance of systematic biology and of the current state of decline in areas of systematic biology.

Defra

6.2. Defra describes itself as "a user of the outputs of systematics and taxonomy" but "not a major utiliser of research from these disciplines" (p 49). Dr Miles Parker, Director of Science at Defra, confirmed that Defra has a "lively interest" in this area but that it only had a lead on certain aspects (Q 97). In our 2002 report, we recommended that Defra should take the lead in setting up a body with the express purpose of bringing together representatives from Government departments, ecologists and conservationists and the systematic biology community, including those based at museums, universities and other institutions (Recommendation 1.8). This co-ordination body's main remit was to have been to identify priority areas of biodiversity for which taxonomic research was most needed by the conservation community, and for other national purposes, such as plant and animal health and agriculture. No such body was established.

6.3. Dr Parker suggested that the very wide community of interest in this area was "a strength" and that Defra placed some emphasis on working with the systematic biology community and co-ordinating activities with them (Q 95) through bodies such as UK BRAG and GBSC (Q 97). However, UK BRAG and GBSC, both under Defra chairmanship, told us that in their view "there remains a need for improved mechanisms to make user needs known to the taxonomic community and to funding bodies" (p 313); and Dr Ian McLean, Head of Targets and Standards at the JNCC, suggested that, as far as he could see, there was no "current mechanism for directly joining up those areas where we recognise there is an increased demand [for taxonomic expertise] … with providers of taxonomy" (Q 213). BioNET-INTERNATIONAL linked this to "the lack of even minimal resources needed for ongoing co-ordination and facilitation of taxonomist/end-user relationships" (p 191).

6.4. The statement by Defra that they have "not identified any specific major impediment to delivering our priorities deriving from the spheres of systematics and taxonomy" (p 49) is contradicted by UK BRAG who comment that "without a reliable inventory, efforts to conserve biodiversity are greatly hampered" and go on to point out that there are "significant national gaps in taxonomic knowledge needed to underpin research in the marine environment" (p 312). Similarly, Professor Battarbee, in reference to the EU Water Framework Directive which requires that all surface waters are restored to good ecological status by 2015 (defined ecologically and

biologically), said that the Environment Agency "do not have sufficient taxonomic expertise … for phytoplankton macro-invertebrates and aquatic macrophytes". He concluded that "the shortage of people with identification skills is serious" (Q 171).

6.5. This lack of awareness on behalf of Defra creates risk on a number of fronts: users risk not having their needs met; producers risk becoming disconnected from their users; researchers risk having to limit the questions they can address through lack of essential tools; and Government risks being unable to deliver policy. Changing taxonomic needs must be discussed with key producers. Lord Rooker expressed concern about not "hearing the noises" about the problematic state of systematic biology (Q 301). For this reason, we have recommended (in paragraph 3.21) that steps should be taken to satisfy a clear need for facilitated dialogue between ecosystem and biodiversity researchers, taxonomy providers, funders and the wider community of users.

DIUS: Research Councils

6.6. NERC states that it is "not primarily concerned with systematics and taxonomy *per se*, focusing instead on using the information" (p 37) and BBSRC, while acknowledging "the fundamental role of systematics in most areas of life science research", has "little involvement in the support of taxonomy" (p 36).

6.7. Dr Alf Game of the BBSRC agreed that "over a number of years, particularly in universities, the amount of activity in taxonomy and in support of collections has probably declined" but he did not believe that this had been reflected "by very much evidence … from the wider science base or the user community of concern about it" (Q 49). However, Dr Game conceded that the Research Councils UK (RCUK) system for detecting issues such as concern about systematics was "very nebulous" (Q 77); and we note that, despite Dr Game's suggestion that there was little evidence of widespread worry about the state of taxonomy, the RCUK itself acknowledges that the Plymouth Marine Laboratory and the National Oceanographic Centre Southampton (both NERC collaborative centres) have raised concerns about succession planning for taxonomy in the marine sciences (p 39). RCUK also submits that the "whole set of skills and expertise to maintain the international standards for identification is disappearing rapidly from the UK" (p 39). RCUK seems unaware of the evidence of concern over the state of systematic biology emanating from its own institutes.

6.8. **The Committee received evidence of widespread concern from the user community about the health of systematic biology in the UK and concludes that the system for communicating this concern is not working. We find the lack of awareness, at RCUK-level, of the state of UK systematic biology to be very worrying.** Since the RCUK take responsibility for training and for maintaining the expertise base in taxonomy (Q 54), it is surprising that communication between RCUK and the users of taxonomy is open to this level of criticism.

6.9. The Research Councils are responsible for the health of the disciplines and they provide an annual health of disciplines report (QQ 48 and 243). Mr Ian Pearson MP, Minister of State for Science and Innovation at DIUS, said that as Minister he wanted to be assured that the Research Councils were paying sufficiently detailed attention "to the health of key disciplines" (Q 283). But

the current system seems to be at such a coarse scale that it would not pick up changes specifically relating to the health of the systematic biology community (Q 243). Since it appears that no effective mechanism is in place to determine routinely the health of systematic biology, it is not clear to us how the Minister can have the assurance he seeks.

DIUS: HEFCE and the RAE

6.10. One of the key drivers of the decline in taxonomy at UK universities has been the RAE (Research Assessment Exercise). The RAE was identified as an important factor by this Committee in our last inquiry. In our 2002 report we recommended that the Higher Education Funding Councils should consider the role of the RAE in the decline of systematic biology in universities and explore ways in which to support this subject, as they do with other minority disciplines (Recommendation 1.4). This was not done.

6.11. Mr Pearson suggested that Higher Education Funding Council for England (HEFCE) did not accept that the RAE has played a role in the decline of minority disciplines and that there was "no conclusive evidence to that effect" (Q 289). However, there is a widespread view in the research community that the RAE emphasis on high impact journals and the low weighting given to measures of esteem in which contributions to informatics initiatives and expertise might be recognised, discourages universities from recruiting systematists (The NHM p 4). The Biosciences Federation conclude that systematic biology research in universities is disadvantaged by the RAE, to the detriment of research and training, and they even refer to the "tyranny of the RAE" (p 196). One very active, university-based group of prokaryotic systematists was "disbanded because of suspected RAE pressures" (p 305). RBG Kew suggested that "the RAE criteria provide a strong disincentive for universities to support taxonomic research and training" (p 15).

6.12. In addition, the RAE is regarded as impacting selectively on the production of larger monographic or revisionary studies. "The absence of this work [production of taxonomy monographs] from universities owes much to the vicissitudes of the Research Assessment Exercise, which penalises those taxonomists whose interests and skills lie in this area" (BSBI p 86). The monographic study, as an output of taxonomy, is "effectively invisible to the RAE" (Systematics Association p 101). The Department of Plant Sciences at Oxford University concludes that "given the current research environment within universities (funding, RAE) it is unrealistic for any active researcher not to pursue high impact hypothesis-driven science" (p 231).

6.13. Professor Mace, a member of the current RAE panel, commented that in the current exercise there was a very different flavour to how outputs are judged—that is, not only on their scientific merit but also on whether they will have a bearing on policy (Q 69). Whilst the Committee welcomes this change, **it is clear from the range of evidence we received that the perception that the RAE criteria do not favour systematics is still widespread in the UK biodiversity research community and that the RAE is still having a negative impact on the choices of career-minded scientists in taxonomy.**

6.14. **The Committee recommends that in developing the replacement mechanism for the RAE—the Research Excellence Framework—HEFCE should take into consideration the way that citation-based**

metrics disadvantage systematic biology and also the bias that would be introduced if grants-based metrics were employed, given that pure taxonomy is not deemed fundable by the Research Councils. It is essential that criteria appropriate to systematic biology research should be incorporated into the new mechanism.

Environment Research Funders' Forum

6.15. The Committee welcomes the decision that taxonomy has been "highlighted for special attention" within the forthcoming skills review by the Environment Research Funders' Forum—a group, led by NERC, of all the main funders of environmental science (Q 243). We note that the findings of the review are likely to be produced in 12 to 18 months. We look forward to seeing them although we are aware that they will provide only a "snapshot" of the discipline rather than reflect longer-term trends.

6.16. **Given the baseline studies of the health of systematic biology already available in our reports published in 1992 and 2002, we recommend that the Environment Research Funders' Forum should seek to identify trends in the state of the discipline when making their review. We also recommend that the Forum should programme a follow-up assessment to take place within five years of their first review.**

DCMS

6.17. The involvement of DCMS in systematic biology is primarily through its role as sponsor and funder of The NHM and of regional museums through the Museum Libraries and Archives' Renaissance in the Regions programme (p 48). DCMS has an arms-length relationship with The NHM as one of its many non-departmental public bodies. Mrs Hodge, Minister at DCMS, who welcomed the opportunity to learn about taxonomy for this inquiry (Q 297), informed us that problems with the health of the discipline or with co-ordination between Government departments had never been raised as an issue with her (Q 298).

Awareness in Government

6.18. As Minister, Ian Pearson of DIUS, wants to be assured the Research Councils are paying sufficient attention to the health of key disciplines (Q 283) but the Research Councils are largely unaware of the widespread concern about the state of health of systematic biology (Q 49). HEFCE does not accept that the RAE is a key driver of the decline of minority disciplines such as systematic biology but we have evidence to the contrary. Lord Rooker at Defra has not heard noises about the problematic state of systematic biology (Q 301) and concerns about problems with the discipline have never been raised with Mrs Hodge at DCMS (Q 298). This lack of awareness within Government may reflect the difficulty that officials must have in gaining an overview of an underpinning, infrastructural discipline but, in our view, the result is that systematic biology appears to be suffering the consequences of a situation where diffuse responsibility results in no responsibility.

6.19. **We recommend therefore that there should be a lead department responsible for systematic biology and that further, because the central issue is the state of health of the discipline, we recommend that DIUS should take on that role**.

CHAPTER 7: CONCLUSIONS AND RECOMMENDATIONS

7.1. In this chapter we set out our conclusions and recommendations in full. The numbers in brackets refer to the relevant paragraphs in the text.

Chapter 2: The role of systematic biology in the delivery of policies

7.2. Measuring progress towards halting the decline in biodiversity is a key international obligation which cannot be achieved without baseline knowledge of biodiversity. Creating baselines and monitoring change is dependent upon the availability of taxonomic expertise across the range of living organisms. (para 2.13)

7.3. Systematic biology underpins our understanding of the natural world. A decline in taxonomy and systematics in the UK would directly and indirectly impact on the Government's ability to deliver across a wide range of policy goals. (para 2.14)

Chapter 3: Health of the discipline in the UK: professional taxonomists, volunteers and recruitment

7.4. We recommend that a study should be commissioned by the Natural Environment Research Council (NERC) to ascertain the current number of taxonomists in the UK and also trends in the number of taxonomists in the UK. (para 3.1)

7.5. The Committee believes that the major taxonomic institutions alone will not be able to meet demand for taxonomy. It is therefore, in our view, critically important that there should be more effective and regular dialogue between the users and the producers of taxonomy on the priorities for developing UK systematic biology. Such dialogue should be facilitated by the Research Councils. (para 3.21)

7.6. We welcome the Government's commitment to promoting voluntary action. The work of the volunteer community is crucial to the vitality of systematic biology. But the voluntary effort is patchy, tending against non-charismatic organisms and in favour of the charismatic. We urge the Government, with the assistance of the taxonomic institutions, to show more leadership in this matter and to take steps to promote voluntary action, giving particular attention to those sectors which cover the less charismatic species. (para 3.24)

7.7. In view of the Committee's concern that demand for taxonomic skills will exceed supply, stimulating the recruitment of new researchers and new volunteers is vitally important. (para 3.25)

7.8. In order to promote awareness of environmental sustainability as an over-arching issue, we consider that, as a matter of high priority, a greater component of biodiversity-related topics, including taxonomy, should be included school curricula. Field study trips and other practical exercises, which have served to introduce generations of children to the diversity of living organisms, should be encouraged as a means of engaging and stimulating young people (as future volunteers) to become involved in biological recording. (para 3.28)

7.9. We welcome the Government's acknowledgement of the importance of the Renaissance in the Regions programme in providing additional resources for

regional museums. At the same time, we urge the Government, through the appropriate funding agencies, to ensure continuity of funding to sustain curation, taxonomic work and outreach in the regional museums. (para 3.29)

7.10. We recommend that steps should be taken, for example by the establishment of a periodic event, to foster personal networking between professional and voluntary taxonomists, the National Biodiversity Network (NBN), and other stakeholders. (para 3.32)

Chapter 4: Tools and technology for the twenty-first century

7.11. We have no doubt that the Internet will play a crucial role in the evolution of taxonomy and it is clear that further pilot studies in web-based taxonomy involving a wider range of types of organisms should be undertaken urgently by the research community. (para 4.3)

7.12. We believe that a roadmap for the delivery of Internet-based taxonomy should be developed. Furthermore, we encourage the taxonomic community to come together to take the lead in its development since, in our view, it will only be effective if it emerges from the community. The process of developing this roadmap should be funded jointly by the Biotechnology and Biological Sciences Research Council and NERC as a high strategic priority. (para 4.4)

7.13. The Committee finds the rate of progress by the UK taxonomic institutions in digitising and making collections information available to be disappointingly low. Unless a more strategic view is taken of how they can contribute to the development of the field of biodiversity informatics, there is a significant risk of damage to the international reputation of major institutions such as the Natural History Museum. (para 4.6)

7.14. This Committee recommends that those UK taxonomic institutions with major biological collections should develop strategic plans for making biodiversity informatics more readily accessible to users through the Internet, and that the Department for International Development should fund selected digitisation projects that focus on the biodiversity conservation and sustainability needs of developing countries. (para 4.8)

7.15. The Committee recognises that certain kinds of big research questions relating to large-scale biodiversity patterns in space and time can only be addressed using large-scale data. UK researchers addressing such questions should be able to apply for Research Council funding to create large scale aggregated datasets. (para 4.9)

7.16. The Committee is concerned about lack of co-ordination of barcoding effort nationally and about the potential for duplication of effort. The efficiency of barcoding as a diagnostic technique increases in proportion to the number of different species barcodes available for comparison. In the case of plant pathogenic fungi, we recommend that UK Biodiversity Research Advisory Group (UK BRAG) addresses the task of how best to co-ordinate barcoding effort across the UK. (para 4.12)

7.17. The Committee recommends that NERC supports research into developing an effective, functioning interface between rapid taxonomic techniques such as metagenomics and traditional morphological taxonomy. (para 4.14)

7.18. In view of the continuing success of the NBN in accessing and serving data, and its importance in engaging with and empowering the large voluntary sector involved in biological recording nationally, the Committee urges Defra

to assist the NBN in moving towards a less fragile funding model. (para 4.22)

Chapter 5: Funding

7.19. The approach of NERC to funding taxonomy appears confused. We are very concerned that the mixed signals perceived within the taxonomic community are detrimental to the transparency which should characterise scientific discourse. We invite NERC to make a clear statement setting out its approach to the funding of taxonomy. (para 5.6)

7.20. We recommend the establishment of a new process for commissioning the production of identification keys and field guides, involving joint actions between users setting priorities, funders supporting fixed-term appointments, host institutions providing access to collections and literature resources, and established series publishers producing the volumes. We also recommend that UK BRAG should explore the options for commissioning the production of new and updated identification guides for the UK fauna and flora. (para 5.8)

7.21. Whilst we understand that there are always many pressures on Government funds, we are concerned about the future of the CAB International (CABI) fungal reference collection given its significance to the stability of fungal systematics. Its loss would deepen the crisis in fungal taxonomy. We urge the Government to acknowledge this significance and to take steps to secure the CABI fungal reference collection into the future. (para 5.10)

Chapter 6: Government awareness

7.22. The Committee received evidence of widespread concern from the user community about the health of systematic biology in the UK and concludes that the system for communicating this concern is not working. We find the lack of awareness, at Research Councils UK-level, of the state of UK systematic biology to be very worrying. (para 6.8)

7.23. It is clear from the range of evidence we received that the perception that the Research Assessment Exercise (RAE) criteria do not favour systematics is still widespread in the UK biodiversity research community and that the RAE is still having a negative impact on the choices of career-minded scientists in taxonomy. (para 6.13)

7.24. The Committee recommends that in developing the replacement mechanism for the RAE—the Research Excellence Framework—the Higher Education Funding Council for England should take into consideration the way that citation-based metrics disadvantage systematic biology and also the bias that would be introduced if grants-based metrics were employed, given that pure taxonomy is not deemed fundable by the Research Councils. It is essential that criteria appropriate to systematic biology research should be incorporated into the new mechanism. (para 6.14)

7.25. Given the baseline studies of the health of systematic biology already available in our reports published in 1992 and 2002, we recommend that the Environment Research Funders' Forum should seek to identify trends in the state of the discipline when making their review. We also recommend that the Forum should programme a follow-up assessment to take place within five years of their first review. (para 6.16)

7.26. We recommend that there should be a lead Government department responsible for systematic biology and that further, because the central issue is the state of health of the discipline, we recommend that Department for Innovation, Universities and Skills should take on that role. (para 6.20)

APPENDIX 1: SCIENCE AND TECHNOLOGY COMMITTEE

Members:

Lord Sutherland of Houndwood (Chairman)
Lord Colwyn
Lord Crickhowell
Lord Haskel
Lord Howie of Troon
Lord Krebs
Lord May of Oxford
Lord Methuen
Earl of Northesk
Lord O'Neill of Clackmannan
Lord Patel
Earl of Selborne
Lord Soulsby of Swaffham Prior†
Lord Taverne
Baroness Walmsley†
Lord Warner

† co-opted member

Declared Interests:

Lord Colwyn
None

Lord Crickhowell
None

Lord Haskel
None

Lord Howie of Troon
None

Lord Krebs
Former Chief Executive of NERC (1994–99)
Member of the Department of Zoology at Oxford University
Trustee of the St Andrew's Environment Prize.
Chairman of the Visitors of the Natural History Museum at Oxford University

Lord May of Oxford
Emeritus Professor of the Department of Zoology at Oxford University
Past Chairman of the Trustees of the Natural History Museum
Past member of the JNCC
Past member of the WWF(UK) Board
Professional academic interest in conservation biology

Lord Methuen
None

Lord Northesk
None

Lord O'Neill of Clackmannan
None

Lord Patel
None

Earl of Selborne
Chairman of Trustees, Royal Botanic Gardens, Kew
Fellow of the Linnean Society
Fellow of the Institute of Biology
Chair, Living with Environmental Change Partners Board

Lord Soulsby of Swaffham Prior
President of Parliament & Science Committee
President of Royal Institute of Public Health
Chairman, Companion Animal Welfare Council

Lord Sutherland of Houndwood
None

Lord Taverne
None

Baroness Walmsley
Chairman of the charity "Botanic Gardens Conservation International"

Lord Warner
None

APPENDIX 2: LIST OF WITNESSES

The following witnesses gave evidence. Those with a ⋆ gave oral evidence.

Henry Barlow

Biological Recording in Scotland

BioNET-INTERNATIONAL

Biosciences Federation

Booth Museum of Natural History

⋆ Professor Richard Gornall, President, Botanical Society of the British Isles

Dr Janet Bradford-Grieve

British Embassy (Rome)

The British Lichen Society

British Mycological Society

The British Phycological Society

Buglife

CAB International

⋆ Dr Mark Hill, Head of Biological Records Centre, Centre for Ecology and Hydrology

⋆ Dr Alastair Culham, Centre for Plant Diversity and Systematics, University of Reading

DCMS:

⋆ Ben Cowell, Head of Museums Sponsorship

⋆ Rt Hon Margaret Hodge, a Member of the House of Commons, Minister for Culture, Creative Industries and Tourism

Defra:

⋆ Dr Miles Parker, Director of Science

⋆ Rt Hon Lord Rooker, a Member of the House, Minister for Sustainable Food and Farming and Animal Health

⋆ Professor Nicola Spence, Head of Plant Health Group, Central Science Laboratory

Department of Plant Sciences, University of Oxford

Henry Disney

DIUS:

⋆ Ian Pearson MP, a Member of the House of Commons, Minister of State for Science and Innovation

European Distributed Institute of Taxonomy Consortium

EMLRC (Leicestershire County Council)

Bill Ely

Dr Genoveva Esteban

European Mycological Association

* Dr Richard Fortey, President, the Geological Society

Global Biodiversity Information Facility

EF Greenwood

Hertfordshire Natural History Society

International Trust for Zoological Nomenclature

Professor Marcel Jaspars

JNCC:

* Dr Ian McLean, Head of Targets & Standards

* Professor Brian Cathcart, Kingston University and Chair of the New Perspectives project

The Linnean Society:

* Professor David Cutler, President

* Dr Sandra Knapp, Botanical Secretary

Patricia Lorber

Professor (Emeritus) Amyan Macfadyen

Mycology sub-committee UK BRAG

National Biodiversity Network Trust:

* Sir Neil Chalmers, Chairman

* Dr Jim Munford, Programme Director

National Federation for Biological Recording

Natural History Museum:

* Dr Michael Dixon, Director

* Professor Richard Lane, Director of Science

National Museums Liverpool

National Museum Wales

Natural Sciences Collection Associations

Adrian Norris

Plant Diversity Challenge Steering Group

Plantlife International

Research Councils UK:

* Dr Pamela Kempton, Science and Innovation Manager, Terrestrial and Freshwater Sciences, NERC

* Professor Georgina Mace, Director, Centre for Population Biology, NERC Collaborative Centre

* Dr Colin Miles, Head, Molecular Cell Biology, BBSRC

* Dr Alf Game, Deputy Director, Science and Technology, BBSRC

* Professor Philip Esler, Chief Executive, AHRC
* Steven Visscher, Interim Chief Executive, BBSRC
* Professor Alan Thorpe, Chief Executive, NERC

Royal Botanic Gardens, Kew:

* Professor Stephen Hopper, Director
* Dr Eimear Nic Lughadha, Head of Science Policy and Co-ordination

Royal Botanic Garden Edinburgh:

* Professor Mary Gibby, Director of Science

The Royal Entomological Society

The Royal Horticultural Society

School of Computer Science, Cardiff University

The Scottish Environment Protection Agency

The Scottish Government:

* Dr Liam Kelly

Society for General Microbiology

Systematics Association

* Professor Richard Bateman, President, Systematics Association

UK Biodiversity Research Advisory Group and the Global Biodiversity Sub-Committee of the UK

* Professor Rick Battarbee, Environmental Change Research Centre, University College London

University of Reading

Dr John Waland Ismay

Professor Roy Watling

The Wellcome Trust

The Wildlife Trust for Lancashire, Manchester & North Merseyside

Yorkshire Naturalists' Union

APPENDIX 3: CALL FOR EVIDENCE

The House of Lords Science and Technology Committee, chaired by Lord Sutherland of Houndwood, is announcing a follow-up inquiry on systematic biology research and taxonomy. The inquiry will provide an assessment on the state of the field five years after the Committee's last report ('*What on Earth? The threat to the science underpinning conservation*') in the context of new scientific, technological and policy developments.

The Committee invites evidence on the following questions. Witnesses are encouraged to focus on those issues of which they have particular knowledge or experience—submissions are not required to cover all questions.

The state of systematics and taxonomy research

1. What is the state of systematics research and taxonomy in the UK? What are the current research priorities? What are the barriers, if any, to delivering these priorities?

2. What is the role of systematics and taxonomy and, in particular, in what way do they contribute to research areas such as biodiversity conservation, ecosystem services and climate change? How important is this contribution and how is it recognised in the funding process? How is systematics integrated in other areas of research?

3. Does the way in which systematics research is organised and co-ordinated best meet the needs of the user community? What progress has been made in setting up a body to lead on this? What contribution do the leading systematics research institutions make both nationally and internationally?

4. What level of funding would be needed to meet the need for taxonomic information now and in the future? Who should be providing this funding?

5. How does funding in other countries compare? Could there be more international collaboration? If so, what form should this collaboration take and how might it be achieved?

6. What impact have developments in DNA sequencing, genomics and other new technologies had on systematics research? In what way has systematics embraced new technologies and how can these research areas interact successfully and efficiently?

Data collection, management, maintenance and dissemination

7. Does the way in which taxonomic data is collected, managed and maintained best meet the needs of the user community? What is the state of local and national recording schemes?

8. What is the role of the major regional museums and collections? How are taxonomic collections curated and funded?

9. What progress has been made in developing a web-based taxonomy? How do such initiatives fit in with meeting demand for systematics and taxonomy information? How do UK-led initiatives fit in with international initiatives and is there sufficient collaboration?

10. What needs to be done to ensure that web-based taxonomy information is of high quality, reliable and user-friendly?

11. How does the taxonomic community engage with the non-taxonomic community? What role do field studies play?

Skills base

12. What are the numbers and ages of trained taxonomists working in UK universities and other organisations?

13. What is the state of training and education in systematics and taxonomy? Are there any gaps in capacity? Is the number of taxonomists in post, and those that are being trained, sufficient to meet current and future needs across all taxonomic subject areas?

APPENDIX 4: SEMINAR AT THE NATURAL HISTORY MUSEUM

6 February 2008

The following presentations were given:

- Overview (Dr Sandy Knapp, Merit Researcher, The Natural History Museum);
- National capacity (Professor Geoffrey Boxshall FRS, Merit Researcher FRS, The Natural History Museum);
- Web-based taxonomy (Professor Charles Godfray FRS, Hope Professor of Zoology, University of Oxford);
- Phylogenetics (Professor Mark Chase FRS, Keeper of the Jodrell Laboratory, Royal Botanic Gardens, Kew);
- Resurgence of the phenotype (Professor Bland Finlay FRS, Queen Mary University of London).

Overview (Dr Sandy Knapp)

Phylogeny, identification and description

Dr Knapp began by describing the three principal activities of the science of taxonomy: phylogeny, identification and description, focusing in particular on descriptive taxonomy which, she said, could be regarded as the "Cinderella of taxonomy" because it was largely ignored. Every species name was a hypothesis about the distribution of variation in nature and species definition was an ongoing discipline that required constant testing. Collections of organisms were critically important to taxonomy because they provided the basis for hypothesis testing.

Global taxonomic effort

It was very difficult to find statistics about global taxonomic effort because there was no standardised global collection of data. The most useful information came from Australia. Amongst other things, it had been found that, in Australia, between 1991 and 2003 the number of taxonomic scientists had fallen but the number of those providing technical support had increased. Despite this, the single biggest impediment to taxonomic activity was identified as lack of technical support. This might be a demonstration of the expanding technology associated with taxonomy. Indicative global statistics with regard to taxonomic effort in flowering plants (by reference to the International Plant Names Index) suggested that another challenge facing taxonomy was an ever-increasing evidence base.

National capacity (Professor Geoffrey Boxshall)

Professor Boxshall focused on two questions:

Why does the UK need a national capacity in taxonomy?

Reasons why the UK needed a national capacity in taxonomy included the following: to monitor and detect change in biodiversity; to understand the functional role of biodiversity; to provide data underpinning conservation; to meet international obligations; to detect and control alien species; to support

identification services; to be a credible player internationally, and to interpret taxon-based knowledge. With regard to the second of these—to understand the functional role of biodiversity—a key concept which had emerged strongly in recent years was "ecosystem services". "Ecosystem services" were "the benefits people obtain from ecosystems". The concept had been broken down by the Millennium Ecosystem Assessment into four types of service: (direct) provisioning (for example, food and fresh water), regulating (for example, climate regulation and flood regulation, pollination), cultural (for example, recreational and educational services) and, the most basic, supporting (for example, primary production and soil formation). "Ecosystem services" was an essential concept connecting biodiversity and the constituents of human well-being, and it had re-set the context for the Committee's inquiry. The ecosystem functioning research community was a source of high level demand for taxonomic skills and that level of demand demonstrated a recognition that taxonomy was essential for their work.

How does the UK national capacity compare in the global context?

Comparison could be made by looking at: collections, digital access to data, output (descriptive taxonomy), contributors to international programmes, capacity building and quality control (peer review).

The UK was a global leader in terms of museums and botanic gardens. The UK had done less well with digital access to data. With regard to output measures—descriptive taxonomy—the UK was still producing descriptive taxonomy but, looking at, for example, data from *Zootaxa* 2001–07 and the league table for animal species, it appeared that the UK global influence in descriptive taxonomy was slipping. Those countries which were doing well, such as the USA, Brazil and Australia, all had taxon-focused funding programmes. With regard to contributors to international programmes, capacity building and quality control, evidence suggested they were all in decline in the UK.

The continuing erosion of national taxonomic capacity reduced the UK's capacity to assess the biological impact of climate change, to study the sustainability of ecosystem services, to meet our formal obligations under the Convention on Biological Diversity and to detect alien species. It also reduced our credibility with the international biodiversity science community and reduced our ability to disseminate and interpret biodiversity information.

Web-based taxonomy (Professor Charles Godfray)

Current uses of the web

Professor Godfray began by setting out four main current uses by taxonomists of the web: enabling taxonomists to talk to other taxonomists (for example, specimen-level databases, type-specimen databases); linking data sources (for example, the Global Biodiversity Information Facility and the National Biodiversity Network); enabling taxonomists to talk to the broader community (via, for example, taxon sites and molecular taxonomic sites such as the Tree of Life), and making available taxonomic information for amateur biologists such as naturalists and gardeners etc.

Threats and drivers

Biodiversity and global change were creating a huge thirst for taxonomic information. Added to this is the greater expectation amongst biologists for

information sources that are both accessible and easier to use. A major driver is the increasing speed of the molecular revolution. Some taxonomic tasks that in the past could only be done by specialist taxonomists can now be addressed by general biologists using sequence data. Programmes such as molecular barcoding will also produce large amounts of taxonomic-relevant molecular data. There is a major risk of a disconnect between molecular and morphological taxonomy.

How the web might be used

The web has the potential to bring together all parts of taxonomy; morphological and molecular, professional and amateur, provider and user. While the web is being used extensively in taxonomy there has yet to be the step-change that is required to address the current major taxonomic challenges. Though there is a plethora of taxonomic eScience projects these tend to be small scale, and there has been insufficient investment in overcoming the major hurdle: putting very substantial content on the web.

In the future, the web could provide improved functionality for many aspects of taxonomy (for example, significantly more information including sound, movies and photomontage, and the application of Digital Object Identifier technologies), greater subject cohesiveness (thereby countering the divide between molecular and morphological taxonomy), greater efficiency and better links with end-users.

Hurdles

Hurdles in the way of developing the web for taxonomic purposes included: the cost and other resource implications of moving information to the web; the need for prioritisation and cooperation; and sustainability.

The unique position of the UK

Despite the decline in UK taxonomy, the UK had significant influence over the future development of the subject. This was linked to its historical role and the collections it housed. The two greatest challenges now facing the UK taxonomic community were leadership and resourcing. Leadership needs to come from the country's major taxonomic institutions, and both "one-off" resources for transferring taxonomy to the web and a business plan for sustainability of this resource needs to be devised.

Phylogenetics (Professor Mark Chase)

The purpose of classification was: to enable an inventory to be created; to develop lists of names which were recognised world-wide; to enable an understanding of relationships; and to enable some degree of predictability (for example, where there was a close relationship between two organisms, the genetics of one could be assumed to be related to the genetics of the other).

Current classification included both clusters of relationships and measurement of confidence, expressed numerically, in the relationship asserted by the clustering. The information behind this type of classification was largely molecular but the effect of this was not to create a discrepancy between molecular and other taxonomies. On the contrary, those who were exposed to the meaning of DNA information were able to integrate the different types of taxonomy.

Phylogenetic trees had a number of purposes: they were useful for assessing relationships between organisms; they assisted in evaluating hypotheses of

character evolution; they were useful in assessing patterns of biogeography—the distribution of plants around the world; they provided information about molecular clocks—the timing of events across the phylogenetic tree; and, a developing area, they assisted in assessing the past effects of climate change and predicting the future effects of climate change on species distributions. Names provided the points of entry into databases and phylogenetics provided the connections. Phylogenetics could be described as the "glue" that connected everything and turned data points into hypotheses. Paradoxically, it was possible to have taxonomic diversity at the same time as a deficit of phylogenetic diversity. Phylogenetic tress were necessary to understand this issues.

DNA barcoding was identification of species based on a short piece of DNA. Eventually it would be carried out using a hand-held device. It would not displace the need for taxonomists since barcoding depended on well-characterised reference bases and accurate use of names. It would relieve taxonomists from having to spend time on routine identifications.

Molecular phylogenetics tended not to be done in universities because it was not well-funded.

Resurgence of the phenotype (Professor Bland Finlay)

To expand knowledge, it was necessary to study the phenotype and whole organism (by observation, description and experiment). Describing organisms solely on the basis of phylogenetic trees provided little relevant biological information, and threatened to dismiss a large body of knowledge accumulated over two centuries. The arrival of molecular markers such as rDNA had the potential to sow confusion with an almost infinite variety of genotypes from a vast global pool of mainly selective neutral mutations that had accumulated over historical time.

Discussion

Professor Richard Bateman, President of the Systematics Association, Dr Chris Lyall, UK National Focal Point, Global Taxonomy Initiative and Professor Georgina Mace, Director of the Centre for Population Biology at the NERC Collaborative Centre gave brief commentaries.

Following a short general discussion, Professor Boxshall summed up the key themes of the seminar:

- The taxonomic landscape, and consequently taxonomic priorities, had changed significantly in recent years with the emergence of the concept of ecosystem services.
- The range of users of taxonomy was expanding and would continue to expand. Allied to this was a tension created by an increasing demand for taxonomists without there being a commensurate increase in resources, in the size of the pool of taxonomic expertise or in the infrastructure.
- Issues relating to support for the amateur taxonomic community needed to be addressed.
- Descriptive taxonomy in particular needed careful attention. The core of experienced expertise in this area of taxonomic activity was the rate limiting factor in the UK's contribution to descriptive taxonomy.

- The idea of taxonomic "national capacity" and a "critical mass of expertise" underpinned the Committee's 2002 report and should continue to be a focus for the current inquiry.
- Technological innovation had created a powerful set of tools for the taxonomist. But the state of taxonomy in the UK was not susceptible to a "quick technological fix". Technology was a driver but also needed to be harnessed and used appropriately.
- The UK had a leadership role to play in promoting taxonomy, a role which required developing and facilitating.

APPENDIX 5: LIST OF ACRONYMS AND ABBREVIATIONS

AHRC	Arts and Humanities Research Council
BHL	Biodiversity Heritage Library
BBSRC	Biotechnology and Biological Science Research Council
BSBI	Botanical Society of the British Isles
CABI	CAB International
CATE	Creating a Taxonomic E-science
CBD	Convention on Biological Diversity
CEFAS	Centre for Environment, Fisheries and Agriculture Science
CITES	Convention on Trade in Endangered Species
CoSyst	Collaborative Scheme for Systematic Research
CSL	Central Science Laboratory
DCMS	Department for Culture, Media and Sport
Defra	Department for the Environment, Food and Rural Affairs
DFID	Department for International Development
DIUS	Department for Innovation, Universities and Skills
EDIT	European Distributed Institute of Taxonomy
GBIF	Global Biodiversity Information Facility
GBSC	Global Biodiversity Sub-Committee
HEFCE	Higher Education Funding Council for England
JNCC	Joint Nature Conservation Committee
NERC	Natural Environment Research Council
NBN	National Biodiversity Network
NHM	Natural History Museum
OSPAR	Convention on the Protection of the Marine Environment of the North-East Atlantic
PDC	Plant Diversity Challenge
RAE	Research Assessment Exercise
RBG Edinburgh	Royal Botanic Garden Edinburgh
RBG Kew	Royal Botanic Gardens, Kew
RCUK	Research Councils UK
RHS	Royal Horticultural Society
RSPB	Royal Society for the Protection of Birds
UK BRAG	UK Biodiversity Research Advisory Group
UK GECC	UK Global Environmental Change Committee

Minutes of Evidence

TAKEN BEFORE THE SELECT COMMITTEE ON SCIENCE AND TECHNOLOGY (SYTEMATICS AND TAXONOMY)

TUESDAY 19 FEBRUARY 2008

Present	Colwyn, L	Selborne, Earl of
	Krebs, L	Sutherland of Houndwood, L (Chairman)
	Methuen, L	Walmsley, B
	Northesk, Earl of	Warner, L

Memorandum by the Natural History Museum

The Natural History Museum (NHM) is one of the world's leading institutions for systematics and taxonomy. The expertise of its scientists and its natural history collections are the international focus for integrated research on the natural world, provision of collections access to many scientists, development and provision of information resources and education and public engagement. Its broad role as a museum is inseparable from its science: it enables the NHM to take innovative approaches to public engagement in science and the natural world. It combines skills and pursues collaboration to meet constantly changing needs for taxonomy around the world and welcomes this opportunity to discuss the future of taxonomy and systematics.

The NHM science mission is to explore the diversity of the natural world and the processes that generate such diversity.

SUMMARY

— The UK has international centres of excellence (both in collections and research) that are providing international leadership for the future of taxonomy and systematics.

— Responses to the biodiversity crisis and to the challenge of climate change, require a transformation in the nature and volume of taxonomy that will require resources and effective development of international strategy. This must develop "industrial scale" acquisition and analysis of taxonomic data. There are great opportunities and challenges for systematic biology and taxonomy, as for other areas of science, but the UK taxonomic community can develop to meet these challenges, collaborating in international networks.

— There has never been a time when so many theoretical and practical tools have been available, coupled with potential for enhanced access to collections. While the NHM is consistently supported by the Department of Culture, Media and Sport (DCMS), resources across the sector for taxonomy and systematics in the UK, are at best level in real terms and the community will be unable to meet the challenges of new technology and expanding need without adequately resourced strategic development.

— A critical mass of taxon-focused expertise, must be maintained to complement the expanding range of technology, but there is increasing concentration of systematic work in just three organisations (two devoted to plants alone) as activity in UK universities and research institutes declines.

— The NHM is responding to the opportunities by providing leadership in the vision of the future of systematics and in exploiting new technology; integration of DNA and morphological approaches, image capture and analysis, and taxonomy on the web. These advances are often limited to exploration in pilot mode: greater resources would be needed to scale up to the level needed by stakeholders.

1. *What is the state of systematics research and taxonomy in the UK? What are the current research priorities? What are the barriers, if any, to delivering these priorities?*

1. The UK is well positioned in development of taxonomy and systematics research, with a core of high-profile institutions and access to good quality infrastructure in the form of collections. There is little difficulty in recruitment of overseas expertise, but there is concern that opportunities in a small number of UK institutions will not support the development of the UK expertise that will be needed to meet future demands. The ongoing transformation of taxonomy means that the infrastructure will come under increasing pressure to deliver within current resources.

The state of research

2. Taxonomy is in a state of change—the extent of knowledge of diversity needed for understanding of ecosystems is immense, requiring new perspectives on research and changing responsibilities and requirements for lead institutions. We need to maintain core competencies on knowledge of taxa while collaborating internationally and fostering the development of research, research scientists and infrastructures for a new taxonomy.

3. Taxonomy comprises three complementary elements[1]: description, identification, and phylogenetic systematics. Their states in the UK and overseas differ, but phylogenetic systematics is strong, with continuing impact on comparative biology, opening up new lines of enquiry in evolution, ecology and development. It is popularly seen as having higher status than the other elements of taxonomy as an academic discipline and is well represented in universities.

4. There is concern for the future of descriptive taxonomy, which does not fit easily into policy definitions of hypothesis-driven research in the UK, and has therefore been seen as less appropriate for competitive research funding. The continuing fertility of phylogenetic systematics as part of the wider enterprise of biological science depends on descriptive taxonomy. Descriptive taxonomy is modernising, enabling taxonomists to collaborate effectively and giving better access to data, wider availability of new technology and more direct engagement with end users.

5. Identification is used in ecology, conservation, quarantine, biomedicine, agriculture, invasive species management—and by the public. National user-needs assessments for the Convention on Biological Diversity (CBD) Global Taxonomy Initiative (GTI) make identification a priority; the scale and diversity of international demand is significant. We anticipate revolutions in DNA barcoding and automatic identification that will enable more rapid and responsive characterisation of diversity; these will need a continued engagement with descriptive taxonomy.

6. Debate continues on describing and delimiting taxa—current processes cannot deliver information in time to be used to address the biodiversity crisis. It may be that the current formal approach will be confined to taxa where precise delimitation and naming is required; leaving the majority of species described "informally" to serve pragmatic approaches.

7. The Third National Reports to the CBD[2] suggest lack of taxonomic expertise is an issue on a global basis, with little being done to change this in many countries. Statistics[3] from the rapidly growing journal Zootaxa indicate patterns in descriptive taxonomy on a global basis, with larger numbers of authors from China, Brazil, the USA and Australia.

8. The NHM assessed UK taxonomic needs for conservation[4] in 2006 in its role as UK focal point for the GTI, and developed a database[5] on UK expertise (primarily description and identification) in 2002. In addition to taxonomic coverage and employers, the data[6] indicate the population of taxonomists: 1.6 per cent aged 21–30; 18 per cent 31–40; 27 per cent 41–50; 27 per cent 51–60; and 20 per cent over 60. 82 per cent were male.

[1] H. C. J. Godfray and S. Knapp. *Phil. Trans. R. Soc. Lond.* B (2004) 359, 559–569.
[2] http://www.cbd.int/
[3] http://www.mapress.com/zootaxa/support/Statistics.htmv
[4] http://www.bionet-intl.org/opencms/export/sites/default/tnaPages/tna-resources/docs-ghana/UK_Taxonomic_Needs_Assessment_Public.pdf
[5] http://www.nhm.ac.uk/research-curation/biodiversity-museum/global-taxonomic-initiative/register-of-uk-taxonomic-expertise/index.html
[6] http://www.editwebrevisions.info/content/uk-taxonomic-expertise

9. The NHM has received good support from DCMS in recent years—the science group receives a relatively constant proportion of the budget and maintains a constant number of science staff. There has been very substantial capital investment in collections facilities over the past ten years. However, as the science undertaken by the Museum becomes more diverse, a smaller proportion of the resource is expended on descriptive taxonomy. This is a difficult but deliberate decision.

Research priorities

10. Research priorities must be linked to the scale of the challenge for biodiversity conservation and responses to climate change. We need better understanding of ecosystem services and the diversity that underpins them; taxonomy is an essential element within this enterprise, but with its core strengths it must develop and integrate new research to generate knowledge on the scale needed.

11. NHM, within the EU-funded EDIT[7] network, recently led on development of a vision for the future of taxonomy. The research priorities for taxonomy, in wide-ranging engagement with other areas of science, emerging from this vision include:

- Developing a credible tree of life, including evolutionary change and the processes of speciation.
- Expanding biodiversity discovery to micro-organisms, using molecular tools to transform scale and speed.
- Incorporating taxonomic information in modelling impacts of environmental change on biodiversity.
- An ecosystem approach based on taxonomy and metagenomics for describing life on earth.

12. On a UK scale, the recent NERC Science Theme Report on Biodiversity[8] says "Systematics and taxonomy are essential underpinning for any work on biodiversity. There are a number of challenges and opportunities for systematic biology including e-science, DNA barcoding, and providing increased human capacity to reverse declining taxonomic expertise." NERC is currently consulting on implementation. Other organisations set out objectives for research on biodiversity and ecology with implicit reliance on taxonomic research, tools and information systems[9]: there are ambitions to investigate biodiversity at different scales and ecosystem function, often using new analytical and information technology, but not always an understanding of what taxonomy can or should deliver.

Barriers to delivery:

13. Parts of taxonomy will move to massive sequencing and other data capture, massive output and analysis and high throughput identifications. This will require integrated teams, which will require a change in the systems for the assignment and evaluation of scientific products. Greater cohesion will enable the community to exploit the excitement, vitality and dynamism of the subject.

14. Facilities are needed to scale up taxonomy; high throughput DNA sequencing; biodiversity informatics development; storage of frozen samples. There is a need for funds for infrastructure development in the same way as has happened for genome sequencing and discovery.

15. Digitising data for wider access is at best receiving level funding and is in competition with other activitie;: it is done at too small a scale to meet future needs. The immense volume of existing analogue data can only be transformed with sustained resourcing.

16. Taxonomy is international science; thus those responsible for UK science policy need to be more closely connected to international initiatives and discussion on biodiversity and taxonomy—in for example, the Consortium for the Barcoding of Life (CBoL); the Global Biodiversity Information Facility (GBIF); the EU Lifewatch; and others. Taxonomy requires policy engagement in the same way as climate change but Defra for example, has consistently struggled to fund the UK GBIF subscription and has depended on support from the NHM and others.

17. Various national regulations related to CBD can consume resources available to research. International agreement on facilitation of collaborative academic research must be pursued: if not by the UK government then via the EU.

[7] Taxonomy in Europe in the 21st century, adopted by the Board of Directors of EDIT (the European Distributed Institute of Taxonomy) in January 2008
[8] NERC Science Theme Report: Biodiversity November 2007
[9] UKBRAG (2007) Research needs for UK Biodiversity. DEFRA

18. A new vision for the discipline includes continuing development of core strengths for research to expand the knowledge of organisms. However, there are concerns that the quality and value of taxonomy is not easily captured by science policy metrics and that there can be adverse career impacts; this possible barrier is being examined by the NHM and other institutions as a policy issue.

19. A significant disincentive for academics to engage in systematic research, particularly taxonomy, in universities, is the lack of credit given to many aspects of their work. The RAE emphasis on high impact journals and the low weighting given to measures of esteem in some units of assessment (in which contributions to databases and expertise might be recognised) mitigates against universities recruiting systematists. Furthermore, systematics, like other minority disciplines, tends to be marginalised in funding boards where voting takes place for prioritisation.

2. *What is the role of systematics and taxonomy and, in particular, in what way do they contribute to research areas such as biodiversity conservation, ecosystem services and climate change? How important is this contribution and how is it recognised in the funding process? How is systematics integrated in other areas of research?*

20. Taxonomy enables diversity to be described and understood. Research on biodiversity, ecosystem services and climate change will rely on taxonomy in investigating diversity, monitoring changes, and modelling vulnerability; policy-makers need information that is underpinned by taxonomy; capacity building and training involve taxonomic expertise; public initiatives and engagement routinely involve taxonomy. In some areas taxonomy is active and involved, in others the potential is emerging.

21. The Millennium Ecosystem Assessment (MEA) said "A major obstacle to knowing (and therefore valuing), preserving, sustainably using and using equitably the benefits of the biodiversity of a region is the human and institutional capacity to research a country's biota." [10] Similarly GTI: "The lack of taxonomists, of collections, of libraries, of field guides and other identification aids, the difficulty in accessing information, coupled with the overwhelming number of species, both described and undescribed, make up the 'taxonomic impediment' to implementation of the Convention on Biological Diversity." [11]

22. NHM research explores natural diversity; what organisms exist and how they interact; where they are; and how diversity changes and develops. This work integrates taxonomy with other areas of research. Our research framework[12] summarises the wider scientific questions to which taxonomy contributes in the Museum or through collaboration. The UK has many specimens not represented in collections of countries of origin, holds literature inaccessible elsewhere and has a high expertise level relative to other countries. Making these available is important both to science and policy.

23. The NHM is active in delivering UK commitments under the Convention on Biological Diversity (CBD). NHM is active in undertaking research with funding from the UK Darwin Initiative[13] and has engaged in policy support and taxonomic needs assessments. NHM has led 27 projects since 1993 (more than any other institution), The Darwin Initiative has funded a series of NHM collaborative projects on biodiversity conservation such as on land snail diversity[14] and termites[15] that have involved exploration of endemism and diversity, ecosystem processes, faunal histories, extinction, conservation and invasive species, combined with development of expertise, collections and information.

24. NHM work shows taxonomy in wider contexts; fish diseases and climate change; parasitic diseases such as malaria and schistosomiasis; use of chironomid midges in monitoring climate change; exploring evolution of nanostructures and the potential for industrial application[16].

25. Taxonomy underpins pest control: agricultural, medical and veterinary. BioNET provides numerous cases showing a cost:benefit ratio of 1:50 to 1:700 for taxonomic intervention in pests. NHM examples are control of cassava mealybugs[17] and control of myiasis-causing New World screwworm fly in North Africa[18]. The European and Mediterranean Plant Protection Organisation (EPPO) declared a state of emergency[19] on plant health in 2004, citing the threat of extinction of taxonomy.

[10] Millennium Ecosystem Assessment, 2005. Ecosystems and Human Well-being: Biodiversity Synthesis. World Resources Institute, Washington, DC. http://www.millenniumassessment.org/en/index.aspx
[11] Guide to the GTI 2007 CBD http://www.cbd.int/doc/publications/cbd-ts-30.pdf
[12] http://www.nhm.ac.uk/research-curation/science-directorate/science-policies-strategy/assets/researchframework.pdf
[13] http://www.defra.gov.uk/environment/darwin/index.htm
[14] http://www.nhm.ac.uk/jdsml/research-curation/projects/tropical-land-snails/
[15] http://www.nhm.ac.uk/research-curation/projects/termites/
[16] A. R. Parker & H. E. Townley (2007) Biomimetics of photonic nanostructures *Nature Nanotechnology* 2, 347–353
[17] http://www.bionet-intl.org/opencms/opencms/caseStudies/caseStudies/case_0002.html
[18] Lindquist, D.A., Abusowa, M., & Hall, M.J.R. (1992) The New World screwworm fly in Libya: a review of its introduction and eradication. Medical and Veterinary Entomology 6, 2-8.
[19] http://archives.eppo.org/MEETINGS/2004_meetings/council_presentations/state_emergency.htm

3. *Does the way in which systematics research is organised and co-ordinated best meet the needs of the user community? What progress has been made in setting up a body to lead on this? What contribution do the leading systematics research institutions make both nationally and internationally?*

26. Stakeholders in taxonomy are diverse and international, ranging from scientists to policy makers, environmental managers, conservation specialists, education, amateur specialists and the public. With research expertise in a growing range of techniques, institutions such as the NHM must continue to be flexible in responding to different needs that will drive the development of taxonomy, with increasing emphasis on developing countries. Institutions must be innovative in engaging stakeholders.

27. NHM sees benefit in international coordination (with the UK playing a part) to deliver virtual research environments and collections that enable increased public use of taxonomy. Access to online taxonomic information will require online diagnostic services using morphological data (automated analyses of images), sequence data (automated assignment of specimens to taxa by sequence) and other modes. Better coordination of all forms of collection—including microbial—and information resources will optimise the infrastructure for taxonomy and science in general.

28. Projects are increasingly undertaken by distributed teams of taxonomists and international institutions are available to play a coordinating role: the UK participates in and benefits from these initiatives. In the UK, the Research Councils have funded e-systematics (such as Creating a Taxonomic e-Science (CATE)[20], which will link into the Encyclopedia of Life (EOL)) on a one-off basis. Sustainability and long-term delivery of research and information relies on participating institutions adopting such approaches as strategic priorities.

29. Funding for taxonomy from different sources in Government and elsewhere is not a disadvantage: it means that taxonomic institutions continually review their potential contributions to policy and to science as a whole. However, some organisations and initiatives assume, in developing strategic plans, that taxonomic research and infrastructure will be available to meet their needs. This assumption may mean that taxonomy is not mentioned—although clearly demanded by the objectives—or, if mentioned, there is no substantive discussion with the institutions providing taxonomic expertise and infrastructure. The previous Inquiry recommended better coordination of taxonomic users, led by government, which would lead to better definition of priorities, gaps and resource needs: this remains to be pursued but could develop a common strategic engagement with taxonomic institutions and infrastructures.

30. There is potential for better integration, rationalisation and optimisation of taxonomic services in the UK—there are small facilities in government departments such as Defra and elsewhere. There should be exploration of the US model of linking specialist staff to major facilities such as the NHM eg US Department of Agriculture (USDA) staff in the Smithsonian Institution.

4. *What level of funding would be needed to meet the need for taxonomic information now and in the future? Who should be providing this funding?*

And

5. *How does funding in other countries compare? Could there be more international collaboration? If so, what form should this collaboration take and how might it be achieved?*

31. Taxonomic information for the future will arise both from new research initiatives and from development of systems that capture, recombine and integrate available information. There are constraints on delivering integrated information: the roles of lead institutions are expanding but the resource for bridging the gap from innovative research to implementation of information infrastructures is not. There is growing international demand for capacity building, information access, support for local biodiversity conservation and other needs but limited resources to meet it.

32. Targeted intervention for taxonomy in the 1990s from NERC and the Wellcome Trust had impacts that are still seen in a small number of universities. However, this did not lead to a lasting understanding in funding agencies of the importance and benefits of taxonomy and as a consequence funding outside the NHM and the Royal Botanic Gardens in Kew and Edinburgh is fragmentary.

33. The USA National Science Foundation provides additional funding for taxonomy[21] through the Biodiversity Surveys and Inventories program of $6 million per year, with other systematics, phylogeny and taxonomy (including revisionary systematics) funding of $6 million per year[22]. The total NSF budget was $5.9

[20] http://www.cate-project.org/
[21] In addition to the funding provided to the Smithsonian Institution and other federal taxonomy providers such as USDA.
[22] Assembling the Tree of Life is separate, with $12 million per year

billion in 2007. The UK science budget in 2007–08 is £2.83 billion (excluding MRC): were the UK to provide the same level of targeted additional funding as the USA, it would allocate £5.76 million. Such a level of funding would develop UK capabilities more widely in the science base but would not fund the expansion of taxonomy in new forms to such as barcoding of life or research on ecosystem services.

6. *What impact have developments in DNA sequencing, genomics and other new technologies had on systematics research? In what way has systematics embraced new technologies and how can these research areas interact successfully and efficiently?*

34. The impacts of DNA technologies in phylogenetics have been considerable, to the extent that DNA data can be regarded very much as part of the taxonomic mainstream and contributes to a creative set of scientific questions about evolution, origins and diversity. Image capture and analysis has not yet had high impact but automated identification using this technology is developing.

35. The NERC Science Theme Report on Biodiversity[23] says "Systematics and taxonomy are essential underpinning for any work on biodiversity. There are a number of challenges and opportunities for systematic biology including e-science, DNA barcoding, and providing increased human capacity to reverse declining taxonomic expertise."

36. A major development has been the use of short DNA sequences in the form of molecular "barcodes" to transform the identification and even discovery of species. NHM is a founding member of the Consortium for the Barcoding of Life (CBoL)[24], which is "developing DNA barcoding as a global standard for the identification of biological species". NHM hosted the first international scientific conference. These techniques and data will gradually be integrated into taxonomy as a whole. Sequencing capacity is adequate for an expansion of barcoding to a much larger scale but resources for specimen collection and processing are not.

37. The impacts of new technologies in systematic phylogenetics are seen in the literature in abundance: we have seen a transition from sequencing for its own sake to a more creative set of scientific questions about evolution, origins and diversity. Taxonomy and systematics will continue to engage with new opportunities as they emerge, just as in many other areas of science. The discussion in section 1 above refers to the integrated development of taxonomy and systematics that includes both existing applications and new techniques.

Data collection, management, maintenance and dissemination

7. Does the way in which taxonomic data is collected, managed and maintained best meet the needs of the user community? What is the state of local and national recording schemes?

38. New technology is leading to improvements in information delivery and analysis. The range of initiatives involving taxonomic data is wide: climate change, invasive species, biodiversity conservation, ecosystem management and biosecurity mean growing interests in global data. NHM is working in partnership to build and operate several international initiatives to meet this need.

39. The following are needed for taxonomic data development:

- Significantly larger biodiversity informatics capability to deal with data from fast DNA sequencing for taxonomy and other activities. Storage capacities will need to expand but costs are likely to fall.
- Information in open access formats. Heritage data transformed into digital form.
- Standard ontologies to ensure consistency in data management and interpretation. A unique identifier system for different data types; different naming systems will coexist.
- Collecting will be essential but may be automated by new technology.
- A common system of geographical data for use with taxonomy.

40. A foundation of databases of names, checked for stability and linked to colloquial names, is required by many users including for both scientific and legal purposes. The NHM has provided the species dictionary for the National Biodiversity Network (NBN)[25] and works on standardisation of terminologies and data standards through the group Biodiversity Information Standards (TDWG)[26]. With Species 2000, RBG Kew, RBG Edinburgh, Cardiff University and CABI, NHM is seeking funding to provide a list of names of all known species on earth—the Catalogue of Life.

[23] NERC Science Theme Report: Biodiversity November 2007
[24] http://barcoding.si.edu/
[25] http://nbn.nhm.ac.uk/nhm/
[26] http://www.tdwg.org/

41. Biodiversity information is made available through the Global Biodiversity Information Facility,[27] and there is future potential in the Encyclopedia of Life, that aims to make all key information about every living species accessible to all[28] through databases and web pages. The NHM is a partner in providing taxonomic information through the Biodiversity Heritage Library[29], which will provide over two million digital volumes to support the work of taxonomists and others.

42. The systems depend on commitment beyond initial funded development; institutions such as the NHM increasingly commit resources to data entry, quality control, IT infrastructures and support and data management. The eventual costs are not always clear because the rapid development of technology can change costs. There is in some cases a commitment to institutional strategic alignment. There is not yet a consensus on how to give appropriate academic credit to research scientists for adding value to data holdings.

43. There is a need for coordination in the UK and more widely for the development of information infrastructures: taxonomy in this sense can be compared to other areas of science such as earth observation or long-term surveys. The population and management of larger scale datasets and strategic integration of these activities is happening, particularly in Europe and between Europe and the USA, but is limited by the resources of the collaborating institutions—if a transformation in the volume and utility of information is to happen, coordination will be of increasing importance.

44. More than 60,000 people are regularly involved in biological recording in the UK, mostly on a volunteer basis, and these efforts have provided over 60 million individual wildlife observations. Many participants are amateurs. The NHM is active in developing its approach to serving amateur interests with its new Darwin Centre and initiatives such as the OPAL project.

8. *What is the role of the major regional museums and collections? How are taxonomic collections curated and funded?*

45. Many areas of science depend on infrastructure. Taxonomy's infrastructure is a sophisticated organisation of collections, libraries and data which are often provided by museums. There is a need in the UK to define important collections for taxonomy, whether in national museums, regional museums, university departments or smaller collections: all of these should be drawn into a common system of access for research and harmonised information provision, which requires resources.

46. Being a museum gives the NHM opportunities to engage amateur experts and wider audiences with collections and expertise; the aim is to develop understanding and involvement in the natural world and in science. The combination of active research, well-curated collections, libraries and analytical facilities means that the NHM is attractive for international research visitors—more than 8,000 each year. The EU-funded SYNTHESYS[30] gives access for scientists to European collections and enables common standards to be developed: The UK partners (NHM, RBG Kew and RBG Edinburgh) received more than twice the number of applications for access than any of the other ten countries involved.

47. Museums need to be a focus for collecting in the future. There is potential for collaboration on coordinated approaches and common facilities—for example in forming consortia for new storage facilities for tissues and microbial diversity with universities and others. The strength of museums as foci for public engagement will mean that they can play an important role in receipt and longer-term use of collections from ecological surveys and observation, but resources will be an issue for all. The scientific value provided by the NHM arises from both research and curation staff: they have essential contributions to make to taxonomy and information needed by stakeholders.

48. Museums have an additional value in being integrated with the cultural sector, which gives opportunities for engagement with other academic areas and to generate public interest in science and the natural world. AHRC is funding collaboration between NHM and Kingston University, scoping the use of taxonomic collections for research in history, art and social sciences.

9. *What progress has been made in developing a web-based taxonomy? How do such initiatives fit in with meeting demand for systematics and taxonomy information? How do UK-led initiatives fit in with international initiatives and is there sufficient collaboration?*

And

[27] http://www.gbif.org/
[28] http://www.eol.org/home.html
[29] http://www.biodiversitylibrary.org/
[30] http://www.synthesys.info/

10. *What needs to be done to ensure that web-based taxonomy information is of high quality, reliable and user-friendly?*

49. Taxonomy as an information science is expanding, with web innovation at the core. The web allows huge amounts of diffuse information to be organised and used in new ways, creating links and allowing new datasets to be assembled from taxonomic data of known quality and provenance. It will be important in particular to combine existing information with the anticipated large numbers of molecular data to enable new scientific research.

50. The NERC-funded Creating a Taxonomic e-Science[31] (CATE) project is to producing a computer application to build demonstrator web-based taxonomies for two conspicuous groups of organisms: Hawkmoths (Sphingidae) and Aroids (Araceae). CATE is a collaborative project between NHM (lead institute), RBG Kew, and Oxford University. EDIT[32] is providing an environment for integrated European web-taxonomy, with the systems for revisionary taxonomy NHM-led. A particular innovation is the development of scratchpads which create flexible spaces for taxonomists to collaborate[33]

51. Resource availability in Europe and the US tend to mean that international initiatives are generally larger and more diverse than those in the UK. Although UK institutions are active and influential in Europe and beyond, resources for collaboration in the UK are limited and the scope for engagement within the UK science base and with smaller collections institutions is correspondingly smaller.

52. The Web is leading to a transformation in the publication of taxonomy—Zootaxa is a good example of a rapidly growing e-journal[34] with growing impact and international involvement.

53. Quality, reliability and user needs are central to the initiatives mentioned. A major risk to web-based taxonomy is that inaccurate information can be disseminated if control systems and expert taxonomists are not fully involved. Peer review, institutional and funder responsibility, engagement and ongoing development with users are all necessary. Business models are developed to ensure sustainability: ultimately the commitment of participating institutions is essential.

11. *How does the taxonomic community engage with the non-taxonomic community? What role do field studies play?*

54. Natural history museums have lengthy histories of providing active involvement for the public and specialists and professionals in other fields with taxonomists. Galleries, publications, events, outreach, education, websites, professional training, consultancy and many other examples are available.

55. NHM collaborated with Lancaster University[35] with ESRC funding on the development of strategies for engaging amateurs as experts in natural history. This experience has been built into the UK Lottery-funded Open Air Laboratories (OPAL), which will support, build capacity and enhance the profile of amateur naturalists and voluntary groups.

56. NHM has worked as part of the Riverfly Partnership[36] to train over 500 anglers in identification skills that have enabled them to monitor and address declines in riverfly populations, including declines in overall abundance and threats to individual species. This has been achieved by bringing together a small number of taxonomists with the anglers, conservationists, watercourse managers to increased knowledge of riverfly populations.

[31] http://www.cate-project.org/
[32] http://www.e-taxonomy.eu/
[33] http://www.editwebrevisions.info/scratchpads
[34] http://www.mapress.com/zootaxa/support/Statistics.htm
[35] http://www.lancs.ac.uk/fss/projects/ieppp/amateurs/resources.htm
[36] www.riverflies.org

Skills base

12. *What are the numbers and ages of trained taxonomists working in UK universities and other organisations?*

And

13. *What is the state of training and education in systematics and taxonomy? Are there any gaps in capacity? Is the number of taxonomists in post, and those that are being trained, sufficient to meet current and future needs across all taxonomic subject areas?*

57. Data on UK taxonomists are given under question 1. The cohort of systematists approaching retirement includes many taxon specialists: younger systematists tend to have been trained in a more hypothesis-driven environment, sometimes with a molecular perspective. Although taxonomy is changing there will continue to be a need for morphological skills. Moving taxonomy to the internet will help keep a virtual knowledge base alive but the apparent decline of taxon specialists is a concern.

58. NHM does not have difficulty in recruiting taxonomists: a majority of applicants for new posts are based overseas. Considerations in making appointments include the potential for producing research outputs of high quality, securing competitive grants, deriving value from working with collections and other considerations: descriptive taxonomy will generally be only one among several factors considered.

59. In the USA the NSF PEET[37] programme supports research on the taxonomy of poorly known groups of organisms, trains new taxonomic experts, and encourages development and use of web-accessible taxonomic resources and products: this is in addition to museum funding. PEET is explicitly in response to "retirement of taxonomic specialists, shifts in academic recruitment and staffing, and reductions in graduate training" that "impede biodiversity research and conservation".

60. The NHM offers student training in taxonomy through the MSc[38] on Advanced Methods in Taxonomy and Systematics run with Imperial College. It is also involved in supervision of 150 PhD students at any one time, providing more than £100,000 each year for CASE studentships and a number of fully-funded students. Taxonomy for undergraduates could be achieved through summer schools, given the reduction in university capacity in recent years.

4 February 2008

Memorandum by the Royal Botanic Garden Edinburgh

Background

As the Royal Botanic Garden Edinburgh has contributed to a wider response submitted by *The UK Biodiversity Research Advisory Group* and *The Global Biodiversity Sub-Committee* of the UK GECC, this submission focuses on the Royal Botanic Garden Edinburgh and its role.

The state of systematics and taxonomy research

1. *What is the state of systematics research and taxonomy in the UK? What are the current research priorities? What are the barriers, if any, to delivering these priorities?*

1a. It is disappointing to report that the state of systematics research and taxonomy has changed little since the review of 2002, with a continued decline in university sector and with expertise largely held now in the taxonomic institutes, the Natural History Museum (NHM), Royal Botanic Gardens, Kew (RBGK), Royal Botanic Garden Edinburgh (RBGE) and CABI, with a few individuals in other institutes and museums.

1b. With respect to cryptogamic plants (ie autotrophic organisms that do not produce seeds) and fungi, UK systematics research and taxonomy are very patchy in coverage, quality and achievements. Many individuals and small groups are highly respected, both nationally and internationally. They make valued contributions to the discovery, description and cataloguing of cryptogam diversity, they examine the evolution and speciation of cryptogams, to provide basic understanding of the origins and maintenance of cryptogam biodiversity, and they provide identification tools and services for fellow professionals and amateurs. Current research priorities are more diverse than in flowering plants and metazoa, partly because of the more primitive state of the field. Aspects that have approached consensus in many macroscopic organisms (such as the nature

[37] http://www.nhm.ku.edu/peet/
[38] http://www.nhm.ac.uk/research-curation/postgraduate/msc/index.html

and circumscription of species) remain controversial in most cryptogam groups and they therefore remain the focus of research. But it has also been important for the health of the subject to engage with advances in molecular technology, for classification and identification. Outside the principal taxonomic research institutes and in the universities, taxonomic and systematic research on cryptogams is almost defunct; the principal exceptions are a few species (eg among phytoplankton) that have reached 'model system' status because of current perceptions of their ecological or economic importance.

1c. At RBGE staff numbers with expertise in systematics and taxonomy have been maintained (but not expanded). Following retirements, there has continued to be healthy recruitment in the area of flowering plants systematics, but for cryptogamic plants and fungi, recruitment and succession present a greater challenge; across the UK there are very few individuals being trained in these specialisms, and the cohort of expertise at RBGE is approaching retirement age within the next five years. However, it has been possible to make significant improvements with relatively small investments, as demonstrated by the revival of lichenology in Scotland. In 2002, RBGE employed one lichen taxonomist, and there was a dearth of taxonomic expertise in Scotland and the UK to deliver national conservation targets in lichenology. Succession planning at RBGE through investment in one extra post has capitalised on the opportunity for collaboration between the lichen taxonomist and a lichen ecologist, invigorating research in lichen biodiversity, conservation biology and climate impacts. More recently RBGE's two lichenologists have won external funding for post doctoral research and they supervise PhD and MSc studentships, further extending the UK capacity in the discipline. Scottish Natural Heritage (SNH) provided funds to the British Lichen Society to support the training of lichen apprentices, led by the RBGE taxonomist. The apprentice programme has provided a core of individuals capable of making conservation assessments and delivering site condition monitoring for lichens. Similar investment is needed at RBGE so that a new generation of researchers in other specialisms in cryptogamic plants and fungi can be trained in post by the current cohort of experts.

1d. There continues to be no UK-wide strategic plan for systematics and taxonomic research (but see response to Question 3). This reflects the fact that the three major taxonomic institutions (NHM, RBGE, RBGK) are funded through different areas of government (DCMS, Defra and Scottish Government), and each has its individual research priorities. The three institutions have active dialogue, and maintain complementary areas of expertise with a broad range of taxonomic capacity across the UK.

1e. The research priorities for RBGE as summarised as

- Conserving biodiversity in the face of global environmental change and mass extinction,
- Provision of baseline taxonomic/botanical data as a foundation science,
- Understanding the evolutionary processes that have given rise to the world's diversity.

A strategic theme in our new Corporate Plan is to *Increase Response to Global Environmental Challenges*—to contribute directly, and in partnership with others, to solutions to the challenges of climate change, biodiversity loss and plant extinction. We aim to build on our track record in research, conservation, education and public engagement so that the public are better informed and become empowered to make changes towards more sustainable ways of living. RBGE will position itself as a catalyst for change through its scientific endeavours and education programmes.

2. *What is the role of systematics and taxonomy and, in particular, in what way do they contribute to research areas such as biodiversity conservation, ecosystem services and climate change? How important is this contribution and how is it recognised in the funding process? How is systematics integrated in other areas of research?*

2a. Systematics and taxonomy provide fundamental knowledge about the nature and origins of life on earth. In doing so, they provide essential underpinning for almost all other biological research and for communication about all aspects of biodiversity. The value of biological data and analyses is fundamentally and inevitably limited by the quality of the taxonomy that was applied (implicitly or explicitly) during data acquisition, by how well it was applied (were identifications correct?), and by how stable the taxonomy in time and space.

2b. The primary importance of systematics and taxonomy to biodiversity conservation, ecosystem services and climate change is recognised in the Convention of Biological Diversity (CBD), with specific reference to the challenge of the 'taxonomic impediment'.

2c. The state of cryptogam taxonomy is highly variable, but we can generalise that it limits dependent research more strongly than does the taxonomy of angiosperms, vertebrates and some invertebrates, especially those species that occur in the UK. Many cryptogams and fungi perform important ecosystem services (eg approx. 50 per cent of net global net photosynthesis, as components of mycorrhiza in terrestrial plant communities), while lichens and diatom microalgae are especially important as ecological indicators (eg for pollution and

climate change). These contributions are increasingly well recognised but have not been translated into support for taxonomy. Basic descriptive taxonomy is lacking for many microalgae and related protists, and even in better studied groups (eg diatoms, bryophytes) recent DNA 'bar-code' studies have shown that the basic taxonomy significantly underestimates ecologically relevant species-level biodiversity. We have no doubt that the quality and long-term value of research is being compromised by the state of cryptogam taxonomy. Most of the funding for basic research in cryptogam systematics and taxonomy in the UK is now provided through the principal taxonomic research institutes (RBGK, RBGE, NHM). In addition, some support comes indirectly as part of ecological or palaeoecological studies (eg during NERC-funded research on environmental change using diatoms). Such work is largely unplanned and is done *ad hoc*, often by taxonomically untrained researchers, eg to allow rational decisions to be made about counting units. Very few taxonomy- or systematics-related projects on cryptogams have been funded directly by the research councils. Research funding is accessible through the Research Councils and both NERC and BBSRC have prioritised support for innovatory tools and subjects for biodiversity. Whilst supporting outcomes from systematics and taxonomic research, this funding in itself does not support the fundamental underlying taxonomic work. Examples include a NERC Fellowship in diatom speciation and bar-coding, and a BBSRC Bioinformatics project on automated identification of microalgae. These are welcome, but give only limited support to taxonomy per se; instead they depend on the prior existence of taxonomic expertise and resources to support and define the research programme. The lack of appropriate information on biodiversity was highlighted in the development of the recent MONARCH report (Walmsley, C.A. *et al*. 2007. MONARCH—Modelling Natural Resource Responses to Climate Change—a synthesis for biodiversity conservation. UKCIP, Oxford). The project set out to study the impacts of climate change on 120 BAP (Biodiversity Action Plan) species, but was able to report only on 32 species. Consultation with taxonomic experts showed that for the majority of species critical biological and autecological data had been missed.

2d. In the review of eligibility to research council funding in 2006, NHM, RBGK and RBGE became ineligible for responsive mode funding from BBSRC. This put a halt on proposals submitted or under development. On appeal, all three institutes now have access to this funding stream; both NERC and BBSRC have clarified their commitment to biodiversity research. This is greatly welcomed.

2e. A challenge for taxonomists has been to use their expertise to provide support to national and international conservation strategies; this has been successful through partnerships in the UK with the conservation agencies, for example, The Plant Conservation Working Group (http://rbg-web2.rbge.org.uk/pcwg/), or overseas through Darwin Initiative partnerships (see Wortley A.H. & Wilkie, P. 2005. *Thematic review of Darwin Initiative's contribution to the Global Taxonomy Initiative*, Defra, ECTF).

3. *Does the way in which systematics research is organised and co-ordinated best meet the needs of the user community? What progress has been made in setting up a body to lead on this? What contribution do the leading systematics research institutions make both nationally and internationally?*

3a. No body has been set up to lead on this, but there is coordination, for example, within *The Global Biodiversity Sub-Committee* of the UK GECC, where all three major taxonomic institutions are represented, and several funders of biodiversity research, including government departments and research councils. The committee has recently reviewed the capacity in mycology in the UK. There is also coordination at Director level and within research groups between NHM, RBGK and RBGE for plants but there remains a huge challenge for continued work in mycology and cryptogamic plants. There are at least two issues here: (1) organisation and co-ordination of systematics research, and (2) interactions between an organised systematics community and the user community. With respect to cryptogam systematics, for each major group of organisms—for example, lichens, bryophytes, algae—valuable interactions between users and the relevant fragment of the systematics community are mediated by national societies, viz. British Phycological Society, British Lichen Society, British Mycological Society, British Bryological Society, and British Pteridological Society. The contacts that these societies help to maintain, together with personal friendships and collaborations, ensure that taxonomists are usually well aware of the needs and frustrations of many current and potential users. The challenge for the institutions is to evaluate and assess the priorities, and provide resources for the taxonomists to respond to the user-community.

3b. Links between systematics research institutes and universities could be improved. Our experience is that it is very easy for the systematics institutes to become isolated from the university community, especially now that there are so few systematists active in UK universities. We have found that valuable links can be developed, but usually only in relation to topical issues (eg shape and pattern recognition, genome evolution, climate change) far removed from the basic taxonomy that still needs to be done in many cryptogam groups.

3c. We have been impressed by the momentum given to systematics in the USA by the Partnership for Enhancing Expertise in Taxonomy (PEET) initiative, and by the Canadian Barcode of Life (CBOL) programme.

3d. Nationally, the leading systematics institutions play a central role in systematic and taxonomic research. Internationally, although some individuals remain competitive in quality, output and innovation, UK institutions' research capacity and reputation has declined in recent years, relative to some institutions in the US, Europe and Japan.

4. *What level of funding would be needed to meet the need for taxonomic information now and in the future? Who should be providing this funding?*

4a. There is a clear need for a large one-off cash injection to deliver digitisation and data-basing (with geo-referencing) of collections now, and for this to be completed in a short time period. Otherwise this issue will rumble on for decades and divert resources from writing taxonomic accounts. This funding can only be provided through central government. Funding by US Foundations, like the Mellon Foundation for digitisation of Africa plant type specimens (www.aluka.org), demonstrates the great value of immediate world wide web access to this type of information.

4b. Most of the cryptogam work that needs to be done is fundamental research to underpin national research and environmental protection. As such, it seems to us that central government is primarily responsible for funding. Since most of the research uses existing research tools and (although often intellectually challenging) rarely introduces or tests novel concepts, we anticipate that research council funds can play only a minor role, unless council policies change significantly. Institutional funding seems the most efficient conduit for funds to cryptogam taxonomy, but there would need to be mechanisms developed for coordination between the departments responsible for RBGK, RBGE and NHM, and the institutes themselves, and with other institutes with relevant activities, such as the National Museum of Scotland, Culture Collection of Algae and Protozoa, CABI, Plymouth Marine Laboratory, etc.

5. *How does funding in other countries compare? Could there be more international collaboration? If so, what form should this collaboration take and how might it be achieved?*

5a. 'External' funding is far better in the USA for systematics, with NSF having a specific systematics panel, another panel for inventory work, and special programmes for the Tree of Life and Planetary Biodiversity Inventories (modern 'team' monographs). There is a clear danger that UK and EU systematics will start to lag even further behind the USA; a clear pattern is developing of increasing numbers of UK researchers trying to develop collaborations with US workers to tap into enlightened programmes there (but the UK does not emerge with the major credit as we cannot lead these grants). The USA has taken steps via the PEET initiative to train new taxonomists though it is not yet clear whether this will have any long-term effect (especially given the recent upheavals at major institutions, eg at the Smithsonian or the Academy of Natural Sciences of Philadelphia). Recently, the Canadian government has invested heavily in the Barcode initiative, which creates major opportunities for spin-off research as well as temporary employment for molecular systematists. From examining outputs at conferences and publications, we estimate that funding is declining in most places, even in countries such as in the former eastern bloc that were traditionally very strong in 'classical' taxonomy.

5b. Through SYNTHESYS, EDIT, Marie-Curie etc., EU funding initiatives mainly support better communication between countries, or support the development and management of natural history collections, with some short term research access for taxonomists to collections.

5c. There could undoubtedly be more international collaboration. For example, the Barcode of Life project is intended to be multinational. However, international collaborations can only work if there is a national commitment of funds, either direct to individual research groups to allow them to perform their part of an international programme, or indirect, via an international funding agency. For some cryptogams we have world-leading expertise on DNA barcoding, but there is no obvious way to fund a continuing leading role. International collaborations usually develop only when local funding and resources are secure.

6. *What impact have developments in DNA sequencing, genomics and other new technologies had on systematics research? In what way has systematics embraced new technologies and how can these research areas interact successfully and efficiently?*

6a. The impact has been huge, on every aspect of our work. Systematics is excellent at embracing new technology, but there is a lack of understanding that when a new technology is taken on, an old one (specifically morphology) cannot be discarded. So there are always resource implications. DNA sequencing, decreasing in cost and increasing in speed offers massive promise to accelerate species delimitation and identification, but this work will need resourcing. DNA sequencing and genotyping are transforming our understanding of relationships, evolution and population biology in cryptogams. IT is transforming our ability to communicate taxonomic information. The impact of improved knowledge derived from angiosperm phylogeny has resulted in the re-organisation of the collections in the herbarium at RBGE (see Haston, E. *et al*. 2007. "A linear sequence of Angiosperm Phylogeny Group II families". *Taxon* 56 (1): 7–12), and the re-labelling of living plants throughout RBGE's four gardens.

6b. Overall, we do not think that embracing new technologies and finding imaginative uses for them is a major problem; nor is finding partners to investigate novel approaches, eg in automated identification. However, better links with universities—especially with non-biological departments—would be advantageous. For RBGE, the obvious partner is usually the University of Edinburgh.

Data collection, management, maintenance and dissemination

7. *Does the way in which taxonomic data is collected, managed and maintained best meet the needs of the user community? What is the state of local and national recording schemes?*

7a. Local and national recording schemes are maintained largely through NGOs and national societies like the Botanical Society of the British Isles, British Phycological Society, British Lichen Society, British Mycological Society, British Bryological Society, and British Pteridological Society. Taxonomic specialists in the institutes support this activity through verifications and enabling access to the herbarium collections; the conservation agencies (eg SNH) have provided funding to transfer paper records to electronic format, to make these available through NBN, the National Biodiversity Network. For lichens, RBGE's taxonomist provides verifications and maintains the UK checklist and red data book.

8. *What is the role of the major regional museums and collections? How are taxonomic collections curated and funded?*

8a. Universities have in many cases been disposing of their collections; for example, all the overseas accessions of cryptogamic plants and fungi at Glasgow University were recently transferred to RBGE—the flowering plants had already been transferred some 20 years previously. The collections of cryptogams in regional museums are often in a poor state. Cryptogam literature and resources are widely scattered, curators cannot keep abreast of taxonomic developments, and have little time to check identifications; the focus of regional museums is often on display and education. There is scope for rationalising the distribution of cryptogam collections among UK institutions. At present it is not cost-effective to use many collections, which are therefore effectively redundant.

9. *What progress has been made in developing a web-based taxonomy? How do such initiatives fit in with meeting demand for systematics and taxonomy information? How do UK-led initiatives fit in with international initiatives and is there sufficient collaboration?—GTI, GBIF*

9a. Whilst the web is essential and central to delivering taxonomic information, it is false to believe it can accelerate the taxonomic enterprise greatly. However, with the increasing use of databases in floristics and monographic research, the products of research can more easily be designed to meet the needs of target audiences, whether to provide access to data through GBIF or produce on-line identification tools.

10. *What needs to be done to ensure that web-based taxonomy information is of high quality, reliable and user-friendly?*

10a. The role of the taxonomist is primarily to ensure the quality and reliability of the data, but engagement with the user community is essential to ensure the design of the output meets their needs.

11. *How does the taxonomic community engage with the non-taxonomic community? What role do field studies play?*

11a. The taxonomic community is strongly engaged with the non-taxonomic community, for example, through its support for conservation action in partnership with conservation agencies, NGOs, landowners and the public. There is close collaboration with the national specialist societies, where field studies are often an integral part of that collaboration. At RBGE the Gateway development (due to open in 2009) will provide a new opportunity for engagement with the public on biodiversity conservation, global change and sustainability.

Skills base

12. *What are the numbers and ages of trained taxonomists working in UK universities and other organisations?*

12a. No detailed review has taken place since that by the UK Systematics Forum, *The Web of Life: a Strategy for Systematic Biology in the United Kingdom* (http://www.nhm.ac.uk/hosted_sites/uksf/web_of_life/summary/index.htm). This report provides figures on training and education and the numbers have declined further since the late 1990s, when this report was written.

13. *What is the state of training and education in systematics and taxonomy? Are there any gaps in capacity? Is the number of taxonomists in post, and those that are being trained, sufficient to meet current and future needs across all taxonomic subject areas?*

13a. With the retreat from systematics in the Universities, training and education in whole organism biology and systematics and taxonomy is increasingly falling onto the taxonomic institutes, thus increasing the work load of the remaining cohort. Perhaps of even more significance it the lack of training in whole plant biology throughout the schools and undergraduate curricula. The recent cut in funding to SAPS—Science and Plants for Schools, by the Gatsby Foundation is regretted. This has been a very successful initiative, providing support to teachers and technicians in the delivery of plant biology from the primary level, and secondary to undergraduate levels. The Gatsby summer school for undergraduates will continue, but without further support and lobbying to get plants integrated into the primary and secondary curricula, there will be fewer students engaged with plant science to even consider this as a university subject.

13b. The three UK MSc courses in biosystematics and taxonomy all involve partnership between research institutes and universities. The University of Edinburgh/RBGE MSc in *Plant (and fungal) biodiversity and taxonomy* is supported through six NERC studentships and regularly has c.16 participants from the UK and overseas, and we supervise > 20 PhD students each year. Across the UK too few are being trained in cryptogamic plants and fungi, with the consequence that when employment opportunities do arrive it is more likely that these will be taken up by people trained overseas. This can have severe consequences for long term stability in both collections management and research, as seen in the case of lichenology at the NHM, where there have been three lichen curators since 2000, all from overseas, and who have each returned home after 2–3 years in post. Succession planning in these disciplines is difficult, and there need to be sufficient resources for a continuation of the approach described in lichenology at RBGE (see Question 1). In the end training will be successful only if there are jobs to apply for.

4 February 2008

Memorandum by the Royal Botanic Gardens, Kew (RBGK)

Summary:

Taxonomy on a scale commensurate with today's needs should be a "megascience", but taxonomy and systematics have continued to be funded as if they are a marginal activity, instead of being viewed as central to meeting the crises of climate change and past ecosystem abuse. The general situation in the UK is one in which the rate of change (and there has been some) is too slow relative to the scale of problems faced. Support for technological advances (laboratory techniques/electronic resources) in areas allied to taxonomy is improving, but there has been no improvement in the numbers of taxonomists being trained. Some critically important areas are still experiencing declines in numbers of practicing taxonomists. In the case of mycology, the situation is so grave as to be generally recognised as a crisis (see separate submission on which RBGK had input: Response from mycology sub-committee of UK-BRAG). Support for collections and core taxonomic activity generally has not improved, and for RBG Kew, grant-in-aid has decreased in real terms.

Demand for easily accessible, user-friendly and tailored taxonomic information is greater than ever. There are also growing expectations of the major taxonomic institutions to respond to the challenges of global environmental change and the commitments of the Convention on Biological Diversity.

UK taxonomists have risen to the new challenges in many instances and can demonstrate significant success in securing resources and responding to new opportunities and user needs. However, the gap between expectations and available resources continues to widen. Unless additional government support is forthcoming, the UK risks losing an opportunity to capitalise on its world class collections and expertise to make a significant science-based contribution to addressing the global environmental crisis.

1.1. *What is the state of systematics research and taxonomy in the UK?*

1.1.1. Some significant positive changes have occurred in the period following the last review in 2001-02. Grant-in-aid funding to major institutions was increased; funding for the Darwin Initiative was increased to £7 million per annum enabling support of many more projects in developing countries; BBSRC agreed to recognise RBG Kew and RBGE as eligible for responsive mode funding; significant steps have been taken towards piloting a web-based taxonomy for the future, with support from the EU and NERC among others; and digitisation of key research materials for taxonomy has advanced rapidly with support from GBIF and private US foundations.

1.1.2. However, many of these developments have been short-term in effect, rather than medium-to long-term, which is essential to put taxonomy and systematics on a more sustainable footing. For example, the £3 million increase in grant-in-aid to RBG Kew in 2003 brought us back to 1996 levels of funding in real terms, but has since been eroded by inflation during successive years of flat or declining grant-in-aid; EU support for web-taxonomy through EDIT is primarily for networking and enhancing integration rather than for actual web-based research; GBIF has picked off the "low-hanging fruit" of biodiversity information and now faces the challenge of scaling up to capture the great bulk of data not yet converted to digital form; US funding has enabled digitisation of type material of plants in UK collections at a hitherto unprecedented scale, but current rates of funding are unlikely to extend to digitisation of the non-type material that forms the majority of our world-class collections.

1.2. *What are the current research priorities?*

1.2.1. In general, research priorities for the field have not changed a great deal in the past five years; they are still focused on describing the diversity of life on Earth, how this diversity came to be and its current status, along with addressing more applied aspects such as how the known organismal diversity can be used more sustainably and conserved for future generations. Most recently, major institutions (including RBGK) have been re-focusing efforts on documenting the effects of climate change on the distribution of biodiversity and predicting the effect of future change. Restoration ecology is also being viewed as an essential component of efforts to conserve plant diversity through seed-banking and other activities.

1.3. *What are the current barriers, if any, to delivering these priorities?*

1.3.1. Current barriers include poor perceptions of taxonomy as a science, especially within the university sector, a lack of trained practitioners in certain key groups and a severe shortage of funding both for maintenance of collections upon which the science depends and expanding of research based on them. These factors are, of course, strongly inter-related, but will be treated separately in the paragraphs that follow.

1.3.2. Names of organisms are hypotheses that are subject to revision as new information is uncovered—taxonomy is scientific. However in terms of the way research output is measured within the UK university sector, taxonomy is simply not viewed as real science because the journals in which taxonomic treatments are published have no or low citation ratings. The RAE criteria provide a strong disincentive for universities to support taxonomic research and training. This in turn has an impact on museums and herbaria that cannot produce new taxonomists/systematists without the support of the universities, not least because most museums and herbaria cannot award degrees. In addition, if we wish to promote "e-taxonomy" (see 9 below), then publication on-line must be considered significant output, which is not presently the case.

1.3.3. Current levels of funding to the major institutions are far below the levels required to meet their statutory obligations in a comprehensive fashion, let alone address new challenges posed by global environmental change, to which these institutions have an important contribution to make. Although substantial progress has been made in diversifying funding sources, experience has shown that these additional sources complement rather than replace the core-funding that government provides through grant-in-aid.

1.3.4. For example, the £10 million raised by the Kew Foundation in 2006/07 from individuals, companies and charitable trusts and foundations was primarily for specific time-bound projects, both operating and capital, that enhanced Kew's ability to deliver its mission. Given the nature and interests of the sources, securing such third party funding for ongoing operating costs, such as collections maintenance, is simply not possible at the scale that would be required to compensate for the declining value of the grant-in-aid. Defra's grant-in-aid to Kew now contributes about half of Kew's expenditure.

1.3.5. Furthermore, although there has been significant success in securing new funding streams to help address new challenges, the medium-to long-term outcome of these successes often involves additional operating costs that cannot always be recovered from the project funder. For example, Kew's major drive towards collections digitisation has been largely funded from charitable sources, but the growing digital collections represent a further asset that Kew has a responsibility to maintain without a guaranteed income stream to support this new activity.

1.3.6. In certain taxonomic fields, decline of taxonomy as a whole is now being reflected in a lack of availability of trained practitioners capable of delivering programmes addressing current research priorities. For example, in recent years Kew has advertised but failed to fill senior position in grass systematics and mycology, because of a lack of suitably qualified and experienced candidates.

1.3.7. Legislation restricting access to biodiversity resources in general and genetic resources in particular, presents a significant barrier to the transfer and exchange of the scientific study materials on which taxonomic research is based. Measures designed to prevent biopiracy have frequently resulted in perverse outcomes, at worst deterring scientists from engaging in research topics of great potential, and at best involving significant additional overheads and time constraints to fieldwork and material exchange.

2.1. *What is the role of systematics and taxonomy and, in particular, in what way do they contribute to research areas such as biodiversity conservation, ecosystem services and climate change.*

2.1.1. Taxonomy and systematics contributes fundamental, baseline information to other fields such as conservation, ecosystem services and climate change; as a minimum, which species were present and where.

2.1.2. The task of halting biodiversity loss by 2010, as agreed by the EU, is impossible if we cannot establish baseline data, and we may fail to achieve this target simply because so few resources are available to support collection of these data. Vascular plants and vertebrates fare relatively well, but most other groups of organisms are poorly documented. In fact, current knowledge is so poor that, even for the relatively well known groups such as vascular plants, we will not be able to say whether or not we have met the less ambitious target adopted by the CBD, of reducing the rate of loss of biodiversity by 2010. Effective conservation analysis and action at a variety of scales depends directly on the biodiversity information provided by taxonomists. For example, the success of Kew's Millennium Seed Bank Project in *ex situ* conservation of seeds of endangered, endemic and economically important plant species depends on a major data gathering and analysis operation in the Kew Herbarium, based on collections data from sub-Saharan Africa.

2.1.3. An understanding of mycological diversity and their fundamental role in ecosystem stability and productivity is essential to development of any meaningful evaluation of ecosystem servicing of human needs.

2.1.4. Taxonomic collections, publications and databases contain a wealth of information relevant to enhanced understanding of climate change. The next generation of climate change models are anticipated to include a much more sophisticated approach to vegetation, underpinned by data collected, organised and maintained by taxonomists. Furthermore detailed analysis of extant genetic variation incorporated into models of climate change, is expected to increase our ability to model and predict the likely impacts of future climate change.

2.2. *How important is this contribution and how is it recognised?*

Names are tools to access and integrate the wealth of biodiversity information that already exists, but without national and international lists of accepted names and their synonyms, we cannot make real progress in addressing all the other areas that depend on baseline data. Baseline data are essential, and, judged by the levels of funding available in the UK/EU, the importance of the contribution by those collecting and synthesising such fundamental data is not being recognised.

2.3. *How is systematics integrated into other areas of research?*

We are encouraged that there seems to be an increasing articulation of the need for baseline data, so that they can be better integrated in other types of research, but funding opportunities to support and develop it are still woefully few. Increasingly we also envisage a need for multidisciplinary practitioners, with a grounding in taxonomy, sufficient to ensure that the strengths and limitations of the taxonomic data made available and used within other areas of research are fully understood, and that the data are interpreted and used appropriately.

3.3. *What contribution do the leading systematics research institutions make nationally and internationally to meet the needs of the user community?*

Demand for baseline data vastly outstrips supply, and delivery is constrained by funding that is not rising at a rate sufficient to meet demand. RBGK works in the UK and internationally, to meet the needs of the vast user community by providing electronic resources and physical access to collections, as resources permit. Users are diverse in their focus, need and geographical location, e. g. UK and EU customs officers implementing CITES, staff of conservation NGOs in Africa developing management plans for actual or potential protected areas, forest managers in SE Asia seeking to apply best practice in accordance with Forest Stewardship principles, and conservation officers in UK Overseas Territories tackling invasive aliens. Skills and data are relied on by forensics officers requiring identifications of fragmentary or degraded plant material to solve crimes, and importers of herbal remedies employ authentication protocols developed by RBGK to help protect the UK public from the potentially fatal consequences of substituted plant material. User needs could be met at a faster pace if more resources were available, but increasingly they have to locate these from non-governmental sources, a time-consuming activity in itself.

4.1. *What level of funding would be needed to meet the need for taxonomic information now and in the future? Who should be providing this?*

We estimate that to meet the need for baseline information on vascular plants for biodiversity conservation, ecosystem services and climate change RBGK would need an order of magnitude increase in funding We believe that government should provide a large portion of this, but we also intend to greatly expand our efforts to raise these funds from non-governmental organisations/general public.

5.1. How does funding in other countries compare?

5.1.1. For capital projects, there appears little difference between many European nations and the UK in the amount of funding targeted at building new facilities. However, in the UK a significant proportion of this funding has been raised from sources outside government, eg recent science buildings at RBGK have relied on support from the Wolfson Trust and the Weston Foundation as well as from Defra. Operational funding has been significantly improved in France. A recent informal survey of young European taxonomists, conducted within the framework of an EDIT symposium, painted a bleak picture of taxonomy in Europe with notable exceptions in Finland and Sweden where recent experiences have led to a more positive view of prospects (http://www.e-taxonomy.eu/files/FUTURE%20TRENDS%20OF%20TAXONOMY.pdf).

5.1.2. In the US, the NSF has launched a series of innovative schemes to address current issues in taxonomic capacity. PEET (Partnerships for Enhancing Expertise in Taxonomy) supports competitively reviewed research projects that target groups of poorly known organisms. The focus is on encouraging the training of new generations of taxonomists, and translating current expertise into electronic databases and other formats with broad accessibility to the scientific community. Planetary Biodiversity Inventories (PBI) awards fund teams of investigators to conduct a worldwide, species-level systematic inventory of a major group of organisms. RevSys seeks to revitalise revisionary systematics, by supporting smaller projects aimed at synthesising available and new species-level taxonomic information, in the context of providing revisionary treatments and predictive classifications for particular groups of organisms.

5.1.3. In Canada, the recent focus on DNA barcoding has attracted significant government investment (ca. Canadian $20,000,000), not only for building and populating new databases but also to support collections and curation that enable these new data to be generated rapidly and be properly documented.

5.1.4. Significant investment in taxonomic infrastructure and capacity has occurred in China as evidenced by the major investments at several botanic gardens, under the auspices of the Chinese Academy of Sciences and the rapid growth of the Chinese Virtual Herbarium.

5.2. *Could there be more international collaboration? If so, what form this should take and how might it be achieved?*

5.2.1. There is significant European collaboration that has been enabled by Framework Programme 6; these projects focus on improving collections management (curation) and facilitating access to collections (SYNTHESYS), pooling resources of systematic biologists (EDIT) and networking between seed-collecting facilities (ENSCONET). Assessments of collection management for major museum and herbarium collections have been made for 20 of the largest collections in European nations (including the Natural History Museum London [NHM] and RBGK). Initial results show that there is a lack of resources for collections management and that training is needed in several key areas for staff who manage collections. In the UK, the large institutions (RBGK, NHM, National Museum of Wales, RBG Edinburgh) continue to play a significant role in aspects of British and overseas biodiversity, climate change and sustainable use of resources.

5.2.2. Greater international collaboration is always desirable to reduce duplication of effort, enhance synergies and achieve critical mass with thinly spread resources. However, most funding for such collaboration, at least at European level, is focused on networking rather than research. Given the severe constraints on funding from other sources, a level of frustration is expressed by scientists who find funds for talking and
generating ideas relatively easy to access, whereas funds for implementing and delivering projects are increasingly problematic to secure.

6.1. *What impacts have developments in DNA sequencing, genomics, and other new technologies had on systematics research? In what way has systematics embraced new technologies and how can these research areas interact successfully and efficiently?*

6.1.1. New technological developments have opened doors to many new and exciting areas that have both scientific and societal importance, and systematists have generally embraced these to the extent to which funding makes this possible (eg Kew established its molecular phylogenetics unit in 1992, and is currently playing a lead role in research aiming to develop DNA barcoding of plants). We can see many applications of new technologies to provide increased insights into processes that have produced the biodiversity we observe today, but this enhanced understanding of process makes it even more important to document what is present before it disappears.

6.1.2. It must be recognised that such technological advancements increase demand for corresponding baseline data, generally without providing funding of the latter (but see under 5.1.3 for a notable exception to this generalisation). The systematics community has demonstrated a willingness to embrace these new technologies and has been reasonably successful in finding ways to collaborate with university researchers and bioinformaticians. These linkages should also be enhanced by CoSyst, a new "system priming" programme developed by BBSRC, the Systematics Association and the Linnean Society, with the goal of supporting preliminary research that will be the foundation of responsive mode proposals to BBSRC or NERC. The first set of CoSyst awards was made in February 2007 when total of £84,993 was allocated.

6.1.3. One of the major areas for which funding has been sought from the UK research councils is DNA barcoding, but they have thus far declined to see this as an important piece of science infrastructure and have asked that it be cast in terms of "blue-skies research". Although for some organisms this is possible, for most it is not. The result of this position is that other countries, such as Canada and China, fund barcoding extensively while the UK falls behind, even with respect to use of this technique on our own biodiversity.

7.1. *Does the way in which taxonomic data are collected, managed and maintained best meet the needs of the user community?*

7.1.1. The UK taxonomic needs assessment (www.nhm.ac.uk/research-curation/biodiversity-museum/global̀taxonomic-initiative/uk-taxonomic-needs-assessment/index.html) identifies the following as important user needs; information on the conservation status of species; habitat requirements of animals/plants and lists of protected animals/plants; information on local species distributions, field guides, lists of scientific names of animals/plants, and distribution maps. This survey, which focused on UK-based users of taxonomic information relating to UK species, is broadly supported by other user needs assessments in biodiversity-rich developing countries that have also identified alien species and common names as important information. The taxonomic data collected and managed through taxonomic projects can meet these needs. However, more investment is needed to increase the global impact of these data by making them more widely available online.

7.1.2. For example, RBGK's collaborative baseline inventory work with the National Herbarium in Cameroon, has identified a major area of conservation importance and led to the creation by the Government of a new National Park; Kupe-Muanenguba. Botanical inventory work has led to the documentation of over 2,500 species, all assessed for their IUCN Red List status. This area is now the most documented centre of plant diversity in tropical Africa, all the more remarkable because it had never been suggested as being of continental importance before this research. This example demonstrates that taxonomic information held in UK institutes is a globally important resource. Our current capacity to disseminate and utilise this information to inform decisions on biodiversity issues could be greatly increased by additional investment in digitisation, web taxonomy and underlying taxonomic skills.

7.1.3. The UK is a world leader in the development and maintenance of authoritative lists of scientific names for living organisms. These resources are in great demand from variety of endeavours in science, education, conservation and sustainable use. For example, the *International Plant Names Index* (www.ipni.org), in which RBGK is a partner, receives over 27,000 hits per day. Building on IPNI, significant progress coordinated by RBGK has been made on the *World Checklist of Selected Plant Families* (www.kew.org/wcsp/), which links accepted plant names and their associated synonyms with geographical information, allowing searches for all the scientific names of a particular plant or the areas of the world in which it grows. This represents a key contribution towards delivery of Target 1 of the *Global Strategy for Plant Conservation*, but a further investment of c. £3.3 million is required to ensure completion by 2010. Ultimately such checklists will form a key part of the web-taxonomy (see under 9 below) and will be maintained and developed within that broader infrastructure.

7.1.4. University of Reading, RBGK and NHM are working together on the highly successful *Species 2000 Catalogue of Life* international project, and now are seeking substantial resources from BBSRC to propel this project forward.

7.1.5. The UK holds a significant proportion of the world's biological specimens (in excess of 100 million). Each specimen provides evidence that a particular species existed at a particular place and time. Collectively these resources provide a unique record of changes in the distribution of organisms through space and time. Digitisation of label data from these collections enables powerful analyses that can offer insights into current issues, e. g. rates of biodiversity loss and potential impacts of climate change. However, less than 1 per cent of the UK's international natural history specimen records are widely available in digital form.

7.1.6. If resources allowed, more efficient use of technology could better support field collections, integration of taxonomic resources, preparation of identification tools, interfacing with complementary non-taxonomic data and use of data in analysing the effects of climate change on biodiversity, thereby greatly increasing the use and impact of taxonomic data.

9.1. *What progress has been made in developing a web-based taxonomy?*

9.1.1. Much attention has been devoted over the past five years to web-based taxonomy, whereby the taxonomic process in its entirety would be conducted within a web environment. The move to a web-based taxonomy will require digitisation of specimens and literature (addressed elsewhere in this submission) but also significant investment in the development of software, infrastructures and working practices.

9.1.2. Initiatives such as the EU-funded *EDIT* (www.e-taxonomy.eu) and NERC-funded *CATE* projects (www.cate-project.org/) are two linked projects that are exploring mechanisms for building taxonomic communities via the web. They are also devising IT platforms within which web taxonomy can be conducted efficiently and delivered to the widest user community. Both these initiatives are influential because they involve numerous partner institutes that are working towards common requirements. Demonstration portals have been mounted on to the web while the long-term IT infrastructure is developed (e. g. www.palmweb.org/ ; www.catèaraceae.org/). It is anticipated that the larger taxonomic institutes will be expected to take responsibility for many of the IT demands of web taxonomy. This expectation is appropriate because the larger institutes are able to offer a degree of stability for important datasets that universities generally are unable to manage. Nevertheless, this represents a major additional commitment that institutes will not be able to meet effectively without additional resources.

9.1.3. Current web-taxonomy projects are largely experimental and supported by short-term funding. If they are to be used as the source of taxonomic data necessary to inform decisions on major environmental concerns, then systems need to be developed to a much larger scale. This will require greatly increased IT resources within taxonomic institutes and taxonomic input to identify, gather, verify and disseminate content. Web taxonomy is dependent on both taxonomic expertise and collections and will place further pressure on already limited resources.

9.1.4 There has also been a large increase in the digitisation of taxonomic data, for example, the *African Plants Initiative, the Latin American Plants Initiative* (www.aluka.org/page/content/plants.jsp) and the *World Checklist of Selected Plant Families*. Nevertheless, as indicated above, only a fraction of the vast specimen data held in the UK has so far been digitised. Digitisation efforts in UK institutes are falling behind those of other major institutes in developed countries such as in the US, Australia and other parts of Europe. Megadiverse countries have also appreciated the value of digitising specimen data. For example, the *Chinese Virtual Herbarium* contains digitised information from two million specimens (www.cvh.org.cn/), and the *Australian Virtual Herbarium* has digitised nearly six million (www.anbg.gov.au/avh/).

9.2. *How do such initiatives fit in with meeting demand for systematics and taxonomy information?*

9.2.1. Experimental web taxonomy systems currently being developed, focus on establishing collaborative networks as a first step to maximising amount and quality of taxonomic data available online. Much digitisation of taxonomic information (which will eventually populate the web-taxonomy systems) is being driven by funding from large overseas funding bodies interested in mobilising scholarly resources (e. g. the Andrew W. Mellon Foundation, who funds the *African Plants Initiative* and the *Latin American Plants Initiative*) or disseminating data on particular plant groups (eg USA National Science Foundation *Solanaceae Source*: www.nhm.ac.uk/solanaceaesource).

9.2.2. In addition to these important activities, funding is needed to direct digitisation and taxonomic problem-solving towards addressing particular environmental issues (e. g. IUCN *Sampled Red List Index* (www.birdlife.org/action/science/indicators/pdfs/iucn_red_list.pdf). This project, currently unfunded, could provide a method for monitoring the rate of biodiversity loss (thus addressing the problem outlined under 2.1.2 above, but for plants it requires data capture from collections of a representative sample of that diversity). This project would assist the UK in meeting commitments to the *Global Strategy for Plant Conservation* and to indicators monitoring the rate of loss of biodiversity, but it does not fit neatly into current funding opportunities.

9.3. *How do UK-led initiatives fit in with international initiatives and is there sufficient collaboration?*

9.3.1. UK-led collaborative projects such as the *World Checklist of Selected Plant Families* (*WCSP*) and *CATE* work with international initiatives and individuals. There is strong adherence to international protocols and standards with several UK institutes supporting the Biodiversity Information Standards (www.tdwg.org). There is good evidence of collaboration; for example, the *WCSP* has involved collaboration of over 120 individuals from 20 countries. *CATE* liaises with the EU funded *EDIT* project co-ordinated from Paris, in which UK institutes lead work packages.

9.3.2. Several global aggregating projects such as *Global Biodiversity Information Facility* (*GBIF*) and *Encyclopaedia of Life* (EOL) rely on UK institutes for taxonomic content. The UK is second only to the US in the volume of digital records relating to biodiversity that is disseminated through *GBIF*. RBGK and NMH are contributing to the *Encyclopaedia of Life* through their participation in the Biodiversity Heritage Library, and are also anticipated to be major contributors of species pages. However, these aggregators provide minimal funding for provision and maintenance of data. For example, *GBIF* seed money grants will only cover 20 per cent of total project costs and are limited to around US$50,000.

10.1. *What needs to be done to ensure that web-based taxonomy information is of high quality, reliable and user-friendly?*

10.1.1. The shift to web taxonomy and necessary maintenance and enhancement of content and systems are not simply about keeping machines running, but about massive changes requiring significant investment and provision of entirely new services. These will involve effective engagement of the widest possible global taxonomic community in building and maintaining these resources; wide engagement with non-professional taxonomists provides valuable additional information and effective quality control of website content.

10.1.2. To make all this happen, we need to build effective and long-term systems supported by the major taxonomic institutes. This demands a move from short-term and limited funding to a new model of significant and ongoing investment in this infrastructure. There will be a need to provide university and other taxonomists with incentives and career development that supports provision of web taxonomic services as opposed to publication-based outputs in journals with high citation indices. To maximise benefits of web taxonomy there is a need to; increase digitisation of specimen and literature records; increase integration of the web taxonomic products with complementary information and services; provide modern interfaces to allow exploitation of

the web taxonomy products by those who could make use of them; and engage user communities in participating and feeding back on web taxonomy. The taxonomic community is willing to rise to these challenges, and web taxonomy will provide huge benefits to society. However, it should be emphasised that this new approach will require significant additional investment.

10.1.3. Digitisation and web taxonomy are just two of a number of major new areas of activity that UK institutes have undertaken over the past two decades, in response to government initiatives and commitments but without any corresponding increase in grant-in-aid in real terms. Others include access and benefit-sharing negotiations and greatly increased international capacity-building programmes. Both of these areas of activity are driven by considerations of CBD compliance. RBGK is committed to honour both the letter and the spirit of the Convention on Biological Diversity, and provides significant support to Defra's International Biodiversity staff on these issues. However, as with collections maintenance, opportunities to support these activities from sources other than government funding are strictly limited and near-negligible in comparison to the demand in these areas.

13.1. *What is the state of training and education in systematics and taxonomy?*

13.1.1. It was noted in the previous House of Lords report on this issue that "most UK higher institutes do not teach systematics and taxonomy". From RBGK's perspective this situation has not changed, and the numbers of biology undergraduates who receive anything beyond a basic grounding in taxonomy continues to be worryingly low.

13.1.2. Taxonomic training at postgraduate level is also limited to a few universities in the UK, including Aberdeen, Edinburgh, Imperial College, Oxford, Reading and St Andrews. Edinburgh, Imperial and Reading continue to offer MSc courses in taxonomy, all of them run in conjunction with the major taxonomic institutes; for example, the Reading course is partly taught by RBGK and NHM staff. These courses are usually fully subscribed, although there is concern that, in the longer term, the lack of taxonomic teaching at undergraduate level may discourage students from pursuing the discipline further. RBGK continues to rely on these universities as sources of personnel; for example, over 50 per cent of the taxonomists currently employed in the Herbarium of RBGK have been educated to MSc or Ph.D. level at Aberdeen, Edinburgh, Oxford, Reading and St Andrews. We increasingly find recruitment difficult (job searches in grass taxonomy and mycology have not been successful), and we hire more and more frequently from overseas.

13.1.3. As well as their role in supporting MSc courses, major taxonomic institutes are increasingly being relied upon to play a more general role in training and educating taxonomists. RBGK has responded with its own increased training provision, ranging from short courses (eg International Diploma in Herbarium Techniques) to Ph.D. co-supervision both in the UK and internationally. Recently RBGK has prioritised its "learning agenda" with the development of core strategies for education at all levels and the appointment of a Director of Content and Learning. Given the necessary resources, RBGK and other taxonomic institutes could (and indeed may have to) take a leading role in future taxonomic training.

13.2. *Are there any gaps in capacity?*

13.2.1. Education and training in "classical" taxonomy continues to be given low priority by educational and funding institutes. With a continuing and urgent need for baseline plant diversity studies in regions of the world where the threats to biodiversity are greatest, it is essential that capacity to undertake such research does not diminish. There is a core requirement for "classical" taxonomists who have the skills to undertake general identification and floristic work for particular regions and/or families, as well as for those who specialise in particular families and can undertake detailed monographic/floristic work to species level. RBGK has taken steps to develop the former, "generalist" skills in-house as staff with the required expertise cannot easily be recruited. There is also a need for multidisciplinary scientists with a strong grounding in taxonomy who can make best use of the increasing availability of large datasets in digital form and facilitate their use elsewhere in the scientific community.

13.2.2. There is concern that taxonomic expertise in some groups is generally diminishing. At RBGK the last taxonomist to work on gymnosperms retired in 2006, and our last fern specialist retired in December 2007. Gaps in expertise thus open up that reduce our capacity to effectively respond to taxonomic needs, especially for conservation-focused inventory. In some cases this loss is mitigated by the availability of expertise in sister institutions e. g. ferns at NHM, gymnosperms at RBGE.

13.2.3. In the case of mycology, the loss of posts and expertise has been so persistent and widespread throughout the UK that the discipline is now generally judged to be in crisis. RBGK has recently renewed its commitment to maintain taxonomic capacity in mycology by accepting a large collection (400,000 specimens) and several mycologists from CABI. This level of additional commitment cannot easily be absorbed given the declining value of grant-in-aid in real terms. However, the alternative, of allowing mycology in the UK to enter terminal decline, was deemed short-sighted and scientifically indefensible. A special request has been made to Defra and other government agencies to support this merger.

13.3. *Is the number of taxonomists in post and those that are being trained, sufficient to meet current and future needs across all taxonomic subject areas?*

13.3.1. Institutes such as RBGK do not have sufficient numbers of taxonomists to cover all areas for which expertise is being requested. Funding limitations mean that taxonomic research foci have to be prioritised; e. g. the RBGK specialises in certain plant families (eg palms, orchids, labiates) or floras of particular regions of the world (eg Brazil, West Africa or Southeast Asia). When a taxonomist leaves post or retires, the capacity for working in a particular group or region is reduced unless s/he is replaced, preferably a few years before retirement to ensure transfer of expertise. Whether or not a replacement taxonomist is appointed depends on whether the institute sees a continuing need for that area of expertise and on funding.

13.3.2. Many institutes, including RBGK, rely on honorary researchers to help maintain their taxonomic output. These are often retired members of staff, retirees from other institutes and well-qualified amateurs. Although these researchers can play a vital role, there is no absolute guarantee of taxomomic output from them over a given period of time.

13.3.3. Taxonomy is a discipline in which expertise develops over the career-lifetime of a taxonomist. For it to be undertaken successfully, it is best to have a stable long-term career structure. Funding priorities increasingly mean that taxonomists have to be employed on short duration fixed-term appointments that do not allow expertise to develop fully. Thus long-term career structures need to be implemented if we are to gain and retain expertise.

13.3.4. The numbers of taxonomists currently being trained in the UK is about adequate for the number of positions currently available, at least in plant taxonomy. However, due to funding constraints demands for taxonomic information at present exceeds the numbers of practising taxonomists available to provide this information. These demands are likely to increase with the need for more baseline plant diversity studies, together with the development of web taxonomy highlighted in Questions 9–10. If future funding is able to match these increasing demands and a larger number of positions become available, a shortage of trained taxonomists will occur unless training capacity is also increased.

Examination of Witnesses

Witnesses: Professor Stephen Hopper, Director of the Royal Botanic Gardens, Kew, Dr Eimear Nic Lughadha, Head of Science Policy and Co-ordination, the Royal Botanic Gardens, Kew, Professor Mary Gibby, Director of Science, Royal Botanic Garden Edinburgh, Dr Michael Dixon, Director, National History Museum, Professor Richard Lane, Director of Science, Natural History Museum, examined.

Q1 ***Chairman:*** May I welcome you very warmly indeed and thank you for the written evidence that has already been submitted, some of which this afternoon we might have a chance to take further and ask some specific questions arising out of what you have written. It is a matter for you whether you wish to embellish or add to that. Thank you very much indeed. I will ask you in a moment to introduce yourselves. This is partly for the record because a recording is taken of this evidence session and that will in due course be on the web, so your every word will be out there for someone to listen to; I will just remind you of that at the start. We are aiming to finish probably not too much after five o'clock, but there is the possibility if afterwards, on reflection, you want to clarify any point you have made, or to add to them, to write in to us and we take the possibility seriously of coming back to you on any specific points on which we would like further discussion. As I think some of you know very well, the Committee has had one briefing session—an excellent day at the Natural History Museum—but this is our first evidence-taking session, so we are warming up to the process as you are. Would you introduce yourselves and say what particular allegiance you have, or which institution you come from?
Professor Lane: My name is Richard Lane. I am the Director of Science at the Natural History Museum.
Dr Dixon: I am Michael Dixon. I am Director of the Natural History Museum.
Professor Gibby: I am Mary Gibby. I am Director of Science at the Royal Botanic Garden Edinburgh, but funded by the Scottish Government.

Professor Hopper: I am Stephen Hopper, Director of the Royal Botanic Gardens, Kew.
Dr Lughadha: I am Eimear Nic Lughadha. I am Head of Science Policy and Co-ordination at the Royal Botanic Gardens, Kew.

Q2 ***Chairman:*** If there is something especially you want to say by way of introduction, there are a few moments for that now, alternatively, we could move straight to the discussion of the questions that we have for you. Have any of you come with a short statement that you wanted us to hear?
Dr Dixon: I welcome this opportunity to present material to this inquiry today. From the Natural History Museum's point of view, we feel that we are one of the world's leading institutions for systematics and taxonomy. It is an important subject. It is important to us because of the nature of our collections and the expertise of our scientists. We also feel that there is a very important public education role that the Museum plays so we welcome both the inquiry and the opportunity to give evidence today.

Q3 ***Chairman:*** We have already been hosted by you very successfully and we appreciate your interest in this. We are returning to this topic as you know because we count it as a very important topic which is why we want to pick it up again and run with it. As a first question, in this, our first question session, I want to ask a broad question, what is the state of play in systematics and taxonomy in the United Kingdom today? Are we well provided for? Are we minimally provided for? We think there is a very vibrant quantity of science going on, but what would you like to add to your comments?
Professor Lane: Perhaps I could start. We need to put the UK into an international context and in that context, the UK does well. It has leadership and a certain amount of capacity. It probably has greater breadth than it has depth and that is quite a key issue. The other key point is that the UK is well provided for in terms of the basic infrastructure to do science—we have terrific collections built up over many years and if you look at the collections represented at this table (NHM,RBGE, RBGK), they are a very significant sample of the biodiversity of the planet. So, we have that base. The main limiting factor is that the subject is expanding enormously and our ability to expand with it and to lead and take the subject forward is the main constraint, and that is about people and obviously financial resources.

Q4 ***Chairman:*** Can I probe you a little on the distinction you drew between breadth and depth. Would you like to spell out what you mean by that?
Professor Lane: Yes, if we consider that technology is allowing us to explore the world in the way that we never could before—everything from metagenomics to very sophisticated bioinformatics, which requires development in its own right and requires development within the context of the subject. Against that is the need to describe and delimit the different forms of life on the planet and that is where the depth that we would have had in the past, of a large number of experts to do that, rather untrammelled, is where the UK is under the greatest pressure. The subject is expanding, the resource base is not expanding at the same rate—that tells you that there has been a shortfall—and our ability to lead is strongly curtailed by our resources.

Q5 ***Chairman:*** Does anyone else want to comment on that broad question?
Professor Hopper: To me, taxonomy is big science in the true meaning of the words. It has been an ongoing enterprise for 300 or 400 years and it is an enterprise that has not finished its work by any stretch of the imagination. What has happened, however, has been a perception that taxonomy is a bit old-fashioned—it has been dropped from many university curricula—except in some areas such as molecular phylogenetics, it is not actively encouraged by our present reward system, and yet it is the fundamental underpinning for all biological science. For all our interactions with other organisms, we need names, we need a predictive classification system and I would argue that never in the history of the planet is there a more urgent need for that fundamental underpinning than now. The challenge that we have is to address the recent historical perceptions of taxonomy; it is a hypothesis-driven science, I believe fervently, and one of the most rigorously refereed in the sense that everyone uses its names, far more so than many of the discoveries in contemporary biology. In that sense, it is refereed on a daily basis. I have this fervent belief that in the UK there is a wonderful and proud tradition of global enterprise, tremendous collections and we need to lift the game in the research sense and the curation of the collections so that they can deliver the urgently needed information for best environmental management of the planet.

Q6 ***Chairman:*** I could ask a fairly blunt question, as you touched on it in your answer, why does it matter? But I will temper that by saying, why is it as important as you imply? Does anyone else want to come in on that?
Professor Gibby: The demands for them on the subject have changed enormously over recent years. There is a great demand for it in the UK and overseas; on the fundamental information to support conservation efforts; to understand biodiversity out in the wilds;

and to see how it will adapt to change. Many people who are doing taxonomy have been encouraged to work in partnership with others to explore these issues and help take those issues forward. So taxonomists are at the heart of that but they are also being asked to diversify in what they do and not just stick to the strict taxonomy but applying that to conservation, to modelling, to see what will happen to populations and species under climate change, and so forth. So, what they are expected to do is widening all the time, and there is a demand there. You ask, should we be doing it? Yes, we should, because there are many people out there wanting that service.

Professor Lane: I would like to add to that. One of the compelling scientific questions of our time is about change in biodiversity. It is changing not only in the species, because we are very aware of the biodiversity crisis and our impending loss of species on an unprecedented scale—certainly in recent times—but also for accurate and fast information. For many developing countries, being able to identify potential pests on their crops, to say either that we can identify these and take action, or perhaps, economically even more important, to say that they do not contain particular pests. That requires us to have two kinds of information: one is that we understand whether the pest is one or several species and, secondly, that we can identify it fast in any stage (of it's life cycle). Those are two scientific activities that are becoming required faster and faster than they were maybe 10 or 20 years ago. The immediacy of knowledge for an ever-increasing variety of society's needs is quite compelling. There is also a large undercurrent of scientific questions about the change in the nature of biodiversity. The taxonomic information we generate is one of the key ways to answering that question.

Chairman: That has opened up the issues for us very well. I will pass over now to Lady Walmsley, who chaired the Committee that produced the previous report.

Q7 ***Baroness Walmsley:*** It is very nice to see Dr Nic Lughadha here, who was our specialist adviser last time, for those noble Lords who do not know that. One of the recommendations in the last report was that systematic biologists should go out and blow their own trumpet a bit more and emphasise the importance and relevance of the subject. We heard at our seminar, a couple of weeks ago, that it has been done to a great extent; there has been much effort to do that, and there have been successes and the whole thing has survived much better, partly because of that, and we must congratulate those who have done it. We have just heard much about the increase in demand for taxonomic information and we also saw it in the written evidence from RBG Kew. In that situation, could you tell us whether you feel that the discipline will be able to fulfil that demand, either by greater effort or by focusing down on the areas of greatest need, or is it simply a matter of increasing capacity?

Professor Hopper: Perhaps I will open and then defer to Dr Nic Lughadha. Regrouping and reallocating existing resources is a pressure that is irresistible to the major institutions in the absence of an increasing budget for this sort of activity. It is an ongoing process and is a process of change that is challenging many staff. If you can imagine, people appointed 40 years ago, had fundamentally different employment regime as taxonomists where, in the main, their challenge was to understand a group of organisms and describe the diversity of life and develop a pretty big classification. Because the funding resources have not kept up with demand, there has been a need to engage with the users of taxonomy in a much more active way, which has meant that the big organisations certainly have had to change some of their core activities to meet that demand.

Dr Nic Lughadha: We have got much better at adding value to our product and translating it into something that is ready for the user, rather than putting out something very dry and academic and saying, "it's out there, they need to look it up and learn how to use it". Of course, that involves additional resources, both the time of the conventional taxonomists and also other people who know how to manipulate texts, images, and so on, to make a more user-friendly product. The people who nowadays call themselves taxonomists are spending a smaller proportion of their time doing descriptive taxonomy and more of their time than 10 or 20 years ago translating it into what the user needs, understanding the user needs, negotiating with the user about how they might cover the costs, both of creating the material and of translating it. We have worked a lot on efficiencies and it is fair to say that the original question was, "can we meet the increasing demand simply through further efforts and focusing down?" The simple answer is, No. We have done that to the extent that we can, we are now in a situation where resources are limiting and we really need some growth in those resources. We are living off capital to a certain extent. We are translating from a base of the collections but we are no longer investing enough in maintaining those collections, or in circumstances where we are investing, we are investing in the collections' maintenance at the expense of the descriptive taxonomy. The balance is out of kilter and it needs further resources invested in the system in order to rebalance so that we can have an appropriate balance of collections development and maintenance, which is the basis for products created not only by the staff employed at our institutions but also at many other institutions around the world who

look to Kew, the Natural History Museum and RBGE for their basic primary research material.

Q8 ***Lord Methuen:*** Concern has been expressed repeatedly that the quality and value of taxonomy does not do well when it is assessed by organisations such as the RAE. How better do you think this might be overcome? This is obviously a general concern, how do you feel that this access to funds should be better tackled?
Professor Lane: Perhaps I will answer, having been involved in a recent RAE. Our institutions do not partake of the RAE and that is quite appropriate. It is an instrument to measure a different sum of output. Parts of what we do, would do reasonably well under the RAE; the phylogenetic, and some of the biodiversity studies, which are broad-based analyses, are competitive. Some of the areas that do particularly poorly are the delimitation of taxa and subsequent description, and the population of databases. That is something, which under the RAE, depending on which unit assessment is being looked at, could either go in measures of esteem or some of those other measures around scholarship. For many organisations that are not sitting at this desk, their inability to show value to a funding council is a major constraint on them taking up taxonomy in their institutions. It is a general challenge for measures like the RAE and other metrics-based systems, and even peer review systems, to give value to the population of data sets and databases when they are used by others, and that is a particular challenge that we face in a significant part of our activities.
Professor Hopper: There is a need to explore new ways of recognising the contribution of taxonomists and rewarding them. That is the way forward. As I mentioned in my earlier comment, if you look at, for example, the frequency with which names are used in the biological literature as a metric, then you might have a fundamentally different perspective on the value of taxonomy.

Q9 ***Chairman:*** Professor Lane, can I follow one other point you made, so that I know whether or not I am clear about this. You seem to suggest that the creation of data sets was not recognised within the RAE in the way in which other types of research are. Was that was you meant?
Professor Lane: The innovative part of establishing a framework for databases, and development of them, is recognised and there are various methods of doing that. But populating those databases and data sets with real data, as opposed to the exploratory data, the scaling up, tends not to be recognised.

Q10 ***Baroness Walmsley:*** Is that because the perception is that it is just an inputting job, without any judgment, skill, experience and professionalism behind it, which I am sure is completely wrong. But is that why? Why do you think that is?
Professor Lane: It is difficult to articulate the intellectual value and value-added that is in seeking data from nature, converting it into a form that can then be put out in a data set, whether they are measurements or whatever. That is a misunderstanding of what the process is of gathering data from nature and transforming those observations into data that can then be analysed.

Q11 ***Lord Methuen:*** Is there a point here of new data versus old data that they would support the influx of new data but they are very reluctant to think about the import of old data?
Professor Lane: I am not sure that the division is between new and old data. It is between funding to start something and funding required to finish—it is the funding required to finish that is a challenge, because the exciting bit is starting.
Professor Gibby: The research councils are very happy to fund that innovative research and that is the problem. If you are doing that innovative research, you are getting out the high-impact papers, pulling in the research grants and you will survive in the university. But if you then want to roll out the exciting product you have developed to make it applicable in the real world, you cannot get the resources for the manpower to help to do that. The research councils would say that it was not at the cutting edge, it is not blue sky, and it should come from Government.

Q12 ***Lord Krebs:*** My question, which is in two parts, follows neatly on from the last point. Obviously, some of the funders of taxonomic research measure productivity and output in terms of the research assessment exercise metrics, but other funders look at things in a different way. I wondered whether we are overplaying the importance of the RAE and its metrics because presumably funders such as Defra, or other Government departments might be looking for measures such as the sustenance of a national institution—such as Edinburgh, Kew or the NHM—without using exactly the same metrics that the Higher Education Funding Council would use. The first part of my question is to ask if the RAE dimension of things is the only driver, or do the users of your taxonomic database for research and curation appreciate that there are other dimensions and are they providing money for you based on those other dimensions rather than the RAE metrics? I will pause at that.

Professor Lane: I quite take the point that RAE metrics are not the be-all and end-all of this, but the point I would make is that if you wish to have a thriving scientific endeavour, individuals need to move between the major research institutes, like ours, and the university community. There should be a free movement of people between those to get value-added. That is where the pressure comes to compete well in RAE metrics rather than on organisations like ours.

Dr Nic Lughadha: To address the second part of the question which was whether the users of the databases appreciate it and secondly, do they pay for it? There are high levels of appreciation but the user-pays model has almost never applied in taxonomy except in very specific instances. The difficulty is that many of the users are international users of our—for historical reasons—very international collections and therefore a user-pays model simply would not be applicable. There is a high level of appreciation and value of the data but not a direct user-paying model. To look at what Defra measures, which was another part of the question, Defra—certainly with regard to Kew—appreciates the breadth of what Kew does and delivers both in a national and an international context, but levels of Defra funding have not been adjusted to accommodate the much broader expectations of Kew, both from Defra and from the world at large, in terms of making data available, implementing the CBD and other international requirements.

Q13 ***Lord Warner:*** May I probe a bit more into that business of users, because they are international users, will not pay. Is it will not pay, cannot pay, should not pay?

Dr Nic Lughadha: In many instances there are users in developing countries. Let me take the example of access to collections. We are slowly, with primarily US funding, digitising our, for instance, herbarium collections, the label data and the images, and making that available on the internet. To expect the users, many of whom are in developing countries, to pay on a per-use basis for that resource is a very problematic model, not least because many of them would say that morally that material would be theirs rather than ours. Where there is scope for payment is, for instance, in the US and that is the model on which we are receiving some of this funding. So, the same resource that would be made available free in Africa and Latin America, will be charged to US universities, for instance, and that is the funding model that makes the current digitisation work possible. But that does not scale up, that picks up the most desirable and most interesting specimens, but does not pick up the volume of material that researchers will need to do large-scale analyses of the material.

Q14 ***Lord Krebs:*** On a specific point, I remember a few years ago visiting CABI International and they seemed to be running a commercial model to provide information to taxonomic information services on a worldwide basis. Could you tell us a bit about how CABI's commercial model works for providing taxonomic information?

Dr Nic Lughadha: I will speak from a Kew point of view, and my knowledge of CABI in that respect is that their model is based on a very small amount of core funding, something less than 10%, just a few percent is core funded now, and the rest is basically on a contract for services basis. They have been remarkably successful in managing to cover their costs in doing that. However, they only cover the costs of the near-to user outputs, they are not covering the costs of their collections. As an example, we at Kew are about to take on from CABI, with CABI's encouragement and agreement , the CABI mycological collections, because CABI's business model simple does not work when you have a big resource like a collection to maintain. You can fund user-driven services on a self-funding basis, but not the collections on which they are ultimately based.

Professor Lane: I would suggest that funding model (user pays) does not work. The non-existence of the International Institute of Entomology's is an example of that; it was unsustainable.

Q15 ***Chairman:*** I would like to push one further point in this area. It is always easier to blame "them upstairs", but what are your own institutions' resource distribution models like? Do they take due account of your own needs, taxonomy? Do they differ, or do they just channel the money down; is it divided upstairs?

Professor Hopper: Perhaps if I can talk about the Kew model. Kew's roots come from taxonomic science and the big challenge perceived by Sir Joseph Banks and subsequent people. About one-third of our staff is involved in science and of that third, I think I am right in saying that, about one-third is in taxonomy and descriptive taxonomy. We also have molecular phylogenetics people in the Jodrell laboratory, so we invest in that side of taxonomy as well. Is that the nature of your question?

Q16 ***Chairman:*** Yes, I know the position personally better in the university system where the argument always is that universities give up their autonomy to the funding streams above and they simply follow what comes down. I was wondering what the position was with your organisations.

Dr Dixon: At the Natural History Museum, we receive grant-in-aid through the Department for Culture, Media and Sport, but that money is not hypothecated in any way, it is up to the executive management and the trustees of the Museum to decide how that is allocated between the various activities that we undertake. Of the money that goes to frontline services—and let us define the science that we do in taxonomy and systematics as frontline services, as is the public side of what we do, the public offer that the museum presents—we spend about 50:50, which has been pretty consistent over quite an extended period.

Chairman: Thank you. That was what I was asking about; what the proportions are.

Q17 ***Earl of Selborne:*** I should start by putting on the record that I am Chairman of the Trustees of the Royal Botanic Gardens, Kew. I would like to get back to mycology, which Dr Nic Lughadha mentioned. When we did a report in 1992, and then under Lady Walmsley's Chair in 2002, on both occasions we described the state of systematic mycology as in crisis. From what we have heard just now that Kew is possibly taking over from CABI mycology and, from the written evidence, it is clear that the crisis continues. First of all, it is necessary to retain a national capacity in mycology and if so, what is being done to ensure the survival of this discipline and of the collections?

Professor Hopper: It is absolutely necessary. Kew, in terms of its funding model, is 50 per cent Government, 50 per cent self-generated revenue and on flat cash; has been for some time in terms of an operational budget, so in real terms is working in a declining fiscal operating environment. Mycology is so pivotal to what the world will need in terms of the fundamental contribution of plants to environmental challenges like climate change, for example, most plants have fungi as partners underground that increase their capacity to grow and assimilate carbon. If you do not understand what is going on below ground, then your ability to repair and restore forests is considerably reduced. There are great potentials in mycology for biofuels, because the business of some fungi is basically degrading and rotting plant materials, so the chemicals that they muster and have mustered through evolution have great potential, if we can get into their biochemistry, in human use of plant energy. There are medicinal and other reasons why fungi are fundamentally important, not only to the UK but to people around the world. Kew has taken the view that, despite the rather difficult financial situation we are in, to go the other route of having the CABI mycological collections mothballed and not available for use in this brave new world we are entering, would be something that we simply should not contemplate and we should take on the responsibility of caring for their collections.

Dr Nic Lughadha: We have made a special submission to Defra asking them for additional funding in light of this additional responsibility.

Q18 ***Earl of Selborne:*** It is clear from what you say that if Kew is not prepared to take the collections from CABI, they would not be accessible for science.

Dr Nic Lughadha: That is right, in effect, they would no longer be curated. They might be accessible in the sense that CABI might be prepared to give someone the key, but as we know, a collection that is not curated and kept up to date scientifically, rapidly becomes intellectually inaccessible and of limited value as a reference collection.

Professor Lane: I would like to make two points, one of which is to follow up Dr Nic Lughadha's comment that one should not consider this just as a collection, the objects are clearly important as a primary data source, but it is the people who are able to interpret them who should be valued. The collection should always be thought of as being objects (specimens) and people; they are indivisible, for the reasons just said. The other point is whether we should have national capacity. That is a political decision about scale of capacity. If we are interested in practical applications then clearly, as has already been stated, the fungi have given us enormous opportunity. If we look at it from a basic science point of view, the group of organisms most likely to be undiscovered in their scale are probably the fungi. So, in terms of new horizons, the fungi will probably be one of the groups of organisms that will reveal extraordinary diversity.

Q19 ***Baroness Walmsley:*** Which country is the world's leader; is there one, in fungi?

Professor Gibby: Until recently, it was the UK. I do not know who it is now, but it certainly was. There is still much mycological research going on in universities. It is still an active subject. It is not related to taxonomy; it is obviously related to the application of certain groups. Edinburgh is hosting the International Mycological Congress in 2010. So there is mycology going on but it is that taxonomic/systematic base that has been left to die out, which is the really sad thing. We have still got people around in their fifties who are really good mycologists and we need that investment. We were in the same position in Edinburgh with two mycologists on the staff; one working on rust fungi; and one on lichens. We have invested in one extra post in science to work alongside the lichenologist, and now we have a group built up with soft funding with five lichenologists who are all working together now and doing more ecological work as well as the taxonomic work. With a little bit of funding, and some from our resources,

some from SNH putting in funding for training apprentices, you can generate more activity, more training, and build up a research group. You can no longer have people working in isolation, it is not effective. So we do not want one representative for each group across the organisations, you need teams of people.

Dr Nic Lughadha: In terms of sizeable teams of systematic mycologists, the Dutch are still leading in Amsterdam, with the focus on living cultures of mycological collections. There is also a sizeable group, I believe still, in St Petersburg at the Commonwealth Institute. Those are the two groups of systematic mycologists that get into double figures, for instance. As Professor Gibby said, it does need to be a scale. Science these days is a scale operation, a team operation.

Dr Dixon: This question raises a very interesting point which is, what defines national capability? Who is responsible for defining what that national capability should be? We all tend to operate as individual institutions and we operate collaboratively and co-operatively, both within the nation and internationally, but when it comes to defining what national capability there should be, that is an interesting point to take forward.

Q20 ***Lord Krebs:*** Is it that mycology is the most important under-represented area in taxonomy, or is it just that mycology happens to be what we are talking about now? Could I, if I were a microbiologist working on bacteria, make the same kind of pitch about bacterial taxonomy? Or if I were working on soil invertebrates, could I make the same pitch about collembola or something like that? How important are fungi compared with other groups that might be understudied?

Professor Lane: There will be a number of organisms that would be candidates for particular care and study. Most of them would be very small organisms; most of them would be protists, single-celled organisms. There will, of course, be the extremely primitive organisms, bacteria and viruses, which we would take on board. Why? Because technology has recently given us an opportunity to investigate them in a way that we could never do before. No longer do we have to worry about, if we can cultivate it, we can describe the species of bacterium, if we can cultivate it, we can generally describe a protozoan. Now, increasingly, we have technology and informatics techniques, which allow us to explore the world that we do not have to culture. That is where, interestingly enough, the debate extends beyond the organisations represented here. Our organisations are built around having objects and for many of these organisms there is not an object that is easy to retain so, historically, we have not done much about them. But now we can, they have come onto the agenda and they have become much more tractable. It is the ability to do that in a way that you could not before. "Metagenomics" is going to allow us to look at whole communities of organisms that it was not possible to investigate, even 10 years ago. That is going to accelerate. In answer to your question, a number of groups of organisms are under-represented, most of them will be small, physically. So if I was interested in soil mites, I probably would not want to start looking at the morphology of mites; I would take what we already know as the skeleton of knowledge and then fill in the extraordinarily large number of spaces with new technology, such as DNA approaches.

Q21 ***Lord Colwyn:*** Perhaps we can move on now to discussing the relationship between systematics and taxonomy and the web. We had an excellent presentation from Charles Godfray a couple of weeks ago, when he talked about the current uses of the web and how it might be used. We also heard of the proliferation of non-professional taxonomy on taxonomy sites, which sounded very interesting. We also heard that there is a relatively slow progress in bringing data from the major UK taxonomic collections on line. If the UK systematics community is perhaps not doing so well, and we heard how it occupies a unique position with two of the top five world biodiversity institutes. Who and where are the users of these data? Is retrospective data capture justified and how should it be funded?

Professor Hopper: I came from Perth in Western Australia before I joined Kew. If I can give you an example there, the herbarium is fully digitised—the historical data collection was completed about 10 years ago. This is a rather applied example but that State is in the midst of an incredible mineral boom and has stringent environmental legislation requiring miners to report on the environmental impacts of their activities, and repair and restore if they get granted approval. Ten years ago, it would have been impossible to advise them as to the likelihood of them encountering a threatened species in the areas of interest to their lease. With the historical collection now databased, it is possible to say for the whole flora based on the information in the collections; there are areas of intense biodiversity richness, where the alarm bells should go off if your mineral interest happens to coincide with it. We can develop predictive models about what would have been in mines sites, if they are into repair and restoration, from the database that is available. The short answer to your question is that getting the historical information that can be located in geographical space is an incredibly powerful tool for an example like that. There are all sorts of intrinsic scientific

questions that become possible when you have a grip on the collections that are available. I said in my opening remarks that I believe that taxonomy is hypothesis driven and every name is a hypothesis about the features of an organism, its geographical distribution and its ecology. The historical collections are part of the database that go into formulating that hypothesis and as incoming collections arrive we get more and more precise. Ultimately, we are able to be much better custodians of the global biodiversity that is our heritage if we have both the historical and the incoming new information digitised in this way.

Q22 ***Lord Colwyn:*** Would you believe that the UK taxonomists are up with the rest of the world?
Professor Hopper: By no means; way behind. The scale of the enterprise is much larger because the UK has these tremendous historical collections—the Kew collection has about 7 million specimens; the Western Australian herbarium collection I am talking about has 600,000. The task is formidable but the pay-offs and benefits of dealing with this very tractable question are not what I would regard as an expensive way forward at all. It is a relatively small investment for significant paths for all kinds of applications of biodiversity knowledge. The UK has a long way to go, but with a modest investment of funds, the job could be done and done well.
Professor Lane: There are two different issues wrapped up in Charles Godfray's comments. One was about primary data, which come from specimens, what they are and where they were found. The second is information—a database on legumes or a group of other organisms—and whereas the latter are mushrooming in all sorts of places, and different groups are now able to do that, it is the primary data points that are lagging behind, so I think we should distinguish between these. We should also be aware that there are initiatives like the Biodiversity Heritage Library, which is putting the biodiversity literature on the web.

Q23 ***Chairman:*** May I ask who is paying for that?
Professor Lane: Currently, the Biodiversity Heritage Library is paid for by US money.

Q24 ***Chairman:*** Government money or charitable trusts?
Professor Lane: US foundations; much in the same way that Dr Nic Lughadha referred to for the African Plants Initiative. So, getting those geo-reference data properly on the web is extremely important. The challenge we face is how to prioritise. Our organisation has 70 million objects; you cannot start in A and go through to Z. We have to look at particular groups of organisms where we believe the information that they generate will be valuable. We cannot do it on our own, because we also need to look at specimens in other organisations. For example, we have been talking to some major museums in North America about putting all the vertebrates from three or four major museums on the web. The general belief is that because they are data in space and time, they will generate lots of hypotheses in their own right, as a genome sequence does, for example, as well as answering fairly focused questions on what has changed and where is it now. It is the need to focus and do some of them first and mine those data which is our biggest challenge.

Q25 ***Lord Colwyn:*** Who and where are the users of this data?
Professor Gibby: It is significant that the Mexican Government has invested in getting access to data on Mexican specimens that are across the world; sending people out to capture that data to take back to Mexico because they need it. The users are all over the world because, of course, our collections are all over the world. Prioritising could be prioritising for individual countries, like the African Plants Initiative for providing information for Africa. That government realised the importance of the historical data and put the money behind it.

Q26 ***Earl of Selborne:*** A recent NERC science theme report on biodiversity highlights, amongst other things, the challenge of "providing increased human capacity to reverse declining taxonomic expertise". We have heard from Dr Dixon that, in fact, it is up to all of the three institutions represented here today to determine how their grant-in-aid from the three different funding streams is spent. If you did somehow manage to increase human capacity in terms of increased taxonomic expertise, would you choose to spend your money in that way, or would there be other areas on which you would wish to spend instead?
Dr Dixon: The first thing to say is that taxonomy is becoming a bigger and bigger science. It has been referred to already as a big science, but what technology enables us to do has expanded dramatically over the years, so it is probably true that we spend a smaller proportion of our overall expenditure on descriptive taxonomy but not on taxonomy and systematics overall. We develop capacity where we can; we are not a higher education institution but we do work with Imperial College; we teach an MSC course on advanced taxonomy and systematics. Over the last decade about 200[1] students have gone through that course. As an institution—I am sure it is the same in Kew and Edinburgh—we host a number of PhD students

[1] This should be corrected to read "over 250".

registered in a range of universities across the UK, in our case, about 90[2] at any one time in the Museum. Although the science theme report points to diminishing proportion of resource spent on taxonomy in some of our institutions, I would not agree with the statement. What we are very adept at doing is looking at external funding streams and using those to pursue our own mission. We have heard about American trust and foundation funding for big projects such as the Biodiversity Heritage Library, the African Plants Initiative, and the Latin American Plants Initiative. DEFRA's own Darwin Initiative is effectively a capacity-building project. The Natural History Museum has probably been one of the biggest recipients of grants from the Darwin Initiative, which is great in that it builds capacity in developing countries, helps our scientists develop new ideas, new lines of inquiry, as well as producing application tools that are relevant for those communities.

Dr Nic Lughadha: I should like to add to what Dr Dixon said by saying that the numbers of PhD students being trained in taxonomy and systematics in the broad sense might give a misleading view on the next generation coming up who might do descriptive taxonomy. At Kew, we have about 80 PhD students registered and if you look at what is going to be in those doctoral theses, only about 15 of those theses will have a substantive portion of descriptive taxonomy. We have become adept, as Dr Dixon said, at identifying sources of funding through which we could fund a PhD student, but usually the topic is outside the standard descriptive taxonomy field. Of those 15 students of our 80, the 15 who will have descriptive taxonomy in their theses, 10 are registered overseas; only five are registered in the British Isles. So the proportion of our students that are learning to be descriptive taxonomists is very limited. I suspect that the same might be true—perhaps the proportion is different—at the Natural History Museum.

Dr Dixon: Another point to mention is that each of our institutions engages with amateur scientists and other communities in developing taxonomic expertise. The Museum, for example, undertook a project with fly fishermen across the UK, which enabled them to identify flies of particular interest to them in pursuit of their hobby, and in developing that expertise they were able to provide useful data on the health of water courses in the UK. Building that capacity, as we plan to do as part of our centre for UK biodiversity in the next phase of our Darwin Centre Project, is also a useful way of building capacity, although not necessarily in the professional sense.

[2] This should be corrected to read "150".

Q27 ***Earl of Selborne:*** But there is a limit to what you can do with amateurs, is there not? If you come to succession planning in your institutions, you are going to have a problem if you run out of suitably qualified taxonomists?

Dr Dixon: Yes, that is true.

Professor Gibby: It is a challenge to find people to appoint to positions because if you are advertising for a lichenologist or someone in mycology, you are not going to find them in the UK; we would have to look abroad. We are trying to get some succession planning, so that with one or two extra posts you can have someone more junior working with the senior taxonomists and perhaps doing more molecular work or more conservation applied work, but learning from the taxonomist at the same time, otherwise those skills are not going to be passed on easily to PhDs. We need to have partnerships with people working alongside as part of a team to pick up those skills.

Q28 ***Lord Warner:*** Could I understand something on which I am not altogether clear. Is it the universities' inability to produce taxonomists for you that is a constraint, or if there was money available could you follow the example of some other fields in science and quasi--science—like medicine—where it has been employers who have developed the capacity to bring new people into the fields. They have not relied on the universities; they may have used validation processes in the universities but it is the employers who have driven the agenda because, in some cases, they got fed up with waiting for the universities to do something. I am trying to understand where the real blockage is.

Professor Gibby: We have to drive that agenda and make sure that we are getting people trained to do the jobs now. That is the situation. We cannot rely on the universities to do it. We can for other aspects of the skills that are useful to the taxonomist now, but the taxonomy has to be something that we teach because we are the only places that hold that expertise.

Professor Lane: I want to make two points. One is that partnership is possible; if you look at the NERC initiative in taxonomy, which was a good few years ago, which sought to link universities and major taxonomic institutions together, it is very clear to see the remaining imprint of that initiative a decade later, with lots of students and a connection between institutions. That is a very good example of a way of working together. The second point is that in our experience, it has not been difficult to hire taxonomists. If we take the broader view—and I defer to the point that was made earlier on about descriptive taxonomists—just to give an example, when we recently looked for senior researchers, professorial level; we advertised and had over 200

applications, 87 per cent from outside the UK. In the event, we hired predominantly people originating from outside the UK. Even if we specify a particular taxonomic group, as we recently did in our entomology department, two of the three people we hired are from outside the UK—from Germany as it happens.

Dr Nic Lughadha: To follow up from Professor Gibby's point. We have completely changed our recruitment model in the past 20 years. Twenty years ago we were advertising for plant taxonomists, entry level graduates. Now we advertise the same level of position as a trainee botanist, so that we make the assumption that we are going to get in somebody who is reasonably bright, has some aptitude and we train them in-house. We no longer expect to recruit taxonomists from the universities at entry level. At a more senior level, and that tends to be where succession planning gets explicit, we have had extreme difficulties in filling gaps at senior level. For instance, in mycology but also in grasses, we have advertised positions and failed to fill them despite extensive searches in the UK and overseas.

Q29 ***Lord Krebs:*** We have already heard some comments about DNA technology from Professor Lane and its role in taxonomy. At the time of the last inquiry of the Sub-Committee, we heard about DNA barcoding as an emerging tool in taxonomy and it would be interesting to hear from you what has happened in the last few years, who is routinely barcoding plants and animals, what proportion of the UK flora and fauna have been barcoded and how is that all being used?

Professor Lane: There was an initiative started in Cold Spring Harbour Laboratory about five years ago on DNA barcoding,[3] and then we hosted at the Natural History Museum the first scientific conference on DNA barcoding which many felt was a risky thing to do for an emerging technology in a museum, but I am glad to see that it has come to life. DNA barcoding has begun to expand hugely in the scope of what it covers by engaging a very much wider group of researchers and users of systematics than other technologies have done. It is very important to say that its primary role is in diagnostics and it is an important aid in species discovery, but it relies on us having an established taxonomic framework in which these diagnostics can be slotted, and that is absolutely crucial. A number of organisations are taking the lead, so that there is an all-birds biodiversity initiative, an all-fish biodiversity initiative, where there is a small sequence for every group—I will leave my colleagues to talk about the plant ones—and we are currently running one based in London on mosquitoes, where we aim to barcode 80 per cent of the world's known mosquitoes; we are certainly on track to do that within the next two years; interestingly enough, funded from an extraordinary diversity of sources, including, again, American foundations.

Professor Gibby: Plants are a little more difficult to work with because the mitochondrial DNA is not changing enough for it to be the right tool. There is an international plant working group to barcode plants and a member of staff at RBG is currently chairing that group. That has had funding from the Consortium for the Barcode of Life, but it is getting funding partly from the consortium on barcoding plants but also with input from the Garden to help fund that work. There is progress: at the Garden, for example, one of things we are doing is making sure that when we are making collections now we are also making DNA collections so that material is collected in the right way. We have a pilot project to barcode the liverwort flora of the UK, because it is relatively small—about 350 taxa—and at the current rate of progress it will be completed in about five years. We are discovering species along the way and are using a group of organisms that are quite difficult to identify, so it is a good technique for trying to see how effective it is as a diagnostic tool in plants. We are also part of an international tree barcoding initiative, working with people around the world on barcoding particular groups of trees. That is in collaboration with people in botany at the Natural History Museum as well as at Kew and many other laboratories.

Q30 ***Lord Krebs:*** I would like to ask one follow-up question for clarification in response to Professor Lane's comment about the need for some framework of taxonomic identification within which the barcoding operates. As you know, at the seminar we heard from Professor Bland Findlay a rather sceptical set of comments about molecular typing of micro -organisms. I quote from one of his paragraphs, "molecular markers have the potential to sew confusion with the almost infinite variety of genotypes from a vast global gene pool". I wanted to be clear in my mind whether, when it comes particularly to under-studied and under-identified micro-organisms, whether molecular typing and barcoding is of limited value. When we hear about Craig Venter going around the world identifying many new species of marine microbes, is that of limited value in taxonomic terms?

Professor Lane: We need to distinguish between micro-organisms[4] and larger organisms; the species concept is quite different. The metagenomics approach that people such as Craig Venter are using, where you retrospectively assemble what you believe

[3] The Consortium for the Barcode of Life.

[4] Especially bacteria.

to be the number of the species in that habitat. The advantage is that is the only technique you can use currently to find out what is there. The disadvantage is that there is no alternative and independent method to assess whether that is a true estimate of life, so it is experimental. Their approaches were taken on much larger genome scans than the DNA barcoding, which is hoping to use relatively small segments and very few of them—the plants use four and in animals, we are trying to use one—eventually, I cannot see us using one, it does not discriminate consistently and we have now got good experiment evidence to show where it does and does not discriminate. The concept whether there is a standard set of short sequences that you could use, I think is showing increasingly to be a very valid diagnostic. Like anything in biology, it is not universal, but we are beginning to understand exactly where its limits are.

Professor Gibby: In the case of diatoms, which are single celled organisms, we have a NERC fellow working at the Garden at the moment in collaboration with a diatom systematist, trying to address the question of whether diatoms are universal or whether there is bio-geographic patterning in those organisms. They are ahead of the game in developing barcoding for diatoms and it is proving a very useful tool to address that question.

Q31 ***Baroness Walmsley:*** It is always tempting to assume that it is better overseas and indeed there are some shining examples like the National Science Foundation work on little known taxonomic groups, and the Canadian Barcode of Life, and we heard from Kew in their evidence about the investment that is going on in China into taxonomic infrastructure. Indeed, I saw that last year when I went to Wuhan Botanic Garden and the facilities there would have made your mouth water. So, the question about that is, why do you think the UK might be slow in responding to the gaps that everybody knows exist in taxonomic capacity?

Professor Hopper: I will be brave and venture an opinion. If you look at the countries where taxonomy is funded, and the contribution to global taxonomy is now in the top two or three, they have a concerted funding campaign and institutions set up to sponsor taxonomic research. There are various institutions and organisations that support some taxonomic research in the UK, but not one single place where you could say that there is the equivalent of the Australian Biological Resources Study, for example, or the NSF in the USA, where they have set up a dedicated systematics programme.

Q32 ***Baroness Walmsley:*** Does it need to be a place, or a virtual place?

Professor Hopper: It could be either; it needs responsibility and a budget.

Q33 ***Chairman:*** In the case of China, could it be because of the perceived power of traditional Chinese medicine and its links in the case of the Wuhan Garden? Is there a force pushing it forward there?

Professor Gibby: It is linked in, because all the botanic gardens in China that have research institutes alongside are very much pursuing the economic aspects of botany, at the same time as doing the classical taxonomy and systematics and the digitisation and databasing of the collections. They all have that applied focus.

Q34 ***Baroness Walmsley:*** What they do not know about kiwi fruit is not worth knowing! They call it Chinese gooseberry, of course.

Professor Lane: It is about scale and many of the big initiatives we are seeing in other countries are about doing large-scale science, or large-scale infrastructure. It has been interesting that our ability to raise funds for systematics collections, as a science infrastructure, has been very successful in Europe—the institutions at this table are part of a consortium to integrate the research collections of Europe; 20 different organisations, funded by the European Commission[5]—and that was the highest rated integrated infrastructure, which is quite something. So, integration is a key driver, but it is also about seeing infrastructure as large-scale enterprises. It is difficult to see which part of the science structure in the UK where it would be easy to go and make a case for a basic infrastructure that cuts across so many different research councils or government departments.

Q35 ***Lord Methuen:*** Local and regional recording schemes provide valuable data for conservation assessments. These smaller organisations express their need for support for managing databases, as well as for training and access to voucher collections. How do the professional taxonomists from the large institutions interact with and support these small organisations, including local museums?

Professor Gibby: All of those organisations get support through specialists in all of our institutions who are working with the amateur community through specialist societies. There is a wide range of specialist societies in which most of the leaders of those societies—and they are a mixture of professionals and amateurs, coming from within the communities such as those sitting around this table—leading, training and helping to take that forward. The Museum is obviously a major player in NBN; all the specialist societies are contributing data to the

[5] And managed by the Natural History Museum.

NBN, but they need the help of the professionals in our organisations to come up with the correct names and synonyms. I know that the conservation agencies have been very supportive, at least in Scotland, SNH has been very supportive, in providing those local recording organisations with the capacity to digitise their paper records and get them linked in with the NBN. It is our organisations, but also the conservation agencies, which are helping support them.

Dr Nic Lughadha: The type of support we provide extends from physically giving them a base—the British Mycological Society, for instance, is headquartered at Kew and uses the Kew address, and the staff there interact with our mycologists continuously—through to support for publication. Perhaps the single most important type of support is identification, being able to provide those specialist identifications through access to the reference collections, and that is what the amateur community most urgently looks for from Kew.

Q36 ***Lord Krebs:*** My question relates to your last point. I wondered what role the national institutions have in standard setting for the amateur clubs and societies around the country. If we are relying on amateur input for national data, which is incredibly important, it is equally important that we have the right standards and perhaps your point about identification is part of that. Could you say a few words more generally about that?

Dr Nic Lughadha: While we call these people amateurs, many of them are very professional indeed and have professional levels of experience. Certainly in mycology in the UK, that interaction is essential. The professionals rely very heavily on the amateurs providing material which fills gaps in distribution and often adds new records of species that are new to the UK, or sometimes even new to science. It is a very productive and close relationship.

Professor Lane: It is fair to say that the relationship is pretty intimate. In our department of entomology, 15 members of staff are national recorders, so they have this "other life" where they can closely interact with the community. Very often the national collections are the reference points where people come for identifications and sometimes our staff provide those, but very often—and that was the point just made—many amateurs are extraordinarily knowledgeable and sometimes we will use those as the authority rather than from inside our organisations. Often the national collections then become the favoured repository for vouchers, in due course, which is how the flow of knowledge comes into our organisations, as well as the earlier flow-out in helping them develop. All three institutions have quite an intimate relationship with either the subject societies or recording groups. There are an extraordinary number of recording groups and we give them house room, as we do other organisations. Our new centre for UK biodiversity is specifically designed to allow many other organisations to come and use our facilities so that they can ramp up the rate at which this work can be done.

Q37 ***Chairman:*** What is the take up like? Are you finding other organisations coming to use these facilities?

Professor Lane: The facility is not open yet, it is just being developed. The interest is extraordinary. When we have gone out and said that we intend to build this, is it something that you could use and how would you use it? there has been much enthusiasm.

Professor Gibby: The conservation agencies are funding posts within the specialist societies to train people and take them forward. We are hosting one of those posts in the Botanical Society of the British Isles—a special Scottish officer, hosted within the Garden—so that makes the networking and communication very effective.

Q38 ***Lord Krebs:*** You obviously represent the three major national institutions of taxonomic collections. There are, of course, a number of other important regional institutions, such as the National Museum of Wales, and some of the big civic museums in Manchester and Liverpool, not to mention Oxford and Cambridge. I wondered how your work integrates with the work of these regional collections; is there sufficient integration, should more be done, how closely to you work together?

Professor Gibby: From the plants point of view, there are some plant specialists in these organisations whose primary responsibilities are curation, local work and identification. They are linked in with our contacts through the specialist societies, so there are no other links because the plant people are not actively undertaking research, they are either looking after the collections or communicating with the public and trying to increase visitor numbers to their museums.

Dr Nic Lughadha: The National Museum of Wales might be the most research active of the institutions mentioned, and Kew has active collaborations there, primarily focused on UK or western European endemic species, and we are working with both population genetics and conservation biology approaches, so that the joint research informs conservation management decisions on species such as whitebeams, hawkweeds, etc. To expand the definition of regional nationals, we wondered whether here we should also be looking at the UK overseas territories, which have very high concentrations of UK biodiversity; There is very

significant scope for integration between the work of our institutions and that of the overseas territories and it is an area that is often omitted when considering the UK biodiversity. It is an area where we at Kew are actively working and where we think there is further scope for integration limited, as ever, only by resources.

Q39 ***Chairman:*** That came up in the seminar that we had. It might be useful, if there are additional things to say, if you could drop us a line giving us a list of the obvious things.
Dr Nic Lughadha: Yes, of course.
Dr Dixon: From the Natural History Museum's point of view, we welcome collaborative projects. We work quite actively with regional museums but it tends to be very project based and across the whole spectrum of what we do. There are real opportunities for further collaboration and we would welcome ways of taking that forward.
Chairman: You might welcome being "urged" to do so by us!

Q40 ***Lord Colwyn:*** Your answers to my previous question showed that the internet may well provide the opportunity to revolutionise taxonomy. UK scientists are showing great leadership in developing the vision of taxonomy, yet pilot schemes and projects that have demonstrated proof of concept of various aspects of web-based taxonomy are rarely translated into new working practices, and I wondered why that was. There is a second part to that question: who in the UK is developing this strategy to deliver this vision and is a UK-wide strategic plan for a web-based access necessary for the long-term survival of taxonomy in the UK?
Professor Lane: Concerning the vision for taxonomy in the 21st century, recently a small group of us was invited to come up with a vision as to how the whole of Europe might work, and that is what I had the pleasure to chair, I took the vision report to a board consisting of the major museums in Europe and I am very pleased to say that it was very well received. Most of the museums in Europe will now use that as their guide for where their museums will develop, as well as this integrated structure for Europe (European Distributed Institute of Taxonomy). We have not yet sat down and worked out what it means for the UK. We have certainly already had some preliminary discussions with colleagues from Kew about converting this vision to some kind of strategic plan, but mainly in the context of how our two organisations play within Europe, but we are also very cognisant of the fact that we need to make a plan for how the UK takes its scientific agenda forward. So, there is work to be done.
Dr Dixon: Inevitably, cost has to be discussed. We talked about some of the American foundation-funded projects and as an example the Biodiversity Heritage Library, which is a big collaboration between nine major institutions, of which certainly those represented around this table are participants. It is funded to the tune of about $25 million over the next three years, which gives you an idea of the scale of the investment required to deliver these kinds of projects. Twenty-five million dollars is approaching half of what the Natural History Museum spends on science annually, which gives you an indication of the size of cost that is required to deliver these projects. Proof of concept or pilot projects can be developed often with external funding and are easy to deliver but the full working version requires resources that we just do not have access to in the main.

Q41 ***Baroness Walmsley:*** We heard from Kew, in your evidence, that without baseline data, progress towards the 2010 objective of halting biodiversity loss is simply not going to be achieved. It makes sense to me that you do not know how far you have come, if you do not know where you have started from. That reminds me of the old Irish joke: how far to Tipperary? Well I wouldn't have started from here! But I wonder if our other witnesses would agree with that piece of evidence that we had from Kew, and whether you think that other colleagues from other institutions would also agree with it? And if not, why not?
Dr Dixon: Broadly, we would agree, but we are also sympathetic to the argument that policy cannot wait for perfect science; somewhere in the middle there is a happy medium. As with many things, it is, are you setting the right targets, and is the setting of those targets well enough informed by good evidence? Largely, we are in agreement with Kew on this point.
Professor Lane: This comes back to the point I was making at the beginning about the major challenges and they are about how life on the planet changes. It is not just setting the baseline—and there will be baselines because this cannot be a one shot—but also it is about devising the science to support measuring change, rather than absolutes. That is quite a challenge, scientifically, and one that we are beginning to tackle in a fairly serious manner. How you set the baseline is important but it is also how you develop a science that tracks changes.
Dr Nic Lughadha: In that context, much of the baseline data that we need sits in the collections. This is not a backdoor argument for digitising everything, but there is an argument to say that a very judicious representative selection of taxa could establish a baseline, which could then be reassessed over time. All of our three institutions are collaborating with the Zoological Society of London on the Sampled Red

List Index, which could provide a baseline of this sort, but, again, needs further resources to enable it to succeed.

Q42 ***Earl of Selborne:*** Regarding the commitments and obligations under the Convention on Biological Diversity, is there any risk that we are going to fail to meet such commitments and obligations because of our lack of strength and capacity in taxonomy?
Professor Hopper: In a word, yes; it is just that simple. You have to understand the units of biodiversity in order to manage and care for them and to do all the access and benefit sharing that CBD also involves UK organisations in. The UK has responsibilities beyond its shores in this regard and taxonomy is the underpinning foundation for implementing the Convention.
Earl of Selborne: Do you think the funding departments understand the significance of this? We have three different funding departments, presumably you remind them from time to time of the obligations of the Convention. Do they respond?

Q43 ***Chairman:*** Or, to be blunt, when did you last remind them of the obligations of the Convention?
Professor Hopper: A few weeks ago.
Professor Lane: I completely agree with Professor Hopper that the answer is categorically that taxonomy underpins just about all of these Convention obligations. The degree of our compliance (to the CBD obligations), given the extraordinary wealth of science and resource that we have, is a political judgment call that needs to be made. Can we deliver to an expected level given the base of both expertise and resource? Within our current resources, the answer is, No. There are large numbers of ways and I have here a document produced by the Global Diversity Information Facility, which lists a number of examples of how species level information of the kind that we were talking and the kind that we should be providing under CBD and others, can be used to make various policy judgments. We need to make our negotiators aware of what our capacity is and also about our limitations to deliver.

Q44 ***Chairman:*** Would it be possible to provide us with a copy of that report? It would be most useful.
Professor Lane: Yes, I will leave this copy here.
Chairman: We are now at the end of the session. I thank you all very much indeed. As I suggested at the beginning, if there are points that you want to amplify or clarify or add to comments that you have already made, that would be helpful. Had we had more time, I might have asked you how we can promote taxonomy to the wider public and community. Many thoughts have been implicit in what you have said, but if you have more explicit comments perhaps you would let us have them; that would be very useful indeed. Thank you all very much; it is much appreciated.

TUESDAY 11 MARCH 2008

Present	Colwyn, L	Northesk, E of
	Haskel, L	Soulsby of Swaffham Prior, L
	Howie of Troon, L	Sutherland of Houndwood, L (Chairman)
	Krebs, L	Walmsley, B
	Methuen, L	Warner, L

Memorandum by the Research Councils UK

1. Research Councils UK is a strategic partnership set up to champion the research supported by the seven UK Research Councils. RCUK was established in 2002 to enable the Councils to work together more effectively to enhance the overall impact and effectiveness of their research, training and innovation activities, contributing to the delivery of the Government's objectives for science and innovation. Further details are available at www.rcuk.ac.uk.

2. This evidence is submitted by RCUK on behalf of the Arts and Humanities Research Council (AHRC), the Biotechnology and Biological Sciences Research Council (BBSRC), the Medical Research Council (MRC) and the Natural Environment Research Council (NERC), and represents their independent views. It does not include or necessarily reflect the views of the Science and Innovation Group in the Department for Innovation, Universities and Skills.

3. AHRC supports research within a huge subject domain from traditional humanities subjects, such as history, modern languages and English literature, to the creative and performing arts. The AHRC funds research and postgraduate study within the UK's higher education institutions. In addition, on behalf of the Higher Education Funding Council for England, it provides funding for museums, galleries and collections that are based in, or attached to, higher education institutions in England.

4. BBSRC is the UK's leading funding agency for academic research in the non-medical life sciences. BBSRC's contribution to this memorandum focuses on developments that have taken place since the Committee's 2003 report[1], rather than on re-iterating its position on systematics and taxonomy, which is very similar to its position in 2002.

5. MRC supports the best scientific research to improve human health. Its work ranges from molecular level science to public health medicine and has led to pioneering discoveries in our understanding of the human body and the diseases which affect us all.

6. NERC funds and carries out impartial scientific research in the sciences of the environment, and trains the next generation of environmental scientists. Details of NERC's Research and Collaborative Centres are available at www.nerc.ac.uk. NERC's contribution is based on the views of the British Antarctic Survey (BAS), Centre for Ecology and Biology (CEH), National Oceanography Centre Southampton (NOCS), Plymouth Marine Laboratory (PML), Scottish Association for Marine Science (SAMS) [2], Sir Alister Hardy Foundation for Ocean Science (SAHFOS) [2] and Swindon Office Staff. NERC's terrestrial science community appears less prominent in this response than is properly representative of its level of relevant activity.

Question 1. *What is the state of systematics research and taxonomy in the UK? What are the current research priorities? What are the barriers, if any, to delivering these priorities?*

7. As recognised by the Committee in its 2003 report, both BBSRC and NERC have an interest in this area, and work closely on some aspects. AHRC has an interest for reasons explained in answer to Question 8. The MRC has a small interest, in particular concerning the evolution of infectivity, virulence and pathogenicity of pathogens.

8. Although it acknowledges the fundamental role of systematics in most areas of life science research, BBSRC has little involvement in the support of taxonomy. It sees taxonomic research as mostly taking the form of scholarship associated with the maintenance of collections, and therefore funded by bodies responsible for those collections, or as relating to the understanding of biodiversity in the natural

[1] http://www.publications.parliament.uk/pa/ld200203/ldselect/ldsctech/130/130.pdf
[2] These centres are also making separate submissions to the Inquiry.

environment, thus falling *inter alia* within the remit of NERC. However, since the publication of the 2003 report, BBSRC has been involved in the active promotion of systematics research through the establishment of a Systematics Working Group within the Council. The remit and some of the outcomes are described in paragraphs 30–36.

9. NERC is not primarily concerned with systematics and taxonomy *per se*, focussing instead on using the information, particularly in the context of how biodiversity contributes to key ecosystem processes and services. The Biodiversity theme in NERC's new Strategy[3] acknowledges the need for tools and techniques to describe biodiversity and to measure the abundance and distribution of its functional components. Some of the other six themes in the Strategy include challenges, such as constructing integrated assessment models linking climate change with changes in, among other things, the natural world, where systematics and taxonomy could contribute (see answer to Question 2). NERC's most relevant research programmes are also outlined in answer to Question 2.

10. The face of systematics and taxonomy has been changing as a result of developments in information technology and molecular biology. There have been moves to increase the accessibility of systematics and taxonomy knowledge through the internet, as recommended by the Committee in its previous report. Developments in the molecular sciences, including the potential for rapid screening via molecular barcoding (DNA Barcoding, eg with the involvement of the NERC Culture Collection of Algae and Protozoa within the framework of the Canadian Barcode of Life Network), are also providing a significant opportunity to advance and revitalise systematics and taxonomy, although there is some concern that the cost of molecular techniques is depriving traditional taxonomy of funds, and that although there is much to be gained in systematics and taxonomy by combining new molecular approaches with classical taxonomy, dedicated funding may be required to support the necessary collaboration.

11. Both BBSRC and NERC have an interest in the development of methods and tools for systematics and taxonomy, and in supporting research projects where new technology can be used for making the knowledge accessible to a wide audience eg through the internet. NERC is currently funding, under its e-Science programme, a consortium project (CATE). Further details appear in response to Question 9.

12. Although there is recognition of the importance of systematics and taxonomy research, and considerable support for it, some barriers remain:

- Limited total funding, combined with competing priorities;
- The relative unattractiveness of traditional systematics and taxonomy, in terms of securing research funding and support for essential underpinning, via culture collections. Grant proposals are generally required to be hypothesis-based, and while grants to assess, for example, biodiversity and ecosystem function in deep-sea communities are funded, the taxonomic effort that is required to underpin such studies may remain unsupported (but see paragraph 27 regarding one of the possible benefits of NERC's new National Capability funding stream);
- The fact that classical taxonomy is detailed and labour intensive. The scientific outputs that taxonomists create for users of taxonomic science (species descriptions, identifications, keys, guides, inventories) require considerable time and resources to provide, and this is not always recognised by the user community or by those providing the funding;
- The sometimes low publication rate, and the failure of systematics and taxonomy to receive coverage in the most prestigious journals, which rarely publish species descriptions, for example; publications often have a low immediate impact factor and/or poor citation rate, and funding bodies may therefore not consider the science to be "cutting edge";
- The knock-on effect on career development, and thus the image of the discipline as a profession;
- The shortage of taxonomists coming into the profession, and the demands on current taxonomists to train their successors (but see comments regarding the identification of skills needs under Questions 4 and 13);
- The perception that there are still some ambiguities regarding the funding responsibilities of BBSRC and NERC in this area (but see paragraph 36 regarding cross-Council working);
- The scale of effort required, particularly for (marine) microbes. In some taxa in deep-sea ecosystems, more than 100 undescribed species may be present in a single small sediment sample. The deep-sea environment is the largest environment on earth, and only a tiny proportion has been sampled; often more than 50 per cent of the species in each sample are new to science. There are estimated to be more than 1.5 million diatom species in the world's oceans, of which fewer than 15,000 have been described;

[3] http://www.nerc.ac.uk/about/strategy/ngscience.asp

— The higher cost of developing and using molecular approaches, and thus the lower capacity overall for taxonomic "volume";

— The need to unambiguously relate molecular and traditional systematics and taxonomic methods; the newer approaches may not always be valuable if not used in conjunction with the traditional methods.

13. Some of the impediments to advances in taxonomy were debated in the journal *Science* in 2004[4].

Question 2. *What is the role of systematics and taxonomy and, in particular, in what way do they contribute to research areas such as biodiversity conservation, ecosystem services and climate change? How important is this contribution and how is it recognised in the funding process? How is systematics integrated in other areas of research?*

14. As indicated above, systematics and taxonomy play a fundamental role in the biological sciences. For example, scientists at NOCS and PML consider that systematics and taxonomy underpin almost all marine ecological research, particularly invertebrate and vertebrate ecology. We need at least a basic knowledge of the species that make up the communities we are studying (including an ability to distinguish between species and recognise the significance of their different characteristics) in order to maximise the gain from those studies, for example to properly measure biodiversity, to understand the implications of biodiversity change and geographical shifts in species, and to fully appreciate the extent and effects of environmental change. For example, BAS comments that taxonomic information underpins its research work in the Antarctic to determine biodiversity distributions (paleo and current day) and the impacts of disturbance by icebergs—a major driver of biodiversity in the South.

15. The value of process-based ecological research becomes much greater when closely linked to the scientific identities of the organisms concerned. Such identities are needed to connect biodiversity, biogeochemistry and ecosystem services; to exploit biotechnological applications, based on useful enzymes, pigments, nutrients or pharmacologically-active compounds; to use the fossil record to interpret past climate changes; and to monitor, predict and control human, animal and crop diseases.

16. An example of the importance of high-quality systematics and taxonomy, is provided by the case of climate-driven changes in relative abundance of two very closely related species of copepod (*Calanus finmarchicus* and *C. helgolandicus,* with maximum abundance at different times of year). These changes are now thought to have greatly accelerated the demise of cod in the North Sea. The taxonomic expertise to distinguish the two copepod species—and recognise the important of the change—had been maintained at the Sir Alister Hardy Foundation for Ocean Sciences (SAHFOS), funded by NERC, Defra and other partners. However, that skill-base was very nearly lost, and the necessary training is no longer routinely provided to undergraduate students.

17. For microbes with novel biotechnological potential (mostly marine)[5], systematics and taxonomy provide the necessary framework for cost-effective bioprospecting—with a taxonomically-based approach increasing the hit rate by 10–100 fold for potentially-exploitable secondary metabolites. NERC's Marine and Freshwater Microbial Biodiversity (M&FMB) and Post-Genomics and Proteomics programmes have developed significant national capability in this area. Instead of just a few thousand different kinds of bacteria, we now know there are many millions, mostly in the sea—with their varied genetics producing an equally wide spectrum of molecular entities, occupying a very much larger, and different, chemical diversity structural space than has been achieved to date by compounds developed through combinatorial chemistry. Smart isolation, de-replication and screening techniques (based on robotics, molecular biology and bioinformatics) now make it possible to isolate and investigate novel organisms and products of interest in weeks or days, rather than years.

18. Taxonomists at NOCS comment that the importance of, and interest in, marine biodiversity is exemplified by the Census of Marine Life, a major world-wide, 10-year initiative funded by the Sloan Foundation to assess and explain the diversity, distribution, and abundance of life in the oceans. The UK requires trained taxonomists to contribute to this endeavour.

19. One of the major discoveries made by the DEEPSEAS Group at NOCS is that abyssal deep-sea ecosystems can undergo major changes over decadal-scale time periods, possibly due to climatic oscillations. At the Porcupine Abyssal Plain, there has been a dramatic change in the abundance of organisms including holothurians and foraminiferans over the past 15 years. In the case of the foraminiferans, many of the species

[4] http://www.sciencemag.org/cgi/content/summary/sci;303/5656/285 and http://www.sciencemag.org/content/vol305/issue5687/#letters

[5] Economic Benefits of Environmental Science, NERC 2006, http://www.nerc.ac.uk/publications/corporate/economic.asp

that fluctuate in abundance are undescribed[6]. A recent study in Nature[7] (subsequently featured in TIME magazine's top 10 scientific discoveries of 2007, and co-authored by scientists from BAS, NOCS and SAMS) reported that during a series of cruises in the Southern Ocean, which took deep-sea samples in only a tiny fraction of this enormous area, more than 1400 species were identified and more than 700 of these were new to science.

20. Taxonomic principles and methods underpin medical research that aims to improve understanding of the evolution of infectivity, virulence and pathogenicity of pathogens—where their identity and lineage needs to be known with precision. An example of MRC research that builds on a strong microbial taxonomy, is research in The Gambia on the effectiveness of TB (BCG) vaccination in people who have had prior exposure to tuberculosis species and subspecies, other than *Mycobacterium tuberculosis*.

21. In at least parts of the systematics and taxonomic community there is a perception that the effort (and funding) in their disciplines has been decreasing. The NOCS DEEPSEAS Group introduces its pessimistic view of the future of its taxonomy work by saying that the "financial support for taxonomy within NOCs is effectively non-existent" (see answer to Question 13), and that "Taxonomic problems arising in postgraduate research are dealt with on a "needs must" basis funded by general grants, or, more usually, ignored. In effect, taxonomy, although vital to all areas of deep-sea biology, is not recognised in the funding process."

22. At PML, the view is that for many years the science effort in taxonomy and systematics has been decreasing. It says that there are still "a reasonable number of marine invertebrate "identifiers"—people who can distinguish one individual from another and assign a name to a specimen as long as it is in the taxonomic key (book) to which they have access. However, a whole set of skills and expertise to appreciate the importance of differences between organisms and to maintain the international standards for identification is disappearing rapidly from the UK, Europe and worldwide. This is important since although "identifiers" may be able to distinguish their own local or national organisms, they will not be able to share these data with others if they are not able to fully use and keep up with conventional taxonomy as well as develop the taxonomy further."

23. NERC does take account of the need for systematics and taxonomy in its funding decisions. About 11 per cent of NERC's Peer Review College members identify taxonomy and/or systematics in their expertise. NERC's main focus is not (and cannot be) on alpha taxonomy *per se*; the systematics and taxonomy that NERC supports must be within the context of environmentally-focussed projects. Recent research programmes with considerable taxonomic components include the Environmental Genomics[8], Marine and Freshwater Microbial Biodiversity[9] and Soil Biodiversity[10] programmes. Current programmes in which systematics and taxonomy are relevant include the Post-Genomics and Proteomics[11]; Sustainable Marine Bioresources[12]; and Quantifying and Understanding the Earth System (QUEST)[13] programmes, and UK PopNet[14] (which aims to place population ecology within the context of landscape change and sustainability). Through the Post-Genomics and Proteomics programme, NERC supports the Environmental Bioinformatics Centre (see answer to Question 7), and, as mentioned above, NERC is also supporting the CATE project under its e-Science programme (see answer to Question 9).

24. As indicated in answer to Question 1, a number of the themes in NERC's new strategy include challenges where systematics and taxonomy could contribute. The Climate system and Biodiversity themes have already been mentioned. The Biodiversity theme in particular presents a good opportunity for the contribution of systematics and taxonomy to broader research areas to be recognised and reflected in the funding process. The Sustainable use of natural resources theme includes challenges such as understanding how the biological, physical and chemical interactions in soils determine the extent to which people can use the land sustainably. The Environment, pollution and human health theme includes the challenge of increasing knowledge of the underlying biological, chemical and environmental processes that cause diseases to spread and determine how pathogens interact with other organisms. The Earth system science theme aims to include research to increase knowledge of the connections between biological evolution and adaptation, climate and environmental change.

[6] Gooday, A.J. & Rathburn, A.E. (1999). Temporal variability in living deep-sea foraminifera: a review. *Earth Sciences Reviews* **46**, 187-212.
[7] Brandt et al. (2007). First insights into the biodiversity and biogeography of the Southern Ocean deep sea. *Nature* **447**, 307-311. http://www.nature.com/nature/journal/v447/n7142/abs/nature05827.html
[8] http://www.nerc.ac.uk/research/programmes/genomics/
[9] http://www.nerc.ac.uk/research/programmes/mfmb/
[10] http://www.nerc.ac.uk/research/programmes/soilbiodiversity/
[11] http://www.nerc.ac.uk/research/programmes/proteomics/
[12] http://www.nerc.ac.uk/research/programmes/marinebioresources/
[13] http://www.nerc.ac.uk/research/programmes/quest/
[14] http://www.ukpopnet.org/

25. NERC's Strategy is currently being translated into theme action plans, which are being discussed with the academic community. It will be for the systematics and taxonomy community to see where they can contribute to the research programmes that derive from these plans, and for other funding applicants to ensure that they involve that community where necessary, or request adequate support for any essential taxonomic background. NERC has evidence that there is a sizeable and organised community of taxonomists interested in applying their skills in the environmental area, and welcomes applications in support of its strategic goals, as well as applications for responsive-mode funding.

26. The Oceans 2025 programme[15], involving NERC's main marine centres and the Marine Biological Association and SAHFOS, is being funded for 5 years and has Biodiversity and Ecosystem Functioning as one if its nine major science themes. The Oceans 2025 programme includes several key projects funded under NERC's new National Capability funding stream. These include the British Oceanographic Data Centre, the Permanent Service for Mean Sea Level, the Continuous Plankton Recorder Survey (CPR, at SAHFOS)[16]; the Marine Mammal Survey; and the Culture Collection of Algae and Protozoa (CCAP, which is the largest protistan culture collection in Europe and the second largest in the world, and interacts with protistan taxonomists worldwide)[17].

27. The National Capability funding stream could overcome some of the barriers that have previously existed regarding the funding of systematics and taxonomy by NERC, and will be used to support taxonomy-relevant research also in NERC's other (non-marine-specific) centres, particularly the Centre for Ecology and Hydrology (CEH), which is the home of the Biological Records Centre (BRC)[18], the British Antarctic Survey (BAS), and the Centre for Population Biology (CPB). It will help to support, for example, the ongoing biodiversity monitoring by CEH and the collections housed by the BRC, which is the national custodian of data on the distribution of wildlife in the British Isles. NERC expects CEH and the other centres to also compete for Research Programme funding and responsive-mode funding. The new CEH strategy is currently being finalised, and places considerable emphasis on biodiversity research.

28. NERC is also a partner in the BiodivERsA ERA-Net, which recently announced the availability of several million Euros for biodiversity research to address the decline in plant and animal species[19], and it contributes to DIVERSITAS[20], an international programme of biodiversity science.

29. NERC also provides annual support to the Linnean Society's Systematics Research Fund[21].

30. The role of the BBSRC Systematics Working Group included the encouragement of multidisciplinary working between systematics and other areas of the biosciences; review of BBSRC structures to identify any measures which could be implemented to improve numbers of appropriate proposals being submitted; and review of the potential for partnerships with other agencies in addressing these problems. Much of this work has been carried out in collaboration with NERC, which was a member of the Working Group.

31. One of the outcomes has been the establishment of the Collaborative Scheme for Systematics Research (CoSyst), for which BBSRC is providing £75,000 per year over three years. The Scheme is administered by the Systematics Association and Linnean Society. The purpose of CoSyst is to encourage researchers in systematics and taxonomy to collaborate with researchers in other areas of biology to incorporate the skills in systematics into those other areas. The Scheme is designed to support small-scale projects to generate important pilot data that are often required before a full grant application is successful. The Scheme was launched in December 2006 and is currently in its second round. The first round resulted in 43 proposals being submitted and 7 proposals being funded. A review of how the Scheme has been implemented will be undertaken during 2008–9.

32. One of the most significant funding developments is that, following a wider government review of eligibility, BBSRC has taken the opportunity to review the funding eligibility of the Natural History Museum and the Royal Botanic Gardens at Kew and Edinburgh. Following written submissions from all three institutions, BBSRC Council has agreed to confer on each the status of Independent Research Organisations eligible to apply for responsive mode research grants. This allows each institution to make investigator-led applications as well as to apply for funding through calls for research in managed programmes. The three organisations were already considered eligible for responsive and managed-mode funding from NERC at the time of the previous inquiry.

33. In addition to CoSyst, the BBSRC Systematics Working Group has led to a number of other practical outcomes, including a Systematics Symposium and a Biodiversity Exhibition.

[15] http://www.oceans2025.org/
[16] http://www.sahfos.ac.uk/
[17] http://www.ccap.ac.uk/
[18] http://www.brc.ac.uk/
[19] http://www.nerc.ac.uk/press/releases/2007/50-biodiversity.asp
[20] http://www.diversitas-international.org/?page=about
[21] http://www.linnean.org/index.php?id=336

34. The Symposium[22], organised by BBSRC and NERC, was held during August 2007 at the Royal Botanic Gardens Edinburgh as part of the Systematics Association Biennial Conference. It showcased systematics research funded by the Research Councils, highlighted the funding schemes and support available to the systematics and taxonomy communities from the Research Councils, and provided advice and contacts for potential applicants. A similar meeting on algal/protistan taxonomy was held at the Natural History Museum in April 2006[23].

35. The exhibition "Biodiversity—What on earth is it?" was launched by BBSRC and NERC in 2005. It is accessible online[24] and describes why biodiversity matters, and some of the work of Research Council-sponsored scientists in the areas of systematics and biodiversity.

36. By working together in this way, BBSRC and NERC hope to address any uncertainties remaining in the systematics and taxonomy community regarding which Council funds what, and regarding possible gaps in funding. A cross-Council agreement is in place regarding decisions on funding for proposals that cross Council boundaries. This agreement has been and will continue to be implemented for systematics/taxonomy proposals that are relevant to the remits of both Councils. There is a need to agree between Defra and DIUS the responsibilities for sustainable funding of microbial culture collections.

37. During next year, BBSRC will lead an activity to commemorate the bicentenary of the birth of Charles Darwin in 1809 with a series of public engagement activities. The aim of the events will be to demonstrate the importance and relevance of evolutionary research today.

38. MRC's investment in research on infections and disease-causing micro-organisms is approximately £45 million pa.

Question 3. *Does the way in which systematics research is organised and co-ordinated best meet the needs of the user community? What progress has been made in setting up a body to lead on this? What contribution do the leading systematics research institutions make both nationally and internationally?*

39. A number of fora address the co-ordination of research relevant to systematics and taxonomy, particularly biodiversity research that uses taxonomic knowledge. These fora include the Environment Research Funders' Forum[25] (ERFF), which recently published a strategic analysis of UK environmental monitoring activity; the UK Biodiversity Research Action Group (UKBRAG)[26], which runs the UK Biodiversity Action Plan; the National Biodiversity Network, which the BRC is helping to develop; the UK Global Environmental Change Committee (UKGECC) Biodiversity Sub-Group[27]; the Soils Research Advisory Committee[28], which was set up by BBSRC and NERC; and the Global Taxonomy Initiative.

40. BBSRC, NERC and CEH are members of UKBRAG; and NERC and BBSRC are members of ERFF and of the UKGECC Biodiversity Sub-Group, which has close links with UKBRAG.

41. At a European Level, the BiodivERsA ERA-Net[29] referred to above involves 19 partners from 14 different countries, and aims to bring together the best minds across Europe to address present and future challenges in biodiversity, linking scientific advancement to policy and practice.

42. At an international level, the DIVERSITAS programme mentioned above makes a significant contribution to international co-operation on biodiversity research, necessary "because the complex scientific questions posed by the global loss and change of biodiversity are beyond the scope of individual countries and disciplines". The programme is a partnership of inter-governmental and non-governmental organisations. Its integrated research framework and international multidisciplinary networks aim to promote, facilitate and catalyse scientific research on biodiversity—its origin, composition, ecosystem function, maintenance and conservation.

43. The bioDISCOVERY core project includes many tasks demanding taxonomic input, and aims to strengthen taxonomic expertise in understudied taxa and regions. Professor Georgina Mace, the Director of NERC's CPB, and Terry Parr of CEH are members of the Scientific Committee. One of the co-chairs of the bioSUSTAINABILITY core project is Professor David Raffaelli, Director of UKPopNet (mentioned above). The third core project is ecoSERVICES.

[22] http://www.systass.org/biennial2007/
[23] The findings of this meeting have been published : ISBN 0-8493-7989-X
[24] http://www.bbsrc.ac.uk/society/meetings/exhibition_biodiversity/home.html
[25] http://www.erff.org.uk/
[26] http://www.jncc.gov.uk/default.aspx?page = 3900
[27] http://www.ukgecc.org/dvl_Biodiversity.htm
[28] http://www.nerc.ac.uk/research/areas/terrestrialfreshwater/soil/
[29] http://www.eurobiodiversa.org/index.php?option = com_frontpage&Itemid = 1

44. The Global Taxonomy Initiative[30] (GTI) has derived from the recognition by Governments worldwide (through the Convention on Biological Diversity) that taxonomy is needed to support effective conservation and management of biodiversity. DIVERSITAS and the Global Biodiversity Information Facility (GBIF)[31] (see under question 9 below), as well as the Royal Botanical Gardens at Kew, are regarded as partners. The activities agreed under the GTI highlight issues, facilitate the exchange of information, and promote technical cooperation.

45. In the medical area, Professor Duncan McGeogh and Dr Andrew Davison of the MRC Virology Unit (Glasgow) both serve as members of the Executive Committee of the International Committee on Taxonomy of Viruses, and are active members of virus-family-specific subgroups.

Question 4. *What level of funding would be needed to meet the need for taxonomic information now and in the future? Who should be providing this funding?*

46. Substantial funding is required to train new scientists and ensure that taxonomic skills do not disappear completely; ideally, the newly-trained scientists should be able to understand and use classical skills as well as new molecular tools. The museums (eg Natural History Museum) and Biological Resource Centres / culture collections (eg CCAP) are probably best placed to guide and train a new cohort of scientists and are aware of the urgent needs in this area. The skills needs review shortly to be conducted by ERFF (led by NERC) should help to clarify those training needs and identify how they can be met.

Question 5. *How does funding in other countries compare? Could there be more international collaboration? If so, what form should this collaboration take and how might it be achieved?*

47. The need for the Global Taxonomy Initiative confirms that systematics and taxonomy are or have been short of support worldwide, and probably no country in the world can claim to have expert taxonomists covering all groups of organisms. The few remaining classical taxonomists are overwhelmed by the amount of work that needs to be done in training new scientists and covering areas which have been very poorly covered for many years.

48. Funding appears not to be significantly more generous in other EU countries than in the UK, but there is relatively generous support and interest in the USA, a position achieved through initiatives such as the Partnerships for Enhancing Expertise in Taxonomy—PEET—programme[32] sponsored by the National Science Foundation, and funding from private foundations (eg Sloan Foundation, Moore Foundation). However, some taxonomists consider that even the PEET programme has some drawbacks, placing perhaps disproportionate emphasis on the computer infrastructure compared with alpha taxonomy[33]. The CCAP has some involvement with PEET and the two Foundations have provided some funding for CCAP initiatives.

49. With regard to systematics and taxonomy research relevant to marine biodiversity and bioresources, the relatively positive position in the USA is seen also in Japan and, increasingly, China.

50. Our answer to Question 3 indicates that European and international collaboration motivated by concerns about the decline in biodiversity is already quite extensive.

51. The UK is also involved in the international Census of Marine Life (CoML), the International Census of Marine Microbes (ICoMM) and international validation/intercomparison initiatives regarding marine microbial barcoding. BAS plays an important role in the Census of Antarctic Marine Life (CAML)[34], which is supported by the Sloan Foundation.

52. In addition to supporting BiodivERsA, DIVERSITAS, and GBIF, NERC supports international collaboration through an International Opportunity Fund award (to Dr I Joint, PML) to enhance wider networking for the Marine and Freshwater Microbial Biodiversity community. This has involved working visits for UK researchers to the USA and elsewhere, an international workshop, and (26 Jan–3 Feb 2008) a science mission to Japan, co-supported by the Foreign and Commonwealth Office (via the UK embassy, Japan). Although the topic of the mission is formally "marine bioresources", a major theme of the visit relates to the isolation, identification and exploitation of novel marine microbes.

[30] http://www.cbd.int/gti/
[31] http://www.gbif.org/
[32] http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5451
[33] R. Wills Flowers (2007). Comments on "Helping Solve the "Other" Taxonomic Impediment: Completing the Eight Steps to Total Enlightenment and Taxonomic Nirvana" by Evenhuis (2007). *Zootaxa* 1494: 67–68. http://www.mapress.com/zootaxa/2007f/zt01494p068.pdf
[34] http://www.caml.aq/

53. The DEEPSEAS Group at NOCS comments that there are very good international collaborations within the taxonomic network. In one member's experience of two particular taxa (Amphipoda, Isopoda), experts communicate well, helping each other with specimens and samples and working on projects together where funding allows.

Question 6. *What impact have developments in DNA sequencing, genomics and other new technologies had on systematics research? In what way has systematics embraced new technologies and how can these research areas interact successfully and efficiently?*

54. Molecular approaches have revolutionised systematics and taxonomy research. The evolutionary relationships between many species, and between higher groups, have been overturned, and the species concept is itself now primarily defined in molecular terms.

55. The NERC Molecular Genetics Facility (MGF, at Sheffield, Edinburgh and Liverpool)[35] has played a major role in that process. As an example, the NERC Culture Collection of Algae and Protozoa (CCAP) is currently working with the MGF to carry out a major taxonomic revision for all organisms CCAP holds in culture (currently $\sim$ 2800 strains), based on the "SSU" and "ITS" rDNA sequences (genes for partial small sub-unit and internal transcribed spacer ribosomal RNA) and other suitable molecular markers. CCAP is also involved in international efforts for the development of barcode sequences for protists.

56. The Plymouth Marine Laboratory has support from NERC (Post Genomics and Proteomics programme) and ICoMM for "metagenomic" sequencing of 16s ribosomal RNA (a component of the 30-Svedberg subunit of ribosomes) in marine microbes (bacteria and archaea) at a long-term sampling site in the English Channel, to study seasonal changes in community composition.

57. BAS also carries out a range of genomic studies, the data from which are submitted to international databases.

58. Despite the promise and power of molecular taxonomy, this new discipline is unlikely to solve all our current taxonomic problems, at least not in the near future. Our current knowledge of biodiversity and ecosystem function is largely based on morphology-based classical taxonomy. It is important that the molecular approach develops alongside the classical approach. The value of a polyphasic approach, marrying traditional taxonomic methods and modern molecular biology, has helped CCAP in a number of case studies.

59. A degree of mis-match between the techniques is inevitable, because the two approaches look at different suites of characters. At least some taxonomists consider that classical taxonomy will continue to be the prime tool for furthering advances for many years to come, although the new molecular tools are already providing massive advances particularly in microbial systematics, where the classical approaches have thus far been less successful. Many of the most interesting systematics and taxonomic discoveries in NW Europe, are now likely to be made as a result of molecular studies.

Data collection, management, maintenance and dissemination

Question 7. *Does the way in which taxonomic data is collected, managed and maintained best meet the needs of the user community? What is the state of local and national recording schemes?*

60. Taxonomy users benefit from easy access to data, hence the drive to increase access via the internet (see answer to Question 9). Web-based taxonomy offers many advantages over paper-based taxonomy, particularly for scientists from developing countries, since many simply do not have access to the necessary research literature.

61. NERC's Culture Collection of Algae and Protozoa (CCAP)[36] has an internet site which allows users to search for strains they wish to order, and provides advice on how to deposit new strains. CCAP is involved in a pioneering collaboration with the European Bioinformatics Institute (EBI), to provide 2-way direct hyperlinks between EBI-held sequence data with CCAP database strain records.

62. The Centre for Ecology and Hydrology's new draft strategy[37] includes an outline of its Environmental Informatics Programme, which addresses the need to ensure easy access to the results of recording schemes such as the Countryside Surveys, Phenology Network, Predatory Bird Monitoring Scheme and the schemes run by the Biological Records Centre (BRC), but most of the schemes covered use, rather than produce, primary taxonomic knowledge.

[35] http://www.nerc-molgen.org/
[36] http://www.ccap.ac.uk/
[37] http://www.ceh.ac.uk/consultation/documents/science_strategy.pdf

63. One scheme that does provide access to primary taxonomic knowledge is NERC's Environmental Bioinformatics Centre[38] (NEBC). The NEBC is a dedicated bioinformatics and data management centre based at CEH Oxford that works to develop and implement solutions for NERC Environmental Genomics and Post-Genomics and Proteomics researchers, although it also has a remit to manage bioinformatics-related data generated by NERC-funded researchers outside those programmes. The Centre was originally set up in 2002 as part of the Environmental Genomics initiative. It is currently expanding its remit to include support for proteomics and metabolomics data management, and integration of solutions in a systems biology context with funding from the Post Genomics and Proteomics Programme. The NEBC team of bioinformaticians and data managers are responsible for the development of a variety of open-source projects.

64. The Natural History Museum is regarded by BAS and other users in the NERC research community as an excellent source of knowledge.

Question 8. *What is the role of the major regional museums and collections? How are taxonomic collections curated and funded?*

65. The AHRC is currently funding a collaborative project between the Natural History Museum and Kingston University called *New Perspectives*. The project is investigating the potential of using taxonomic collections as a research resource for the wider Arts and Humanities academic community. The *New Perspectives* Advisory Group consists of external academics from a range of disciplines and Museum staff. The Advisory Group is seeking wider input to its deliberations through a series of workshops, up to June 2008.

66. Preliminary findings of the project have confirmed that taxonomic collections, (their history, acquisition, interpretation and public display) represent a significant and yet largely untapped resource for academic research in the following areas:

- Museum studies
- Art (art history, contemporary art and design)
- History (social history, empire studies and history of exploration)
- Social Sciences

67. This project is detailed as a single example only; there are other arts and humanities interest, research and expertise that could add to the body of knowledge in an area usually thought of as scientific only.

68. The AHRC's remit also includes research in the fields of collections management and exhibition design, as well as broader institutional and organisational practices (eg collecting, conservation, display, interpretation, exhibiting, management, curatorship etc), material culture and the history of and relationship to objects.

69. Interdisciplinary research has the potential to bring academics from a wide range of disciplines into close contact with museum taxonomic collections and specialist curators. This interchange encourages knowledge transfer and the development of innovative ideas. A major benefit for university departments conducting such interdisciplinary research in a museum context is the opportunity to make academic outcomes accessible to a wide and varied public audience through museum exhibitions and formal and family learning programmes.

70. NERC's CCAP is funded as National Capability within the 5-year Oceans 2025 programme and managed by the Scottish Association for Marine Science, one of NERC's Collaborative Centres. It has the most genotypically diverse holdings of any national biological records centre. This provides a world-class resource to the scientific community, with research foci, relevant to this inquiry, on the elucidation of taxonomic questions and the *ex situ* conservation and genotypic stability of conserved taxa.

71. BAS has a variety of collections, marine and terrestrial, including a very comprehensive collection of Antarctic mosses and lichens. These are maintained by NERC core funding, and available through the Antarctic Environment Data Centre.

72. NOCS holds an internationally important collection of deep-sea specimens dating back to the 1970s. The specimens are extremely valuable (because they were difficult to collect and include a high proportion of species new to science), but there is no funding for curation or maintenance; there is no obvious organisation to apply to for such funding.

73. The BBSRC-sponsored Institute for Food Research holds the National Collection of Yeast Cultures and is funded from the Core Strategic Grant from BBSRC. The National Collection of Industrial and Marine Bacteria has been partially funded by short-term grants from BBSRC.

[38] http://nebc.nox.ac.uk/

Question 9. *What progress has been made in developing a web-based taxonomy? How do such initiatives fit in with meeting demand for systematics and taxonomy information? How do UK-led initiatives fit in with international initiatives and is there sufficient collaboration?*

74. Considerable progress has been made in developing a web-based taxonomy. There is almost a proliferation of online taxonomic databases, including the Encyclopedia of Life (EoL)[39], the European Register of Marine Species (ERMS)[40], the Global Biodiversity Information Facility (GBIF)[41] mentioned in answer to Question 3, the International Plant Names Index (IPNI)[42], and the Integrated Taxonomic Information System ITIS[43].

75. Both NERC and BBSRC have continued their support for the GBIF, whose objective is to facilitate the digitisation and global dissemination of biodiversity data (with particular emphasis on developing the tools to share this information through the internet). The software on which the global dissemination of information is based originated from a Bioinformatics Initiative research project funded by BBSRC and Engineering and Physical Sciences Research Council.

76. As mentioned in answer to Question 2, NERC is funding, under its e-Science programme, the CATE[44] project—Creating a Taxonomic e-Science. The particular goal of CATE is to test the feasibility of creating a web-based, consensus taxonomy using two model groups, one from the plant and the other from the animal kingdom. The wider aim is to explore practically the idea of "unitary" taxonomy[45] and promote web-based revisions as a source of authoritative information about groups of organisms for specialist and non-specialist users. The project involves scientists at Imperial College London (in NERC's Centre for Population Biology—CPB), the Natural History Museum, the Royal Botanic Gardens Kew, and the University of Oxford—the last being where Professor Charles Godfrey, former director of the CPB and inspiration for the project[46], is now based.

77. The answer to Question 7 refers to the role of the NERC Environmental Bioinformatics Centre, in developing web access to genomics, proteomics and metabolomics data.

78. NERC's CCAP website is being developed as a comprehensive protistan knowledge-base and now also provides access to a wider range of related data including images, biogeographical, chemical, literature reference and sequence data. Several online image libraries now exist for difficult-to-identify organisms; eg the communal "micro*scope" website[47], the PLANKTON*NET[48] website sponsored by the European-Commission and German research organisations, and the University of Liverpool's "Harmful Plankton Project on the Internet"[49] site. The Natural History Museum also offers a Microbiology Video Collection[50] online.

79. The Plymouth Marine Laboratory comments that in marine nematode and polychaete taxonomy there have been some limited initiatives towards web-based systems, but that as with all things taxonomic, setting up the necessary databases of known species is an enormous task and has been beyond the funding scope of most UK projects.

Question 10. *What needs to be done to ensure that web-based taxonomy information is of high quality, reliable and user-friendly?*

80. Close collaboration between taxonomists, web-designers and users is obviously critical.

81. High quality can only be ensured if taxonomists are involved. This places demands upon their already limited time, especially in the context of falling numbers of experts. Information for the databases has to be correct and up to date, but few resources appear to be available to taxonomists to support their involvement in the editing process.

[39] http://www.eol.org/
[40] http://www.marbef.org/data/erms.php
[41] http://www.gbif.org/
[42] http://www.ipni.org/
[43] http://www.itis.gov/
[44] http://www.cate-project.org/
[45] http://www.cate-project.org/unitary_taxonomies.html
[46] Godfrey, C. (2002). Challenges for taxonomy. Nature 417, 17-19. http://www.nature.com/nature/journal/v417/n6884/full/417017a.html
[47] http://microscope.mbl.edu
[48] http://planktonnet.awi.de
[49] www.liv.ac.uk/hab
[50] http://internt.nhm.ac.uk/jdsml/research-curation/projects/protistvideo/index.dsml

Question 11. *How does the taxonomic community engage with the non-taxonomic community? What role do field studies play?*

82. As indicated earlier, NERC's interest in systematics and taxonomy is focused on the ways in which these disciplines can contribute to understanding in environmental science. Field studies are a major component of much of the research that NERC funds, and many of these involve work requiring access to taxonomic knowledge, for example the work of the BRC.

Skills base

Question 12. *What are the numbers and ages of trained taxonomists working in UK universities and other organisations?*

83. There is taxonomic expertise in some of NERC's Research and Collaborative Centres. Some details are provided below, but not for CEH (which is mainly a user of taxonomy) or CPB. NERC currently funds or has agreed to fund seven fellowships[51] under the science topic of systematics and biodiversity, but this number does not include other academics in Higher Education Institutions who might be working with NERC funding on systematics or taxonomy-related research.

84. Although taxonomy is essential to the research at BAS on the possible impacts of climate change, for example through the warming oceans, it does not have an explicit long-term programme on taxonomy, ie it is a user not a generator, and has no dedicated taxonomists.

85. In the DEEPSEAS Group at NOCS, which studies deep-sea benthic biology, there are five taxonomic experts, with a range of expertise in different taxa. These are defined as; scientists currently working on resolution of alpha taxonomic problems (describing new species, resolving and revising taxonomic groups), rather than "users of taxonomy". Of the five experts, three are already retired (but have access to the collections and to office and laboratory space and computing facilities), and one is only a few years from retirement, whilst the fifth is several years from retirement. The expert close to retirement works part time and is funded to do other work that, while requiring use of taxonomy, does not actually contribute to the advancement of the science.

86. At PML, the really skilled marine invertebrate taxonomists are already in retirement, or close to it. Those who could become skilled are not working on taxonomy or systematics because no funding for this has been obtained. They use their skills as identifiers or to train others to identify organisms for ecological research.

87. Among SAMS scientists, there is expertise in the green and brown algal lineages, for some groups of protozoa (ciliates) and bacterial taxonomy. Also, there is expertise in coastal and deep-sea marine invertebrates. Among the approximately 8 staff with taxonomic expertise, the age profile ranges from 30 to 50.

88. SAHFOS has 15 taxonomic analysts (3 of whom are due to retire within the next 2 years); their ages are; one 20–30, seven 30–40, one 40–50, four 50–60, and two over 60. These include contract analysts. SAHFOS is looking carefully at succession planning for skills transfer.

89. A significant point to note is that much of the taxonomy of the British flora and fauna is done by amateur workers. This is often to a professional standard, but inevitably tends not to include elements which require professional facilities, eg molecular-based investigations. Amateur work makes a major contribution in many areas, for example bryophytes. For it to thrive, such workers need support from professionals in both national and regional museums, both in providing permanent repositories for specimens and also (ideally) a corpus of workers who can collaborate with the amateur taxonomists to provide a professional input. Such partnerships can be very productive and rewarding for both sides. NERC is involved through the BRC, which works with many such amateur taxonomists through its various recording schemes. The BRC acts as a database which may hold the results of taxonomic revisions as records (though not specimens), even though the primary taxonomic support must come from the major collection holders.

Question 13. *What is the state of training and education in systematics and taxonomy? Are there any gaps in capacity? Is the number of taxonomists in post, and those that are being trained, sufficient to meet current and future needs across all taxonomic subject areas?*

90. There are currently (at 4 February 2008) 42 PhD students registered as holding NERC studentships (including CASE awards) in the science topic or science area of systematics and taxonomy[52]; most of the projects involve using taxonomy; some address taxonomy *per se*.

[51] http://gotw.nerc.ac.uk/list_short.asp?classtype=Science+Topic&classification=Systematics+and+taxonomy

[52] http://sotw.nerc.ac.uk/list_med.asp?pge=class_scitopic&classtype=Science+Topic&classification=Systematics+and+taxonomy
http://sotw.nerc.ac.uk/list_med.asp?pge=class_sciarea&classtype=Science+Area&classification=Systematics+and+taxonomy

91. NERC also supports relevant masters courses[53], ie

- Biodiversity and Taxonomy of Plants at the University of Edinburgh, School of Biological Sciences;
- Advanced Methods in Taxonomy and Biodiversity/Biosystematics at Imperial College/Natural History Museum, Biological Sciences;
- Biodiversity and Conservation at the University of Leeds, Institute for Integrative and Comparative Biology;
- Biodiversity, Conservation & Management at the University of Oxford, School of Geography and the Environment.

92. BBSRC has funded 42 PhD studentships in the area of systematics and taxonomy since 2003.

93. As indicated earlier, the number of trained alpha taxonomists is generally regarded as insufficient to meet current needs, and the imminent retirement of many experts will exacerbate this situation unless the efforts to train new generations of practitioners (preferably in classical and molecular methods) are successful. It may be necessary to consider whether enough PhD projects are focused sufficiently on alpha taxonomy rather than on evolution or population genetics and biogeography, and who should fund them if alpha taxonomy is their principle focus. The ERFF skills needs review mentioned earlier will hopefully help to identify ways in which the training needs can be met.

94. Although increased capacity is probably necessary to cope with the climate-change-related increase in biodiversity and conservation research that requires taxonomic input, the need for taxonomy to support research in these areas can be overstated, especially for environments where there is already good taxonomic knowledge (as opposed to environments where a high proportion of species remain to be described). Where there is already good knowledge, what is needed at least as much is field scientists with a knowledge of taxonomy (able to identify species) who also understand ecology and dispersal, for example.

95. PML and the NOCS DEEPSEAS Group have raised concerns about succession planning for taxonomy in the marine sciences. The latter Group says that there are apparently no plans or resources to replace the taxonomic skills of the retired scientists in the Group when they retire properly. They comment that "the deep-ocean floor is the world's largest reservoir of biodiversity, and we cannot begin arrive at any estimate of the total diversity of life across this vast habitat, or understand macroecological and biogeographic patterns, unless we have more input from trained taxonomists". They cite a 1998 paper stating that "The present level of taxonomic resources is inadequate for the proper documentation of taxa whose existence is known, let alone for the discovery and identification of the taxa whose existence is suspected."[54], and point out that "in 2008 we still do not have the taxonomic resources to properly document the taxa that were known in 1998, let alone those that have been discovered subsequently".

96. CCAP comments that although the aging of UK-based traditional taxonomists in protistan-related disciplines should be highlighted, a pool of talent remains particularly in Eastern Europe. If these skills could be linked to UK skills, there might be opportunities for reciprocal knowledge exchange with significant benefits to both groups.

February 2008

Memorandum submitted by DCMS

This memorandum is submitted in response to the call for evidence by the House of Lords Science and Technology Committee. It is intended to complement the fuller and more detailed evidence submitted by Defra.

The main interest of the Department for Culture, Media and Sport (DCMS) in this inquiry relates to the role that museums and other historic collections play in contributing to systematic biology research and taxonomy. Several of the institutions that the department sponsors are active in taxonomical studies, and help to promote

[53] http://www.nerc.ac.uk/funding/available/postgrad/awards/masters/2007.asp
[54] Australian Biological Resources Study, 1998. The Global Taxonomy Initiative: Shortening the Distance between Discovery and Delivery, Australian Biological Resources Study, Environment Australia, Canberra.

wider public engagement in issues such as biodiversity. Beyond this, the department itself does not seek to engage directly in this area of scientific endeavour. Consequently, this submission offers views on just one of the questions set out in the Committee's call for evidence:

8. *What is the role of the major regional museums and collections? How are taxonomic collections curated and funded?*

The Natural History Museum is a non-departmental public body (NDPB) sponsored and funded by DCMS. It performs a wide range of functions, not least as a major international research institute; as one of the UK's leading visitor attractions; as a means of promoting public engagement in science and education; and as a source of expertise on the curatorial and conservation challenges faced by taxonomical collections. The separate submission made by the Museum sets out the detail of its hugely significant role in systematic biology research.

The Museum is one of 14 national museums funded by the department. In fact, it receives the largest proportion of government support of any of the UK's national museums. In the current year (2007–08), the Museum's grant in aid is £45.09 million, comprising a resource GIA of £41.84 million and capital GIA of £3.25 million. Under the comprehensive spending review allocations announced by the Secretary of State in October 2007, the Museum will enjoy an above inflation increase in its resource GIA over the next three years (rising from £43.27 million in 2008–09 to £46.32 million in 2010–11) in respect of the additional running costs of the new Darwin Centre Phase Two project. In addition, the Museum was awarded capital funding of £18.2 million across the three years (compared to £7.6 million over the previous three years—an increase of nearly 140 per cent), to enable it to complete the building work on Darwin Centre Phase Two.

DCMS has an "arm's length" relationship with its NDPBs. In practice this means that although the department has strategic aims and objectives which it looks to its NDPBs to help deliver, it steps back from involvement in how they manage their operations on a day-to-day basis. DCMS's strategic objectives include encouraging more widespread enjoyment of culture, media and sport; supporting talent and excellence in culture, media and sport; and realising the economic benefits of the department's sectors. The Museum has helped to deliver these objectives in a number of ways, for example:

- Welcoming nearly four million visitors a year to its two branches (one million of whom are children)
- Offering a wide range of curriculum-linked learning experiences for all ages and abilities in an uplifting and motivating environment
- Running the Real World Science partnership with three regional museums to promote science engagement among secondary school pupils (funded by the DCMS/DCSF Strategic Commissioning fund)
- Promoting public engagement in natural sciences more generally, such as through coordination of the Darwin200 programme
- Generating £6.58 million in 2006–07 from its trading activities

Many of the department's NDPBs, including the Natural History Museum, also work towards meeting wider cross-government objectives, including those around environmental sustainability. The Natural History Museum has a clear scientific remit to explore the diversity of the natural world and the processes that generate such diversity. Its research effort therefore focuses on, among other things, the determinants of biological diversity, how large-scale physical and biological processes and their interactions influence the evolution of the Earth and other planets, and the relationship between biodiversity and ecosystem functioning. Original new research conducted at the Museum results in over 500 peer-reviewed papers each year, and the Museum is able to raise significant amounts of funding from other sources to pursue these ends. It also runs its research collection of some 70 million items as a major scientific infrastructure, receiving 8,000 scientific visitors a year.

Beyond the national museums, DCMS supports regional museums through the Museum Libraries and Archives' Renaissance in the Regions programme. This allocates £45 million of funding (2007–08) to museums across the country, with funding set to increase further in line with inflation over the next three years. Renaissance hub museums that feature important natural history collections include, among others:

- Horniman Museum (also a DCMS-funded NDPB)
- Tyne and Wear Museums (600,000 specimens at the Hancock Museum/Great North Museum and Sunderland Museum; also core-funded by DCMS directly)
- Oxford University Museum of Natural History
- Leicester City Museums

The MLA also supports the new Collections Link service (www.collectionslink.org.uk) which offers advice for the management of natural history collections.

Memorandum submitted by DEFRA

Summary of Defra submission

The Defra submission covers various aspects of the Inquiry, and can be summarised as follows:

- Whilst Defra is a user of the outputs of systematics and taxonomy, it is not a major utiliser of research from these disciplines.
- Defra invests in systematics and taxonomy mainly through its research agencies (CSL, Cefas and VLA) and the RBG, Kew.
- Other Defra contributions are through the Darwin Initiative, Convention on Biological Diversity, Global Biodiversity Information Facility and the Convention on Trade in Endangered Species.
- Defra's current and medium term research priorities are described in our *Evidence and Innovation Strategy 2005–08.*
- We have not identified any specific major impediments to delivering our priorities deriving from the spheres of systematics and taxonomy.
- Defra investigated the options for setting up a coordinating forum to address issues of the disciplines but, considering the history of previous fora, had doubts about the viability of a new body outside the professions themselves.
- Whilst recognising the role that directly Defra funded organisations and other publicly funded institutions play both nationally and internationally, we conclude that the issue of funding itself is not straight forward.

Introduction

The Department of Environment, Food and Rural Affairs submits evidence to the inquiry from two standpoints:

- as an investor in research and monitoring activities which require the use of systematic or taxonomic science;
- as the owner of three laboratory agencies—the Central Science laboratory (CSL—see annex 1); the Centre for Environment, Fisheries and Aquaculture Research (CEFAS) and the Veterinary Laboratory agency (VLA)—which supply systematic and taxonomic expertise among the other services they deliver to the Department.

Defra also has an interest in this issue as the provider of Grant in Aid to the Royal Botanic Gardens, Kew, which is one of the major UK centres of systematic and taxonomic science. As an independent body, RBG Kew has provided evidence directly to the Enquiry.

From these viewpoints, Defra can answer some of the questions into which the Committee is enquiring, but others will be better placed to answer the questions about basic research and development in these fields.

The State Of Systematics and Taxonomy Research

Q1. *What is the state of systematics research and taxonomy in the UK?*

1.1 Defra has limited direct involvement in systematics research and taxonomy, but has contributed to the discussions within the UK Biodiversity Research Advisory Group (BRAG) and the Global Biodiversity Sub-Committee (GBSC) of the Global Environment Change Committee on the state of these fields in the UK and generally supports their submissions on this aspect of the Inquiry.

Q2. *What are the current research priorities?*

2.1 Defra's current and medium term research priorities are described in our *Evidence and Innovation Strategy 2005–08*. Systematics and taxonomy contribute in a number of areas.

2.2 With regard to conservation and enhancement of biodiversity, specific research needs included:

— Improve understanding of genetic variation in wild populations, and of genetic diversity for species of economic or conservation importance;

— Identify innovative control techniques, develop and test methods for wildlife crime and regulating the use of endangered species held in captivity.

2.3 Defra has recently funded a number of projects to develop identification techniques to support implementation of the Convention on International Trade in Endangered Species:

— Molecular Genetic Identity of Basking Shark Population (CR0247)

— DNA Markers for Birds of Prey (WC05005)

— Forensic identification of CITES listed Timber and Wood products (WC0702)

2.4 Defra also funds the Darwin Initiative which aims to promote biodiversity conservation and sustainable use of resources around the world. It uses UK expertise, working with local partners, to help countries rich in biodiversity but poor in resources to fulfil their commitments under the CBD. Since it began in 1992, the Darwin Initiative has provided funding for over 50 projects which have included taxonomy as their main focus. Through these projects, the Darwin Initiative has contributed to all key areas of the Global Taxonomy Initiative operational objectives.

2.5 At CSL, systematics research and taxonomy are an integral part of the work of the Plant Health Group, which uses a combination of morphology, molecular biology and bioinformatics approaches, to meet research priorities identified by DEFRA customers. In addition, in response to concerns highlighted by a National Audit Office report about loss of taxonomic skills, DEFRA fund an annual taxonomic fellowship, which may be a PhD studentship or a defined R&D project to ensure appropriate investment in taxonomic skills. Recent examples include:

— University of Nottingham/CSL: Plant Health PhD studentship on "The taxonomy of phytoplasmas: a molecular approach"

— University of Edinburgh/CSL: Plant Health PhD studentship on nematode identification using DNA bar coding "Aphelenchus and related taxa: molecular systematics and molecular diagnostics"

— Imperial College/Forest Research: Plant Health PhD studentship "Species boundaries in *Phytophthora* pathogens of trees"

— CSL: Plant health Fellowship: Generic imaging solutions to solve diverse taxonomic problems

2.6 At CEFAS, in the context of marine environmental management, taxonomic science contributes to understanding the impact of human activities in the sea, for example through assessment of the vulnerability and resilience of benthic fauna, eg to fishing, aggregate extraction, disposal of material to sea, oil and gas activity and non-renewable energy exploitation or through the assessment of changes in plankton populations and their impact on fisheries.

2.7 Although not strictly systematics and taxonomy research, VLA's interests in this area focus on understanding the emergence of new and emerging diseases such as avian influenza and the re-emergence of diseases like bovine tuberculosis. Changes in pathogenicity, and ability to evade existing control measures that could lead to important epidemiological variations are of special interest

Q3. *What are the barriers, if any, to delivering these priorities?*

3.1 We have not identified specific barriers to delivering our requirements. Generically, as in all research issues of finance, prioritisation and availability of suitable staff, affect the progress of individual studies. In this sector, access to appropriate taxonomic collections, often held in other countries, is an important factor.

3.2 New DNA sequencing technology is advancing and permitting rapid analysis. The block will be the overload of data for which robust *in silico* analytical tools are not fully available and providing sufficient capital investment to exploit the rapid advances in technology.

Q4. *What is the role of systematics and taxonomy and, in particular, in what way do they contribute to research areas such as biodiversity conservation, ecosystem services and climate change?*

Q5. *How important is this contribution and how is it recognised in the funding process?*

Q6. *How is systematics integrated in other areas of research?*

4.1 Systematics and Taxonomy underpin any research on biological diversity, including, among those of importance to Defra, that on conservation, ecosystem services, the biological impacts of and adaptation to climate change, the exploitation of natural and farmed resources and the management of pests weeds and diseases.

4.2 Defra invests in research and field data gathering (monitoring) to meet particular needs to develop or implement policy. Where these require input of systematic or taxonomic expertise, this will be factored into the contract. Defra does not fund basic research in systematics or taxonomy. In other words, these disciplines are not utilised on their own but in integrated research with other disciplines such as ecology and population dynamics.

4.3 See also the response to Q20 in relation to Defra's provision of Grant in Aid to RBG Kew.

Q7. *Does the way in which systematics research is organised and co-ordinated best meet the needs of the user community?*

7.1 Systematics research is undertaken in a diverse range of organisations, varying greatly in size, capability, collections and significance, both in the UK and abroad. In general, as users, we benefit from this diversity and, where needed, use our own investment to ensure that different elements are coordinated appropriately to meet our needs. In our experience, the systematics and taxonomics community is one with a long history of cooperation and interchange.

Q8. *What progress has been made in setting up a body to lead on this?*

8.1 Following the previous report of the Committee, Defra contacted a range of stakeholders to understand more fully the then recent history surrounding previous attempts to set up a forum to collate information and exchange views for the profession.

8.2 In considering the options, particularly in the light of the fate of an earlier forum, we developed doubts both as to whether anything new could be achieved to justify the effort and expenditure or that Defra itself would perhaps be best positioned to lead an activity best driven by the community itself. We believe that this scepticism is possibly shared by the profession—for instance a view expressed at the Inquiry Seminar on Wednesday 6th February 2008.

8.3 However, we have in the meantime promoted work in the relevant community as it operates in BRAG and GBSC to identify issues and develop solutions. We have also participated in a review of user needs through the UK Taxonomic Needs Assessment (See in particular the answer to question 17).

Q9. *What contribution do the leading systematics research institutions make both nationally and internationally?*

9.1 The major UK research establishments, including the Royal Botanic Gardens at Kew, are widely recognised as playing a globally significant role both in their research and their collections.

9.2 Defra's own laboratory agencies such as CSL and CEFAS have expertise and collections which are important nationally and in some cases internationally (see Annex 1 with respect to CSL's management of collections for example).

Q10. *What level of funding would be needed to meet the need for taxonomic information now and in the future?*

Q11. Who should be providing this funding?

10.1 There is no simple answer to this question. Basic research requirements are a matter for the Research Councils. Defra will continue to invest to meet its own requirements for information, but these will vary according to policy need. We will also continue to provide Grant in Aid for RBG Kew.

Q13. *Could there be more international collaboration?*

Q14. *If so, what form should this collaboration take and how might it be achieved?*

13.1 There are already many well-developed mechanisms for international collaboration though there could always be more. Defra encourages its contractors (including its agencies) to work with national and international institutes and other bodies through, for example, funded projects or mobility grants, to improve R&D collaboration and technology transfer. Among other benefits, this supports policy development at the EU level. However, the recent policy changes by RCUK does potentially limit national collaborations between PSREs and other research organisations.

13.2 In the field of biodiversity research, valuable international collaborations include the Global Taxonomy Initiative under the Convention on Biological Diversity and the Global Biodiversity Information Facility (both of which Defra provides funding to). The European Platform for Biodiversity Research Strategy provides a forum for the identification and prioritisation of research needs across the European Union; a forthcoming meeting is expected to address taxonomic needs.

13.3 In the marine environment, EU sponsored networks of excellence such as MarBEF (www.marbef.org) provide a forum for exchange of information and collaborative research between 94 European organisations involved in systematics and taxonomy, including CEFAS.

13.4 CSL is responsible for the administration and management of EUPHRESCO, an FP6 ERA-NET involving the partnership of 24 organisations funding phytosanitary research representing 17 European countries. A key achievement has been the confirmed country funding commitment for eleven pilot projects. Various leaflets, newsletters, press releases and articles to publicise the Project have been produced.

13.5 CSL has also coordinated an EU 7th Framework proposal "PRATIQUE" on the enhancement of pest risk analysis techniques; participated since its formation (1996) in the European Mycological Network to assist in Europe-wide R&D projects in addition to development of EPPO Diagnostic Protocols; worked with the Netherlands PRI/PD on diagnosis of new viruses/viroids, with the USDA on techniques for the diagnosis of fruit viruses, with AAFC, Canada on the diagnosis of *Pepino mosaic virus* and with Plant Health Services in Estonia, Lithuania, Poland, Hungary, Bulgaria, Russia, Croatia, USA, Mexico, Chile among others, as well as in the international bodies EPPO and IPPC.

Q15. *What impact have developments in DNA sequencing, genomics and other new technologies had on systematics research?*

Q16. *In what way has systematics embraced new technologies and how can these research areas interact successfully and efficiently?*

15.1 See reply to Q2. Defra has funded research to apply DNA sequencing to identification of plants and animals regulated in international trade, to the population dynamics of endangered species (Basking Shark) and to the health of marine organisms.

15.2 Defra agencies have made extensive use of these new technologies (see Annex 2 for a detailed reply from CSL). In the aquatic environment molecular techniques have been well embedded in microbiological areas such as pathogen identification. These techniques are being migrated into environmental studies such as research conducted at CEFAS on microbial ecology, the identification of toxin producing harmful algal blooms and in the area of fish stocks management by identification of fish eggs and larvae that cannot be speciated by conventional means. In the animal and zoonotic diseases area DNA sequencing, genomics and bio informatics are having a huge impact on our understanding of the spread of new and emerging diseases, as well as being an integral component of the national response to the incursion of exotic diseases such as FMD and avian influenza. At VLA, DNA sequencing techniques are used for the rapid identification of diseases and sequencing is used as an important disease tracing tool as well as providing clues to the evolution of organisms during disease outbreaks. As sequencing becomes more accessible with whole viral and bacterial genomes being sequenced routinely, genomic databases will provide detailed and important clues to the identity and characteristics of new and emerging diseases.

Data Collection, Management, Maintenance and Dissemination

Q17. *Does the way in which taxonomic data is collected, managed and maintained best meet the needs of the user community?*

17.1 The UK Taxonomic Needs Assessment, undertaken as a contribution to the Global Taxonomy Initiative of the Convention on Biological Diversity by the Natural History Museum focussed on the needs of the biodiversity conservation communities in the UK and its Overseas Territories for taxonomic information and services, or information that is reliant on the availability of taxonomic expertise. The Assessment was undertaken by the Natural History Museum and was completed in 2006.

17.2 Defra accepts the findings, from the consultation with users in the UK that the following types of information, were identified as important for biodiversity conservation but not sufficiently accessible (listed in order of priority):

1. Habitat requirements of animals/plants
2. Information on local species distributions
3. Information on regional species distributions
4. Geographic Information System (GIS) data
5. Information on name changes
6. Lists of invasive alien species
7. Specialised identification services (taxonomic)

17.3 The UK Taxonomic Needs Assessment suggested that further action was needed by both the taxonomic and biodiversity conservation sectors to:

— Facilitate the generation and delivery of the taxonomic information needed for biodiversity conservation in forms appropriate for users;

— Develop ways to translate the interests of stakeholders, including conservationists, environmental managers, statutory agencies and commerce, into the research priorities of both taxonomic research institutions and funding bodies;

— Identify those urgent taxonomic information needs that correspond with a genuine gap in UK taxonomic expertise, as opposed to a failure in information management or dissemination;

— Foster best practice in the dissemination of taxonomic information, and passing on of taxonomic skills to stakeholders eg through online information services, field guides, courses, qualifications.

17.4 Defra has contributed to addressing these needs through support for the National Biodiversity Network and Local Record Centres (see 18.1 and 21.5 below) and GBIF (see 13.2 above) and through engagement with BRAG and GBSC (see 8.3 above).

Q18. *What is the state of local and national recording schemes?*

18.1 Biodiversity recording in the UK is largely undertaken by National Schemes and Societies or by Local Record Centres (LRCs). National Schemes and Societies usually have a hierarchical structure, with identified experts for specific taxa to ensure the accuracy of records. LRCs collate and manage biodiversity data for a geographical area (usually a County or Unitary Authority). A recent review of LRC activities[55] identified four areas requiring development in order to sustain local biodiversity recording:

— Financial security. This is the key barrier preventing LRCs from making biological records widely available because they rely on charges made for this service.

— Efficiency. A large proportion of LRC data holdings are paper based and responding to data requests is often a laborious, manual process. Data capture, management and dissemination to end users needs to be streamlined, providing access to existing and new species and habitat data via the NBN Gateway as soon as possible after the data has been captured.

— Coverage. There are currently 35 record centres across England covering 83 per cent of counties. Some counties have little or no coverage.

— Consistency. Individual record centres vary considerably in their adoption of standards relating to verification and validation of records, data management and data exchange.

[55] Review of Local Record Centres (2007), Natural England.

18.2 In August 2007 Defra announced a Fund for Innovation in Local Biodiversity Recording. The overall aims of the Fund are to build capacity in local record centres and to increase the geographic scope, quantity and quality of biological information available to the general public and key public sectors through the National Biodiversity Network (NBN) Gateway. The Fund is administered by Natural England and £181,000 is being made available in 08/09.

18.3 Defra also provides ad-hoc funding for specific national recording schemes, particularly where the data provide a source of information for assessing status and trends in biodiversity. Examples in the current year include the development of the Butterfly Monitoring Scheme and the production of trends from the various national bird surveys coordinated by the British Trust for Ornithology. CSL participates in providing identification services for statutory survey work for Defra eg potato ring rot surveys.

18.4 In the marine environment, Defra fund CEFAS annual trawl surveys and the UK Marine Monitoring and Assessment Programmes that provide data on biodiversity trends in fish and benthic invertebrates respectively, as well as contributing to international assessments of biodiversity such as those coordinated by the International Council for Exploration of the Sea (ICES).

Q19. *What is the role of the major regional museums and collections?*

19.1 Taxonomic collections fulfil a number of roles. They provide a resource to field workers, both for the amateur and professional, for verification of identification; research into systematics and evolutionary biology; environmental change research and in the training of a new generation of taxonomists. Defra does not use these collections directly, but has an interest in ensuring that they continue to meet the needs of the taxonomic user community.

Q20. *How are taxonomic collections curated and funded?*

20.1 Curation of collections at the laboratory agencies is done by specialists (see Q26) and funded principally by DEFRA; for example Plant Health Division currently funds maintenance of the plant pathogen collections at CSL. CSL add value to this by bidding for external funding by EU and other projects. Cefas holds national reference collections of fish viral, bacterial and fungal pathogens of fish. Some phytoplankton, zooplankton and fish reference materials are a retained at Cefas, but only the benthic invertebrate collection would be regarded as a nationally important reference in the museum sense of the word. Defra funds the maintenance of these collections.

20.2 Defra currently contributes £17.6 million per annum as Grant in Aid to the Royal Botanic Gardens, Kew, plus a sum for capital investment (£7.6 million in the last year). Whilst Grant in Aid is not hypothecated for specific purposes, this level of public funding recognises and directly contributes to the important global role that Kew plays in taxonomy and systematics. Recently, Defra capital allocations have made a very significant contribution to the extension and refurbishment of the Herbarium.

Q21 *What progress has been made in developing a web-based taxonomy?*

Q22. *How do such initiatives fit in with meeting demand for systematics and taxonomy information?*

Q23. *How do UK-led initiatives fit in with international initiatives and is there sufficient collaboration?*

Q24. *What needs to be done to ensure that web-based taxonomy information is of high quality, reliable and user-friendly? How does the taxonomic community engage with the non-taxonomic community?*

Q25. *What role do field studies play?*

21.1 Advances in computer technology, particularly the ability for large numbers of people to access powerful databases and the ability to display and cross reference data geographically has greatly improved the way in which collection and management meets the need of the user community.

21.2 The establishment of the Encyclopaedia of Life (EOL) Project, is an important step towards ensuring consistent identification and classification of taxa. EOL is an international project but is supported by a number of UK institutions, including the Natural History Museum and the Royal Botanic Gardens at Kew. It aims to document all named species on Earth and to make these data available to amateur and professional

taxonomists alike. There are a number of linked projects, notably the Barcode of Life project which aims to integrate the use of DNA sequencing as an international standard for the identification of species. These initiatives are important for the user community, as in the past it has not generally been possible to document global biodiversity change precisely because of uncertainty about the identification and classification of species.

21.3 The problem of inconsistent identification and classification is seen as less serious in the UK, largely because of our longer history of well organised taxonomy. However, classification and nomenclature have changed over time and many species have been recorded under different synonyms. The Natural History Museum, on behalf of the National Biodiversity Network (NBN) Trust, has established a species dictionary which lists all synonyms for species in the UK. This has been central in the process of collating data on species abundance and distribution as it allows data from all sources to be displayed together. In turn, this has allowed for the data to be used to assess biodiversity change. Defra have contributed to this process through their funding of the NBN-Trust.

21.4 On-line identification guides are growing in number, and Defra has funded some development in this area. For example, Defra funding helped to provide on line keys to coral identification (project code WP01024, see www.arkive.org/coral/Coral/coral.html) and identification of CITES listed plants (project code WC01005, see: http://www.kew.org/conservation/cites-profile.html£cap).

21.5 In the UK, the development of the National Biodiversity Network to collate and manage biological records and display them via the web-based NBN Gateway has significantly improved the value of the data to the users. The main barrier to fully meeting the needs of the user community is that not all schemes and societies are willing to pass all of their data to the NBN, either because they rely on it for income or because they are older schemes that have developed their own systems to handle the data.

21.6 Defra is the major UK funder of the Global Biodiversity Information Facility (GBIF), which provides a similar service to the NBN Gateway at a global scale. GBIF also funds work to improve accuracy and availability of taxonomic and biological data.

21.7 CSL are exploring advances in imaging technology, in order to enhance our existing taxonomic expertise and thus underpin the UK's Plant Health diagnostic capabilities. We are building on our reference collection of indigenous and non-indigenous pest and disease symptoms, by adding to our photographic collection already made available through our web-based Plant Health Information Warehouse. Plans to use this resource as an e-teaching aid are in hand and should generate an international exchange of experts in diagnosis and identification. CSL's web-based information warehouse is accessible to the UK Plant Health Service (PHD, PHSI, CSL), and plant health officials in Scotland (SASA). CSL collaborate with other UK and International collections. Evidence of this is the current EU FP7 call, where CSL is a lead partner, bidding for over £300,000 of funding to DNA bar-coding statutory plant health pests & diseases.

21.8 Cefas collections are routinely exchanged with other expert laboratories around the world. There are a number of initiatives to provide wider access to this material including working with industry to provide diagnostic kits for pathogens. Access benthic invertebrate material is via the National Biology Analytical Quality Control scheme which forms part of the UK Marine Monitoring and Assessment Strategy.

21.9 Generally, because of high levels of user engagement the initiatives mentioned in Q21 provide a good fit with requirements for conservation management. UK-led initiatives are closely aligned with international work. For example the National Biodiversity Network provides the UK node of the Global Biodiversity Information Facility.

Skills Base

Q26. *What are the numbers and ages of trained taxonomists working in UK universities and other organisations? What is the state of training and education in systematics and taxonomy?*

Q27. *Are there any gaps in capacity*

Q28. *Is the number of taxonomists in post, and those that are being trained, sufficient to meet current and future needs across all taxonomic subject areas?*

26.1 Defra can reply only with respect to its own laboratories. CSL has a team with a range of expertise and depth of knowledge on pests and diseases, which is unsurpassed in the United Kingdom using morphology

and taxonomy to state of the art molecular techniques. This is also drawn upon to provide advice to plant health consultants and researchers within Plant Health Group and other Groups at CSL in addition to technical advice directly to Defra. As recognised experts, diagnosticians at all levels provide the key parts of the many PHSI training courses organised throughout the year. In this team there are approximately 12 trained taxonomists as follows:

— Nematology—2 specialists aged 50's and 20's

— Virology/phytoplasmas—2 specialists aged 30's

— Mycology—3 specialists aged 30's

— Bacteriology—2 specialists aged 40's

— Entomology—3 specialists aged 30's and 40's

26.2 At Cefas there are a large number of taxonomic experts engaged for a small or large part of their time in species identification as part of research and monitoring programmes. This includes:

— 12 Viral, bacterial and parasite experts

— 5 phytoplankton and 4 zooplankton experts

— 2 meiofaunal, 8 benthic and 10 epifaunal species experts

— 3 highly specialised experts and a further 20 scientists involved in fish identification

26.3 Specialists at CSL and Cefas are also engaged in policy advice and diagnostic service provision as well as providing taxonomic services.

Annex 1

THE CENTRAL SCIENCE LABORATORY

The Central Science Laboratory (CSL) is an executive Agency established within the Department of Food and Rural Affairs (Defra), formed from the amalgamation of 5 scientific laboratories and completed in 1999.

The primary responsibilities of CSL are the provision of quality scientific development, research and technical support to public sector departments and agencies, and private customers. The main focus for the scientific work is food safety, agriculture, agrochemical safety, product development, safeguarding the food supply, and environmental management, protection and conservation.

The Plant Health Group of the CSL provides scientific support to the Plant Health Division of Defra facilitating international trade in plants and planting material and protecting the UK industry and environment. The strong research base with international expertise in diagnostics and quarantine pest and disease biology engenders vital links with other organisations and academia both within UK and internationally. The CSL is also the depository for the national plant health reference collections; a unique and internationally important collection of plant pests and pathogens.

CSL is the curator of several unique and internationally important taxonomic collections which underpins systematic biology and pest and disease identification services for Defra and other customers. The core invertebrate collection contains over 135,000 specimens. In addition to the existing collections of plant and food pests, including both insects, nematodes and mites, CSL is also acquiring The Rothamsted Collection, consisting of over 14,000 plant-parasitic nematode specimens. This is one of the most extensive and renowned collections of its type in the world. Combined, these form one of the most comprehensive reference collections of plant pests, found anywhere in Europe. CSL also holds internationally significant collections of fungi, viruses, phytoplasmas and bacteria. CSL is also the curator of the national Collection of Plant Pathogenic bacteria (NCPPB)

As the UK's premier plant health laboratory, this combined reference collection is indispensable; underpinning the disease and invertebrate identification work at CSL and thus providing vital support to the identification & diagnostic work of Defra's Plant Health Division. This work underpins Defra's policy for plant and bee heath. The collections are vital for CSL to maintain its status as one of Europe's leading Plant Health Laboratories and thus enabling it to remain as a prime candidate for European reference Laboratory status in the future should EU policy develop in this direction.

Specialists at CSL develop international status as diagnosticians, with unique experience in the identification of pests of worldwide origin. They are required to distinguish pests from non-pests and to recognise those of quarantine significance. We have experience in well-established taxonomic methods, such as microscopical examination or culturing, but have also been in the forefront of adapting and using new and innovative methods and techniques to improve the comprehensive identification service. Techniques must be robust and rapid as well as accurate, sensitive and inexpensive.

Annex 2

CSL Detailed responses to Qs 15 & 16

Q15. *What impact have developments in DNA sequencing, genomics and other new technologies had on systematics research?*

DNA sequencing:

Taxonomic collections are vital to existing and future DNA sequencing R&D projects. For example, molecular studies (such as DNA bar coding) rely on the accurate identification of voucher specimens and their storage in properly curated collections, such as those held at CSL. Hence in order for this new technology to develop and be successful, strength must be maintained in traditional taxonomic/morphological areas, running in parallel to the DNA-based technologies. So indeed the organisations based placed to take bar-coding forward are not simply those with molecular expertise, but probably more importantly those with morphological expertise. An excellent example of this is the current EU FP7 call, where CSL is a lead partner, bidding for over £300,000 of funding to DNA bar-coding statutory plant health pests & diseases. This project will be underpinned by access to validated specimens, deposited and maintained within the CSL invertebrate collections. Again reiterating the importance of the collections.

Digital reference collections:

The use of morphological characteristics still underpins the identification of many organisms of plant health significance, including both the fungi and the invertebrates; insects, mites and nematodes. However many species are extremely hard to distinguish, as diagnostic morphological differences are often small and/or hard to visualise. Even when such features can be readily seen, it is important to be able to capture images of these, for a variety of reasons. For example to provide a permanent record associated with a particular identification for quality assurance and legal purposes. Such reference images are also extremely useful for training, data sharing with overseas collaborators and also the cataloguing of information for reference purposes.

This latter area is becoming increasingly important with the development of new molecular techniques, such as DNA barcoding. This technology offers the potential for enhancing phylogenetic and taxonomic investigation, through the production of comprehensive, validated sequence databases. However, in order to ensure the robustness of such DNA databases, the information held in them must be correctly assigned to the taxonomic framework. The best way to achieve this is to relate sequence information to specific, individual specimens. Ideally, this should be a real "voucher" specimen, but increased capability to archive the specimen digitally, through both image analysis software linked to either light- or electron microscopes, will contribute to both the permanent record of the molecular sequence and the ability of researchers at varying locations to access that information. In this way "virtual" or "digital" reference collections, containing high-quality images are an excellent complementary resource to "real" reference collections, containing actual preserved specimens.

Q16. *In what way has systematics embraced new technologies and how can these research areas interact successfully and efficiently?*

Our reference collections serve as routine "tools of trade". However, as a result of our increasingly unique responsibility in diagnosis and identification of alien organisms, they are assuming a national and international importance. We must continue to invest in curation of these to maintain and build on this reputation. Traditional reference collection methodology will be supplemented by more "portable" technologies (digital images and molecular sequences etc.) to enable the international use of these unique reference standards.

ADDITIONAL ISSUES

In addition to laboratories, which are the basic requirement for taxonomic work, CSL has a scanning and transmission electron microscopy suite, essential for examination of pest and fungi characteristics and virus diagnosis respectively.

The quarantine glasshouse, laboratory, growth rooms, cabinet facilities and quarantine pest facilities enable contained longer-term examination and identification of both alien and indigenous pests and diseases. State-of-the-art microscopy laboratories, incorporating the latest developments in computer enhancement, are used to improve the study of pests.

Our reference collections of alien pests and disease organisms are an increasingly important national and international resource and are managed by the pest and disease identification team. Improved curation of our important Arthropod sub-collection has led to the invitation to participate in the Insect Collections Managers Group which represents the main entomological collections in the UK (NHM, National Museums of Scotland and Wales). The National Collection of Plant Pathogenic Bacteria maintained within the Group is part of the UK National Culture Collection.

CSL has invested in unique molecular (DNA/RNA) diagnostic and analytical facilities (Molecular Technology Unit (MTU)), including real-time and conventional PCR[56], genetic fingerprinting, sequencing and microarrays. This unique facility is in the forefront of providing molecular diagnostic and analytical services for both statutory and non-statutory samples including those related to plant and bee health and participates in R&D activities including method development, ring testing and validation. Seedcorn funding has been used to develop an integrated equipment booking system and other electronic management systems to make efficiency improvements (eg electronic information systems).

February 2008

Examination of Witnesses

Witnesses: DR PAMELA KEMPTON, Science and Innovation Manager, Terrestrial and Freshwater Sciences, NERC; PROFESSOR GEORGINA MACE, Director, Centre for Population Biology, NERC Collaborative Centre; DR COLIN MILES, Head, Molecular Cell Biology, BBSRC; DR ALF GAME, Deputy Director, Science and Technology, BBSRC; PROFESSOR PHILIP ESLER, Chief Executive, AHRC; and PROFESSOR BRIAN CATHCART, Kingston University and Chair of the New Perspectives project, examined.

Q45 ***Chairman:*** May I welcome you very warmly and thank you also for the evidence that you have already submitted. That has been available to the Committee so you do not need to go through that again but we have a series of questions partly arising out of the evidence you have submitted that we would like to put to you. My name is Lord Sutherland. I chair the Committee. You will see we are all labelled, as you are, but I will ask you in a moment to introduce yourselves for the sake of the recording. I take the opportunity to remind you that this is recorded and will be on the public record. I wonder if you would like to introduce yourselves and that will be noted.

Dr Game: My name is Alfred Game. I am the Deputy Director of Science and Technology at BBSRC.

Dr Miles: My name is Colin Miles. I am Head of Molecular Cell Biology at BBSRC.

Dr Kempton: I am Pamela Kempton. I am the Science and Innovation Manager at the Natural Environment Research Council.

Professor Mace: I am Georgina Mace. I am the Director of the Centre for Population Biology at Imperial College, London, which is an NERC Collaborative Centre.

Professor Esler: I am Philip Esler, the Chief Executive of the Arts and Humanities Research Council.

Professor Cathcart: I am Brian Cathcart. I am Professor of Journalism at Kingston University and I am here because I am principal investigator on the New Perspectives project.

Q46 ***Chairman:*** Thank you. We have quite a number of questions we would like to put to you in the hour or so that is available but I fear I have to warn you that there may well be a division bell. It is something that is perhaps close to your heart, it is on the Climate Change Bill and at that point we will have to suspend proceedings while Members go to vote. We will be back as quickly as we can but there are no alternatives to that procedure so I hope you will bear with us should that happen. That being said, can I perhaps begin with an opening question? It has to do with the submission from DIUS that the research councils are providing expert input on behalf of DIUS in support of Defra's lead on policy issues relating to systematics and taxonomy. Can I ask who in your experience

[56] Polymerase Chain Reaction.

represents DIUS in discussions on cross-government strategy, because clearly there are cross-government issues at stake here, and I will pick up some additional concerns, but would anyone like to start?
Professor Esler: I think it is probably my job to answer that question. I think the answer depends upon the level and the nature of the issue to be discussed at the meeting. In the event that the matter is fairly scientific in nature, we would expect DIUS to ask a representative from one or more of the councils to attend. In the event that it is a more strategic or policy-driven meeting, we would expect DIUS itself to attend and in the event that it were a Defra-only meeting, which seems to be contemplated in the question, we would expect that DIUS would not attend such a meeting or a Defra strategy meeting.

Q47 ***Chairman:*** You have been content at the level of the people who have turned up for these meetings? They are pitched appropriately?
Professor Esler: We are not aware of any unhappiness at the level of representation.

Q48 ***Chairman:*** One of the central questions that I would like to put you because of evidence we have received relates to the concerns that many have about the infrastructure in terms of personnel in the areas of taxonomy particularly. How many people are in the system? Is there a drop in the number of people available who are trained and equipped? How much attention does DIUS pay to that?
Professor Esler: Certainly the research councils each year provide an annual return on health of disciplines. The figures that relate to this particular area have been provided in some detail in the written submission, I believe. As far as further details on the population, I think I will turn to my learned friends here who represent research councils on the science side.

Q49 ***Chairman:*** Can I perhaps underline one of the concerns here is that the volume and level of skills available in this area on some of the evidence we have had is declining. Is that a reality and, if so, what can or is being done about it?
Dr Game: I think most people would accept that it is the reality; over a number of years, particularly in universities, the amount of activity in taxonomy and in support of collections has probably declined. You have to set that in the context of the fact that this is something which happens all the time, that disciplines and areas change in terms of their priority and so forth, and whether one does anything about it depends on whether people affected by the situation are asking you to do anything about it. I could draw examples from other areas: informatics, for example, in biology, where representation from the pharmaceutical industry has caused quite a lot of activity to be done by research councils. I am not sure that the change in the state of taxonomy in universities has necessarily been reflected by very much evidence from what might be described as the wider science base or the user community of concern about it. One specific exception might be a report that the Biosciences Federation produced a couple of years ago, which we did respond to.

Q50 ***Chairman:*** Do you know if any representation was made to DIUS about the decline in skills in relation to the last Comprehensive Spending Review?
Dr Game: Personally, I do not.
Chairman: Does anyone know if this was raised? As I say, the evidence we are getting is that there is a decline in skills, we have seen it elsewhere, and at some point somebody has to point this out to those who supply the funds.

Q51 ***Baroness Walmsley:*** The users may not be indicating yet that there is a problem but in some evidence that we have, the systematics community seems to think that there is going to be very soon. NERC and Defra, I gather, are telling us that they are users of systematic information but not involved primarily with research. You may recall that one of the recommendations of our previous report was that the systematic community should focus its outputs on making it useful material for users and the evidence that we have taken recently indicates that that has been done to a very great extent, and the community are now telling us that they have focused as far as they have been able to do and cannot really go any further, and now they are living off capital. The question really is, as self-declared users as well as key funders, what is your response to that claim from the systematic community?
Professor Mace: I cannot answer that question in its full extent except to say that NERC does fund a lot of taxonomy as part of scientifically-led research grants, and if those research questions require taxonomic knowledge, if that is available, it will be used; if it is not available, NERC will pay for the taxonomy to be done to support that science. In fact, over the last six or seven years NERC has funded a couple of hundred grants that include taxonomic research within them. The key point is that those grants are awarded on the basis of the scientific question, not on the basis of the taxonomy that is in them.

Q52 ***Baroness Walmsley:*** Is that not scientific?
Professor Mace: The descriptive taxonomy on its own would probably not qualify for a NERC grant because NERC grants tend to be based around hypothesis-driven science. There is an open question,

which is one that we have talked about recently, for new areas of science that NERC has prioritised in its strategy that is being launched this year. It is about how we would ensure that the taxonomic knowledge that is required to deliver some of that science would be funded and gathered. That is a question that NERC is considering at the moment.

Q53 ***Baroness Walmsley:*** Am I right in understanding that the taxonomy that is funded is directly related to another research project and only that?
Professor Mace: Yes, I think that is true.
Dr Kempton: Yes, I think that is true.

Q54 ***Lord Krebs:*** Could I come in behind that and ask really two related questions. First of all, I am a bit surprised that NERC says it has no responsibility or little responsibility for taxonomy *per se* given that back in the 1990s, when I was chief executive of NERC, we had a taxonomy training initiative which was specifically to increase capacity in the British system. I wonder if NERC has taken a strategic decision to move out of taxonomic capacity, and if so, why? Secondly, I wonder if you can give us an indication of the total amount of money that NERC on the one hand and BBSRC at the moment spend on taxonomic research in the way you have described, what proportion of the budget that is and how that has changed over time.
Professor Mace: Perhaps I can answer the first one, the capacity issue. My answer related to research funding. NERC certainly takes responsibility for training and for maintaining the expertise base in taxonomy. One of the reasons that we have been able to fund a lot of grants in that area is that many of those taxonomists trained as a result of the taxonomy initiative in the 1990s are now embedded within research groups and, arguably, that is the right place for many of these people to be. To me, one of the measures of success of that training activity is that we have the capacity for the skilled people in taxonomy to answer the research questions that NERC is funding.
Dr Kempton: It is partly because of that embedding of the research into the projects that it is a bit difficult to say exactly how much we spend on taxonomy. I did some checks through our grants on the web facility just before coming, and since 2000 we have funded over 200 grants with a total cost of nearly £29 million that have taxonomy as a component. The amount that is allocated to taxonomy, because in each application they have to estimate approximately how much they fit into different categories, and the amount estimated was that a little over £7 million of that work was on taxonomy. That is just for the responsive mode grants and it does not include the amount that we spend on training of PhD students and Masters students or the taxonomy that we would fund through our research for centres. That is a minimum that we are spending on taxonomy.

Q55 ***Lord Krebs:*** £7 million out of how much over those five years? What is the total budget of NERC over five years?
Dr Kempton: I do not know what responsive mode funding is. I am sorry. I do not know that figure.
Professor Mace: We can get that figure.
Chairman: If you could, that would be very helpful.

Q56 ***Lord Haskel:*** I wonder if we could look at the marine sector, because we have been told that there are difficulties in this sector. In the Research Councils UK evidence the NERC marine centres and the British Antarctic Survey all comment that taxonomy underpins marine ecological research and they give an example. The National Oceanographic Centre in Southampton states that taxonomy is "vital to all areas of deep sea biology" but they also state that "financial support for taxonomy within NOCS is effectively non-existent." The position is similar for the British Antarctic Survey and the Plymouth Marine Laboratory. How are these NERC institutes planning to meet their taxonomic needs in the future?
Dr Kempton: The reason we fund our research centres is at least in part to provide long-term datasets, monitoring and survey activities, things that we are now calling national capability. Within that would be some element of taxonomy as needed to deliver the strategies of these various research centres. We would basically leave it to those research centres to do the planning for how they would provide the tools that they need to deliver their strategy.

Q57 ***Lord Haskel:*** Are you saying that it is up to these centres to allocate funds and carry out their own training?
Dr Kempton: NERC provides training of PhD students and Masters students and so on, but in terms of providing taxonomic experts within the staff of the research centres, that would be up to the directors of those centres to decide how to allocate their resources to take that into account.

Q58 ***Lord Haskel:*** But they tell us that they have not got enough resources to do this.
Dr Kempton: It is a matter of prioritisation, I guess, then.

Q59 ***Lord Methuen:*** With the decline in teaching of taxonomy and systematics at UK universities, the natural history collections in university museums are under increased threat. How will important teaching

collections be supported now that the current HEFCE-funded scheme is coming to an end?
Professor Esler: My Lord Chairman, I have undertaken to answer this. One of the issues is that we are not exactly sure what the evidence is that your Lordships have seen in relation to this issue. We feel that, certainly our position is that, HEFCE should provide an answer to this and I cannot speak for HEFCE, nor can any of my colleagues on this particular issue. We would suggest, if your Lordships were so minded, they could approach HEFCE to get some more specific details on this issue.

Q60 ***Chairman:*** Have you any evidence yourselves in terms of noise from the sector? Academics are quite good at telling you if they are short of cash.
Dr Game: Yes, in the sense that the issue of the maintenance of collections is a problem that has gone on for many years because you are tensioning resources for something which is, if you like, maintaining the resource against front-line research, things that are going to produce papers and all the rest of it. Clearly, there is an issue of priorities, which is what Pamela was referring to. One of the things that I think becomes a problem here is simply the fact that there are collections of large numbers of things now. My own organisation did a quick survey and discovered we have 91 collections in our institutes, most of which we were probably centrally completely unaware of. These are maintained by people as part of the process of doing their research and they are used for their research. One of the questions we have been asking through our activities in tools and resources is should we be maintaining them at all, should we be doing more to make them available to other people, what kind of things are needed to be put in place? It is very difficult to see a blanket answer to that through the fact that so much resource in bioscience is now being accumulated. If you look back 100 years ago, what was in the museums and the gardens and so forth was the front-line resource for doing 90 per cent of what was going on in biology. You now have DNA collections, all kinds of sample collections, the European Bioinformatics Institute, huge amounts of data and so on and so forth. I think we are probably still grappling with the answer to that question, which is really how you resource bioscience in the way that physics and engineering were resourced 50 or 100 years ago. These things are like the equivalent of these big laboratories, synchrotrons and Heaven knows what else. They are a different kind of resource but they are a resource, and I do not think any of us really have an answer to that yet because it is such a new phenomenon, in some ways. There has been a trough of activity depending on these things and it is rising again now.

Q61 ***Lord Krebs:*** May I just come back to the question here because I heard Professor Mace say earlier that NERC does have responsibility for maintaining taxonomic expertise in universities, and I would have thought that that would include the teaching of taxonomy and systematics in universities and therefore go with it the responsibility for supporting the wherewithal to sustain that teaching, yet I am hearing from Professor Esler that this is not seen as the responsibility of the research councils. Could you clarify what appears to me to be a contradiction?
Professor Mace: I do not think there is necessarily a connection between university museums and the maintaining of capacity for teaching and skills in taxonomy. In the environments that I know about where that teaching and training goes on they are using other national museums' collections elsewhere rather than in the university museums. I am thinking of the Imperial College Natural History Museum link and the Edinburgh Botanic Gardens link.

Q62 ***Lord Krebs:*** It would certainly be different if you looked at a university like Oxford or Cambridge or Manchester or Cardiff, which have very substantial collections.
Professor Mace: I have to say I know nothing about how those university museum collections are maintained or whose responsibility it is for funding those. I am sorry.

Q63 ***Chairman:*** I can understand that Imperial and in a different way Edinburgh have huge national collections on their doorstep, quite literally, but there are other institutions perhaps who are not yet aware of the potential problem coming down the line that the HEFCE scheme is changing and therefore the universities will have to set priorities within their own resources to decide whether these collections are maintained or whether, on the advice of the scientists, they are not necessary. Any view you have on that would be very helpful. Even if you do not have views now, if on reflection you wanted to comment in writing, we would appreciate that very much.
Professor Mace: I can give you a personal view on that. As a trained zoologist, there is absolutely no replacement for the real object. I think taxonomists, zoologists, botanists, as part of their training need to have access to the specimens themselves, but I am afraid I am not in a position to comment on how that is or is not being funded.

Q64 ***Lord Soulsby of Swaffham Prior:*** The written evidence suggests that the Research Assessment Exercise, the RAE, was a significant driver of the decline in minority disciplines, such as taxonomy, in UK universities. How will DIUS, via HEFCE,

ensure that the proposed replacement mechanism, the Research Excellence Framework, does not have the same adverse effect?
Professor Esler: The situation is that HEFCE is at present in the midst of its consultation and, once again, clearly HEFCE would be in a position when it has sorted out the terms of its Research Excellence Framework to answer that question. At present one does not know.

Q65 ***Baroness Walmsley:*** Could I just ask a supplementary? Professor Mace, you mentioned that NERC actually funds a number of Masters and PhD students. Could you tell us how many of those this year are working on purely taxonomy and systematics or have a substantial element of that sort of work within the projects that they are working on?
Professor Mace: I really cannot give you those figures. I have personal knowledge of the MSc course that runs between Imperial and Natural History Museum, which has, I think, 25 students on it. I can get the exact numbers. Most of those will do projects that are really lying within taxonomy and systematics. I cannot comment on the other courses. I really do not know. That course over the last 10 years or so has generated over 250 trained Masters students. Many of those now work in research teams where they are exploiting that taxonomic knowledge, sometimes for the benefit of further taxonomy, sometimes for the benefit of other science.

Q66 ***Baroness Walmsley:*** Those students could not do their work if those teaching collections did not exist, could they?
Professor Mace: That is certainly true.

Q67 ***Baroness Walmsley:*** So somebody has got to fund them.
Professor Mace: Yes.

Q68 ***Lord Soulsby of Swaffham Prior:*** I wonder if you could tell me about the Research Excellence Framework. I am not sure I understand it fully.
Professor Esler: My Lord, it is a programme that HEFCE are developing to take the place of the current Research Assessment Exercise. It was initiated by the Chancellor's statement some two years ago that it was desirable to move to a more metrics-driven approach to research assessment for the excellence of research. What they have done essentially is to consult with some experts on citations as a guide to excellence at Leiden University and they have prepared a full consultation document on a new approach which would be driven by citations. This is for science, technology and medicine subjects, with a somewhat different approach for arts, humanities, social sciences and mathematics. They are at present in the midst of collating and considering the responses to their consultation. They will then have to produce shortly the vision for the replacement of the Research Assessment Exercise, and that will be the basis upon which they allocate money to universities for research in the future.

Q69 ***Chairman:*** I guess one of the principles of Welsh rugby I understand is to get your retaliation in first. I just wondered if the taxonomy community were trying to get their retaliation in first before policy is formulated on this, because there are real concerns that a difficulty with the RAE may simply be reduplicated.
Professor Mace: I cannot comment on the Research Excellence Framework but I can comment on the current RAE which is under way at the moment. The last report from the Select Committee that Baroness Walmsley chaired made a specific comment about changes that could be made to RAE processes that would look more kindly on small subjects and subjects that did not deliver hard science outputs, like taxonomy. I am a current member of a RAE panel doing the work at the moment and I can tell you that there is a very different flavour to how outputs, which are publications and so on in science, are judged. They are not only judged on their scientific merit but also on whether it is strong science that will have a bearing on significant bits of policy. So I think there is some movement in that direction as a result of comments that came last time, not only in taxonomy but other areas as well.

Q70 ***Lord Krebs:*** But surely, if one moved to metrics-based system just those kinds of judgements would be eliminated if it was based on citations.
Professor Mace: I think that is one of the difficulties about the metrics-based system, is how you incorporate policy relevant outputs into those assessments.
Chairman: I have no doubt that in our report we will want to consider whether there is something we should be saying about the new system, and its impact on taxonomy in particular. Again, if there are further thoughts on this, we would be very keen to receive them. Put it this way: I do not think it is simply a matter for HEFCE because HEFCE want to hear what the community think and, if we can reflect some of that, it would be helpful.

Q71 ***Lord Colwyn:*** Amongst the paperwork we have there is a memorandum from Defra that outlines a limited involvement in systematics research and discussions and a contribution to those discussions with the UK Biodiversity Research Advisory Group. What are the current mechanisms to make user needs known to the taxonomic community and the funding

bodies, and how can the belief of the UK Biodiversity Research Advisory Group that these mechanisms should be dramatically improved actually be implemented?
Dr Kempton: I will try to answer at least part of that. It is interesting that submission actually comes from UK BRAG because, to my knowledge, there is not a UK co-ordinating body for taxonomy in the kind of sense that you are talking about here. UK BRAG and the Global Biodiversity Sub-committee of the Global Environmental Change Committee, both of which are chaired by Defra, by the way, deal with largely biodiversity issues and in the context of conservation in large part. So they are not dealing with things like agriculture, fisheries, and health and so on, but at least in that context of biodiversity conservation, UK BRAG and GECC are bodies which are a forum for providing at least some import for user needs into the science community. Those issues are raised at those meetings. It is interesting that it is actually BRAG itself that is flagging the need for improvement there. The other thing I would add is that in this particular area the volunteer community is very important and the National Biodiversity Network is one mechanism for actually trying to co-ordinate that really important element of the research.

Q72 ***Earl of Northesk:*** Taxonomy underpins research into the biological effects of climate change and ecosystem services. In the USA acceptance of this argument has resulted in strong National Science Foundation funding for taxonomic research via programmes such as the Partnerships for Enhancing Expertise in Taxonomy and similar initiatives. So far as I am aware, no such RCUK-funded programmes exist in the UK. That begs the question as to why this argument has not been made effectively in the UK. If I could also ask as a codicil to that, where do you believe responsibility for maintaining national capability in taxonomy should lie?
Professor Mace: Shall I address the first half of that question? NERC would consider this a very important issue. Much of the science that is prioritised in NERC's new strategy deals with the biological effects of climate change and the ecosystem services, but also the role of biodiversity in the processes that enable natural systems to respond to those feedbacks from biodiversity into the climate system and so on. It is quite clear that there will be new kinds of information that we need on the taxonomy, particularly of micro-organisms, that play a significant role in those ecosystem processes. Much as we referred to before as components of research funding directed at those questions, NERC will fund that science. It is true that there are not obvious programmes such as the NSF one but NERC has funded large consortium grants in this kind of area. There has been a recent one on deep sea marine biodiversity. There has been the e-science consortium grants in taxonomy which try to address these issues at a similar sort of scale to NSF. I would imagine that, as we move forward with looking at ways to implement the new strategy, there will be a discussion about how to fill that gap and keep it to taxonomy that contributes to those very important areas of science.

Q73 ***Lord Krebs:*** Again, I seem to always come back to money. Could you give us an indication of what the size of the budget for these initiatives might be? I realise it is an emerging strategy but has NERC a concept of whether it is £100,000, £1 million or £10 million or what over five years?
Professor Mace: I can comment on the size of those consortium grants, which have been in the order of a few million on the whole.

Q74 ***Lord Krebs:*** Two grants of a few million?
Professor Mace: There are more than that. Those are just two examples.

Q75 ***Lord Krebs:*** How much of that is taxonomy?
Dr Kempton: The e-science one is totally about taxonomy.
Professor Mace: The marine biodiversity one is quite a substantial amount. We could look at the consortium grants, Chairman, but the question about going forward I am afraid I cannot answer.
Dr Kempton: I suppose all I can really say on the forward look is at the moment we are in the process of developing theme action plans. Our new strategy is composed of seven science themes. We have theme leaders who are responsible for developing action plans to deliver on the challenges in those themes and biodiversity is one of the themes. Within the draft action plan at the moment there is an action to consider what we are going to do in taxonomy. So it is on the agenda at that level. That is being considered by our Science and Innovation Strategy Board and by Council. I cannot actually say what will come out the other end until Council have made their decision.

Q76 ***Chairman:*** There is a rider to Lord Northesk's question as he put it, which is who ultimately has responsibility for maintaining capability in this area?
Dr Game: I think if we are talking about the health of the science base, it depends what part of the base you are talking about. We would take the view that responsibility for the health and functioning of the great institutions, the museums and gardens, rests with their sponsoring departments. The research councils have a view, particularly with regard to universities, but in a broader sense of the research

base as a whole, so you have to ask the question how we decide that there is a problem with the research base and how we have to intervene given that we operate first of all in a very competitive financial model and also in a situation where actually the science base does change and develop. In the end, it resolves itself to either a major strategic issue—in other words, is capability being lost? Users are telling us we need to invest in these areas—or is there an area of key scientific endeavour where UK excellence is not being demonstrated? If you take the area of biodiversity informatics, we intervened there. We led to push the UK into joining GBIF, we funded the work at Reading, Professor Bisby, which has provided most of the technology underpinning the Catalogue of Life that they are developing and so on. So I think there are examples of the case being made and the scientific example being there and the intervention. I think it is much more difficult when you say there is a problem with the whole area, because you have to really ask whether it is true. The museums and gardens are very internationally competitive. They are world-class. They are still succeeding in that way. It is an issue about whether the overall health of the science base is really being endangered to such a great extent by what is effectively a movement from the universities to the great institutions, which I think was the issue as we described it at the last inquiry and I do not really think we have seen anything change.

Q77 ***Lord Warner:*** Could I just probe a bit more about how the research councils know whether there is a problem? Do you wait for noise to emerge from the system, which is the classic British public-sector approach to these sorts of things, or do you actually have systems for monitoring whether the research base is in effect threatened by shortages of taxonomists? I am trying to understand. There is certainly an elusive quality to some of this discussion around how we can actually find out what the systems are and who is responsible. Just take the collection of the research councils—do you have some systems in place?
Dr Game: We have a good system for communicating with each other in major areas of science at all sorts of levels. I take your point about the noise from the system being important, because I do not think you can compare the user environment and the culture in one discipline to another, and everything is changing all the time. What I would say is that we ourselves do challenge the system quite frequently, so, for example, being aware of the concern about systematics on a number of occasions, I can recall that we have actually said to consultative bodies and committees and so on that we are working with "Is this an issue? Should you be thinking about it? What should we do?" and have had responses of one kind or another which have not really reflected, except in this area of informatics, an area where we should intervene. But I agree it is a very nebulous system.
Dr Kempton: Might I just follow on from that to say that the Environment Research Funders Forum, which is an organisation that co-ordinates the major environmental funders, is about to undertake a project on the health of disciplines. Taxonomy will obviously be one that they will look at, so I suppose that is on the agenda.
Professor Esler: My Lord Chairman, each year all of the research councils survey the health of disciplines in the domain of research that they cover and a return is provided to DIUS. This approach picks up things such as the numbers of researchers in particular disciplines, their age ranges, the number of postgraduates, the number of postdoctoral research students. As I sit here now, I am not sure what this says in relation to taxonomy and systematics, but there is a cohesive system for surveying the health of disciplines that the research councils work on each year.

Q78 ***Baroness Walmsley:*** I wonder if I can just pick up Dr Game on something that he said. You said that the major museums and botanic gardens in this country of course are world-class and compete very well globally, but my mind goes back to a piece of evidence we had when we did the previous report. We actually paid a visit to Kew and they pointed out to us that there were certain areas of research that they were having to put on ice. They are having to draw a line and say "No, we cannot do any more of that because we simply haven't got the money." Yet this was valuable work that they felt would have been an advantage to the whole scientific community if they had been able to continue that work. So it is clear to me at that time they were certainly struggling. Do you think the situation is different now?
Dr Game: No, but I would not necessarily say it was any different to the generally competitive nature of science as it is. With the BBSRC, about 60 per cent of the grant proposals it gets are internationally competitive and only 25 per cent of them are funded. In the Medical Research Council in some areas it is less than 20 per cent. You would not expect to visit any major scientific institution without understanding that they were having to cease some areas of work in order to develop new ones, or that there were some areas of work which they could not do. I think any institution that could fund all the ideas it had would certainly be lacking in ideas.

Q79 ***Lord Colwyn:*** Are there systems in place to prevent duplication of research, worldwide or European?

Dr Kempton: At least in the UK, the Environment Research Funders Forum performs that sort of function.

Q80 ***Lord Colwyn:*** I am thinking more worldwide.
Professor Esler: The peer review system ensures that every application is scrutinised by experts who will almost always be of international standing, and it would be odd if they were missing things. That is part of the peer review process.

Q81 ***Lord Soulsby of Swaffham Prior:*** My experience of the USA, especially with the National Science Foundation, is that it is a single body in the sense that it is not a number of different organisations that we have just heard about in the last few minutes. What does this country need to do to get to the stage, as this did, in this question of having a National Science Foundation for the United Kingdom, for example, taking forward this issue in a determined way rather than, as it seems to me, there are a number of separate institutions—all doing good work, all doing good research but not co-ordinated as with the National Science Foundation—or am I wrong in that assessment?
Dr Game: I would say that the situation in the UK is different but not necessarily in the way you would describe. One of the advantages of UK life sciences is that there is a plurality of funding sources, which means there is no monolith saying "This is the only way you can do work." That is one of the things which contributes to the health and vitality of life sciences generally in the UK. It is actually also true in the US. Although the National Science Foundation would be regarded as the main public body for the support of life sciences research, the amount of funding going in from private foundations and endowments and other activities in universities is huge compared to the investment from the NSF. The NSF I do not think even in systematics would consider itself to be the largest funder. The comparison is slightly different. In terms of how we get to a situation where a body like the NSF decided that it could put resources behind a big area, as it is doing at the moment, partly it is able to do that because it is not primarily responsible for the health of the science bass in the area, I think. There is an issue there about it being able to set priorities in a dramatic way because it has a great deal of flexibility of its money, because there is state funding into universities, there is effective endowment funding into the great institutions and so on. So it can move money quite substantially in different directions without causing damage to the people from whom it takes away in the big sense of the effect on the science base.
Professor Esler: Could I just add one piece of information that relates to that question and to an earlier question? In paragraph 32 of our Council submission, it is pointed out that the BBSRC has agreed to grant independent research organisation status on the National History Museum and the Royal Botanic Gardens at Kew and Edinburgh. This means that the researchers in those institutions will now be able to apply to the BBSRC for responsive mode funding, so they now do have a door open to them for considerably more money than they have had hitherto.

Q82 ***Lord Krebs:*** My question really was a follow-up to something that Dr Game and Professor Esler said. The question is, do the research councils strategically pump-prime areas that are currently weak but could potentially be or are perceived to be of national importance, or do you simply respond to current areas of strength? I ask this because in response to Baroness Walmsley's question you said the problem with Kew is that they are maybe not competitive in this area and that is why their research is unfunded but, if the research was strategically important but nevertheless the UK was not sufficiently strong, would the councils have a view that you have a responsibility to grow capacity so that it will become competitive? Are you entirely reactive?
Dr Miles: I will answer on behalf of BBSRC to say that there are particular areas in science where we can identify particular issues and certainly communities of people we would like to put together to evolve the science. There have been particular examples, and Alf has already cited one, where a few years back we identified systematics and computational approaches to serving systematics as an area of potential strategic importance. We held a workshop and groups of people from both communities came together, and the product of that was a project to develop the software, the underpinning of the Catalogue of Life. There are other examples off the subject of systematics, for example, in bio-imaging, where we have held workshops which have encouraged astronomers and particle physicists to join with biologists to try and get the technologies developed for those areas. Most recently we have held a particular activity called CoSyst, which is a small strategic initiative designed to put together people who are interested in systematics research with the mainstream of biological research to encourage the interactions between those groups of people. We are able to offer small pump-priming grants to begin the process of establishing the basic information to allow them to compete better in responsive mode. We have had a number of successes already. We have held two rounds of CoSyst, and this has been in collaboration with NERC, and we have funded approximately 16

grant applications to develop new technologies which eventually we hope will feed through into responsive mode research grant applications. I know one has already been successful which NERC has funded recently. The other 15 or so we hope very much that that will feed through too. We also hope that following a review the system will prove to be a useful one and that we will continue funding in that way. So there are examples where we have taken a strategic approach and decided where there is potential and then followed it up with a special, albeit small, funding scheme.

Q83 ***Chairman:*** Is that effectively ring-fenced money for that project?
Dr Miles: The funding that the BBSRC has offered is essentially ring-fenced, yes.
Dr Kempton: Can I follow on, just to say that NERC also takes the view that there are areas that need capacity building and pump-priming and there are several examples of that. In recent years we have had capacity building programmes in nanotechnology, the environment and human health. We had quite a big push to try to bring genomic techniques into the environmental sciences. I suppose that one is the best example in terms of the life history that we expect from these things that we have ring-fenced funding for environmental genomics and a programme that followed that, post-genomics and proteomics, and having had those two programmes, we felt that basically we have now built that community and they need to move into responsive mode at that point, but these are issues that have to be tensioned. If there are things that need capacity building or some sort of help, that has to be viewed holistically against NERC's whole remit.

Q84 ***Chairman:*** It is helpful to know how you see it working.
Dr Game: I just wanted to say that, to avoid giving the impression that our ability to intervene is only small, if I take another area where there has been a dramatic decline in university activity, which is integrative mammalian physiology, the research councils, the pharmaceutical industry, got together and have launched three centres which are of substantial size. This is in order to deal with the problems in attracting enough trained people to work *en masse* in drug testing and so forth. The example of being able to ring-fence resources and nucleate activity is well proven, and I think we could all cite other examples as well. The point about this is really the evidence of need and also the evidence of where the intervention needs to be made in a way which is realistic and strategic in order to address it.

Q85 ***Lord Krebs:*** I know that NERC is in the process of restructuring the Centre for Ecology and Hydrology and as part of that the Monks Wood research station is being closed down. I wondered if you could tell us what is happening to the funding of the Biological Records Centre at Monks Wood and also to the long-term datasets that are associated with the Monks Wood research station.
Dr Kempton: I cannot speak specifically to the datasets from the Monks Wood site but I do know that the main purpose that we see for our research centres is for the care of these long-term datasets and for survey and monitoring, and it is an activity that we are now calling national capability and, because that is the *raison d'etre* for these centres, activities like the Biological Records Centre are protected.

Q86 ***Lord Krebs:*** How many long-term datasets are you funding under this national capability funding stream at the moment?
Dr Kempton: I cannot give you the answer to that.

Q87 ***Lord Krebs:*** Would it be possible, Chairman, for us to receive the answer in writing?
Dr Kempton: I can try to find out.

Q88 ***Chairman:*** Thank you very much. Can I pick up a question about the New Perspectives project? Professor Cathcart has been sitting there very patiently. It would be interesting to hear from you how this might improve the general perception of the importance of these areas, and then, as a follow-on, how that can move from effectively an AHRC context more broadly into the scientific community?
Professor Cathcart: As a first step, it can improve the perception of taxonomy simply by improving awareness of it. One of the striking things when you visit the museum is that most people in the public who experience the place think of it as a place of exhibition. By engaging scholars on one level you inform the scholarly community and through their outcomes you inform the public. We have made a priority in New Perspectives that the outputs of the research that we are looking to foster will be of high value to the public offer of the museum, the website, the exhibition and so on. So on that level I think it can improve perception enormously. This humanises the whole process, brings it closer to the public, and the arts and humanities understanding of these things I think we would all accept is probably more accessible to the public and we can bring it to life, as it were, in that way. Your second question, the benefits to taxonomy, I see that really as a factor of the first, but I do not think it directly feeds in in terms of money. I think that further down the line, through interdisciplinary exchanges, perhaps it can generate some additional funding but I do not think that is a

priority. I think it is better to think of it in terms of adding value to the taxonomic effort that is already there.

Q89 ***Chairman:*** We are in favour of education of the general public. Have no doubt about that. We wish the project well.
Professor Esler: My Lord Chairman, I have sought permission to tender some visual material that relates to this topic. Might I do so at this point and then speak to it briefly?

Q90 ***Chairman:*** Very briefly, yes. *(Document handed in)* Perhaps you could pass them out but we have to be brief because I think we are running out of time.
Professor Esler: I am handing out, my Lord Chairman, material that I have obtained from the Bodleian Library in Oxford in the last couple of days, just to lead on from Professor Cathcart's submission. The last item in the bundle really takes us back to Linnaeus. The second one is Erasmus Darwin, whom you all know. Another one is an earlier flora illustration. The point we are trying to make by this is to say that the materials in the museums and libraries, not just the physical material but this kind of material, have the power to fire the public imagination in ways that can very significantly enhance this area. We at the AHRC regard the research landscape as a unified one and, by exposing this kind of material to our community, we can have them working on the history of science, on science and cultural history in Britain, understanding British landscapes, British art, *et cetera*. We feel that by pushing in these directions we can touch the public imagination and build up support for the project in ways that simply would not be possible without this. If you think about Edmund Gosse's memoir *Father and Son*, you will see the extent to which the public imagination can be fired by the efforts of a naturalist to taxonomise around the coastlines of Victorian Britain. We very much support our colleagues in this and certainly Professor Cathcart's initiative is a pioneering one, but we have funded other work. For example, we have funded a project on John Walker, who was an early geologist in Edinburgh. He was very interested in taxonomy. Our research community, we submit, has a lot to contribute and certainly we are willing to encourage our colleagues to become active in this area.
Chairman: Certainly your reference to Edmund Gosse produces a very positive response from me, I have to say. I wonder if we have time for one more question.

Q91 ***Baroness Walmsley:*** A few minutes ago we were asked for some evidence of need, and this question relates to the speed of digitisation and dissemination of biodiversity information. We have had evidence from GBIF that the current rate of digitisation is actually hampering work in the UK, and indeed globally. GBIF urges the funding agencies such as yourselves to actively collaborate to ensure that the full catalogue of living things is completed. That, of course, would include retrospective data, of which the UK has an enormous heritage. Could you tell us what funding streams are available in the research councils to support a strategically important initiative of this sort? I understand that research councils are clear and recognise that the editing process, which is so vital, the expert editing process, actually lacks resources.
Dr Miles: Allow me to try and answer that one. On behalf of BBSRC, I will say that there are no special funding schemes at the moment that we are promoting but we are operating a scheme to encourage longer, larger research grants. This requires an outline application to start with, an approval of that outline application, and the receipt of a full application, and obviously the peer review and ranking of that application against all the other applications received. In that particular context, we have received a research grant application that aims to improve the capture of data as a test, if you like. This comes from someone—unfortunately, I cannot mention the name as the grant application is pending at the moment—but essentially it builds on past support provided by BBSRC and EPSRC, the European Union, the United States and Japan. It is only in outline stage at the moment. When it comes to its full stage, of course, we will be inviting our colleagues to co-consider that application. It is designed to complete the Catalogue of Life. Whilst I would accept the responsibility for dealing with the technological aspects of that, the actual digitisation of the collections themselves, we believe, in BBSRC, is the responsibility of the institutions to carry out. We may settle the technological aspects of it and prove that you can do it in that way but the actual cataloguing of all the specimens, we believe, is the responsibility of the institutions such as the Natural History Museum.

Q92 ***Baroness Walmsley:*** It is a massive amount of work, is it not, when you have got an enormous heritage of collections?
Dr Miles: Indeed it is, absolutely.

Q93 ***Baroness Walmsley:*** Do you think it is really feasible?
Dr Miles: I think you might have to be a little selective about how you go about it and you might start with some important groups.

Professor Mace: Perhaps I could make a comment on this one, too. I agree absolutely that there is an enormous backlog in digitising really significant international collections in the UK. I think this goal to create a catalogue of all known life on earth is an absolutely enormous project, and if you look back over the last few years you will see repeated failures to devise plans and develop funding to achieve that goal. I think we have to be very wary about embarking into saying that the funding streams will be available for that because it is such a massive undertaking. One of the key things that needs to be done here is for the various communities that depend on this information to set realistic plans for priority setting around what data is needed first, perhaps some of these things that we have already talked about, there are some that are very important to strategic bits of UK science, there are some that are very important to the amateur naturalist community, and some that are very important to the museums and gardens themselves, but we need to see a set of clear achievable plans and funding bids that are within reasonable limits of what can be provided. Some of those may come from research councils; some of them probably will not, but I do think this task needs to be broken down into some achievable objectives. Secondly, it will require collaboration amongst the institutions and the major holders of this information who are the ones who are responsible for digitising it. They are going to need to act collaboratively and I am very pleased to see that things like the EDIT programme in Europe has started bringing together the big collections in a way that they will be able to collaborate to develop those kinds of activities and actually make them more achievable.

Chairman: Thank you all very much indeed. That has been a very helpful hour and you have been very concise and precise, which we appreciate very much. If on reflection there are matters that you would like to expand on in writing in response, and you have mentioned one or two on the way through, then we are very happy to receive that. Thank you both for your presence and for your written evidence.

Examination of Witnesses

Witnesses: Dr Ben Cowell, Head of Museums Sponsorship, DCMS; Dr Miles Parker, Director of Science, and Professor Nicola Spence, Head of Plant Health Group, Central Science Laboratory, Defra; and Dr Liam Kelly, The Scottish Government, gave evidence.

Q94 ***Chairman:*** Welcome to our new set of witnesses. I think you have been listening, by and large, to what went on so I can reduce the preliminaries to reminding you that we are on air and what you say is being recorded and possibly, according to that sign, being broadcast at the moment. Also if you have further comments you want to put to us, we will be very happy to receive them. Finally, we are predicting that there might well be a vote in two or three minutes and we will have to stop at that point if necessary. That being said, may I say that I am Stewart Sutherland, Chairman of the Committee, and we are very pleased to be in front of you and my colleagues around the table have name labels. Would you like to introduce yourselves so that the recorder can pick up your voice and simultaneously your name.

Dr Cowell: I am Ben Cowell, Head of Museums Sponsorship from the Department for Culture, Media and Sport.

Dr Kelly: I am Liam Kelly, I am from the Rural and Environment Research Analysis Directorate of the Scottish Government.

Dr Parker: I am Miles Parker and I am Director of Science at Defra.

Professor Spence: I am Nicola Spence and I am Head of the Plant Health Group at the Central Science Laboratory, which is an agency of Defra.

Q95 ***Chairman:*** Thank you very much. Can I launch into the first question which is a theme that we have been pursuing, our search for where ultimate responsibility lies for oversight of this whole area, and that has to do, not least in view of the witnesses we have now before us, with devolved government and responsibilities as well as research councils which are a Westminster responsibility. Who would like to speak on this?

Dr Parker: Perhaps I could take that up, Lord Chairman. The written question that we received talked about fragmentation here, and I think, if you look at it another way, what we have is a very wide community of interest in this area. We have users, we have basic researchers, we have those interested in the funding of some of the major institutions, and on the whole we find it a strength that there is a wide community here, and the emphasis that we have put into this is on working with that community and co-ordinating our activities with them.

Q96 ***Chairman:*** I understand the value of a broad spread and that point was well made earlier in relation to research funding and so on, and with one stream it may miss the target, but, even so, there is always the danger—and we have seen this in other reports that we have put together on different topics—of things falling between the cracks if you

have a series of bodies with responsibility. The Government Office of Science for example might be one source that one would look to have an overall grasp of what is happening. Is that too fanciful and would there be problems?
Dr Parker: I would not necessarily look to the Government Office to focus down on any one discipline in this way. I think again it is really important that with an area like this we do co-ordinate across the silos and boundaries. It is true not just of this discipline, I can think of a wide range of others where we need to work outside, for example plant science.

Q97 ***Chairman:*** But the evidence we have from various departments (and the non-evidence in some cases, no response) might suggest to us that Defra takes the lead. Is that a fair perception or would that be a mistake?
Dr Parker: I think we have a lively interest in this area. I do not think we have a lead on all aspects of it. On some aspects we will look to the research councils and others we will look to other government departments or to other institutions. What I do think we have taken a lead on is encouraging the community concerned to get together in organisations like the Biodiversity Research Action Group and the Global Biodiversity Sub-Committee, which were mentioned by the previous witnesses, and in that sense, we do take initiatives to try and promote co-ordination.

Q98 ***Chairman:*** I cannot but ask the question about how far the devolved administrations feel that there is adequate interchange? We find this patchy and variable across a whole range of topics not just in science.
Dr Parker: I will turn to my colleague here.
Dr Kelly: I think the existence of UK BRAG, in which we also participate, we find is a useful platform in which to discuss a number of issues relating to biodiversity. As we heard earlier, perhaps the issue is not one strictly and directly of taxonomy, which is obviously the focus of today. However, again without wishing to feel as if I am repeating Miles's views, there are a number of areas across which taxonomy touches, and so therefore I think the best way in which we can try and interact on these, amongst other issues, is by participating in the UK groupings that are headed up by and large by Defra and associated departments.

Q99 ***Chairman:*** So pragmatic principles apply?
Dr Kelly: Yes, I think very much so.
Chairman: I am pleased to hear that. Lord Krebs?

Q100 ***Lord Krebs:*** I would just like to be clear in my own mind about Dr Parker's response. We heard that the BBSRC has little involvement in the support of taxonomy and NERC is not primarily concerned with systematics and taxonomy *per se*. I have not quite got it fixed in my mind which bit of the overall funding system for science in Britain or the United Kingdom feels that it has responsibility for taxonomy *per se*? Whose job is it?
Dr Parker: I do not think it is any one organisation's job. I think a good many of us are users of taxonomy and we will fund appropriate work on taxonomy to meet our own particular needs. We will draw from quite a number of different sources and we have had considerable value out of previous NERC and BBSRC initiatives when developing taxonomy in the past, and you will find people that came out of that embedded in many of our programmes. We hire a good many people who we put to taxonomy work but I do not think that gives us responsibility for taxonomy as a field. As a field of study that does not seem to me to belong to somebody.
Baroness Walmsley: I have three little questions that are all linked together. Firstly, Defra states that when they commission research that requires the input of systematic work, that will be "factored into the contract", but we can only assume that that has not succeeded in the case of systematic mycology because we have had evidence that that particular discipline is really at crisis point. Our first question is what is being done to ensure the survival of this discipline and relevant collections? The second thing is that in its evidence Defra states that whilst it "is a user of outputs of systematics and taxonomy, it is not a major utiliser of research from these disciplines." I think it is not just a philosophical question but a practical one about what do you think is the difference between research and outputs. Perhaps I will put the third one when we have voted.
Chairman: You are going to have some time to think on what your answer is. I am afraid we will have to pause now while we vote downstairs.
The Committee suspended from 4.53 pm to 5.02 pm for a division in the House
Chairman: One or two of our colleagues are still stuck in the voting lobbies but will be back here very soon, I have no doubt. We were in mid question from Baroness Walmsley.

Q101 ***Baroness Walmsley:*** We had just had the one on what is the difference between research and outputs, and it is not just a philosophical question! The third bit is we have heard that following the recommendations of our previous report on this subject, which I chaired, the systematics community has been quite successful in focusing on user-friendly outputs, outputs that really are of use to people, and they just do not feel they can go too much further in

that respect and that they are getting to the point where they are living off capital really, so what we would like to ask you as self-declared users as well as funders is what is your response to that claim? You have had 10 minutes to think about those three little questions!
Dr Parker: I will attempt to answer them and then I will bring in a colleague on the first one. On the issue of mycology in particular you were asking what I meant by factoring in particular requirements into contracts. In general, when we put out a call for tenders and proposals we will describe a problem, which is usually a policy-based problem, and outline where we think some of the scientific inputs might be, but we are looking largely to the science community to look at the problem and tell us what they think the appropriate avenues are, so we will expect the scientific community, among other things for example, to identify that this project might need an input on mycology. That is the general answer to the question. On the more specific one where a discipline is of importance and we have realised we are not getting what we need, we have a number of mechanisms which we can use to support or develop expertise. We have used fellowships for example to develop the expertise available to us in areas such as epidemiology, which was a major shortfall a few years ago. I would like to turn to my colleague Professor Spence to tell you about some of the things we have specifically done around mycology.
Professor Spence: In relation to taxonomic needs in mycology to support and underpin plant health, Defra will identify, in conjunction with the science base, where the gaps are and they have funded taxonomic fellowships which are typically either a PhD student, possibly a masters programme, or a specific piece of taxonomic research that needs to be done to support that gap that has been identified.

Q102 ***Baroness Walmsley:*** Is that mainly in relation to fungi that produce plant disease or are we talking also about the mycology of soil?
Professor Spence: This would be in relation to fungi that cause a plant health issue. They might be soil-borne. Typically a number of soil-borne pathogens are of plant health concern. One example at the moment which is very topical is *phytophthora* diseases of trees, so typically here you have air-borne spores and you also have spores in the soil so you actually need to look at the taxonomic needs around the disease risks in that genus and there is a Plant Health Division of Defra-funded taxonomic fellowships specifically on *phytophthora* in order to address that gap.
Dr Parker: If I can pick up your second question then just to clarify what we meant here; we are users of taxonomic skills and many of the people who work on our research programmes will be ecologists or, for example, plant disease specialists and so on but they will be applying taxonomic skills in their work and that was what I was getting at in that response. What we are not using directly is research on systematics as such. It is an underpinning science (although obviously the nomenclature is impossible without systematics) and it is the taxonomic skills that we make use of.

Q103 ***Baroness Walmsley:*** In terms of the final part of the question, the taxonomic community feel that they have gone pretty well as far as they can in focusing on outputs and they are living on borrowed time really. The question is what about the pure science related to the relationships between taxa and that kind of thing, who is going to fund that?
Dr Parker: Pure systematics research is a basic research discipline which I would expect to find in the universities and normally I would expect to find being funded through the research councils. That is not a discipline that we would fund. We do not generally fund disciplines; we invest in areas of research which will actually play directly to our policy requirements.
Baroness Walmsley: That is an interesting point there.

Q104 ***Lord Krebs:*** Could I just come back on that because I asked you earlier about responsibility and we were told by NERC and BBSRC that they do not have responsibility for funding pure taxonomy, they see themselves as users of taxonomic research not creators of taxonomic research, so I do sense there is a slight shifting of responsibility amongst the bodies that we have been talking to this afternoon.
Dr Parker: I wonder do I need to be clear about how I am using the terms? I am talking about the skills that we need in ecological programmes, for example, to ensure that we are accurately identifying organisms, and that is a skill we unquestionably need. The underlying science behind that in systematics is not something that I think is for a government department to fund. I am aware you asked that question of the research councils but I think part of the answer of the research councils is that they have funded a number of initiatives in systematics and that has in turn led to, for example, people like us employing some of the outputs from those programmes.

Q105 ***Lord Warner:*** I am getting a bit confused about Defra's role in this area. I would like to ask a few questions around this. In the previous sub-committee's follow-up inquiry it was recommended that Defra take the lead in setting up a new co-ordinating body. That is where we started from. No new body was in fact set up and Defra in their written evidence tried to explain why this was not taken forward and I just quote one bit, it said that: "Defra

itself would perhaps be best positioned not to lead an activity best driven by the community itself." That seemed to be Defra's position. I listened very carefully to some of your answers to the first questions, Dr Parker, where you said Defra had a lively interest in the area, and you said that it did have a responsibility for co-ordinating the wider community when you gave an answer to the Lord Chairman, and you did mention that you saw yourselves as having a role of co-ordinating across what you called the silos and the boundaries. I am not quite sure where we are on that. If I could just finish a little bit more. The UK Biodiversity Research Advisory Group believes that "there remains a need for improved mechanisms to make user needs known to the taxonomic community and the funding bodies." So there is a feeling out there to some extent that there is some need for co-ordination. You seem to accept in your oral evidence there was a need but the written evidence from Defra says it is not for us to take the lead. Could you perhaps, for a simple soul like me, clarify what Defra's role actually is in this area.

Dr Parker: I think the important distinction I am making here is between what you might call co-ordination of systematics and taxonomy as opposed to co-ordination of work on conservation and biodiversity, and I do not think those are quite the same thing. In relation to the effort to follow up your earlier recommendation, when we came to look at the task that had been put before us there, many of the possible lines of action that we saw looked to us as if they were going to simply repeat what had gone before and were not going to take things further forward. In parallel with that, though, we were putting in place the thinking that led to the setting up of the Biodiversity Research Action Group and the Global Biodiversity Sub-Committee because we did see a real value in co-ordinating research in those areas across the boundaries. One of the issues that comes up in both those groups is the availability of taxonomic skills and the underlying research that leads into those, so these issues have been dealt with but in a wholly different context, a much broader context, which is the applications of those areas of science to, in our case, the policy requirements of biodiversity conservation. I hope that helps to explain that I am not being totally self-contradictory in this. One other thing I would say here is you cite BRAG as saying there would be value in improving the levels of co-ordination but I think the report itself goes on to say that the answer to that is provided, at least in part, in the conservation area by BRAG and by the Global Biodiversity Sub-Committee. There are other co-ordinating bodies in areas for example like plant health which are also addressing these issues, but again in the context of the applications of the areas of science like systematics and taxonomy in other contexts.

Q106 ***Lord Warner:*** But would I be right in interpreting then Defra's position as meaning that across the science territory which impinges on Defra's responsibilities, insofar as you are co-ordinating taxonomy and systematics, it is within a much bigger framework? You are not actually seeing those as issues which you need to co-ordinate for themselves for their own contribution to your capability of research to deliver for you in the areas for which you are responsible? You seem to be embedding them in some much bigger co-ordinating mechanism. Is that my correct interpretation of what you are trying to do?

Dr Parker: I think that is fair but what I am saying is what we are embedding in that wider co-ordination activity is the applications and uses of systematics and taxonomy to particular problems. That is not quite the same as co-ordinating systematics and taxonomy themselves when you are talking about a discipline and I do not think that is a job that we would attempt to do or think we were appropriately positioned to do.

Q107 ***Lord Warner:*** What would happen if your science base was unable to deliver for your research needs, if there was a shortage of taxonomists and systematicists?

Dr Parker: We have had problems where we have had shortages in particular skills or specialties before and, as we touched on in the answer to Baroness Walmsley, the answer that we have locally within Defra is found in initiatives like fellowships and so forth which help us to train in some areas of specialty. Within our own institutions, we do a fair amount of training in the laboratory and in the field, for people that we recruit, so there are a number of different ways in which you can approach that. What the two committees have discussed is the broader issues, in the context in which they are dealing, of "have we addressed the requirements for taxonomic skills" and, yes, that is one of the things that we have discussed, in fact we are still in the process of discussing.

Q108 ***Lord Soulsby of Swaffham Prior:*** This question is about EU funding. UK BRAG also submits there is little recognition for systematics in EU Framework Programmes and RBG Kew submits that EU funding is mostly focused on networking and not on delivering projects. I am not quite sure what that means so perhaps you will explain it to me. If systematics could be more successful as large-scale science is more delivery-focused and capacity-directed funding, is that an issue that the Government should take up at an EU level? Perhaps you could explain what is meant by "more focused on networking" and not the practicalities of the issue.

Dr Parker: To pick up the point BRAG was making in relation to networking and projects, the EU funds in a number of different ways but two of the bigger ones are direct project funding through multi-lateral agreements between institutions in different countries to deliver research projects and, secondly, funding through a system known as the "ERA-Nets", the European Research Area Networks, systems which bring together networks of research funders and the major organisations concerned with research programmes. This is something that the UK has supported quite strongly because we see real value in bringing national resources together and so we found that quite helpful. We would though part company with BRAG in their interpretation of what is going on. I would like, my Lord Chairman, if that would be agreeable to you, to submit some additional information mainly because I cannot remember the long list of acronyms that applies to all the projects, but there really is quite a substantial number of both networks and projects addressing issues around taxonomy and systematics, largely again in the context of the use to which these are put. Where BRAG is correct is in saying the framework programmes do not focus on systematics nor on any other disciplinary science. What the Framework Programmes focus on is the needs of the Treaty which are focused on the competitiveness of the European economy and the other chapters of the Treaty, in other words agriculture and the other chapters. It is very much a policy-focused set of programmes. You will find that there is quite a lot of activity within the European Union but it is largely in an applied context, and in that context you will find, for example, there is an infrastructure project which is setting up the sort of network that you are thinking of and pulling together data providers. There is the Biodiversa Programme which is fundamentally a network but is also putting more than €20 million into projects over the next five years and so on. I can provide a much longer list but actually there is quite a lot of activity going on.

Q109 ***Chairman:*** Additional written material would be very helpful but on the understanding you translate the acronyms for us because we do find that we are deluged with them.
Professor Spence: Perhaps if I can just give an example, there is a Research Area Network co-ordinated by Defra in the plant health area. This was identified by the Chief Officers of Plant Health in Europe as a need and Defra took the lead in co-ordinating this project, and we now see the benefits of a co-ordinated approach in that there are research calls and infrastructure calls coming out of the Framework Programmes which support particularly research needs but also taxonomic skills to support and underpin the research around the plant health area, so I think there are some good examples of where it is quite well-co-ordinated.

Q110 ***Lord Krebs:*** I just wanted to follow up on your comment about the Framework Programme to ask you whether you know anything about the funding of taxonomic research by the European Research Council, which does of course fund basic research and not policy or applied research?
Dr Parker: I cannot answer on that, I am afraid. The European Research Council issues are largely for the research councils in the UK. We would be happy to try and follow up the question but I cannot help.

Q111 ***Lord Haskel:*** Continuing the discussion about Europe, in the Defra evidence you point to the European Platform for Biodiversity Research Strategy. You say this is a forum for identification and prioritisation of research needs across Europe. At their meeting held in November 2007 they recommended that "particular attention should be paid to secure taxonomic expertise on marine organisms and to foster capacity to deliver appropriate information in support of ecological work". Who are these recommendations directed at? Where do the recommendations go? Who picks them up and what happens?
Dr Parker: They go in a number of directions. The primary direction is to the European Commission and that will pick them up in terms of proposals it puts forward for the work programmes under the Framework Programme. Secondly, the EPBRS recommendations go to people known as European Nature Directors who are those people in the individual Member States responsible for biodiversity conservation policy, so at a national level the directors will receive the advice of the EPBRS and factor that into their own thinking about their own national programmes. Thirdly, we pick up EPBRS recommendations in bodies like BRAG and the GBSC and look at what is emerging in the way of suggestions for prioritisation, so there is a number of avenues in which they can get back into the thinking at both the European and national level about what our next research priorities might be.

Q112 ***Lord Haskel:*** Do you have any impression as to how well these recommendations are picked up? Are they acted upon or are they ignored?
Dr Parker: No, they are certainly acted upon. I am sorry I cannot give you an immediate example on that but certainly the outcomes of EPBRS have played a big part in formulating the relevant parts of the work programmes under the Framework Programme and nationally we have picked up on them in establishing our own priorities. They are one source among a number of others and there are other bodies doing similar sorts of work but there tends to

be a coincidence in the priorities when you look across them.

Q113 ***Lord Haskel:*** A recommendation from them would influence you to fund research in that particular area?
Dr Parker: Yes, not least because our own input into EPBRS will have come from our own officials and our own participants in research programme, so reflecting what is going to emerge from our own thinking about priorities and then the engagement with other countries.

Q114 ***Lord Methuen:*** The most important environmental issues, such as assessing the impact of climate change on ecosystems, are global in scale. How can the global requirements for leadership in the provision of taxonomic training and research outputs be factored into consideration of national capacity?
Dr Parker: I would first refer back to the Global Biodiversity Sub-Committee which is part of the wider Inter-Agency Committee on Global Environmental Change. This is designed to help the various funding organisations and various delivery organisations look at the relative and relevant priorities. Taxonomy is one of the issues that comes up in that context. The GBSC has discussed systematics issues several times and in fact we are part way through a discussion at this point on what the priority issues are. Secondly, the government departments concerned play a big role in the Convention on Biological Diversity which itself has identified some of the key issues affecting the use and availability of taxonomy and they have identified the "taxonomic impediment". That in turn has been followed up by action at a national level. We carried out a national needs assessment a few years ago and we have been following up the recommendations from that to try and improve provision in certain areas.

Q115 ***Lord Methuen:*** To what extent do you go outside the UK to gain the experience?
Dr Parker: I am sorry, I did not quite hear the question.

Q116 ***Lord Methuen:*** To what extent do you consult beyond the EU on what is going on elsewhere in the world?
Dr Parker: The Convention on Global Biodiversity is a global affair so the inputs to the discussion there have been from all sources. Nationally the main sources of expertise in this area are also very, very well plugged into global networks—Kew and the Natural History Museum for example.

Q117 ***Lord Krebs:*** You described Defra as a user of taxonomic research to meet your policy objectives, and obviously over time those policy objectives would change. For instance, a high priority has been in conservation in relation to the UK Biodiversity Action Plan and it may be that in the future policies related to ecosystem services could come to the fore. What I wanted to ask you is whether as the policy changes the requirement for taxonomic expertise changes and, if it does, how do you assure yourselves or find yourselves in a position where you have access to the new kind of taxonomic expertise that you need for a different policy?
Dr Parker: I do not think the requirement changes significantly as between the more traditional approaches to conservation and the ecosystem approach as now applied. What has made a difference there in particular I think has been bringing economists and others into the story. Am I missing your point here?

Q118 ***Lord Krebs:*** It was an open-ended question whether the taxonomic expertise that you require changes and the answer seems to be, no, it is the same kind of taxonomists that are applying their skills to different questions.
Dr Parker: I think some of the ecological questions change quite a lot but that is not an area where we have difficulty in obtaining expertise.

Q119 ***Earl of Northesk:*** As we all know, the UK has a broad range of obligations and commitments under various EU Directives and UN Conventions and of course these responsibilities extend to many British overseas territories many of which have high, in some cases very high biodiversity. Is our taxonomic capability strong enough to enable us to deliver on our EU and UN and indeed overseas territory commitments? Flowing on from that, much the same question as I asked the research councils: where does responsibility lie to maintain capability in taxonomy at that sort of global level?
Dr Parker: I am not sure that I can entirely answer the question, although I would refer back to the answer I gave Lord Methuen about the role that is played by the Global Biodiversity Sub-Committee and the work that has been done on the Convention on Biological Diversity. In relation to the overseas territories, the Global Biodiversity Sub-Committee did pick up this issue and we have received a report on the issues that affect the overseas territories. That is work in progress. We are looking at the moment at two further issues to do with this, one simply a matter of costing priorities, because there is always an issue there, but the other is to look at what the funding streams available to the overseas territories are. As I understand it, they are fundamentally responsible for their own ecosystem management but there are

various ways in which they can receive support and help from the UK.
Professor Spence: Can I add to that that where there is a regulatory obligation then Defra supports and develops capacity amongst its delivery bodies, principally the agencies around fisheries, livestock and CSL.

Q120 ***Chairman:*** We are virtually out of time but I wonder if I could very quickly put two questions to you. One is to DCMS and it is about progress on appointing a chief scientific adviser. This Committee in other guises, for example in its report on science and heritage, pressed the case and we were rather hoping, not least because there are implications for this report, that progress was being made. Can you tell us how far you have got?
Dr Cowell: As you know, we are engaged in a look at how best we ensure scientific advice is supplied to the Department and its ministers to enable us to formulate policy appropriate in our various different areas. We continue to consider options, most recently discussing with the new Government Chief Scientific Adviser on how best to proceed. We thought it a good idea to consult the new appointment. We are now considering options around a possibility of a part-time appointment from academia to carry out this role. Clearly the issue will be from which part of the broad scientific community that adviser might come. It is unlikely, I suspect, that it will come from the systematics or taxonomic field, more likely perhaps a social scientist, but we are progressing the discussions with the Government's Chief Scientific Adviser.

Q121 ***Chairman:*** We press the taxonomic case because of your responsibility for museums which is very much within the DCMS area. I have to say I hope that the considering of options does not go on much longer because we feel you have had a fair crack at that and it would be quite nice to see progress. Could you keep us in the picture on that?
Dr Cowell: Absolutely, we will keep you updated as things develop.

Q122 ***Lord Krebs:*** If I may come in behind that, in the interim whilst you do not have a chief scientific adviser in DCMS, I wonder how you determine whether the amount of investment in taxonomic infrastructure in the museums, both nationally and regionally, is the right level? How do you make those judgments? If you had a chief scientific adviser, he or she would help you perhaps through an advisory committee to reach those judgments; how is it done at the moment?
Dr Cowell: We very much rely on the advice given to us by the experts in the institutions that we fund, not least the Natural History Museum that I believe you have already heard from. I have to say this perhaps relates more to other departments' chief areas of interest than our own, but we are very happy to fund the Natural History Museum to the degree that we do (which gets a substantial allocation from the Department). It is the most generously endowed museum of all the museums that we sponsor. That in part reflects the excellent work that they are doing in this field, so the answer is that we rely on their judgments and advice at Spending Review time in making the allocations that we do among the different bodies that DCMS sponsors.

Q123 ***Lord Krebs:*** Could I just come back, if I may Chairman. I can see that this seems to be a very nice position for the Natural History Museum to essentially tell you how much money they want; I wish I was in that position myself! What about the regional museums? You talk about this Renaissance in the Regions programme and you are spending £45 million, which sounds like a big number to me, but how do you judge whether that is the right number given that you list these incredibly important collections in a number of regional museums? I should at this point declare an interest as the Chairman of the Oxford University Museum of Natural History. How do you determine whether you are giving those museums the right amount of money? Is it the same process that you ask the director how much he or she wants?
Dr Cowell: Of course there are many competing claims on DCMS funds and we cannot possibly satisfy everyone, so we do rely on the expert advice in our sponsored museums which we then have to weigh up very carefully at Spending Review time. When it comes to the Renaissance programme, this of course is a programme of support for museums generally not just for natural history and collections. We talk very closely with the Museums, Libraries and Archives Council and we are very pleased that that particular programme continues into the new Spending Review period. Indeed, they have had an inflationary increase in their budget. I think the degree to which we seek expert advice on natural history collections I have to say does probably not come into the allocation decisions in a great capacity except insofar as MLA tell us there are particular needs in those particular areas.

Q124 ***Baroness Walmsley:*** My question was quite similar to that of Lord Krebs really. I am sure you get excellent advice from the directors of these institutions about how much they should have, but it can hardly be said to be independent, can it, and when you have a lot of these competing claims, what is the mechanism for prioritising? Do you get independent advice to advise you on which are the most worthwhile to fund?

Dr Cowell: We have a series of performance measures to be applied to each of the museums that we sponsor and that helps us to determine how we might allocate future spending priorities. For example, a museum that performs well consistently is one that we know we can trust with investment going forward. In addition, in relation to the Natural History Museum part of the uplift they received in the most recent Comprehensive Spending Review was in respect of the fact they have a major new capital development that will require on-going running costs into the future, the Darwin Centre Phase Two, which will be a major contribution in this field in particular.

Q125 ***Chairman:*** You have got the message that we are watching. A last question since we have got representatives of both the Scottish Government and Defra: we have had—and this has been a theme throughout the afternoon—what we think is possibly conflicting evidence about whether there is a shortage of capacity and skills. The Scottish Environmental Protection Agency for example indicated that they were having difficulty meeting their responsibilities to comment on the Water Framework Directive in terms of recruiting the right sorts of specialists and one of the Defra reports, the Ecosystems Approach Action Plan, suggested there were challenges in a comparable area, and yet sometimes the message washes back that all is in order, there are enough people around and the concerns of the community are overstated. Would each of you like to comment on that?

Dr Kelly: I think first and foremost we should also be clear that there are a number of ways in which taxonomy is being used. This is a regulatory focus rather than a research-only focus. That is not to decry the value of it in any way but it is a slightly separate discipline from perhaps the type of materials you might associate with longer term research projects. I suspect that the Framework Directive has, if you like, created a demand which has not been met over the longer term, coming forward to the point at which the arrangements for the Directive are now coming into force, but I would imagine that there is sufficient capacity for training both within SEPA and outwith SEPA in other organisations—universities and other sectors—which would permit that skill base to be widened fairly quickly. I am not saying that that is not evidence of a shortage, because clearly if they have said there is a shortage they are feeling that, but what I would suggest is that these are short-term demands which I think any system struggles with regardless of what expertise you look at.

Dr Parker: I would rather echo that. I think the apparent inconsistency that you have picked up in that paragraph is more apparent than real. I say that without getting complacent about the fact that you will get flow problems and we will not always have what we need when we need it. The normal reaction to this is exactly the one picked up by bodies like SEPA, and that is to train in-house. I would argue that there is immense value in taking people with basic biology and training them in-house in the specialist needs to fit the requirements of our particular types of programmes. Incidentally, Professor Mace referred earlier to just one Masters course with what seemed to be a colossal throughput. A lot of those people are finding their way into our programmes. They will not arrive knowing exactly what it is we need and we have then got a job to do to train them.

Q126 ***Chairman:*** I understand the point you are making, there are ups and downs and flows and so on, but I was very struck by the fact that when I went to the launch of the outcome of the three-year Funding Review for research councils there were two Ministers present and the chief executives of research councils present making speeches and the speech from the research councils said there are three major global problems—global climate and warming, water, and the other was demography and ageing. Water is not one that I think is going to come and go because there is major and international concern about ensuring the adequacy and purity of water supplies. I am not convinced when you say this is a temporary thing; I think water may be a special case.

Dr Parker: If I could just comment on that. I think the issues of water supply that you are talking about are undoubtedly global and major. The issues that we are facing through the Water Directives are largely about water quality and there are some quite specific biological criteria that get applied there, and it was finding the right people to help us deliver those that was posing some of the initial problems. I think that the context is slightly different.

Chairman: I hear what you say. Can I say thank you very much to each of you for coming, giving us your time and also for the written evidence that you have submitted. If you have further comments, and some of you have suggested that you will have, that would be very welcome also. Thank you very much.

Supplementary evidence from the Research Councils UK (AHRC, BBSRC AND NERC)

1. *The total NERC budget for responsive mode funding over five years (ie what proportion of the total does the £7 million spend on taxonomy constitute) (Q55). The Committee would also like to know these figures for BBSRC responsive mode funding and how much of NERC's and BBSRC's budget is spent on systematics and taxonomy studentships.*

NERC

1. The systematics and taxonomy research supported by NERC is effectively classified as a subset of biodiversity research[57]. Over the five years from 2002 to 2006, NERC awarded £104.2 million in responsive-mode grants for projects judged by the applicants to include at least an element of biodiversity research, and £11.3 million of that was for projects judged by them to include systematics and taxonomy (under "Science Topic"). This means that nearly 64 per cent of all responsive-mode funding in 2002/03–2006/07[58] went to projects considered by applicants to include a biodiversity component, and nearly 7 per cent to projects considered to include a systematics and taxonomy component, involving 62 per cent and approximately 8 per cent of awards, respectively.

2. The size of the component judged to correspond to biodiversity or systematics and taxonomy research depends to a large extent on how many other issues or topics the applicant considers to be relevant. If others are chosen as well, the percentage "allocated" to biodiversity or systematics and taxonomy is inevitably lower. Therefore although over half of the biodiversity-related and a quarter of the systematics and taxonomy-related project funding in 2002–2006 was classified by applicants as corresponding to those subjects, these proportions may underestimate the real contribution, particularly at the Science Topic level. Many relevant projects are classified under other relevant Science Topics in addition to or instead of systematics and taxonomy, for example under population genetics and evolution, environmental genomics, environmental microbiology, and palaeobiology. With the move to more molecular approaches to systematics and taxonomy, classification under the environmental genomics Science Topic has become increasingly common. We therefore stress that the figures quoted in the first paragraph (and below) regarding investment in projects including systematics and taxonomy should be considered as the minimum investment in this area.

3. The figures in the first paragraph do not include funding for biodiversity or systematics and taxonomy through programmes, national capability, fellowships or studentships. Programme grants including systematics and taxonomy amounted to £2.4 million over the five years from 2002–2006, of which roughly one fifth was judged by the applicants to be classifiable as systematics and taxonomy.

4. Over the five years from 2002–2006, 9 of the 154 fellowships awarded by NERC included an element of systematics and taxonomy. Their total value was just over £2 million, of which £0.3 million was classified by the applicants as systematics and taxonomy. In the three years 2005 to 2007[59], 42 of the PhD studentships awarded by NERC included systematics and taxonomy; 412 were classified under biodiversity. The respective annual averages of 14 and 137 compare with an annual average of 332 PhD studentships awarded by NERC over the financial years 2005–06 and 2006–07[60]. The cost per student is generally around £70,000 over the three years of the studentship; it varies according to the location (need for London allowance) and the extent of fieldwork involved. The average allocation in the period 2005–2007 for systematics and taxonomy PhD studentships was therefore in the region of £1 million per annum.

5. The reference to "£7 million over five years" in this question and in Q55 (11 March 2008) requires correction, as does the reference to "£7 million since 2000" made in the answer to Q54. The latter should have referred to grants (responsive mode *and* programme grants) and fellowships awarded since *1996*; it did not

[57] NERC asks applicants for grants to classify their research according to Science Area, Secondary Classification (if appropriate), Environmental and Natural Resource Issues (ENRI), and Science Topic http://gotw.nerc.ac.uk/classification.asp. In the context of systematics and taxonomy, the most relevant ENRI is biodiversity (one of 5 major ENRIs), and the most relevant Science Topic is systematics and taxonomy. When applicants classify their research, they must ensure that 100 per cent of the funds sought are allocated to one or more (up to four out of 51) Science Topics. NERC does not alter the classifications provided by applicants, whose allocations may be influenced by perceptions of how their research proposals will be seen in the light of NERC's strategic objectives. The figures obtainable from NERC's Grants on the Web system for allocation to specific Science Topics should be regarded as estimates only.

[58] Data on systematics and taxonomy spend from Grants on the Web, by year of award round; data on total responsive-mode awards from NERC's annual reports, by financial year.

[59] Data for earlier years not available.

[60] Final figures for 2007/08 not yet available.

include national capability funding or studentships. To confirm, it referred to the component of the grants allocated by the applicants to systematics and taxonomy (see comments above). We apologise for not correcting these points sooner.

BBSRC

6. BBSRC spent £26.8 million on projects that include systematics and taxonomy through responsive mode between 2002–3 and 2006–7 (using the definition of systematics and taxonomy from the Committee's 2002 report *What on Earth?*[61]). This represents 5 per cent of the BBSRC responsive mode budget in that period or 2.1 per cent of the overall BBSRC budget. This figure does not include funds spent on systematics and taxonomy projects through initiatives, institute projects or studentships which would have contributed an additional £30 million in that period.

7. In 2006–7 BBSRC spent £0.58 million on studentships involving systematics and taxonomy research, equivalent to 1.44 per cent of the BBSRC studentships budget or 0.2 per cent of the overall BBSRC budget.

2. *Any views the witnesses may have, on reflection, on the possible impact of the end of the HEFCE-funded and AHRC-administered museums and galleries programme on university museum collections (Q63).*

8. There is an agreement between AHRB/C and HEFCE that in 2009 the arrangement where the AHRC distributes core and project funding to museums and galleries in English HEI's on HEFCE's behalf will cease. HEFCE should be approached in relation to its current plans for that stream of funding beyond this date.

3. *How many students currently on NERC-sponsored MSc and PhD courses are working on purely taxonomy and systematics or have a substantial element of these subjects in their projects? (Q65)*

9. Of the 40 PhD students currently (at 29 April 2008) registered as holding NERC studentships (including CASE awards) in the Science Topic of systematics and taxonomy[62]; most of the projects involve using taxonomy; some address taxonomy *per se*. Please see Annex for a list of project titles.

10. The numbers of students supported by NERC on the most relevant masters courses in 06/07 and 07/08, and the funding provided by NERC, are shown in the table below.

Course title	*Institution*	*Number of students*		*NERC funding (£k)*	
		06/07	*07/08*	*06/07*	*07/08*
Biodiversity and Taxonomy of Plants	University of Edinburgh, School of Biological Sciences	8	7	73	75
Advanced Methods in Taxonomy and Biodiversity/ Biosystematics	Imperial College/Natural History Museum, Biological Sciences	9	9	86	88
Biodiversity and Conservation	University of Leeds, Institute for Integrative and Comparative Biology	5	5	38	39
Biodiversity, Conservation and Management	University of Oxford, School of Geography and the Environment	4	4	60	59

11. NERC also funds several other Masters courses relevant to biodiversity.

[61] http://www.parliament.the-stationery-office.co.uk/pa/ld200102/ldselect/ldsctech/118/11801.htm
[62] http://sotw.nerc.ac.uk/list_med.asp?pge=class_scitopic&classtype=Science+Topic&classification=Systematics+and+taxonomy

4. *Any further thoughts the research councils may have on the proposed Research Excellence Framework and its impact on taxonomy in particular (Q70).*

12. None of the three Councils has anything to add to the comments made at the evidence session on 11 March at this stage.

5. *How much of the current consortium grants is taxonomy? (Q75)*

13. The "Creating a Taxonomic e-Science" consortium referred to in the oral evidence falls under the eScience programme and involves total funding of £0.487 million over 3 years (2005–2008) to research groups at the Natural History Museum, the Royal Botanic Gardens Kew and the University of Oxford. Over 60 per cent of this funding was classified by the applicants as systematics and taxonomy.

14. Under the Post Genomics and Proteomics programme there is a consortium investigating "Plant responses to abiotic stress at range margins: mechanisms and limits to adaptation", which is receiving £1.345 million over 4 years, of which 5 per cent is classified by the applicants as systematics and taxonomy—with 40 per cent being classified separately as environmental genomics.

15. A new consortium (4 years from April 2008) will be investigating "Chemosynthetically-driven ecosystems south of the Polar Front: biogeography and ecology". The total value of the award is £2.111 million. One module of the grant (£124,000) includes 30 per cent classified as systematics and taxonomy and 40 per cent classified as population genetics and evolution. Another module (£575,000) includes 30 per cent classified as population genetics and evolution.

16. Another consortium in the marine biodiversity also includes a high proportion of research classified as population genetics and evolution. The ECOMAR (Ecosystem of the Mid-Atlantic-Ridge at the Sub-Polar Front and Charlie Gibbs Fracture Zone) consortium is receiving total funding of £1.662 million over 4 years to 2010, and the applicants classified one quarter of the work as population genetics and evolution.

6. *How many long-term datasets is NERC funding under the national capability funding stream at the moment? (Q86)*

17. The Environment Research Funders' Forum recently completed a strategic review of the long-term environmental monitoring schemes in the UK and created a monitoring database[63]. The database includes 42 ongoing long-term schemes (most older than 20 years) funded by NERC, the majority of them in terrestrial ecology, freshwater ecology or freshwater chemistry.

18. The ERFF database does not yet include the monitoring schemes of the Biological Records Centre (BRC). Its activities and long-term datasets are being transferred in full to Wallingford (card legacy data is likely to be scanned before the move). The BRC is fully sustaining its monitoring schemes, including the Butterfly Monitoring and Harlequin Ladybird schemes, and is sustaining and possibly increasing its contribution to the National Biodiversity Network.

7. *The research councils are focusing on taxonomic/systematics outputs. But who is funding pure taxonomic research? Is it not a problem that universities carrying out this research can't apply for research council grants to do this, since the research councils are focussing on outputs?*

19. AHRC does not consider this a matter for it to comment on, and therefore defers to BBSRC and NERC.

NERC

20. NERC expressed the view in its written submission that it "is not primarily concerned with systematics and taxonomy *per se*, focussing instead on using the information, particularly in the context of how biodiversity contributes to key ecosystem processes and services." We are concerned that this has been interpreted as meaning that we don't fund *any* of the systematics and taxonomy that underpins, for example, the ecosystem process research. It is true that we do not fund alpha taxonomy *in vacuo*. However, we do fund it, and other systematics and taxonomy research, where it is required to address important scientific questions. Our support includes funding for a large number of projects investigating evolutionary relationships between species and the species composition of ecosystems. We are also funding increasing quantities of genomics research with relevance to systematics and taxonomy.

[63] http://www.erff.org.uk/data/

21. Underpinning systematics and taxonomy is commonly embedded in the broader research projects when it is not already available. It is important that applicants consider their taxonomic needs when applying for funding, and incorporate any underpinning research in their application. Although applicants can apply for funding for stand-alone taxonomic research, applications are unlikely to be successful in the face of stiff competition from proposals whose scientific importance is more obvious. Essentially, NERC's funding decisions, based in the case of responsive mode grants on the recommendations of its peer review college, have to take into account the finite resources available, and to prioritise investment where it is most needed to support hypothesis-based science. NERC therefore has some sympathy with the view expressed by BBSRC in the final paragraph below regarding the funding of pure taxonomic research not required for this purpose.

22. One area that could be considered as pure taxonomic research that we do prioritise is research into taxonomic methods, ie research into the new molecular techniques, web-based tools and bioinformatics systems, and we are likely to continue to fund such research in responsive and programme mode. We are also well aware of our responsibility to support training in the taxonomic area, which obviously includes training in pure taxonomy.

BBSRC

23. BBSRC's role is to support high quality basic, strategic and applied research, training and knowledge transfer towards an improved understanding of the non-medical biological systems. BBSRC operates a responsive mode funding mechanism where any proposals within the remit of the Council can be submitted for funding. Very few "pure" taxonomy research proposals (ie proposals to research monographs on specific taxa) are submitted to BBSRC each year and very few of those have been funded. This is because it is impossible to establish their competitiveness relative to other proposals (within or outside taxonomy) unless there is a strategic argument put forward: eg the understanding of the phylogeny will inform the utilisation of the organism in research or industry, it will clarify a particularly important question in evolution or the methodology to be employed is in some way novel and of potentially generic application.

24. Unfortunately most pure taxonomy is not motivated by such factors: the choice is usually driven by the role of the applicant in collecting, curating and understanding a particular group of taxa within a museum, herbarium or other collection. As such, this pure taxonomy is the scholarship integral to the curatorial role and BBSRC believes that support for taxonomic research carried out by staff employed in the museums and gardens should be provided by the parent government departments responsible for their employment.

RCUK

April 2008

Annex

CURRENT NERC PHD STUDENTSHIPS IN THE SYSTEMATICS AND TAXONOMY SCIENCE TOPIC

NERC Reference	*PhD Studentship Project Title*
NER/S/A/2005/13593	A re-evaluation of the carpoids
NER/S/J/2005/13938	Biodiversity, population structure, and ecology of sarcomonad Cercozoa (Protozoa)
NER/S/A/2005/13224	Biogeography and Molecular Evolution of Oleria (Ithomiinae)
NER/S/A/2005/13579	Building and testing a global DNA barcode database of dung beetle assemblages
NE/F009011/1	Comparative morphometrics of evolutionary changes accompanying major ecological shifts
NER/S/C/2006/14274	Corals and Climate Change in the Cenozoic: A Case Study based on the Staghorn Coral Acropa.
NER/S/A/2006/14013	DNA barcoding and phylogenetic information content: studying food webs of woodboring insects
NER/S/A/2006/14217	Ecology of the intertidal crab Dotilla wichmanni from tsunami-impacted beaches in Thailand
NER/S/A/2006/14347	Environmental and Geological Controls on the Diversity and Distribution of Sauropod Dinosaurs'

NERC Reference	*PhD Studentship Project Title*
NE/F012128/1	Evolution of sex and recombination in parasitic protists
NER/S/A/2006/14086	Evolution of snake venom composition: causes, correlates and consequences
NER/S/A/2005/13358	Evolution, gene discovery, and lateral gene transfer in the ecoloigically most important soil Protozoa: Cercozoa.
NER/S/A/2005/13357	Evolutionary Ecology of Avian Malaria.
NER/S/A/2005/13337	Genetical Ecology and Molecular Evolution in the Genus Plantago
NE/F00222X/1	Genetics and Evolution of Echolocation
NER/S/A/2005/13252	Gigantism in palaeozoic arthropods: palaeobiological and phylogenetic perspectives
NER/S/A/2006/14031	Investigating the impact of Late Quaternary environmental changes using ancient DNA from small mammals.
NE/F006489/1	Late Palaeozoic wetland plant communities: palaeoecological, palaeobiogeographic and evolutionary significance
NE/F007655/1	Linking benthic dynamics to pelagic ecosystem functioning in shallow seas
NER/S/A/2006/14303	Metapopulation dynamics in relation to species distribution across a fragmented landscape: "ground-truthing" herbarium-based conservation assessments
NER/S/J/2005/13506	Molecular approaches for studying microbial biodiversity in the deep Indian Ocean
NER/S/A/2005/13423	Molecular evolution and adaptation in pitvipers
NE/F008600/1	Origins and evolution of invasive weeds
NER/S/A/2006/14052	Palaeobiology of Silurian trilobites from North Greenland.
NER/S/C/2006/14277	Phylogeography of the European Schizoporellidae: a combined morphological, molecular and palaeontological approach in a family of fouling bryozoans
NER/S/C/2005/13461	Population genetics and mating systems of the Long Snouted Seahorse (Hippocampus guttulatus) and Short Snouted Seahorse (hippocampus hippocampus)
NER/S/J/2006/14365	Post-glacial expansion and loss of self-incompatibility in Arabidopsis lyrata
NE/F012098/1	Speciation in plants on an oceanic island.
NER/S/A/2006/14173	Systematics and functional morphology of fossil and extant Hyracoidea (Mammalia)
NER/S/A/2005/13488	Taxonomy, Systematics and Evolution of the British Theropod Dinosaur Megalosaurus
NER/S/C/2006/14279	The Evolution and Palaeoecology of the Woolly Rhinoceros (Coelodonta antiquitatis)
NE/F006802/1	The Evolution of Echolocation in Bats
NER/S/A/2005/13931	The ecology and conservation of island red-backed voles with particular reference to the Skomer vole
NE/F008147/1	The evolution of animal signalling systems in relation to variation in life history
NER/S/A/2006/14213	The evolutionary history and phylogeny of (Southern Ocean) King Crab
NE/F008198/1	The importance of local arthropod diversity in oil palm plantations.
NER/S/A/2005/13222	The influence of population history, geography, and historical climate change on forest-based diversity in Southern Asia with particular reference to Northwest Indochina
NE/F009534/1	The presence, distribution and utilisation of novel phosphonate metabolising enzymes in the marine environment
NER/S/A/2005/13317	The role of photoacclimation upon distribution of hermatypic coral species
NE/F002289/1	Tomographic investigation of exceptionally preserved arthropod fossils from France.

Supplementary memorandum submitted by DCMS

QUESTIONS:

1. How much does the Department spend on taxonomy and why does it consider this to be right amount? This would include information on how much money from the Renaissance in the Regions programme is allocated to taxonomy. (follow-up from Q123)

2. *What are the Department's principal performance measures and how are the science elements of these measures compiled and compared in order to inform funding assessments? (follow-up from Q124)*

DCMS RESPONSE:

1. We are not able to identify a single sum that is devoted to taxonomy. Rather, we provide ongoing grant in aid support for a number of institutions that include taxonomy among their responsibilities, not least the Natural History Museum. It is up to those institutions to identify which elements of their grant in aid are dedicated towards specific taxonomical purposes.

2. I attach a list of the performance indicators in the current funding agreements. These do not relate explicitly to scientific endeavour. However, they provide a "balanced scorecard" of measures against which the performance of individual museums can be assessed. In addition to this, we take note of the record of achievement set out in annual reports and other corporate documents.

Performance indicators: overall totals for 18 DCMS sponsored museums & galleries for 2006–07

Performance Indicator	*2006–07*
Visit numbers	
Total number of visits to the Museum (excluding virtual visits)	39,059,875
Number of adult visits	29,271,856
Number of children aged 15 and under visiting the Museum	8,388,795
Number of over 60s visits	5,472,651
Number of overseas visits	14,256,408
Number of repeat visits	19,694,464
Percentage of UK visitors aged 16 and over from an ethnic minority	9
Number of adults aged 16 and over from lower socio-economic groups attending the Museum (NS-SEC groups 5-8)	4,271,820
Percentage of visitors who thought the museum overall was good/very good	91
Educational Programmes	
Number of learners in onsite educational programmes	3,491,878
Number of learners in educational outreach programmes	5,513,879
Nos of children in on & off site organised educational sessions	2,914,154
Website visits	
No. of unique website visits	109,431,494
Loan venues	
All venues to which objects from the collection are loaned	304
UK venues to which objects from the collection are loaned	875
Overseas venues to which objects from the collection are loaned	637
New in 2003/04: No. of venues in England to which objects from the collection are loaned	1,322
Collection care	
Percentage of collection stored in correct environmental conditions (average)	78
Access to collections	
Percentage of time open (average)	48

Performance Indicator	*2006–07*
Income	
Grant-in-aid per visit	£7.97
Revenue generated from sponsorship and donations per visitor (average)	£2.76
Non grant income per visitor (average)	£5.84
Net income from trading (including corporate hire)	£55,691,789
Efficiency	
Efficiency savings	£8,053,000
Sick Absence	
Average days lost sick per employee excluding long term sickness (average)	4.7

28 March 2008

Supplementary memorandum submitted by Defra

4. *UK BRAG also submits that there is little recognition for systematics in EU Framework Programmes. RBG Kew submits that EU funding is mostly focussed on networking and not on delivering projects. If systematics could be more successful as large-scale science, is more delivery-focussed and capacity-directed funding an issue that the Government should be taking up at EU level?*

4.1 We consider the current EU Framework Programme for Research & Technological Development (FP7) to be an improvement on the previous FP6 now that the environment has its own dedicated theme (which includes biodiversity as a priority activity), and agriculture and fisheries research have both been re-introduced into a major theme. The funding available for research is also expected to increase by approximately 40 per cent from 2010. As a member of the programme committees for both the "Environment" and the "Food, Agriculture and Fisheries, and Biotechnology" themes Defra plays an active role, alongside the science community, industry and other stakeholders, in the development of the annual work programmes, aiming for the inclusion of UK priorities.

4.2 In its written evidence RBG Kew stated (para 5.2.2) that most funding for [international] collaboration, at least at European level, is focused on networking rather than research. In fact, the bulk of funding in the Framework Programme is allocated to collaborative research in the European Research Area and wider. The Food, Agriculture and Fisheries, and Biotechnology theme and the Environment theme each have approximately €2 billion of funding across 2007-13 for collaborative research.

4.3 Having said that, support for networking is vital and the EU is funding projects such as the Network of Excellence, EDIT (European Distributed Institute of Taxonomy), that (over five years from 2006) is aiming to reduce fragmentation in European taxonomic research and expertise and to coordinate the European contribution to the global taxonomic effort. Another EU funded project, SYNTHESIS (Synthesis of systematic resources), aims to create an integrated European infrastructure for researchers in the natural science through the collaboration of 20 European natural history museums and botanic gardens, and is led by the Natural History Museum in London.

4.4 The establishment of effective networks should put the research community in a better position in the face of a very high level of competition for funding under FP7, both in terms of influencing the European Commission during the development of work programmes, in establishing the priorities to be addressed, and in forming the relationships necessary to build effective consortia that include organisations from across Europe (and wider).

4.5 BRAG is correct about the place of systematics in the FP insofar as the Framework Programmes focus not on disciplines, but on the need to address major challenges and to support the development and implementation of policy, including the objectives of international treaties. In reality there are more opportunities than might be immediately apparent for research engaging the disciplines of systematics and taxonomy. Recent examples include the UK (CSL) as a lead partner in a consortium bidding for FP7 funding for a project on DNA bar-coding of statutory plant health pests & diseases. UK partners are also involved in an Austrian-led proposal, under the FP7 Capacities Programme, to support taxonomic skills in the EU.

4.6 Phytosanitory research includes an important element related to the identification of plant pests and diseases. Defra has been successful in winning Framework Programme funding to lead an European Research Area Network (ERA-NET) to coordinate the national phytosanitary research programmes of 24 organisations across 17 European countries. By coordinating the research activities of the funding organisations, and developing common research agenda, we should be able to get better value from the research funding available. The UK is also active in a number of other EU networks such as the Mycology and whitefly networks.

6. *The most important environmental issues, such as assessing the impact of climate change on ecosystem services, are global in scale. How can the global requirements for leadership in the provision of taxonomic training and research outputs be factored into consideration of national capability?*

6.1 Governments, through the Convention on Biological Diversity, have acknowledged the existence of a "taxonomic impediment" to the sound management of biodiversity, and have developed the Global Taxonomic Initiative to remove or reduce the impediment.

6.2 The Global Taxonomic Initiative (GTI) was created to remove or reduce the "taxonomic impediment". The GTI has been established by the Conference of the Parties (COP) to address the lack of taxonomic information and expertise available in many parts of the world, and thereby to improve decision-making in conservation, sustainable use and equitable sharing of the benefits derived from genetic resources. This is the first time in history that taxonomy has had recognition at such a high level in international policy.

6.3 As part of its responsibility for implementing the GTI, the UK carried out a taxonomic needs assessment between 2004 and 2006. The scope of the needs assessment was broadened beyond strictly taxonomic needs to include wider needs that had a taxonomic component, such as for surveillance and improved access to distributional data. Many of these needs are being met through existing initiatives such as the National Biodiversity Network, the UK Biodiversity Research Advisory Group (BRAG) strategy for non-native species research, and the surveillance and reporting strategy being developed by JNCC. We do, however, recognise the need for more follow up work on the strictly taxonomic priorities.

6.4 At the UK level, we have contributed to the GTI through.

- national funding for the National Biodiversity Network.
- 50 funded projects, which include taxonomy as a main focus under the Darwin Initiative.
- funding under the WSSD Implementation Fund for a project "Biodiversity needs assessment in Ghana", which aimed to enable Ghanaian biodiversity bodies, funders and taxonomists to target and prioritise taxonomic work and remove the taxonomic impediment to meeting WSSD targets and CBD implementation.
- membership of and funding for GBIF, which constitutes an essential step forward in global systematics (naming and classifying species; and organising information) in related biodiversity and ecological research, and in applied uses including decision making for biodiversity conservation.
- support to both NHM (under the Darwin Initiative) and RBG Kew (under core funding) provide input into the Encyclopedia of Life which aims to provide an online database for all 1.8 million species known to live on Earth
- funding to various projects (some taxonomic) to UNEP WCMC who provide syntheses, analyses and dissemination of global biodiversity knowledge, providing authoritative, strategic and timely information for conventions, countries, organisations and companies to use in the development and implementation of their policies and decisions.

Question 8. *The UK has a broad range of obligations and commitments under various EU directives and UN Conventions. These responsibilities extend to British Overseas Territories many of which have high biodiversity. Is our taxonomic capability strong enough to enable the UK to deliver on its EU and UN commitments? Whose responsibility is it to maintain national capability in taxonomy?*

8.1 The UK Taxonomic Needs Assessment assessed needs in relation to implementation of the CBD and EU Nature Directives in the UK, and its Overseas Territories. It found that availability of information was not sufficient in a number of areas, in particular, in relation to habitat requirements and species distributions. Within the UK, Defra and its delivery agencies have sought to improve capability in these areas through investment in, for example, the National Biodiversity Network.

8.2 Defra has also provided funding through:

- The Darwin Initiative, which focuses on capacity building, to achieve real impact and legacy for biodiversity conservation, it allows for the funding of experts from UK to assist developing countries (including the British Overseas Territories) in implementing their biodiversity commitments. Through the Darwin Initiative, we have supported at least 50 global projects which include taxonomy is a main focus—either developing or using taxonomic knowledge.
- The International Sustainable Development Fund (previously WIF) which has provided the Natural History Museum with funding for the project "A biodiversity taxonomic needs assessment in Ghana" which provided training to enable Ghanaian biodiversity bodies, funders and taxonomists to address the taxonomic impediment to meeting WSSD targets and CBD implementation.
- Grant in Aid to RBG Kew
- Project awards (some taxonomic) to UNEP WCMC who provide syntheses, analyses and dissemination of global biodiversity knowledge, providing authoritative, strategic and timely information for conventions, countries, organisations and companies to use in the development and implementation of their policies and decisions
- MarLIN (the Marine Life Information Network)

Funding under the Overseas Territories Environment Programme (OTEP) assists the Overseas Territories to deliver their Environment Charter commitments. Funding for OTEP comes from DFID and FCO who each allocated £1.5 million for the OTEP for the period 2003/4—2006/7; FCO has approved a further £469,000 per annum for OTEP for 07/08.

20 March 2008

TUESDAY 25 MARCH 2008

Present	Colwyn, L	Northesk, E
	Haskel, L	Selborne, E
	May of Oxford, L	Sutherland of Houndwood, L (Chairman)
	Methuen, L	Walmsley, B

Memorandum by the Botanical Society of the British Isles

The Botanical Society of the British Isles (BSBI) has about 3000 members and combines of a body of professional scientific expertise with an active and committed corpus of skilled amateurs. It promotes the study of the British and Irish flora by supporting and conducting research into taxonomy, biogeography, ecology and conservation.

THE STATE OF SYSTEMATICS AND TAXONOMY RESEARCH

— Taxonomy: the science and practice of classification, including identification & nomenclature.

— Systematics: scientific study of the diversity of organisms & of their relationships—a wider definition.

1a) *What is the state of systematics research and taxonomy in the UK?*

Confined largely to major botanic gardens and museums; almost extinct in universities, remaining in a few places only, eg Oxford, Cambridge, Imperial College, Edinburgh, Reading and Leicester. Even in these places, in order to attract funding, the discipline is often represented by particular offshoots, eg conservation genetics, population biology, cytogenetics & genome organisation, rather than by taxonomy or systematics themselves.

1b) *What are the current research priorities?*

At present it is difficult to identify a nationally agreed set of priorities, instead each institution or organisation follows its own agenda (some notable collaborations notwithstanding).

In Britain we need research into the numerous taxonomically difficult groups, many of which are of conservation or ecological importance, and which have long posed problems but for which there are now approaches that would lead to a significantly improved understanding.
Globally, we need:

— a species inventory, which means writing a) monographs, b) Floras of regions that are under-explored, and c) identification keys.

— an understanding of species diversity and evolutionary relationships, especially but not exclusively in the context of environmental concerns and social needs, such as climate change, medicine, food and industrial applications. Although making significant advances, there are major gaps in building a natural relationship of all life on earth, extending to "non-life" including viruses, prions and other infective particles. There is weak understanding of the nature and consequences of hybrids and horizontal character transfer in most groups, and analytical techniques are inadequate.

— a better understanding of characters—what and how can characters be measured, what is primitive, what is advanced or derived, what and how are they controlled by genes?

1c) *What are the barriers, if any, to delivering these priorities?*

There is a widespread view that the solution of taxonomic problems entails little in the way of original ideas or novel research, merely the application of trusted methods that have already been developed. Much taxonomic research is thus seen as derivative rather than innovative, and consequently unworthy, even ineligible, for funding.

Firstly, this is a specious perception and one only has to look at the enormous advances, made almost exclusively in major national institutions in Britain and in universities *outside Britain*, in our understanding of phylogeny at all levels (reflected in recent taxonomies) to see that taxonomic research can be innovative. See

also Q6. Secondly, it has meant that the writing of monographs and Floras, although relatively inexpensive, is scarcely carried out outside the major nationally funded institutions. The very products that are so sorely needed are deliberately left unfunded in universities because the methodology is regarded as derivative. The absence of this work from universities owes much to the vicissitudes of the Research Assessment Exercise which penalises those taxonomists whose interests and skills lie in this area: first class taxonomic products in the form of monographs, Floras and identification keys, receive scant recognition because they are not produced on the backs of big grants. One consequence of this is that taxonomists move out of this area into a much broader area of biodiversity research in the hope of attracting funding. Another consequence is that young taxonomists are now hardly ever recruited into university departments.

2a) *What is the role of systematics and taxonomy and, in particular, in what way do they contribute to research areas such as biodiversity conservation, ecosystem services and climate change?*

The role of taxonomy and systematics is to understand and catalogue the nature, diversity and relationships of life on earth. Today this requires rigorous scientific measurements exploiting curated archival and new collections, underpinned by comprehensive databases feeding the requirements of users. Methods inherent in making the measurements range over the widest possible range from satellite sensing at the ecosystem, continental and ocean scale, to nano-measurement using molecular biology and electron microscopes. The people, or increasingly research groups, providing these data require extensive and broad skills of techniques and interpretation, starting with a foundation of formal training but invariably honed by experience going well beyond a "job specification", requiring recognition and support of their work of decades. Users of taxonomy and systematics information and expertise range up to the highest intergovernmental levels—for example, What is this disease? What is being traded? What is dying?—where the consequences of having an inadequate or wrong taxonomy can have globally or regionally catastrophic consequences. For every individual biologist, whether studying disease, physiology, genomics or the areas above (biodiversity, conservation, ecosystem services, climate change), a framework of taxonomy and systematics is vital. Biodiversity conservation is underpinned by knowledge of genetic variation patterns at a range of levels from phylum to individual and gene, ie taxonomy & systematics. Ecosystem services use species as their currency—taxonomy & systematics. Climate change will impact on both extinction and speciation rates, as well as on geographical distribution patterns. None of these can be properly understood or even researched unless an adequate taxonomy is in place. In many of the above areas, the UK has international treaty obligations, fulfilment of which necessarily depends on a sound taxonomy.

2b) *How important is this contribution and how is it recognised in the funding process?*

n/a

2c) *How is systematics integrated in other areas of research?*

See (2a).

3a) *Does the way in which systematics research is organised and co-ordinated best meet the needs of the user community?*

Systematics research is not coordinated on a national level. The needs of the user community are usually discussed between the directly interested parties. In other words it is usually all done largely on an ad hoc basis.

3b) *What progress has been made in setting up a body to lead on this?*

There are important learned societies such as the Systematics Association and the Linnean Society, but they are constrained by insufficient funds. They have nothing like what is required either to set an agenda or stimulate concerted research. In this respect the government needs to take a lead role (see also Q4b).

3c) *What contribution do the leading systematic research institutions make both nationally and internationally?*

The leading systematic research institutions are largely the national botanic gardens and museums. They have a world-class track record at research following their own particular agendas, but they do not take on a leadership role in the national, ie British, context, in terms of setting research priorities, facilitating training, etc.

4a) *What level of funding would be needed to meet the need for taxonomic information now and in the future?*

This question can only be answered properly following consultation with all the interested parties. Current funding opportunities are widely scattered over a variety of organisations and it is not possible to deduce how much money actually is given to projects that have an emphasis on taxonomy or systematics. In my experience, however, very little is actually awarded to taxonomic projects in the strict sense, ie monographs, revisions and Floras/Faunas, and yet these remain some of the most valuable and useful products, with a very long shelf-life.

4b) *Who should be providing this funding?*

What is needed is a Systematics Research Council, funded primarily by government, but also contributed to by the major learned societies and other smaller bodies. Current sources are very diverse and most individually do not add up to much: there is a need for greater synergy to achieve critical mass. Given an appropriate budget, such a Council could effectively set the agenda and galvanise taxonomic and systematic research in this country.

5a) *How does funding in other countries compare?*

n/a

5b) *Could there be more international collaboration? If so, what form should this collaboration take and how might it be achieved?*

International research collaborations are fairly commonplace, with most practising taxonomists and systematists having at least one overseas partner in some project or another. Further development of such arrangements are best left to individuals or institutions, unless any national taxonomic agenda that might emerge suggests otherwise.

Where there could be more international collaboration is in the area of supervision of overseas PhD placements, funded by the foreign government; the intention here would be to help foster research skills in the foreign country. At the moment there is no co-ordinated approach to this, with each institution following its own policy.

6) *What impact have developments in DNA sequencing, genomics and other new technologies had on systematics research? In what way has systematics embraced new technologies and how can these research areas interact successfully and efficiently?*

Molecular biology has now become almost routine in many areas of systematics research, whether it be for phylogeny reconstruction, analysis of genetic variation on a population level, or in the context of evolution & development (evodevo) studies. It has also revolutionised certain aspects of species identification, eg mycorhhiza species. In the last context the prospect of portable DNA analysers allowing species identification in the field is on the horizon. It is doubtful, however, that morphologically-based identification will be superseded in any major way (except in special cases): taxonomists and their identification skills and products will continue to be needed.

Data collection, management, maintenance and dissemination

7a) *Does the way in which taxonomic data is collected, managed and maintained best meet the needs of the user community?*

The botanical user community is well served by a variety of databases, probably the most useful of which are the web-based index of published plant names (IPNI), and list of scientific publications (Kew Record). There are many other important databases that contain a variety of information, usually prepared by individual researchers and to be found on their institution websites; some learned societies also make it their job to disseminate taxonomic information eg the Botanical Society of the British Isles database. Several Floras are also available as CD versions. But effort is largely ad hoc and reliant on individual initiative.

Raw, specimen-based observations and measurements, however, are not usually generally available. The taxonomic/systematic community itself would benefit enormously from having compatible databases containing original observations freely available.

7b) *What is the state of local and national recording schemes?*

Local and national recording schemes are almost entirely the province of the amateur enthusiast, who is frequently as, or better, skilled at identification than many a professional. These amateurs are typically members of a learned society that coordinates their activities. The taxonomic scope of their work is uneven, with many groups being covered quite well, eg land plants, but others, eg some invertebrate groups, not covered at all. Major surveys of vital importance in the field of environmental monitoring have been produced by cohorts of volunteers—thousands of man-hours work, effectively free of charge, eg the *New Atlas of the British and Irish flora*, a recently published project of the Botanical Society of the British Isles. Biological records produced by these specialist societies are posted on the National Biodiversity Network (NBN) website for all to see. It is grossly unfair that funding rarely devolves to these highly productive societies (birds are one exception), despite the fact that they are the ones who generate and interpret the vast bulk of the data.

The role of the NERC-funded Biological Records Centre is important in helping with computerised data handling, although societies are becoming increasingly sophisticated in what they can achieve by themselves with their own networks of digitised databases.

8a) *What is the role of the major regional museums and collections?*

Major regional museums and collections are an essential archive providing essential reference material (specimens) for biological records. Preserved specimens are a vital historical record of our biological past. As such they contribute to an important base line for studies designed to monitor the effects of climate change. In a botanical context, many smaller herbaria lie packed away in boxes, scarcely to be seen and largely undocumented (see Q8b). These are especially vulnerable: fortunately the larger museums often provide a safe home for these smaller collections that might otherwise be thrown away. For example, of the 602 herbaria present in Britain after 1945, 97 have been destroyed or cannot be traced, 230 have been transferred to existing institutions, the whereabouts of 106 are currently unknown, leaving 169 extant (unpublished, not yet completed BSBI survey, 2007/8).

8b) *How are taxonomic collections curated and funded?*

In Universities, curators typically are appointed primarily as lecturers and researchers, with an expectation that curatorial duties can somehow be fitted in. In museums, outside the major national and regional centres, the picture is patchy. Owing to the exigencies of local authority funding, many collections are often not curated at all and lie packed away in boxes,.

9a) *What progress has been made in developing a web-based taxonomy?*

Far more could be accomplished here. Initiatives such as DELTA and LUCID, developed in Australia, are important.

9b) *How do such initiatives fit in with meeting demand for systematics and taxonomy information?*

Demand for detailed taxonomc information is usually met by direct contact with the researcher concerned. The Botanical Society of the British Isles also strives to make as much data as possible available freely on its website. See also Q7a.

9c) *How do UK-led initiatives fit in with international initiatives and is there sufficient collaboration?*

n/a

10) *What needs to be done to ensure that web-based taxonomy information is of high quality, reliable and user-friendly?*

This is surely a question for resolution by the taxonomic community and its user-groups, rather than a matter of policy. We would all agree with the goal.

11a) *How does the taxonomic community engage with the non-taxonomic community?*

Organisations like the Botanical Society of the British Isles provide a focus for the products of taxonomic work. The members are avid consumers of Floras, field guides and identification keys. Such natural history society members have the necessary field experience to provide useful feedback to taxonomists regarding the utility of these products, although there is no formal mechanism by which this is achieved. Government organisations like Defra also use taxonomic products such as species checklists in order to plan their environmental strategy, but they are not commissioned.

11b) *What role do field studies play?*

Field studies provide the context in which the Floras, field guides and identification keys can be tested. They also provide a valuable opportunity for the research worker to see organisms living and growing in the wild, rather than simply as dead museum specimens or bits of DNA in a tube.

Skills base

12) *What are the numbers and ages of trained taxonomists working in UK universities and other organisations?*

The remaining taxonomists in universities are largely over 50 years old, but I know of no recent statistics. In the major national botanic gardens and museums the situation is different: there appears to be a steady flow of young talent coming through, but chiefly on soft money; permanent posts are still in short supply. A survey of taxonomic expertise and needs in Britain would be worth doing, simply to bring us up to date with what is actually happening in the community. A programme of surveys repeated at appropriate intervals would be even better –perhaps a web-based form allowing self-registration is all that is needed?

13a) *What is the state of training and education in systematics and taxonomy?*

Virtually none in either schools or at undergraduate level. Where it exists, it is largely restricted to isolated modules. There is, however, some provision at post-graduate level: there are M.Sc. courses in taxonomy at RBG Edinburgh/University of Edinburgh (plants & fungi), Imperial College/NHM (biology), and University of Reading (plants & fungi). There are also several other post-graduate courses that involve taxonomy in some indirect way but not as a primary focus. The decline in systematics training at undergraduate level is an extreme example of the decline seen generally in whole-organism biology. Universities nowadays react to market forces and the decline reflects in part a lack of interest by school students. This in turn is a consequence of the curriculum they have to study: botany at secondary school, for example, is typically restricted to the biochemistry of photosynthesis, which must be among the biggest of turn-offs ever for the adolescents of today; no wonder there are only seven botany degrees offered in Britain. More imaginative teaching of whole-organism biology at school would help matters.

13b) *Are there any gaps in capacity? 13c) Is the number of taxonomists in post, and those that are being trained, sufficient to meet current and future needs across all taxonomic subject areas?*

Species identification skills and other field skills are scarcely taught at undergraduate level in universities. This has major consequences for conservation organisations and ecological consultants who find it almost impossible to hire adequately trained staff, either now or in the foreseeable future. Research posts in taxonomy, however, are few: production of systematics research-oriented graduates needs to be balanced against the likely number of available jobs.

1 February 2008

Memorandum submitted by the Linnean Society of London

The Linnean Society welcomes the opportunity to assist the Select Committee on Science and Technology, with evidence on the state of taxonomy and systematics in the United Kingdom, from our perspective as one of the oldest learned societies dedicated to the study of natural history, of which taxonomy and systematics form an important part. The Society, because of its broad Fellowship, is able to take a broad view of the issues, and is not tied to any institution with its own particular agenda. We benefit from a world-wide Fellowship, and can relate to issues that extend beyond the UK, but which have a bearing on what we can deliver.

Despite two inquiries into the state of these areas of research endeavour, little has changed in the overall UK research environment, with a continued decline being seen in the subject in universities and no substantive increase in support for our world-class taxonomic institutions. Some notable exceptions of course exist, and we will highlight these in our evidence.

Data to answer questions posed by the Committee are hard to come by, although we are ever mindful of the underlying issues that affect the state of systematics and taxonomy in the United Kingdom and abroad. Nonetheless, we have attempted to gather together best-available information to support our statements, whilst in other areas we provide only anecdotal evidence gleaned from the perspective of our Fellowship which represents a broad cross-section of the natural history community, both professional and amateur. From our perspective, the following clear points emerge:

— The basic descriptive taxonomy upon which both identification and phylogeny depend has suffered comparably more than other sectors of taxonomic science.

— Integration of taxonomy into other biological projects is critical for taking a truly comparative view of our changing world.

— Significant new funding should be directed to taxonomy, in order that the UK scientific community can benefit from and be at the forefront of the exciting new opportunities and responsibilities for taxonomic science. Reallocation of existing resources will not be adequate for this expansion.

The state of taxonomy and systematics research

1. *What is the state of systematics research and taxonomy in the UK? What are the current research priorities? What are the barriers, if any, to delivering these priorities?*

1.1 Systematics and taxonomy can usefully be divided into three overlapping major tasks: identification (working out what an organism is), description (working out the limits of species, genera and higher groups) and phylogeny (working out how organisms are evolutionarily related). Each of these areas of research has a different dynamic, and each is at a different state in terms of support and health.

1.2 Our Fellows have indicated that they consider descriptive taxonomy to be the most "at-risk" sector of the research endeavour, not only in terms of ability to describe new species and document the biodiversity of ecosystems, but in order to refine, better understand and even diagnose the species we already know. These descriptive data provide the baseline for understanding, and are not really an end in themselves. Natural history, the science to which our Society is dedicated, encompasses both the naming and documenting of nature, and also to the understanding of its role in ecosystems.

1.3 In our evidence to the 2002 inquiry, we suggested a number of projects spanning the activities of taxonomy (phylogeny, description and identification). We will not reiterate these here, but instead suggest that one clear research priority in descriptive taxonomy is the provision of working lists of species, such as that mandated by Target 1 of the *Global Strategy for Plant Conservation*: "a working list of all known plant species, as a step towards a world flora." Such lists are feasible in some taxonomic groups, such as plants or Lepidoptera, but currently unrealistic in groups such as nematodes or bacteria.

1.4 The single biggest barrier to delivering research priorities in taxonomy and systematics is the static (if not declining) population of scientists with expertise in the taxonomy and biology of organisms. The staff complements at many of our major museums and herbaria remain constant, while others (particularly the smaller nationally-funded museums such as National Museums Liverpool, who have large systematics collections) have seen a significant decline. While these numbers are reinforced by grant-funded staff, the numbers of tasks and types of research done by core staff are expanding greatly.

1.5 The Society greatly appreciates the honorary curators of our own collections, all of whom come from the Natural History Museum. The Museum's collegial spirit in allowing their staff to assist us with the care of the important historical collections we hold, is one of many ways in which these institutions collaborate to improve the state of taxonomy in the UK. But even in the Natural History Museum, the UK's largest taxonomic institution, the percentage of staff involved in descriptive taxonomy is declining, although staff numbers have remained relatively constant (5.5 per cent decrease). This is not to say that the Museum is not setting the correct priorities for research (that is, after all their prerogative and responsibility), but that the increasing scope of the research environment in taxonomy means that even in our largest institution devoted to taxonomy and systematics, the core descriptive part of the science is declining, just as society perhaps needs it most.

Department	*Core funded staff*		*Percent of core staff undertaking descriptive taxonomy as some part of their job*	
	1992–93	*2006–07*	*1992–93*	*2006–07*
Botany	50 (30)	49 (20)	60%	41%
Entomology	73 (39)	67 (33)	53%	49%
Zoology	77 (28)	73 (18)	36%	24%
All Life Sciences	**200 (97)**	**189 (71)**	**50%**	**38%**

1.6 The Linnean Society contributes to the user community through its three peer-reviewed journals: Biological (BiolJLS), Botanical (BotJLS) and Zoological (ZooJLS) Journals of the Linnean Society, each of which is published 12 times a year and is distributed to more than 60 countries. Through its network of reviewers and editors, the Society makes a major contribution to the publication of original research on taxonomy and systematics. We consider the decline in the percentage of UK-based authors in our journals (see below) to be reflective of the decline in taxonomy in the UK; this is most marked in our journals that concentrate on descriptive taxonomy.

Journal	*Authors 2001*	*per cent UK authors 2001*	*Authors 2007*	*per cent UK authors 2007*
BiolJLS	135	14%	225	14%
BotJLS	117	14%	196	9%
ZooJLS	58	29%	101	17%
Total	**310**	**17%**	**552**	**12%**

Data courtesy of Wiley-Blackwell

2. *What is the role of systematics and taxonomy and, in particular, in what way do they contribute to research areas such as biodiversity conservation, ecosystem services and climate change? How important is this contribution and how is it recognised in the funding process? How is systematics integrated in other areas of research?*

2.1 Descriptive taxonomy provides the ability to discern the units of biodiversity—species delimitation is essentially a hypothesis about the distribution of variation in nature, plus providing a name with which to communicate information about those hypotheses. Large vertebrates are today largely described at the species level, while insects, nematodes and many other invertebrate phyla are largely undescribed. This means that the level at which diversity is described will differ between taxonomic groups. The units and types of data needed for predicting and documenting the effects of environmental change will also differ between taxonomic groups. New technologies will help with this task, but sufficient capacity across the taxonomic spectrum will need to be maintained in order to interpret the data.

2.2 Repeatable identification allows monitoring through space and time, possibly the most important tool for assessing the effects of environmental change on the Earth's biodiversity. Diagnostics of many kinds, from molecular to image-related, will be needed in order to best monitor biodiversity in the face of such change. More identification guides and tools—from field guides to more technology-based tools—will need to be produced in order to shift the burden of identification from a diminishing taxonomic community to society at large. Citizen participation in monitoring, is critical to achieving the volume of data needed for predictability; taxonomists with expertise in particular groups will be needed to train this new generation of citizen scientists. Similar training needs to be extended to scientists and parascientists throughout the developing world as their impressive biodiversity particularly needs study in order to address issues associated with biodiversity loss, invasive species, sustainable development and environmental monitoring.

2.3 The collections held in taxonomic institutions also provide key data for predicting and monitoring change. Range changes in insects and plants have been both shown and modelled using data derived from museum collections; this baseline data needs to be synthesized and made publicly available in usable ways, which will entail additional resources for museums and other collections. Making these data available is a support task for taxonomy as well as for environmental change monitoring, but is intimately linked with the use of these same collections by taxonomists, who give them added value.

2.4 Taxonomy, like all science, is an on-going task and estimates of the number of people needed over a finite time for open-ended tasks are invariably unrealistic. What is necessary for taxonomy to contribute effectively to a response to environmental challenges such as climate change and biodiversity loss, is recognition of its role and provision of funding for taxonomists in the context of larger, interdisciplinary projects.

2.5 Integration of phylogeny into other areas of biological research has become the standard, but the recognition of the importance of descriptive taxonomy and/or identification is lagging behind. Molecular and morphological phylogenetics remains founded on descriptive taxonomy and the need for accurate identification and the deposition of voucher specimens remains central to the discipline. Disturbingly, many researchers employing phylogenetics tend to use the scientific names of their organisms with little thought as to how that species might be circumscribed, or identify species in a study without citing the identification guide used to undertake those identifications.

3. *Does the way in which systematics research is organised and co-ordinated best meet the needs of the user community? What progress has been made in setting up a body to lead on this? What contribution do the leading systematics research institutions make both nationally and internationally?*

3.1 We have seen no progress at all on setting up a coordination body for systematics research, but we see little point in having such a body if there are not substantial funds available with which to help direct research through competitive funding. Coordination best done through dialogue and interaction, as is happening in the EU-funded EDIT project (see below) through the collaborative working of European taxonomists. *Ad hoc* groups looking at the future of a subject that contain both practicing scientists and institutional managers would, in our view and given the current funding structure, be a more effective way of coordinating and organising research priorities in a flexible and proactive way than the establishment of a top-down, centralised coordinating body with no funds to disburse. Importantly, although biodiversity, molecular evolution and phylogenetics are said to be integral to UK Research Council strategies (notably NERC and BBSRC) none of these grant awarding bodies have taken a substantial lead in releasing significant funds dedicated to systematics or taxonomy.

3.2 The UK is fortunate in having major taxonomic institutions that have a global perspective, have world class collections and research and are internationally recognised as centres of excellence. Staff in these institutions undertake research in all aspects of taxonomic science. As stated earlier, all our honorary curators are drawn from NHM staff, and our Council regularly has members from all three of the major UK systematics institutions (RBGKew, NHM, RBGEdinburgh), universities and other institutes (eg, Royal Horticultural Society) with taxonomic expertise.

4. *What level of funding would be needed to meet the need for taxonomic information now and in the future? Who should be providing this funding?*

4.1 Need for information on names and distributions of organisms is met by descriptive taxonomists, and will continue to be met by future generations of descriptive taxonomists. Because new collections need to be assessed against current identification and classification schemes, taxonomy, like any science, is an on-going endeavour. In order for taxonomy to remain responsive to expanding user needs and the institutions providing information to provide it in increasingly diverse ways, the UK systematics institutions need stable funding.

4.2 The Linnean Society, with the Systematics Association, operates a competitive grants scheme for work in taxonomy (in the broadest sense). These grants, though small, are extremely competitive (see table below). The Systematics Research Fund (SRF: with £20,000 from the Linnean Society, £6,000 from the Systematics Association, £5,000 from the Bentham-Moxon Trust and £5,000 from NERC) funds small projects, the average request in 2007–08 was £1,026. Applicants to the SRF for the current round were from 33 countries (USA, 36 applications, UK 35 applications), up from 22 countries in the previous year. The BBSRC Collaborative Scheme for Systematics Research (Co-Syst—also managed by the Linnean Society and Systematics Association) is a three-year programme (£75,000/year, £225,000 total), to fund collaborative research between systematists and non-systematists that is judged will lead to full Research Council proposals in due course. In the last round, the Linnean Society contributed an additional £9,993 to the fund, in order that six full projects could be funded. The scheme does not allow institutions to claim overheads, and although we appreciate the scheme's aims in general, we would like to point out that the total sum over three years is less than the average single 3-year BBSRC responsive mode grant (£245,000 in 2006; see BBSRC 2006 report at http://www.bbsrc.ac.uk/organisation/structures/council/2006/0610_hei.pdf).

2006–07	*SRF*	*Co-Syst*
Number of applications received	98	48
Applications funded	37	6
Success rate	37%	12.5%
Funds disbursed	£36,000 (see above)	£84,993 (see above)

5. *How does funding in other countries compare? Could there be more international collaboration? If so, what form should this collaboration take and how might it be achieved?*

5.1 If we consider that the funding the Society and its partners provides constitutes the only real source of dedicated grant funding for primarily taxonomic projects in the UK, the competitive grant funding for taxonomy *per se* amounts to less than £200,000 per year. In contrast, in the United States, the National Science Foundation through its Division of Environmental Biology programmes dedicated to taxonomy (eg, Biotic Surveys and Inventories cluster (including the Planetary Biodiversity Inventory [PBI] and Partnerships in Enhancing Expertise in Taxonomy [PEET]; REVSYS [supporting revisionary taxonomy] etc.) provides more than $12 million per year to the taxonomic community (not including the $14 million of new money dedicated to the Assembling the Tree of Life project [AtoL] all data provided by NSF). In Australia, the ABRS (Australian Biological Resources Study) currently provides some Aus$ 1.5 million per year for taxonomic research, in addition to the funding of infrastructure in systematics institutions such as herbaria and museums (http://www.dest.gov.au/NR/rdonlyres/031861A1-5FA2-45A0-8037-F7244657C680/2853/ABRS.doc). The Swedish government has made a significant long-term investment in the documentation and publication of the Swedish flora and fauna through the Swedish Taxonomy Initiative, a 20-year programme that has been fully funded since 2005 (http://www.artdata.slu.se/svenskaartprojektet/svenskaartprojektet_eng.asp).

5.2 International collaboration is central to the PBI projects (see below under Q9) and several UK teams are partners in these projects. The EDIT (European Distributed Institute for Taxonomy) project, funded under Framework 6 of the European Union, has brought together a vibrant team of European partners in exploring collaborative methods for taxonomic work. These initiatives are largely concerned with web (or electronic) taxonomy, and thus international collaboration is becoming more extensive. Our Fellows and members of our Council have been or are actively involved in these activities.

6. *What impact have developments in DNA sequencing, genomics and other new technologies had on systematics research? In what way has systematics embraced new technologies and how can these research areas interact successfully and efficiently?*

6.1 Taxonomists have embraced new technologies eagerly where they have proved useful—ie molecular phylogenetics, new generation sequencing (pilot project participation by taxonomists). The use of DNA sequence data has become standard for phylogeny reconstruction in most groups of organisms. The increasing sophistication of molecular techniques and diagnostics has made the analysis of precious archival material possible, and this year allowed sampling of one of Linnaeus' own specimens, resulting in the resolution of a tricky taxonomic problem in the green algae (see http://www.nature.com/news/2007/071220/full/news.2007.396.html). New techniques are added to the repertoire of those already used and found useful; this increase in types of data used is reflected in our library accessions, which have expanded considerably in the last decade (to more than 500 volumes per year).

Data collection, management, maintenance and dissemination

7. *Does the way in which taxonomic data is collected, managed and maintained best meet the needs of the user community? What is the state of local and national recording schemes?*

7.1 User communities for taxonomic information are diverse and many. Digital access to taxonomic data, both in terms of names and specimens is increasingly the standard, but maintaining these data does not come without cost. The Linnean Society embarked on a major programme to digitise the Linnaean collections in 2006; this year we have completed—(with funding of our own and from the Lisbet Rausing Charitable Fund [now Arcadia] Foundation totalling £1.1 million over 3 years)—the plants (17,000 images, 2.2 Tb of disk space) and insects (27,000 images, 1.1 Tb of disk space), and we are now beginning with the rest of the specimen

collection. The storage, security and maintenance arrangements for the amounts of data we now provide digitally represent for us a significant annual additional budget item, and the same is true for any institution providing data in this way.

8. *What is the role of the major regional museums and collections? How are taxonomic collections curated and funded?*

8.1 Collections held in major UK museums, both national and regional, are a priceless record of the distribution of life on Earth. The role of such institutions is in part to safeguard these data (objects) from the past and interpret them for the future. This requires not only curation of the objects themselves, but the maintenance of staff who use the collections to ask scientific questions. Thus, the dual curation/research role of these institutions is essential.

8.2 The Linnean Society has a Botanical Collections Managers Special Interest Group, that serves as a forum for discussions and collaboration on matters pertaining to collection curation and care. In general, the group has concluded that in regional collections and museums curation tends not to be well-resourced and often required to take the same approach to curation as that given to the care of museum artefacts (eg paintings, sculpture, books etc.). This approach fails to recognise the differences inherent in the care of natural history collections (eg loan policies, documentation) and certainly does not resource research on these regional collections or even providing essential collections information to the public. An example of this is the Herbaria@Home initiative (http://herbariaunited.org/atHome/), which is endorsed by the Linnean Society, but not by the University of Manchester, which has responsibility for the herbarium where the initiative is being developed by staff. The potential for co-ordinating collections through the internet is amply demonstrated by the collaborative work of the Australian herbaria, see Australia's Virtual Herbarium *http://www.anbg.gov.au/avh/*, which if developed in the UK would provide access to a wider audience and enable them to appreciate the benefits of securing these unique collections of biodiversity.

9. *What progress has been made in developing a web-based taxonomy? How do such initiatives fit in with meeting demand for systematics and taxonomy information? How do UK-led initiatives fit in with international initiatives and is there sufficient collaboration?*

9.1 Huge progress has been made in establishing various different models of web taxonomy since the National Science Foundation funded the first Planetary Biodiversity Inventory (PBI) projects in late 2002. The Encyclopedia of Life (EoL—with the challenging goal of a web page for every described species in 10 years) is the most exciting project on the horizon; we will watch how it develops with great interest. Many of our Fellows have expressed interest in contributing, and when E.O. Wilson spoke at the Society in December, lively discussions ensued. The single web taxonomy project (Creating an e-taxonomy, CATE) funded in the UK by NERC has established an interesting working model; with a re-compilation of existing data and development of a peer-review system. The many PBI projects in the USA are all web-available, and the initiative has established a good set of people all working with different models and learning from each other. This we suspect will lead to an evolutionary process in the development of web taxonomy, with projects borrowing good elements and becoming better through competition. The PBI initiative is international in scope; in the UK several of the major systematics institutions are partners in these projects (eg, NHM & RBG Kew—funded projects on *Solanum*, parasitoid wasps; proposals for palms, mosquitoes, *Encasia* wasps, *Porphyra* algae). Few enough people are developing these initiatives that collaboration is extensive—for example, both the NERC project and one UK-based PBI project are actively involved with EoL.

9.2 Issues associated with web taxonomy have been debated at the Linnean Society recently. In November 2007 we held our annual Systematics Debate and the topic was electronic publication of new names. Over 100 people attended, indicating these issues are of great interest to the community. Recently, some of our Fellows have established an e-taxonomy Special Interest group. These groups have budgets provided by the Society with which to hold meetings and workshops, so we expect to see more activity centred around web taxonomy in the Society in the near future.

9.3 In 2007 the Linnean Society and the Natural History Museum completed the Linnaean Plant Name Typification Project, that established type specimens retroactively for the 9,000 plant names of species coined by Linnaeus, so that the names can be correctly used. The results are available both on-line and in print and the data are linked to the Society's herbarium specimens on-line. The Society is now investigating making the information available in a wider context through such initiatives as the Biodiversity Collections Index.

10. *What needs to be done to ensure that web-based taxonomy information is of high quality, reliable and user-friendly?*

10.1 Quality control is essential for web taxonomy to be authoritative and reliable. Peer review is an important way in which this can be achieved—management of this is still evolving. Our provision of images and associated of Linnaean material has been rigorously reviewed, and we feel that the quality of the data is as important as the quality of the images. Quality, however, does entail cost, and assuring the high quality of web-available data requires expertise in not only technology but in the organisms.

10.2 In collaboration with our publishers, Wiley-Blackwell, we are making ca. 40,000 pages of back issues of our journals (see 1.6 above) web-available in the near future. This means all the work published by the Society, including the original papers describing the theory of evolution by natural selection by Darwin and Wallace, will soon be accessible to all. Also with Wiley-Blackwell, we are exploring models for establishing an electronically disseminate, rapid publication for new names of plants (the journal *Zootaxa* fills this niche for animals). The trail of models for electronic publishing of new names is particularly important as taxonomy moves towards the Internet.

11. *How does the taxonomic community engage with the non-taxonomic community? What role do field studies play?*

11.1 The Linnean Society is an organisation whose Fellowship is open to all with a passion for natural history and our Fellows come from all walks of life. Meetings at the Society are therefore an opportunity for interaction between the taxonomic and non-taxonomic communities interested in natural history. Our meetings are well attended (averaging 73 attendees with sell-outs for more popular events), indicating to us that at least amongst those attending, there is a willingness to engage and interact.

11.2 The Linnean Society has been pleased to work hand in hand with the Field Studies Council in the production of a New Series of Synopses of the British Fauna. Such synopses have proved a vital starting point for the subsequent production of keys and guides (not least by the Field Studies Council), which have in turn enabled practising biologists, students and citizen biologists, to carry out field studies vital to an understanding of the distribution and consequent conservation management of British animal biodiversity. However, many groups remain without such a basic tool, and there are many gaps in the availability of specialists with both the knowledge and the time to carry out this work.

11.3 While field studies play an important role in enthusing interest in natural history among non-specialists, museums also play an important role. School visits to see biodiversity collections in museums at KS2 level can provide that initial spark of inspiration which leads to a lifetime's interest in natural history, as is evidenced by the experience of many of our Fellows.

Skills base

12. *What are the numbers and ages of trained taxonomists working in UK universities and other organisations?*

12.1 We have no direct data on the numbers and ages of trained taxonomists working in the UK, but we are concerned with the aging structure of our Fellowship, which to a certain extent reflects that of the taxonomic community (or that part interested in natural history).

13. *What is the state of training and education in systematics and taxonomy? Are there any gaps in capacity? Is the number of taxonomists in post, and those that are being trained, sufficient to meet current and future needs across all taxonomic subject areas?*

13.1 The Linnean Society itself does not provide training in systematics and taxonomy, but acts as a venue for meetings and workshops, which complement training. The Society also awards the Irene Manton prize for best botanical PhD done in the United Kingdom, demonstrating support for students. Training is undertaken at our major systematics institutions (RBGs Kew, Edinburgh, NHM) and we participate in this through tours of our collections, loan of our library (to which all Fellows have open access) and our meetings programme.

13.2 We are currently looking at our potential role in education at a variety of levels as part of our strategic plan. Given adequate financial support for training programmes, we have the talented resources among our Fellows to enthusiastic and rigorous training in taxonomy and systematics to a wide range of audiences, and are open to integrating with others having the same aims.

4 February 2008

Memorandum submitted by the Systematics Association

1. Executive Summary

1.1. The Systematics Association is convinced that previous attempts to remedy the decline of systematics in general, and taxonomy in particular, in the UK have (a) been insufficiently ambitious and (b) have not taken adequate account of the interconnectivity of related disciplines. We emphasise that many of the chronic problems besetting taxonomy reflect several recent changes in the academic environment that have together conspired to damage all research disciplines that are inherently long term. This realisation raises the broader question of whether the UK's present strategies for research policy and funding are competent to maintain the research programmes that underpin not only biodiversity assessment but also monitoring of environmental changes and climatic shifts—all fundamentally long-term goals.

1.2. After reviewing the challenges that presently face systematic biology in the UK, the Association concludes that the following actions are of highest priority (they are presented in logical rather than priority order):

(1) Establish a new independent body to coordinate UK systematics activities.

(2) Conduct a thorough and inclusive survey of the current status of the UK systematics community and the requirements of its user communities.

(3) Undertake a detailed consultation with all current and potential substantial funders of systematics and biodiversity research.

(4) Agree a prioritised list of goals for the UK systematics community, and agree the best methods of achieving those goals.

(5) Recognising the global success of "Genbank", agree a prioritised list of databases and a set of inducements to encourage systematists to routinely deposit other categories of relevant information in those preferred databases.

(6) Develop a mixed economy for funding that spans the full possible range from small, short-term awards to very large, long-term programmes.

(7) Coordinate funds from multiple sources in order to guarantee funding for prioritised long-term research goals over unusually long time-scales.

(8) Establish a new national Institute of Biodiversity Research, requiring a substantial number of permanent salaried taxonomic positions to be inaugurated within several pre-existing systematics institutes, biodiversity monitoring institutes and research universities.

(9) Assign the majority of these new taxonomic posts to the university sector.

(10) Apply to these new university appointees a set of RAE-style assessment criteria specifically optimised for performance in the taxonomic field.

(11) Introduce more organismal biology into the national curriculum, and restore previous levels of laboratory experimentation and field excursions in schools and universities.

(12) Provide increased resources and improved coordination for organisations that encourage the acquisition and constructive use of taxonomic skills by amateur natural historians.

1.3. The Association believes that the above challenges can be met only by bringing genuinely new resources into systematic biology. The series of HoL reports has, until now, relied largely upon recommendations that redeployed existing resources. It is sometimes stated that such practices are akin to rearranging the deckchairs on the Titanic. However, given the level of resources currently available to systematic biology, it would be more accurate to describe many of the recently suggested remedies as repositioning the cushions in the lifeboats.

2. The nature and aims of the Systematics Association

2.1. The Systematics Association and Linnean Society together represent the primary independent bodies responsible for the UK's contribution to systematic biology and biodiversity studies. Although pursuing a broad remit of evolutionary biology, these organisations place particular emphasis on describing, identifying, comparing and understanding organisms using a broad spectrum of analytical techniques.

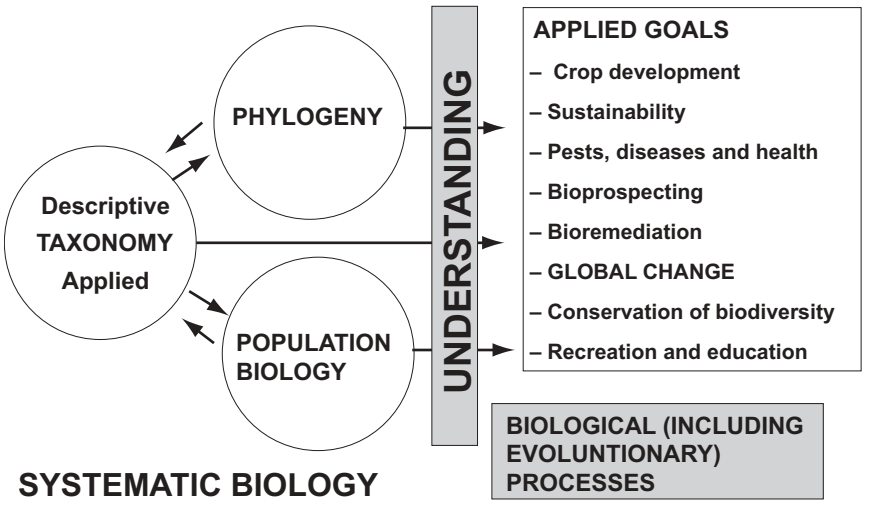
2.2. The Systematics Association separated from the Linnean Society in 1937, in order to become a fast-moving, forward-looking, relatively youthful organisation, able to represent active professional systematic biologists at both the national and international scales. It aims to maximise its impact on the international systematics community within the constraint of its limited financial resources. This strategy has precluded acquisition of paid staff or dedicated accommodation but has permitted the Association to take the lead in initiating two modestly funded but highly subscribed grants schemes (Systematics Research Fund and CoSyst). The primary role of the Association is to coordinate, and publish the proceedings of, professional conferences targeted on specific topics (the next such meeting will be held in Dublin and will address the topic of *Systematic Biology and Climate Change*). In recent years the Association has become more deeply involved in science policy, both directly and indirectly, via the Biosciences Federation. Working together with four other systematics associations representing other western European countries, we recently co-founded the lobby group BioSyst EU. Thus, the next international biennial conference of the Association will be held in the Netherlands, under the auspices of BioSyst.

3. The nature of systematics: terminology used in this submission

3.1. The core sister-disciplines within systematic (comparative) biology are taxonomy and phylogenetics (see Figure). Taxonomy concerns the delimitation, description, and identification of all species and other taxa, both extant and extinct. This has traditionally been pursued via global treatments of a relatively narrow range of species (monographs) or regional treatments of a much wider range of species (inventories leading to floras/faunas), typically based primarily on reference collections of specimens. Taxonomy is increasingly integrating information from various nucleic acid-based approaches such as population genetics and "DNA bar-coding". Phylogenetics explores the evolutionary relationships among the species and other taxa that have been generated by taxonomists, using various comparative approaches to explore both morphological and DNA-based information. Its ultimate aim is to reconstruct and interpret the "tree of life". Both taxonomy and phylogenetics are integrated into the naming of taxa and their organisation into hierarchical systems of classification.

3.2. It is commonly (and correctly) stated that taxonomy provides the essential framework for any biological study, by providing the formal classifications and names, and also the standardised terminology, to reference, describe and identify the organisms that constitute the Earth's biota. It can justly be argued that any biological study, and certainly any comparative biological study, is rooted in taxonomy. Taxonomic activities can usefully be categorised in two subdisciplines (see Figure). Descriptive taxonomy is comparatively creative and proactive, inevitably requiring specialist knowledge and involving the formal (indeed, highly prescriptive) description of new taxa, followed by their redescription as further relevant data are gathered. Applied taxonomy is generally more reactive, encompassing the subsequent use of those classifications to identify organisms, and the dissemination of the resulting data on species recognition and distribution. Recent attempts have been made to reduce the level of specialist knowledge needed to identify organisms. Applied taxonomy generates information that is fed back into descriptive taxonomy in a positive feedback loop, either directly or through other more obviously charismatic disciplines encompassed by systematic biology, notably evolutionary comparison of species (phylogenetics) and populations (see Figure). This mutual support among systematic disciplines is critical to the success of systematic biology; positive or negative impacts on one discipline have corresponding effects on the remaining disciplines.

3.3. Taxonomy and phylogenetics are intellectual challenges sufficiently rigorous to be justifiable on their own merit. However, in recent years they have been justified primarily on the grounds that they feed directly into a wide range of other biological disciplines; they are essential to our understanding of evolution and speciation, biogeography, ecology (including sustainability and environmental issues), conservation, agriculture s.l. (including horticulture, forestry and fisheries), biomedicine and biotechnology (unfortunately, the inter-dependency of these disciplines is still not immediately obvious to non-systematists). Systematics also underpins more general interests in natural history and social phenomena such as education and leisure. In addition to generating such data, much recent discussion has focused on improving methods of disseminating systematic information, notably via networked databases. It is widely accepted (not least by the 2002 House of Lords review) that it is taxonomy rather than phylogenetics that has suffered the most serious decline during the last two decades (phylogenetics was especially strongly promoted by the 1992 House of Lords review). However, it is important to recognise that any future prescription aiming to benefit taxonomy should also consider the likely downstream impacts of such recommendations on phylogenetics, and on the many user groups exploiting taxonomic and phylogenetic information.



3.4. A joint Systematics Association/Linnean Society working group sought to identify the key priorities for these organisations, and in March 2005 recommended that we:

(1) Increase the resourcing and impact of systematic biology in its broadest sense.

(2) Achieve a better balance between, and better integration of, whole-organism and molecular science.

(3) Promote systematics as a discipline that is both scholarly and socially relevant, primarily through meetings and a diversity of publications.

(4) Improve access of actual and potential users to scientific information and publications.

(5) Restore routine teaching of organismal biology and the "informal apprenticeship" that ultimately generates professional systematists.

(6) Facilitate the substantial contributions to natural history of student, retired and amateur researchers.

(7) Translate accumulating scientific knowledge into high-level policy, notably via research and education strategies.

Further strategic planning is ongoing within the Association's council.

4. Association's view of the 2002 Lords review *What in Earth?*

4.1. The Systematics Association gave *What on Earth* a broadly positive reception upon its publication in 2002, and we remain supportive, while recognising that the environment in which we operate has change substantially during the subsequent six years. We considered the 2002 report to be well-informed and each of its recommendations to have merit. However, we found it disappointingly conservative in several respects; the number of recommendations was small (9) and their content unduly modest. Few of the recommendations required significantly increased investment from government, instead focusing on reallocating within the UK, the limited resources then available to systematic biologists and/or suggesting actions to be taken by (generally reluctant) intermediate organisations.

4.2. We assumed that the modest number and negligible cost to government of the Lord's proposals was intended to encourage the government to enact those proposals rapidly and effectively. We were therefore especially shocked by the dismissive tone and minimal content of the government's formal response (Anon. 2002). Although a minority of the recommendations were implemented rapidly, wholly or in part, at least one relatively simple recommendation was only enacted four years later (Recommendation 5, BBSRC analogue status for the Royal Botanic Gardens). Moreover, other recommendations were ignored, and at least one resulted in withdrawal of funding (Recommendation 9, arguing for increased spending by Defra on the Darwin Initiative, was initially followed, but funding of the Initiative was suspended of the grounds of fiscal expediency in 2007/8). Primarily due to inaction on the part of various supposedly interested parties, the 2002 Lord's review had negligible impact on the UK's systematics base, and had appreciably less impact than the 1992 Lord's review.

5. Does facilitation or long-termism lie at the core of taxonomy?

5.1. The Association suspects that one of the main reasons that there have been two full reviews (1992, 2002) and two interim reviews (1997, 2008) of the UK's systematic biology base by the House of Lords, is the continued argument that systematics in general, and taxonomy in particular, is a "special case" and therefore merits equally special treatment.

5.2. The many unusual features of taxonomic research were summarised in HoL 2002 as being those characteristic of an "enabling" (facilitating, foundation) science. Although we do not deny this commonly expressed perspective, in our view taxonomy differs from the majority of disciplines primarily in being a science that requires long-term stability of activity and funding. Taxonomic skills take a long time to acquire. The outputs (floras/floras and monographs) remain scientifically highly relevant for a long time but equally they take a long time to produce; they may be better accumulated gradually through time in an electronic environment. Such databases take a long time to fill with sufficient data to become sufficiently useful to justify the investment. Also, the most important applications of the resulting data, such as monitoring climate change, ecosystem dynamics and population-level evolution, require a substantially longer time-scale to address than is typically accommodated by funding bodies (or by particular government policies).

5.3. The majority of the issues raised by the decline of British taxonomy therefore, present a broader challenge to policy-makers and funders—specifically, whether the UK is sufficiently committed to the more general category of long-term scientific research. The laudable leadership recently shown by the British government in publicising and addressing global climate change—the archetypal long-term challenge—should provide an unparalleled impetus for all relevant bodies to collaborate in solving the crucial general issue of how to reliably maintain long-term research programmes. However, we note that, as one corollary to long-termism, many of the potential remedies will inevitably take a long time to yield their full benefits.

6. Preliminary comments regarding the present Lords questionnaire

6.1. As with the original House of Lords report, the Association has some reservations regarding whether the present set of questions posed by the Select Committee encompass the entire range of crucial challenges currently facing systematic biology. Thus, although we have, as requested, used the Committee's questions as the framework of our response, we have subsequently summarised some additional issues and principles that we believe are of particular importance, as well as recommending a small number of key actions that we believe would most effectively remedy current deficiencies in the discipline. We recognise that this document is unusually long for a parliamentary response. In our defence, we note that (a) this enquiry strikes to the heart of the Association's raison d'etre and (b) that we have in effect been set 30 questions to answer, as well as wishing to raise a few additional key issues that we believe have been overlooked by the Select Committee.

6.2. The Association should also state at the outset that it regrets that the majority of its responses to the following questions are often based on anecdotal evidence. The Association has argued since before the 2002 Lords review that a comprehensive survey of the UK's systematics base is urgently needed, to compare with that conducted by the UK Systematics Forum in 1994/5 and published in 1996. The most recent relevant post-1996 output is the UK Taxonomic Needs Assessment, prepared by the Natural History Museum on behalf of the Global Taxonomy Initiative in February 2006, but this survey involved a limited sampling of both producers and users of systematic information, and considered only taxonomy rather than the full breadth of systematic biology.

The (present) state of systematics and taxonomy research

7. Q1. *(a) What is the state of systematics research and taxonomy in the UK? (b) What are the current research priorities? (c) What are the barriers, if any, to delivering these priorities?*

7.1. We cannot give a definitive account to Q1A because of the lack of strong current baseline data. The answer should consider four main areas of activity; morphological and molecular approaches, respectively, to phylogeny reconstruction, and taxonomic description and identification. Current evidence suggests that molecular phylogenetics is the best supported and thus most rapidly expanding discipline, in part because it is being widely pursued in the university sector as well as in the major institutions. Surprisingly, molecular taxonomy ("bar-coding"), which is rapidly expanding in some other countries, has found relatively little favour with the major funding bodies in the UK, despite our strong initial contributions and continued enthusiasm among practitioners (see Q6). Morphological phylogenetics appears to be diminishing, having been replaced in some programmes by molecular phylogenetics. The area of greatest concern continues to be

classical morphological taxonomy, where both the number of the practitioners (especially professionals), and the average amount of time spent on practical taxonomy by each remaining practitioner, continue to decline.

7.2. With regard to Q1B, although the Association can (and has) developed its own prioritisation of major research areas, and has highlighted a few of the most relevant in this document, it cannot justly claim to speak for the discipline as a whole. In general, there have been far too many systematics-related initiatives during the last decade at every scale (national, European, global), thereby diluting effort, slowing progress and eventually prompting ingrained cynicism. And the systematics community has itself been surprisingly slow in reacting to changes of emphasis at the policy level that directly affect its applied user groups, most notably the scientific enthusiasm for climate change studies that preceded the Stern report and the political enthusiasm that followed it.

7.3. In addition, systematists have continually found difficulty in agreeing the criteria for prioritisation among projects. Relevant issues that are still widely debated include (a) is it necessary to address specific scientific hypotheses, (b) if so, which kinds of hypotheses are most important, and (c) should those hypotheses be selected proactively by the systematics community to satisfy its own needs or reactively, in response to expressed needs of the many user-communities? We must also decide (d) which are the most appropriate taxonomic groups for addressing those hypotheses, and (e) which are the most appropriate methods for analysing those groups to yield the necessary data?

7.4. These issues are discussed most acutely in taxonomy, where there is a strategic dichotomy between two schools of thought that could be termed encyclopaedists and integrationists. Encyclopaedists believe that priority should be given to beginning to fill the many vast gaps in our current taxonomic knowledge. They are inspired by frequent statements that estimates of the number of species on Earth generally exceed 10 million, whereas only approximately 1.7 million species have so far been described (and that at the current rate of description it will take 200–500 years to complete these descriptions). This school of thought is driven by the urgency instilled by the biodiversity crisis, and more specifically by the belief (most likely correct) that species are currently becoming extinct more rapidly than they are being described. Moreover, the questions addressed are so broad and simple (ie does a particular species exist, and how many species presently occur on Earth?) that some observers will not accept them as bona fide scientific hypotheses. The integrationist viewpoint gives greater emphasis to more specific hypothesis-testing and to the requirements of our user-groups. It recognises that although taxonomic description is an essential first step to any biological study, robust recommendations regarding practical issues such as conservation, ecosystem services and climate change monitoring and remediation cannot be made until a great deal more is known about a particular species than its name. Key criteria include its appearance, anatomy, mode of reproduction, behaviour, genetics, habitat preferences, distribution, evolutionary relationships with other related species and ecological relationships with other, generally unrelated, species. The integrationist mind-set implies a closer relationship between taxonomy and other related disciplines, and a belief that a considerable depth of knowledge is a necessary pre-requisite for effective human intervention in complex biological systems.

7.5. Question 1C is best addressed by questioning why taxonomy in particular has all but disappeared from the UK university sector. British universities have been impressively (and destructively) homogenised during the last two decades by the Research Assessment Exercise (RAE)—specifically, by its emphasis of a small number of arbitrary targets. The present route to success for an academic relies heavily on just two criteria—the ability to publish just one paper a year in a journal of high impact factor (ideally, *Nature* or *Science*) and the accumulation on behalf of their host institution,a large amount of overhead that now accompanies most research grants. In addition, in order to reduce administration costs and to encourage more integrated science through team building, most major funding bodies have adopted a Big Science strategy. They allocate smaller numbers of larger grants, though these remain typically three years in duration and never more than five; moreover, grants are most readily made large by proposing expensive, high-tech approaches to particular problems, irrespective of whether the question could be solved using a lower-tech solution. The target-based approach to managing the UK's science has had profound negative effects across the science base, encouraging low productivity from individual grants and the mutual back-scratching inherent in publishing cartels. However, the most serious damage of holding all researchers to the same few assessment criteria, is the inevitable homogeneity of their response when chasing these arbitrary targets. The ability of the UK's science base to support disciplines that do not readily fit the prescribed mould has inevitably collapsed.

7.6. Sadly, few if any disciplines fit the mould as poorly as does taxonomy. With the arguable exception of pilot schemes in DNA bar-coding and automated identification (see Q6), taxonomy is a low-tech activity. The greatest actual cost is the salary of the taxonomist, and the greatest hidden cost is the considerable period of time needed for that taxonomist to reach the desired levels of skill and knowledge. Further (and generally hidden) costs, often resented by university administrators, are likely to be incurred if the taxonomist's collections require curation. At present, the typical outputs of taxonomy are either geographically restricted

faunas/floras or taxonomically restricted monographs. Each such output takes far longer to produce than a single grant from an existing scheme would permit. These are produced either as infrequently generated books or as series of frequently generated shorter articles in journals that are of low impact and rarely cited (though, unlike most science, they can remain valid and current for centuries). Such kinds of output are effectively invisible to the RAE. A more modern approach to disseminating taxonomic information, adopted with enthusiasm by the 2002 HoL report, seeks to largely replace these traditional outputs with electronic equivalents. At present, these kinds of output are equally invisible to the RAE. In addition, there remains a widespread perception (one that is increasingly inaccurate) that taxonomists are too individualistic to make good team members. Moreover, some grant-awarding bodies hold rather parochial views of teams, considering them to operate within single organisations and thus effectively ignoring the fact that electronic communication has permitted researchers world-wide to become strongly networked. In summary, taxonomy is cheap science that offers good value for money, traits that mean it is heavily penalised by the tyranny of the RAE. We had hoped that the succeeding Research Excellence Framework (REF) would prove more amenable, but its current draft form suggests an equally damaging obsession with short-term citation.

8. Q2. *(a) What is the role of systematics and taxonomy and, in particular, in what way do they contribute to research areas such as biodiversity conservation, ecosystem services and climate change? (b) How important is this contribution and how is it recognised in the funding process? (c) How is systematics integrated in other areas of research?*

8.1. Terminological rigour is especially crucial in answering Q2A, which depends on understanding the interrelationships between several research disciplines (see Figure). After establishing the framework of systematic biology in Section 3, and before considering below the broader applications of systematic data, we emphasise here that systematic biology is an intellectually rigorous discipline in its own right, and that its success should not therefore be wholly dependent on its immediate applications. In particular, comparative biology is the source of most of our knowledge on evolutionary patterns and processes. Nonetheless, we recognise that the interests of the present enquiry are likely to be applications in general and climate-change issues in particular. We also wish to emphasise that the user communities still inevitably make occasional unreasonable demands on existing taxonomic knowledge. One of the most common fallacies is to prefer classifications that are (a) fixed and/or (b) built upon relatively flat hierarchies (eg focus on species at the expense of infraspecific taxa). Such static approaches remove the scientific element of taxonomy by discouraging further evolution of classification in response to an increasing range and quantity of relevant data.

8.2. It is difficult to conceive how high-priority applied disciplines such as biodiversity assessment/ conservation, ecosystem services/ sustainability, and monitoring/ remediation of climate change could even be discussed in the absence of the framework provided by the formal names and ranks inherent in taxonomic classifications. As is widely stated, taxonomy is, in this sense, an "enabling" science. However, when passed through the interpretative filters of other disciplines, both within systematics (eg phylogenetics, evolutionary biology) and immediately adjacent to systematics (eg ecology), it becomes an interpretative science that is competent to offer constructive advice on these high-profile, socially engaged issues. Thus, maintaining effective communicative and collaborative links among these disciplines is crucial to making effective practical use of systematics data.

8.3. Many initiatives at different hierarchical scales have been established in attempts to improve communication and collaboration. They have achieved varying degrees of success, but overall, there have been too many such initiatives and they have failed to garner sufficiently widespread or committed support. Such initiatives are still badly needed, but it is important that lessons are learned from past mistakes, and that the relevant government(s) offer sufficient inducements to encourage stronger commitment from systematists, researchers in related disciplines and more applied user groups.

8.4. While there has been a superfluity of schemes designed to improve networking, the number of institutions operating within the UK that are capable of generating taxonomic data has fallen, most notably in the university sector. At the same time, the number of institutions that applied these data to practical problems such as biodiversity monitoring has also declined (eg the recent rationalisation of NERC's Centre for Ecology and Hydrology). Arguably the best way to monitor climate change would be to closely link taxonomically competent institutes to ecologically competent institutes, yet in recent years the UK has suffered severe reductions in both constituencies.

8.5. Linkage between producers and users of taxonomic information is especially important because, in the current highly competitive funding environment, it is rare that funds are awarded to activities that affect the desired practical outcomes indirectly rather than directly. Partly for this reason, phylogenetics and population genetics are currently substantially better funded than taxonomy. Moreover, within taxonomy, it is currently

easier to fund dissemination of existing knowledge than generation of new knowledge. Reversing the long-term decline of descriptive taxonomy will require radical actions, including: ensuring better representation of systematists (especially taxonomists) on grant-awarding panels; better integration of taxonomic work into hypothesis-testing projects; assessment systems that give appropriate credit for the outputs of descriptive taxonomy (monographs and floras/faunas) in both the traditional printed and modern electronic forms; establishing a stable funding basis for long-term research in critical policy-related areas.

8.6. Lastly, we note that Q2A implicitly under-estimates the number of key users of taxonomic information. In addition to conservation, ecosystem services and climate change, taxonomic research feeds critical information into attempts to remediate the effects of damaging organisms such as invasive species and pathogens of humans, domestic animals (including fisheries) and crops.

9. Q3. *(a) Does the way in which systematics research is organised and co-ordinated best meet the needs of the user community? (b) What progress has been made in setting up a body to lead on this?* (c) What contribution do the leading systematics research institutions make, both nationally and internationally?

9.1. At present, the organisation and coordination of the UK's systematics research base is far from optimal, reflecting both the unwillingness of any particular body to take responsibility for, and fund, a coordinatory body (Q3B) and the large number and recalcitrant nature of the challenges faced. The community is strongly influenced by several government departments and collectively has many funding bodies; all are poorly communicative and have goals that at best only partially overlap. The systematics base is divided between dominantly professional and dominantly amateur organisations, and active research is conducted at every conceivable scale, from major institutes through regional centres to local societies. It is our impression that these organisations have actually become less well coordinated in recent years, as regional and local governments have set their own (often conflicting) priorities and organisations that were formed specifically to provide cohesion, such as the Joint Nature Conservation Committee and National Biodiversity Network, have been consistently under-funded.

9.2. Defra have failed to respond in any meaningful way to the 2002 Lord's review requirement, that they show leadership to Britain's systematics community. Six years later, no action has been taken toward the Lord's 2002 recommendation that "Defra takes the lead in setting up a body with the express purpose of bringing together representatives from government departments, ecologists and conservationists and the systematic biology community" to guide the UK's biodiversity and conservation efforts. When challenged by the Institute of Biology and Linnean Society in 2006 to justify their chronic inactivity, Defra cancelled a previously agreed discussion meeting and announced that "as a result of the tight financial position in Defra, prioritisation of our objectives and strategic outcomes has resulted in progress in systematics falling below the threshold to command the necessary resources." A similarly defensive reply was given to a query from the Biosciences Federation and the Systematics Association a year later. Given these responses, we can only reach the extraordinary conclusion that Defra have failed to perceive the crucial connection between the outputs of systematic biology and the critical areas of government policy for which they are at least partly responsible, such as agrarian diseases (and epidemics), remediation of environmental degradation and, of course, climate change.

9.3. Despite the apparent lack of interest from any relevant government department, the UK systematics community could still have taken actions independently to improve coordination and prioritisation of tasks. However, in the absence of government guidance, the systematics community failed to organise itself sufficiently well to establish priorities that reached beyond individual organisations. None of the major research institutes has shown strong interest in achieving this goal, and those discussions that have taken place since HoL 2002 have been by no means inclusive; smaller and/or dominantly amateur organisations, which play a proportionately increasing role in taxonomy in particular, are rarely included. The ideal coordinatory body would be led, or at least chaired, by a broadly based independent organisation. The Systematics Association is certainly willing in principle to take on this task, but it would require funds to supplement its present meagre resources.

9.4. The overall trend of the last two decades has been for taxonomy to gradually diminish in the universities and the user-groups of such information (eg the NERC institutes), and to become relatively concentrated in the major systematics institutes and the "amateur" sector. Phylogenetics has, in contrast, spread from the major institutions into the university sector, encouraged by its proven effectiveness and by the funding priorities of the research councils. This in turn has understandably encouraged greater emphasis on evolutionary biology in the major systematics institutes, thereby effectively reducing the emphasis on taxonomy. With the exception of the diminution of taxonomy in the university sector, these trends have not necessarily had effects that were negative overall. Nonetheless, it seems likely that the bulk of the UK's

taxonomic research is now conducted in just three institutions: the Natural History Museum, and Royal Botanic Gardens of Kew and Edinburgh.

9.5. This apparent centralisation of taxonomy offers considerable advantages to coordinating and prioritising work internally, but less effort has been made in recent years to achieve these goals between the major institutes. In addition, there has been diminishing encouragement of staff in these institutes to show leadership to the many "amateur"-dominated societies who now in practice generate the vast majority of the biodiversity data produced for the UK. The Association is not convinced that the many national and international schemes designed to improve networking and data flow among systematists, and between systematists and their many user-groups, have come close to achieving their potential. We need to critically assess, and then select among, such schemes, preferentially resourcing those of greatest potential. The major institutes have a clear role to play in this strategic process, but they need to take full account of the broader requirements of the taxonomic community.

10. Q4. *(a) What level of funding would be needed to meet the need for taxonomic information now and in the future? (b) Who should be providing this funding?*

10.1. There is no straightforward answer to Q4A. Several recent statements have suggested that it will take at least 200 years at the present rate to give basic descriptions of most of the species on Earth. One might therefore conclude that the UK's contribution to this global endeavour could double its speed if its funding base were to be doubled. Such an analysis would actually be grossly simplistic, since the depth of knowledge on species is important, and there is understandably increasing emphasis on encouraging taxonomists to be better networked and more interactive.

10.2. Much of the evidence offered to the House of Lords review in 2002, singled out the UK research councils (especially NERC and BBSRC) for particular criticism. The Association believes that this widely held view was simplistic; the research councils are inevitably held accountable to policies set by relevant government departments, and ultimately to the Treasury. We also sympathise with the belief long held by the research councils that research funded through normal channels should be genuinely hypothesis testing. Nonetheless, there have been very limited gains in the enthusiasm shown by the Research Councils toward systematics in general and taxonomy in particular. The Association, supported by the Linnean Society, successfully initiated and now administers CoSyst, a pump-priming small-grants scheme that received total funding of £225,000 over three years (2007–9) from BBSRC and moral support from NERC. The intention is that the successful CoSyst proposals will ultimately lead to full responsive mode proposals to the research councils, and the initial application rates have been unexpectedly high (only 5.5 of 48 applications could be funded in 2007, and a further 36 applications were received in 2008). However, full responsive mode systematics applications have long fallen down the cracks that separate the supposedly overlapping remits of the research councils, and in practice they continue to bounce like footballs between councils. Proposals containing more than a modest amount of taxonomy still do not receive funding, and the councils still appoint very few systematists, and no classical taxonomists, in their grant-awarding panels. It also remains difficult to gain funding from most likely sources for the cost of curating and/or databasing materials used for taxonomic studies. The Systematics Association and Linnean Society together, address a further funding gap by offering small grants of up to £1500 toward a wide range small-scale systematics projects (in 2007, the total available spend of £36,000 funded 37 of 98 applications; in 2008, applications have risen yet again, to 140, yet the previous annual contribution of £5,000 from NERC has been withdrawn). Thus, there remain substantive issues that the research councils should address urgently.

10.3. If we are disappointed by inaction in the funding area by the research councils, we are even more disappointed by certain actions that *have* been taken. In particular, both NERC and BBSRC have pursued long-term rationalisation programmes of the research institutes for which they provide substantial core funding. The relatively recent rationalisation of NERC's Centre for Ecology and Hydrology (including the closure of research institutes such as Monks Wood and Windermere) inevitably reduced the effectiveness with which taxonomic data is deployed to monitor and, where possible remedy, environmental change. The systematics community is constantly encouraged to disseminate its information to key users, but this laudable goal is made far more challenging when critical users of that information are eliminated.

10.4. The Association has long noted that the British systematics community relies on funding from an exceptional diversity of sources. The three largest systematics institutes in the country (in order of decreasing size the Natural History Museum, Royal Botanic Gardens Kew and Royal Botanic Garden Edinburgh) each still gains at least half of its recurrent funding from a different government department (DCMS, Defra, and the Scottish Executive's RERAD, respectively). This diversity offers some buffering against the vicissitudes of allocations to these departments by the Treasury, as few external phenomena can affect all three organisations

simultaneously. However, it complicates any attempt to develop stable joint initiatives among these institutes, and leaves each at the mercy of often radically contrasting policy priorities that must be met if even modest levels of core funding are to continue.

10.5. The Association is especially disappointed with the performance of Defra in recent years, over and above their inaction with regard to establishing a new coordinatory body for UK systematics (Q3B). We recognise that Defra has been obliged to respond rapidly to a series of resource-sapping, agriculturally-related crises, some caused by epidemics and others by suboptimal administration. However, Defra do not appear to have perceived the link between these epidemics and our ability to identify, predict and remedy their causes—activities that rely heavily on information and techniques that are central to systematic biology. They have significantly reduced core funding of the one major research institute for which they hold direct responsibility, RBG Kew. They suspended payment the funds promised for the current round of Darwin Initiative grants, thus undermining a globally respected initiative designed to allow British researchers to provide practical assistance on biodiversity and human welfare issues, targeted especially at communities in developing countries. They have reduced funding to organisations that help to translate systematic data into practical outcomes within the UK, notably JNCC and the Environment Agency. Such decisions make it far more difficult for systematists to deploy their outputs as components of practical, socially applicable programmes.

10.6. If, as we have argued, reliable long-term funding is the single most critical need for improving the UK's taxonomic base, substantial changes need to be made in the way that funding is apportioned. At present, typical funding periods from both government funders (eg the research councils) and independent charity funders (eg the Wellcome and Leverhulme Trusts) is three years. There have been welcome signs that five-year funding may be considered more seriously in future (the most encouraging being the development of substantial five-year "Lola" grants by BBSRC). In our view, both the fundamental taxonomic enterprise itself, and the uses that feed off that fundamental data (eg monitoring biodiversity to assess the effects of climate change), need guaranteed core funding for periods measured in decades rather than years. We therefore recommend that research funders and relevant government departments convene a novel body to develop an initiative that will guarantee such funding, by pooling resources from multiple sources toward a mutually agreed set of biodiversity-related goals. Any such initiative should distinguish clearly between (a) conducting creative taxonomy, (b) disseminating existing taxonomic information (including identification), and (c) more applied uses of systematic information.

11. Q5. *(a) How does funding in other countries compare? (b) Could there be more international collaboration? (c) If so, what form should this collaboration take and how might it be achieved?*

11.1. During the 19th century and first half of the 20th century, the global centre of gravity for systematics research lay firmly in Europe. In the second part of the 20th century, the phylogenetics revolution was primarily driven by Europe and North America (focused on the Natural History Museum, London and the American Museum of Natural History, New York). However, in the last decade in particular, the USA has invested far more heavily in its general systematics base (as assessed on both absolute and per capita measures) than have European countries. In particular, the American National Science Foundation invited a series of systematists to work for them for several years to establish a complementary suite of programmes covering phylogenetics (Assembling the Tree of Life: AToL), species descriptions, biodiversity inventories and collections enhancement (Planetary Biodiversity Inventory: PBI), and training young taxonomists (Partnerships in Enhancing Expertise in Taxonomy: PEET). These schemes have benefited, both directly and indirectly, collaborators in other countries, including the UK. The Australian Biological Resources Study (ABRS) also attracts substantial government funding. The EU-funded European Distributed Institute for Taxonomy (EDIT), a relatively recent innovation, is built on far more modest basis than its broader US and Antipodean equivalents. Other countries have chosen to focus their investments on specific activities, such as DNA bar-coding in Canada and bacterial systematics in South Korea.

11.2. Major international collaborations such as the Global Biodiversity Information Facility (GBIF) tend to be handicapped by the expectation (possibly the necessity) that one country (or one organisation within that country) should take the lead role in that initiative. The commitment to that initiative of the other subordinate countries tends to be reduced, often ultimately leading to that country developing a similar initiative that it can then claim to lead.

11.3. Thus, although developing international collaborations remains an important goal, improving international communication among systematists is a more straightforward goal. This is the simple way to avoid duplication of effort and to improve complementarity among research projects across the globe. Such communication has also brought considerable benefits in the area of standards—for example, data spectrum and quantity, database platforms, collection curatorial standards, shared analytical protocols, common

conceptual frameworks. And such international networking belies frequent statements, fuelled by a now ubiquitous Big Science ethos, that critical masses of researchers (and curators) within specific institutes are essential, such that the traditional concept of individualistic taxonomists should be superseded in the modern research environment. Rather, the modern research environment, increasingly dominated by the mixed blessing of electronic communication, means that no systematists need operate in isolation, irrespective of their physical location. The opportunity exists to make successful on a long-term basis one or more integrated, yet flexible, international networks in systematic biology. This goal requires comparative assessment followed by prioritisation.

12. Q6. *(a) What impact have developments in DNA sequencing, genomics and other new technologies had on systematics research? (b) In what way has systematics embraced new technologies and how can these research areas interact successfully and efficiently?*

12.1. This question is best answered by distinguishing between molecular and morphological approaches. Within the DNA sequencing realm, two main categories of technology are being explored. The first, for long forecast by several distinguished proponents (not least Lord May), is the pocket-sized sequencer. The American military recently demonstrated to the Association at its Biennial Conference that they have already effectively achieved this goal, having produced a portable field device that can sequence a chosen region of the genome for about 100 specimens within ten minutes. At present the device is the size of a laptop computer and requires the stability of an environment such as the back of a vehicle, but it is predicted to shrink to genuinely pocket size within a year. It should soon be possible for field surveyors to analyse a significant number of samples in the field and use satellite technology to compare the resulting DNA sequences with databases such as Genbank, and thus to obtain probability statements regarding the identification of the organisms while still in the field. We note that these techniques can readily be applied to juvenile, senescent or otherwise non-reproductive organisms that fail to show crucial diagnostic characters of their morphology, or to the many organisms (most relatively primitive) that show little morphological differentiation at any stage in their life histories (on the negative side, higher animals tend to evade field sampling). In short, field-based DNA identification is within reach. The question is less whether the technology exists than when it will become available (a) to non-military researchers and (b) to field surveyors at an affordable price (past experiences with GPS technology suggest that it could occur within five years).

12.2. However, exaggerated claims have been made regarding the efficacy of DNA bar-coding/ DNA taxonomy, which is liable to be constrained less by the sequencing technology than by the nature of the data held in the databases. Although Genbank is by far the best-populated and best-maintained database relevant to systematic biology, it remains deficient in both quantity and quality of data. Even most described species remain wholly unrepresented in the molecular databases, and a significant proportion of the sequences that have been entered into the database have been misidentified, often because the relevant taxonomic expertise was unavailable or otherwise not consulted when sampling took place. In addition, thus far there has been insufficient exploration of the range of genetic variation exhibited within species, to determine how likely a novel sequence is likely to represent a novel species. In our view, DNA taxonomy has revolutionised systematic studies of organisms that truly show little if any morphology, but for the remainder of the Earth's biota, it is the combination of morphological and DNA data obtained from the same organisms that permits genuine understanding and explanation.

12.3. Parallel improvements in sequencing protocols and robotics, driven in part by the human genome project, have combined to permit an exponential increase in the number and diversity of sequences available to systematists. These have proven especially influential in the fields of population genetics and molecular phylogenetics. An important debate is currently gaining momentum within molecular phylogenetics circles between proponents of an analytical strategy that analyses a modest but well-chosen range of genes for a large number of species and approaches that analyse entire genomes (in eukaryotes this is the nucleus, inherited from both parents, or more often the plastids or mitochondria, usually inherited from only one parent), inevitably encompassing a much smaller range of species. As sequencing technology advances further, this debate will become less polarised. The main challenges will become (a) dealing statistically with the massive volumes of data generated, and (b) understanding better the biological implications of these genetic data, not least their mode of expression within organisms (thus linking genomics to another rapidly expanding biological field, proteomics).

12.4. Some current research projects are attempting to emulate the increasing automation of DNA-based systematics in morphology-based systematics, using automated image-recognition systems. These have shown promise thus far, albeit within relatively narrow taxonomic ranges (eg comparing the wing patterns of mosquitoes). Informed opinion is currently divided regarding how much further promise such systems hold

for taxonomy. A more pragmatic approach has been developed that uses imaging technology to interface with taxonomic experts. A problematic organism, such as a parasite, can be imaged in 2D or even pseudo-3D in the field and then the image sent electronically to a specialist to aid in identification. Similarly, a critical type specimen in a museum collection can be imaged and sent to the field worker for comparison. However, such approaches are labour-intensive, and tie up the taxonomist in relatively low-level identification procedures—in other words, in using taxonomies rather than creating and improving them. The American military has simplified such a system, by providing field-based para-taxonomists with organism identification guides that can be projected onto the interior of a sophisticated visor, allowing them to compare electronic images with the problematic organisms placed literally under their noses.

12.5. Overall, the Association believes that the systematics community has maintained a sensibly pragmatic attitude to technological innovation. This is a considerable achievement, because recent debates could easily have become polarised between (a) enthusiastic advocates of technological fixes who exaggerate the potential of any new technique before it has been adequately explored, and (b) the views still expressed by many sceptics within the systematics (and especially the taxonomic) community that only conventional approaches yield data that will stand the test of time. However, the Association believes that the UK had the opportunity to show stronger global leadership in initiating and developing such innovations, but that progress has been avoidably slow due to the reluctance of funding bodies to endorse sufficiently ambitious pilot studies to determine the all-important boundaries inherent to these novel approaches. Greater commitment to technological innovation is therefore recommended (as strongly advocated in DUIS policy), along with better coordination among organisations so that several smaller pilot projects can more often be superseded by a single networked project.

Data collection, management, maintenance and dissemination

13. Q7. *(a) Does the way in which taxonomic data is collected, managed and maintained best meet the needs of the user community? (b) What is the state of local and national recording schemes?*

13.1. As a generalisation, databases are of limited value until they have been populated with the bulk of the information that they are intended to contain. It is therefore especially unfortunate that it has long been, and remains, relatively easy to obtain external funding for the establishment of a new database (especially a meta-database intended to give greater cohesion and/or user-friendliness to several existing specialist databases) but in contrast it is extremely difficult to fund the costs of populating those databases to the point where they become cost-effective. It has also proven feasible to fund the establishment of databases at several different levels (institutional, local, national, European, global). The net result has been a proliferation of databases that often overlap considerably in objectives and/or content. Attempts to coordinate or unify content, presentation, platform, or other crucial properties have been handicapped by the proliferation of the databases and the lack of carrots or sticks sufficient to strongly encourage adherence to such standards. The number and diversity of databases mean that ease of access to data can be problematic for any user-group, including systematists themselves, unless they have prior knowledge of the range of databases available and are asking very specific questions.

13.2. In many cases, the justifications put forward for developing meta-databases have been undesirably weak. Perhaps the most important factor is whether any particular database can be accessed via the Internet. If so, it can usually be located reasonably easily by intelligent use of a search engine such as Google. There is no doubt that meta-databases can greatly enhance ease of access to the relevant data, but this can be achieved most effectively by applying standards and standardisation both to the databases, thereby improving their interconnectivity, and to the data themselves, thereby improving their quality and reliability. In other words, a widely recognised validation procedure is highly desirable. Overall, improving the quantity and quality of data available in the Internet is arguably at least as important as improving its user-friendliness.

13.3. As noted under 12.2, by far the most influential database currently available that underpins systematics (and many other disciplines) is Genbank. This has befitted from many years of evolution and data-population, though even here the reliability of the data is mediocre. But the main secret of its success has been the decision by most relevant journal editors to make submission of DNA sequence data to Genbank a pre-requisite for publication of the resulting research papers. It is this compulsion that has allowed both standardisation of, and rapid population with, data. Attempts to establish similar systems for various kinds of morphological systematic data (eg Morphobank, Morphbank) have been far less successful, because (a) fewer such data are now generated, (b) the journals that publish such data are less influential, and (c) very few of those journals have made deposition of the underlying data compulsory. Britain could show a lead in this area by identifying a suitable international morphological database for further development as the preferred repository, ensuring

that appropriate standards of data content and validation are established and that UK-based journals identify that database as the preferred repository.

13.4. Bacterial systematists have taken the radical step of identifying a single journal as the outlet for all new taxonomic descriptions of their organisms. This centralisation permits easy detection of trends in bacterial taxonomy (notably the rapid rise of South Korea at the expense of the UK, which now contributes only 3 per cent of the world's new bacterial descriptions), though we believe that it would be impossible to impose such a restriction on the larger volume and greater diversity of taxonomic works encompassing groups of more complex organisms. However, a more pragmatic suggested change is increasingly debated within taxonomic circles—specifically, whether a single centralised repository should be identified for all newly described taxa, and whether registration of new taxa in that repository should be made compulsory. The weight of opinion within the systematics community appears to be shifting toward this idea. Again, the UK systematics community could lead the international community in identifying a suitable repository for Linnean names and making their registration a firm requirement.

13.5. Each major group of organisms (eg animals, plants, bacteria) has long had its own legalistic code dictating how those organisms are classified and named. Each of these codes has evolved to suit that particular group of organisms, but now there is an understandable desire to unify (or at least bring closer together) the content of those codes, and to modernise them to better accommodate more recent data sources such as DNA sequences, and to be made fully compatible will electronic publication of taxonomic data. UK-based systematists have long had a strong influence over the content of these codes. Thus, development of a unified view within the UK regarding the most appropriate route to unification would have a good chance of influencing the (often conservative) international bodies that regulate the codes.

13.6. With regard to Q7B, Britain's biodiversity is better known than that of any other country. Most local and national recording schemes for biodiversity data are run increasingly by amateur (or retired professional) systematists. Even where actively employed systematists are directly involved, in most cases their contribution is made in their own time, without encouragement or recognition from their employer. Most of these schemes are poorly resourced, and many are experiencing increasing difficulties obtaining funding at a time when demands for data are increasingly rapidly. It does not help that the government department most closely associated with the majority of the schemes (Defra) has proven especially unpredictable in its resource allocations, due in part to its vulnerability major spends in response to various environmental/ agricultural crises. This has undermined the activities of organisations such as Joint Nature Conservation Committee and the Environment Agency. The recent rationalisation and reduced resourcing of NERC's research institutes constituting the Centre for Ecology and Hydrology has also negatively affected national recoding schemes.

13.7. At the local level, the UK gradually built up a network of County Biological Records Centres during the latter part of the 20th century, feeding into (and funded primarily by) local government. Many of these CBRCs became highly effective, but for reasons that the Association does not fully understand, the network has been in decline for several years, and several CBRCs have become moribund. This has placed even more reliance for national biodiversity recording on the many specialist societies, which play critical roles in biodiversity recording and assessment. They are most commonly populated by highly skilled and experienced but ageing amateurs, acting voluntarily. Such groups cannot (and should not) have their priorities dictated externally, either by government or by umbrella organisations such as the National Biodiversity Network. Sensitivity is required in several areas. At a practical level, new technologies such as electronic recording systems should be introduced carefully, after being rendered maximally user-friendly. At the political level, these increasingly rare generators of primary data (as opposed to synthesisers of other people's data) need to be given full credit for their efforts; credit (and resources) rarely pass unmolested from the top down, through increasingly complex recording networks, to the shop floor. And where professional systematists are involved in such schemes, they are unlikely to receive credit from their employers, especially where those employers are universities held in thrall to the RAE. In short, greater political and practical emphasis needs to be given to individuals and schemes that focus more on generating new systematic data than on recycling old data.

14. Q8. *(a) What is the role of the major regional museums and collections? (b) How are taxonomic collections curated and funded?*

14.1. The multiplicity of roles fulfilled by the larger regional museums possessing natural history collections (and botanic gardens/zoos possessing living and preserved collections) makes them especially difficult organisations to manage. Together with other biological records centres they provide a vital focus for local, regional and national natural history organisations, and thus for biodiversity recording and monitoring. Clearly, they play a vital role in education, from interested members of the public through to at least undergraduate level. Higher education roles are particularly important in cases where associations have been

forged with universities—universities that today are unlikely to employ taxonomists, and so increasingly rely on museum staff for expert advice and/or tuition. As noted above (Q5B, C), the argument requiring a local "critical mass" of taxonomists does not withstand close inspection; it is extremely important that students in biology and related disciplines are exposed to systematics and taxonomic concepts, but far less important which particular taxonomic group is pursued by that particular researcher in that particular post.

14.2. One can also argue that there is even greater reason to digitise smaller research collections than larger, because (a) it is a more tractable task and (b) they are likely to attract fewer physical visits. However, in this context, digitisation is a double-edged sword, because collections in general, and regional collections in particular, rely heavily on physical visits by specialists to modernise that naming and arrangement of their collections—in other words, for the most creative aspects of curation. In addition, as the staffs in regional institutions diminish in number, dominantly reactive educational and identification roles often detrimentally displace more proactive research initiatives that would increase the academic profile of the institute, particularly where the majority of departments in the institute are not required to pursue academic research.

14.3. In this context, programmes that fund physical visits from international researchers for research and/or skills acquisition have been well-subscribed and successful in their aims, even though inevitably they have preferentially benefited institutions holding the largest collections. The concomitant influx of expertise and modest finances into an organisation, such as that achieved through the long-running (but near-ended), EU-funded SyntheSys programme, can have a disproportionately beneficial impact on the organisations concerned. Such programmes merit continuation beyond SyntheSys, which has received its maximum number of renewals and must now end.

14.4. Just as the larger systematics organisations have primary relationships with different government departments, the smaller organisations rely on a great diversity of sources for their (usually modest) funding. Few of those sources are wholly reliable long-term. Local and regional government often give relatively low priority to such institutes, annually allocating resources that are effectively residual, determined after funding for most other areas of activity has already been decided. And externally funded grants require much effort to obtain, are often relatively small, and are never long-term. It is not surprising that maintaining such organisations and associated collection has proven so challenging over the last two decades, and has led to many casualties.

14.5. However, it is instructive to see what has happened when organisations have made conscious decisions to attempt to revitalise their collections-based research. For example, both Oxford and Cambridge Universities considered donating at least some of their natural history collections to other, even larger collection holders. Instead, decisions were ultimately made to enhance the housing of these collections and to encourage greater activity associated with those collections. In the case of Cambridge, one outcome is the current construction of an ambitious and well-funded plant diversity research institute within the botanic garden. Similarly positive decisions need to be encouraged in other organisations that have less ready access to substantial resources.

15. Q9. *(a) What progress has been made in developing a web-based taxonomy? (b) How do such initiatives fit in with meeting demand for systematics and taxonomy information? (c) How do UK-led initiatives fit in with international initiatives and is there sufficient collaboration?*

15.1. In many ways, the issues facing web-based taxonomy mirror those facing web-based systematics databases in general. Consequently, several of our more detailed answers to Q7A also apply to Q9 and Q10. With regard to Q9A and Q9C, the enthusiasm shown in the 2002 Lords report for web-based taxonomy helped to accelerate an already expanding debate among systematists and their user-groups regarding how best to pursue taxonomy on the web. Several pilot projects have been developed under the auspices of the Planetary Biodiversity Inventory (PBI) in the US and in Europe the Distributed Institute for Taxonomy (EDIT; see 11.1). Once again, the main project operating within the UK is far more modestly funded (by NERC): Creating an e-Taxonomy (CATE). And once again, the corresponding global initiative (in this case, the Encyclopedia of Life; EoL) is experiencing difficulties in attracting sufficient resources and the necessary political momentum.

15.2. Over the last five years, discussions have led to better understanding of the relative usefulness of different categories of data and the standards needed to ensure quality of data. There have also been significant technological advances in how such data are stored and electronically distributed. Static texts, images and keys can readily be mounted, though more interactive systems (eg interactive keys or Wikipedia-style modifiable classifications) remain technically challenging. However, we have now reached a state where theory is arguably stronger than practice. Those standards and prioritisations should be more widely applied, and the taxonomic databases adequately populated. The internationally binding nomenclatural codes need to be revised and

brought closer together in order to better accommodate electronic descriptions, and a very small number of web-based initiatives need to be identified as primary repositories, ideally on a global rather than a national scale. UK initiatives have paid much greater attention to (and often informed) European and global programmes, suggesting that international collaboration is indeed improving (Q9C). It is achieving international agreement that remains the greatest challenge to genuinely global web-based taxonomy.

15.3. Similarly, it is important to recognise the constraints on web-based taxonomy and identification. Although web-based taxonomy can be a boon to utilising taxonomies (notably to rapid identification), its benefits to creating taxonomies (ie description and revision) and curating reference collections are less clear-cut. For example, digitised images of specimens act as a valuable catalogue, informing a remote user which specimens are available in which collections worldwide, but all of the detail needed for rigorous taxonomic revisions is unlikely to be visible; the specimen needs to be physically examined and perhaps sampled (eg for microscopic characters or DNA analyses). The serendipitous finds of relevant specimens in collections, and the improved curation of those collections (eg improved identifications), that result from the physical visit of a specialist to a collection are less readily achieved remotely. Also, interaction among specialists is most effective when they are present in the same room. In short, physical visits and exchanges among taxonomic specialists will continue to remain important; they can be enhanced, but not replaced, by electronic consultation and dissemination.

15.4. The needs of the user communities for systematics data remain largely anecdotal; a thorough survey remains highly desirable. The most up-to-date data were gathered in 2004, in a survey coordinated by the Natural History Museum on behalf of the Global Taxonomy Initiative. The results were undesirably narrow, since (a) they focus on taxonomy rather than the broader discipline of systematics and (b) they consider primarily the need for information to inform biodiversity conservation within the UK. The resulting priorities surprised many systematists, because all of the most commonly reported priorities focused on geographical distribution and/or habitat preference (ie on the composition of particular ecosystems) rather than on taxonomic identification, which appeared relatively low on the prioritised list. This reflects the fact that the British biota is the best understood and best surveyed of any in the world, due to a combination of many factors (small country, relatively low biodiversity due to temperate location and recent glaciations, dense population, unusually large proportion of amateur natural historians, unusually large number of natural history societies). Consequently, identification is less of a barrier to conservation in the UK than inadequate understanding of the species and the ecosystems that they form (here termed the "ecological impediment"). In other words, there is more of a systematic and ecological impediment than a taxonomic impediment in the (arguably unusual) case of the UK. Of course, the taxonomic impediment will become more severe as the number of skilled taxonomists in the UK continues to decline. The taxonomic impediment remains more severe in developing countries, leading to what might be termed the "ecological impediment" to achieving effective social improvement schemes.

16. Q10. *(a) What needs to be done to ensure that web-based taxonomy information is of high quality, reliable and user-friendly?*

16.1. There is only one credible answer to this question; experienced taxonomists need to first set and then monitor, via authoritative peer review, standards for the quality of the data in those databases identified by systematists and user-groups as being most useful. This is in some ways unfortunate because, like identification, monitoring of data quality diverts taxonomists away from actively pursuing the more creative aspects of taxonomy for which they are uniquely qualified, specifically establishing and revising classifications. It emphasises the need for a greater number of experienced taxonomists.

16.2. It has recently been argued that DNA taxonomy (including DNA "bar-coding") can free taxonomy from the need for much of the specialist knowledge inherent in morphological taxonomy. However, apart from paucity of comparative data, the greatest weakness of the databases that underpin DNA-based identification is sequences attributed to the wrong name, because the analyst lacked the skill and/or the determination needed to identify the "yardstick organism" correctly. In many cases, the organisms in question are not deposited in reference collections, precluding other researchers with greater taxonomic knowledge from subsequently checking, and then correcting, the erroneous original identification. Thus, for all but the most primitive groups of organisms (which exhibit comparatively little morphological variation), cross-referencing between morphology-based and DNA-based taxonomies will remain critical. DNA-based taxonomy can only supplement morphology-based taxonomy; it cannot realistically replace it.

17. Q11. *(a) How does the taxonomic community engage with the non-taxonomic community? (b) What role do field studies play?*

17.1. Due in part to the restrictive definition we have employed, the majority of professional systematic biologists currently operating in the UK are not primarily taxonomists. Thus, in our view, taxonomists are most likely to interact with non-taxonomic systematists, notably phylogeneticists, and then with the related academic disciplines of evolutionary biology and ecology. However, we suspect that the motivation behind this question is primarily to explore how much progress has been made ensuring that taxonomic products reach the users of taxonomy, particularly those addressing increasingly high-priority environmental questions.

17.2. In this context, we would argue that there is still considerable room for improvement in how taxonomic data are fed into more applied disciplines. As previously discussed, provision of raw taxonomic data to applied user communities is unlikely to constitute effective delivery. Rather, the significance of the information is likely to require explanation. Thus, in some circumstances, feeding data through other disciplines (phylogenetics, evolutionary biology, ecology) makes good academic use of the data and also adds meaning to the data, thereby presenting the applied user with a more rounded and intelligible understanding. However, placing applied users more in control of their own destiny is likely to accelerate the rate of progress of projects such as climate-change monitoring. The more effort that users make to understand both the concepts and terminology that underlie taxonomy, the more successful collaborations with taxonomists are likely to be, and the more readily information will pass from "producer" to "consumer". Nonetheless, despite the existence of several promising pilot projects, we have noted a relative reluctance on behalf of both producers and consumers to expend much time addressing these issues.

17.3. We now turn to Q11B. Anecdotal evidence suggests that a remarkably high proportion of the current cadre of systematic biologists entered the discipline as a result of a series of connected positive experiences—most commonly, inspiration from particular teachers/lecturers or media popularisers such as David Attenborough, combined with increasing exposure to natural habitats, together with living collections maintained in zoos and/or botanic gardens and non-living collections in natural history museums. Also, the relatively high proportion of amateur natural historians within the UK, who often enter the field as activists in their more mature years but nonetheless make important contributions to biodiversity monitoring (eg via specialist societies to the National Biodiversity Network), also generally gain interest through field experiences. The two groups then constructively interact when professionals volunteer to act as mentors, helping to develop the skills of the amateurs. Field experience is vital across a far wider range of natural history disciplines than systematic biology, including ecology, conservation and various environmental topics. It also helps researchers to comprehend the importance of rigorous experimental design.

17.4. In addition, as was recently noted in a policy paper issued by the Biosciences Federation, laboratory studies of whole organisms (such as dissections and behavioural studies) have suffered reductions of similar magnitude to field studies, and remain equally important if students are to develop an adequate understanding of organismal biology and natural history.

17.5. The Association is convinced that the radical reduction over the past 25 years in fieldwork (in its broadest sense) and in organismally-oriented laboratory studies, particularly in schools (GCSE/A-level) and undergraduate courses, does not reflect reduction in the inherent interest shown by students in these activities. Rather, it reflects a combination of their systematic elimination for curricula and the increasing unwillingness of teachers/ lecturers to invest time in such enterprises in the face of the cost implications and increasingly constraining health and safety regulations. These practical constraints would most likely be overridden if field studies figured more prominently in the relevant curricula, which would also assist the surviving field studies centres.

Skills base

18. Q12. *(a) What are the numbers and ages of trained taxonomists working in UK universities and other organisations?*

18.1. Again, precise figures are badly needed in order to give definitive answers to this and similar questions. However, the anecdotal evidence is sufficiently strong to give a clear overview. We are confident that the number of researcher (and curator) hours being devoted to taxonomic activity have declined greatly throughout the last half-century, and this decline is ongoing. This is partly because of the number of practising taxonomists in the UK has steadily fallen, but also for a reason that is rarely discussed—the remaining taxonomists (particularly those in employment) are obliged to spend decreasing amounts of their time actively engaged in taxonomic research. Over the last half-century we have seen the focus of the UK's professional

taxonomic activity shift first from the universities and wide range of national and local-government-sponsored institutes to a small number of government-sponsored institutes (notably the Natural History Museum and the Royal Botanic Gardens of Kew and Edinburgh). Even here, overall taxonomic effort has declined (see evidence presented by the Linnean Society). At present, the relative role of researchers not in paid employment is increasing, as the dwindling number of remaining taxonomists age and retire (admittedly, in many cases they remain active long after retirement).

18.2. The experiences of recently retired taxonomists help to illustrate the second cause of the reduction of overall taxonomic activity in the UK. Very often, the productivity of taxonomists substantially *increases* upon their retirement. This reflects the diversion of skilled taxonomists time away from taxonomic description and revision towards a host of other activities. Decreases in curatorial staff mean that taxonomists generally have inadequate staff support and must curate their own specimens. They are often responsible for various dissemination initiatives such as specimen digitising and data-basing. The electronic age means that they are far more likely to spend large amounts of time reacting to identification enquiries (identification is an important activity, but it does not in itself directly progress the science of taxonomy). If they are fortunate they may still be able to contribute to initiatives designed to train taxonomists. The acquisition and subsequent utilisation of specimens have been rendered far more bureaucratic by a raft of national and especially international legislation, diverting yet more time away from hands-on research. A dedicated researcher is likely to be spending increasing amounts of time preparing funding proposals, and to be interacting far more directly and deeply with key user groups. He or she is also likely to be spending more time writing reports, summaries and overviews to assist those user groups—an important task, but yet another diversion of time of the skilled taxonomist away from conducting primary research. Mirroring a trend common in modern life, the relationship between manufacturing and retailing (in this case, of taxonomic information) has become seriously imbalanced in favour of the latter, which is where the easy profits (and kudos) presently lie.

18.3. In summary, the Association believes that the single most informative key measure of taxonomic activity in the UK should be the cumulative number of person hours spent directly pursuing taxonomic description and revision. We are confident that this figure, if correctly assessed, would be shockingly low. There are two obvious remedial measures to the current situation: (a) return the remaining taxonomists to full-time research activity by appointing a new generation of interstitial staff members whose job is to translate the outputs of the taxonomy for the various user-groups or (b) to accept that the role of a modern taxonomist now includes all of these additional "epi-taxonomic" activities and thus add to the present taxonomic cadre a new generation of more rounded and integrated taxonomists, specifically directed to interact with other systematists and with the various user groups. The Association believes that this second solution would be more effective, but emphasises that this new generation of taxonomists must be an additional resource, rather than falling into the trap of previous remedies by simply reallocating existing resources to fill perceived short-term needs. It is essential that any solution should be based on stable, long-term increases in resources available to systematic biology.

19. Q13. *(a) What is the state of training and education in systematics and taxonomy? (b) Are there any gaps in capacity? (c) Is the number of taxonomists in post, and those that are being trained, sufficient to meet current and future needs across all taxonomic subject areas?*

19.1. Over the past two decades, systematic biology has almost been eliminated from schools and undergraduate curricula in the UK (despite a recent marginal increase in the natural history content of the national curriculum). This has been part of a broader decline in the educational status of organismal biology and natural history in general, which has also strongly negatively affected previously popular topics such as ecology and evolutionary biology. Broadening consideration even more, it is also consistent with a move of undergraduates away from traditional subjects such as biology, zoology, botany, microbiology and ecology towards "softer" interdisciplinary degrees such as sports science and food science. Concerns regarding costs (increasingly passed onto the students rather than borne by the school) and health and safety constraints, have together greatly reduced the exposure of both school and undergraduate students to laboratory based organismal practicals (eg dissection and behavioural studies) and to excursions for both fieldwork in natural habitats and visits to natural history collections in museums and botanic gardens—experiences that began the careers of many of the present cadre of systematists. Also, in the rare cases where some systematics is made available at the schools or undergraduate level, it is likely to be taught by someone with little knowledge or experience of the discipline. These declines seem bizarre in the light of the enthusiasm for natural history still clearly shown by the UK population for natural history, typically inspired primarily by media figures such as David Attenborough.

19.2. A more positive account can be given of the availability in the UK of Masters-level training in systematics, where several well-respected courses are available. However, the level of research council support for these courses is limited, and most of these courses currently rely heavily on students who originate from outside the UK. Also, the paucity of previous exposure of the students to systematic biology, means that an undesirably large portion of these typically one-year courses must be spent teaching basic knowledge that previously the students would already have possessed. The situation worsens again at the doctoral level, where positions are uncommon for both stand-alone doctoral grants and those linked to larger-scale research grants. In particular, for many years there have been exceptionally few doctoral students pursuing projects that are primarily taxonomic. This situation extends to the postdoctoral level, where we suspect that the few systematics-oriented researchers experience a larger percentage of researchers either transferring to other research fields or leaving science altogether than most other research disciplines. The near-elimination of taxonomy from the university sector means that it is extremely difficult to find the required university supervisor for any erstwhile doctoral student. We also suspect that, for the lucky few who eventually obtain "permanent" positions, the period between obtaining their doctorate and their first permanent job is unusually long.

19.3. We also note that other, more "vocational" routes into a systematics career, passing though a phase of employment as a technician or curator, have become less effective. This has occurred partly because there are fewer professional technicians and curators and partly because employment hierarchies within organisations have become more rigid, permitting far less fluidity of movement between these roles and research positions as individuals gain skills and maturity.

19.4. We are confident that there is already a profound taxonomic skills deficit in the UK. However, because of the long periods of time required to generate a skilled systematist via the "informal apprenticeship" (school for inspiration > undergraduate for background knowledge > masters for specialist knowledge > doctorate for research experience), the effects of the deleterious trends listed above will take a long time to become fully apparent. However, we also note that any attempts to remedy the decline will similarly require long periods to take effect.

19.5. Fortunately, tuition in systematics in general and taxonomy in particular is much stronger in many other countries, so that the UK's "gaps in capacity" can usually be filled, albeit not always satisfactorily. The majority of postdoctoral and permanent research posts in systematic biology advertised in the UK are now being filled by applicants who have been trained abroad (eg North America, Australasia, Scandinavia, and increasingly eastern Europe). This outcome is not intrinsically problematic, though some applicants lack the conceptual rigour desired by many employers (and collaborators), and others are sufficiently shocked by the disparity between the cost of living and academic salaries in the UK that they either reject the initial offer or accept but remain in post for a disappointingly short period.

19.6. Given the above observations, the Association believes that it is highly desirable that Britain generates a stronger pool of systematics researchers, capitalising on the globally recognised strength of its research universities, and on the exceptional expertise and collections available in its major systematics institutes. Specifically, we strongly advocate rebuilding the UK's "informal apprenticeship" in systematics and biodiversity, preferably from the bottom up: (a) Organismal biology and systematics need to be enhanced in secondary schools, preferably via modifications to the national curriculum; (b) Increased use of field studies by schools should be strongly encouraged, deploying not only knowledge-based arguments but also criteria favoured by the current government, such as remedying social exclusion; (c) Increased exposure to systematics in schools should lead to increased demand for specialist undergraduate courses in at least some higher education institutes (ideally, systematics should be made a core element of all biological bachelors degrees); (d) This undergraduate demand would in turn require restoration of some of the lectureships in systematics that have been lost over the last two decades—a goal that merits especially high priority; (e) Government should encourage selected research universities to specialise in systematics and biodiversity. At least some universities should operate in partnership with the major research institutes and/or possess their own actively curated natural history collections; (f) Organisations such as the Systematics Association and Linnean Society should work alongside the universities and research institutes to develop up-to-date teaching materials and to initiate summer schools and/or workshops for individuals who wish to enhance their systematics knowledge.

19.7. We suspect that reinvigorating systematics teaching would have a beneficial effect in related areas currently under-subscribed by students, such as ecology and evolutionary biology. This outcome is especially desirable if, as we believe, significantly increased numbers of skilled researchers are going to be required to address high-profile, long-term challenges such as sustainability and climate change.

20. *Overarching recommendations*

20.1. *Recommendation 1: Establish a new independent body to coordinate UK systematics activities.*—Neither the UK government nor the systematics community has made significant efforts to respond positively to Recommendation 8—that Defra should coordinate the establishment of a body to give leadership to the UK's systematics community, identifying weaknesses and priorities, and campaigning for increased resourcing. In theory this remains a highly relevant and desirable recommendation. However, such a body, named the *UK Systematics Forum*, existed from 1990 to 1998 (led by a past-President of the Association, Prof. Stephen Blackmore). The Forum became defunct as a result of a lack of bipartite support in general and of funds in particular. Steps would therefore need to be taken to ensure that such a fate did not befall any future replacement body. This would require inducements (ideally, both carrots and sticks) to encourage the major systematics institutes and organisations, and the major user-groups of systematic information, to take the initiative seriously by genuinely committing to the goal of developing a shared strategy. It would be important that this body was seen to be balanced and objective, which suggests that an informed, yet neutral, coordinator is required. The Association would be willing to play that role, provided that (a) adequate, long-term resources were made available to manage the steering group, and (b) the steering group had considerable influence over the allocation of resources, and the establishment of high-level policy, within the UK systematics community.

20.2. *Recommendation 2: Conduct a thorough and inclusive survey of the current status of the UK systematics community and the requirements of its user communities.*—One of the first priorities for this new coordinatory body should be to rapidly, but thoroughly survey the UK systematics base, so that reviews such as the present HoL inquiry need no longer rely largely on anecdotal evidence to underpin their deliberations. An appropriate level of detail would be required, including breakdowns on time spent by each systematist on different activities and the resources used in undertaking those activities.

20.3. The systematics community could have shown more prescience and proactivity in responding to policy-driven priorities of the UK government. Although we continue to believe that the UK systematics community should have ultimate control of its own destiny, it would equally be inappropriate for it to set its own priorities without consideration of (a) the priorities of potential sources of substantial funding and (b) the needs of its many major user groups. Improved dialogues are highly desirable, as many systematists remain ignorant of the needs of their user groups, and user groups often fail to understand the constraints on systematics research, consequently making unreasonable demands on systematists. In addition, some funding bodies and policy makers have failed to make the direct connection between systematics research and environmental monitoring. Until resourcing improves, there is limited motivation for pursuing recommendations 4–7:

20.4. *Recommendation 3: Undertake a detailed consultation with all current and potential substantial funders of systematics and biodiversity research.*

20.5. *Recommendation 4: Agree a prioritised list of goals for the UK systematics community, and agree the best methods of achieving those goals.*

20.6. *Recommendation 5: Recognising the global success of "Genbank", agree a prioritised list of databases and a set of inducements to encourage systematists to routinely deposit other categories of relevant information in those preferred databases.*—The UK should better capitalise on the lead it has previously shown, in establishing international agreements for data standards, and for strongly encouraging deposition of relevant data in a very limited range of internationally accessible databases, mirroring Genbank. It could also show leadership in modernising nomenclatural practises and registration, and the fact that many professional journals are based in the UK could help to incentivise researchers to populate favoured databases. However, our global influence in these areas has declined as a consequence of the apparent unwillingness of UK-based funding bodies to elevate successful pilot schemes into fully-fledged, long-term programmes.

20.7. The most obvious funding trend in the UK in recent years has been to concentrate resources in a smaller number of larger research grants. Until recently, there has been no sign that these grants could be awarded for unusually long periods. It has become abundantly clear to us that systematic biology needs a mixed economy of funding. The Small and "fairly small" grants schemes run jointly by the Systematics Association and the Linnean Society are extraordinarily strongly subscribed with high-quality proposals. Moreover, 12 years experience of the Small Grants scheme strongly suggests that it has been cost-effective. We would therefore like to see funding bodies take such schemes more seriously. In theory, there is no corresponding problem with the availability of medium to large-sized grants, since these have become standard. The problem here for systematists in general, ands taxonomists in particular, is acquiring such grants. Perhaps the most important battle-ground is at the most expensive end of the spectrum. Rather than see large grants awarded to consortia of many researchers over short periods, we would like to see large grants awarded to a smaller number of researchers over a longer time-scale—one more compatible with both taxonomic description and practical applications such as climate-change monitoring.

20.8 Recognising the ongoing reluctance of major funding bodies to allocate resources for periods of more than five years hence, we suggest that the government should encourage "joined-up funding", where multiple funding bodies each take partial responsibility for maintaining key long-term research programmes.

20.9. *Recommendation 6: Develop a mixed economy for funding that spans the full possible range from small, short-term awards to very large, long-term programmes.*

20.10. *Recommendation 7: Coordinate funds from multiple sources in order to guarantee funding for prioritised long-term research goals over unusually long time-scales.*

20.11. The Association supports the consensus view that, within the UK's systematic biology community, the most serious damage sustained over the period of the four HoL reviews has been to taxonomy. This reflects three main causes; (a) The RAE-mediated near-elimination of taxonomists from the university sector in the UK, due to low overhead potential and producing outputs of limited immediate impact; (b) The reduction in other long-term users of taxonomic data for identification purposes in the public sector, as a result of over-emphasis in addressing narrowly focused, tractable questions through short-term funding; (c) The diversion of time among the few remaining qualified taxonomists away from descriptive taxonomy towards a rapidly expanding range of other responsibilities (eg identification and education/PUS, together with increased bureaucratic burdens imposed by international agreements such as CBD/CITES and the Freedom of Information Act) or the movement of taxonomists wholly into other, more lucrative research fields. The pyramid of activity appears to have become inverted, with fewer researchers generating novel data than recycling existing data. These observations lead to a further series of recommendations (8–10), which are a logical sequence that collectively is designed to redress all three of these negative effects on taxonomy.

20.12. *Recommendation 8: Establish a new national Institute of Biodiversity Research, requiring a substantial number of permanent salaried taxonomic positions to be inaugurated within several pre-existing systematics institutes, biodiversity monitoring institutes and research universities.*—Appointees would pursue previously prioritised, and interrelated, research programmes, some providing the descriptive taxonomy "pull" and others the applied taxonomy "pull", and with input from collaborators in other disciplines through the establishment of "taxonomic colleges". Ideally, this scheme would be funded by the Department of Universities, Innovation and Skills (DUIS) and administered by joint research councils (NERC, BBSRC and perhaps EPSRC). Much of the initial focus would most likely be long-term monitoring, particularly of climate change. It would require careful prioritisation of appropriate habitats and taxonomic groups. We note that experience suggests that this scheme would not be cost-effective, if only short-term or medium-term funding was provided.

20.13. *Recommendation 9: Assign the majority of these new taxonomic posts to the university sector.*—Admittedly, this guideline is hardly a unanimous view of the Association's council. However, university positions should have maximum positive effect because they will reinvigorate university undergraduate teaching in systematics, and will provide; essential university-based supervisors for postgraduates studying taxonomy (thus revitalising the "informal apprenticeship" in taxonomy); university-based co-applicants for inter-institutional funding proposals in systematics; foci for local/regional natural history societies and, where still in existence, for natural history collections.

20.14. *Recommendation 10: Apply to these new university appointees a set of RAE-style assessment criteria specifically optimised for performance in the taxonomic field.*—Protect these taxonomic researchers from the profoundly negative effect of the RAE (or, more accurately, its successor, the REF) by either (a) placing the relevant academics wholly outside the auspices of the REF or (b) greatly diversifying the criteria required by the REF, such that the standard outputs of a descriptive taxonomist (long-lived and most likely increasingly electronic) would allow systematists to be put forward for the REF while benefiting, rather than prejudicing the well-being of, their host department. In other words, the REF need to be revised to be more flexible, and in particular to better fit the needs of long-term research.

20.13. Lastly, we offer two recommendations (11, 12) designed to better channel the ongoing enthusiasm shown for organismal biology by schoolchildren, retired and other "amateur" natural historians:

20.14. *Recommendation 11. Introduce more organismal biology into the national curriculum, and restore previous levels of laboratory experimentation and field excursions in schools and universities.*—The interests of both the country and its citizens will be best served by relieving some of the fiscal and bureaucratic pressures that have, in practice by stealth, systematically suppressed the innate love of Britons for the study of their natural history. This will in turn revitalise the flow of natural historians through the UK's educational infrastructure, eventually (after a considerable lag period) restoring the "informal apprenticeship" that once generated the world's best taxonomists. Achieving this goal would require only modest increases in funding for school-based science and a pragmatic reappraisal of the relevant Health and Safety regulations.

20.15. *Recommendation 12. Provide increased resources and improved coordination for organisations that encourage the acquisition and constructive use of taxonomic skills by amateur natural historians.*—Although organisations dominated by amateur natural historians are now responsible for the bulk of biodiversity recording conducted in the British Isles, professionals play key roles in providing training (eg through specialist workshops) and, on occasion, leadership. However, the combination of increased workloads and decreased credit for such work from most employers means that it is becoming increasingly difficult for employed researchers to fill these key roles; clearer recognition is badly needed. Nationwide recording and data-dissemination schemes, notably the National Biodiversity Network (NBN), have long been chronically under-funded, as have most of the specialist societies that generously supply NBN with original data. Papers and articles generated by amateurs (and by poorly funded professionals) require subsidies against, or preferably absolution from, the substantial costs of the rapidly expanding "author-pays" open-access concept of publishing. An even greater contribution from government would be to properly acknowledge the major contributions made by amateurs to biodiversity assessment, by (a) formally recognising those who have acquired appropriate vocational qualifications as para-taxonomists and (b) providing a central fund to cover their travel and subsistence.

20.16. Most importantly, none of the above recommendations should be implemented by reallocating the meagre resources already vouchsafed to the systematics community.

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3 February 2008

Memorandum by University College London

TAXONOMY AND AQUATIC ENVIRONMENTAL CHANGE

Taxonomy is fundamental to environmental change science in two principal ways, (i) using organisms as biological indicators; and (ii) more directly in biodiversity studies

At UCL we have been especially interested in the use of *diatoms as indicators of water quality.*

Diatoms

Diatoms are a very distinctive group of algae. They occur in all kinds of aquatic environment in great abundance and diversity and they are especially sensitive to changes in water chemistry. Because they have a resistant siliceous cell wall, they are preserved in lake sediments and can be used, not only to track contemporary water quality changes, but also to reconstruct past water quality over previous decades and centuries.

In this context we have been and are concerned especially with problems of;

1. *eutrophication* of surface waters through waste-water discharge and fertiliser runoff from agricultural land;
2. surface water *acidification* as a result of acid rain;
3. impacts of *climate change* on aquatic ecosystems

Surface water acidification: an example

Taking the example of surface water acidification we were able to show from diatom analysis of lake sediments that acidification in Britain began in the mid 19th century and was indeed caused by acid deposition from the combustion of fossil fuels. Our results helped to persuade the Thatcher government that Britain needed to sign up to the various UNECE and EU protocols and directives and agree to reduce emissions of sulphur and nitrogen gases.

For the last 20 years on behalf of Defra we have been monitoring lakes and streams across the UK to assess the extent to which surface waters in the UK are recovering from acidification (but see below). We are now especially interested in whether climate change may influence the recovery process.

This work has depended on (i) establishing a rigorous high resolution taxonomy for diatoms found in upland waters of the UK; and (ii) matching the distribution of diatoms across the UK (and adjacent parts of North-west Europe) with associated environmental data to define the indicator value of individual species.

The role of taxonomy

The taxonomic work involves:

1. Field sampling from different streams and lakes
2. High magnification inspection of the samples using light microscopy and digital photography
3. Identification of unknown species using reference literature and type material in museums, especially the NHM
4. Harmonisation of taxonomies between research groups using taxonomic quality control techniques ("blind" counting, microscope workshops).
5. Cataloguing decisions (using the web) and archiving slides (ideally with copies at the NHM).
6. Developing statistical models to describe the relationship between species distribution and environmental variables (eg pH, phosphorus).

Development in diatom taxonomy

Considerable progress has been made over the last 30 years, in particular:

1. Most diatom taxa in N.W.Europe are now well described and published;
2. We have built large databases, some available on the internet, that describe the distribution (mainly with respect to water chemistry) of most taxa
3. European scale research projects (eg EDDI, European Diatom Database Information System) have been successful in harmonising taxonomy (but not nomenclature) between national research communities
4. Diatoms are now used routinely by environment agencies across Europe as environmental (mainly water quality) indicators, facilitated by electronically available identification keys
5. The NHM has been able to maintain staffing in the diatom section, despite threats of closure in the 1980s. It sustains it's own research programme and curates the worlds largest collection of diatom slides
6. We (UCL) have maintained an international diatom analysis training programme for over 20 years and conduct workshops in the UK for Environment Agency staff.

Future concerns

Despite the progress there are also worrying trends. In particular there has been an overall decline in the *training of freshwater biologists* and a related decrease in the taxonomic competence of staff employed by environment agencies and related bodies. This applies not just to diatom analysis but also to other aspects of freshwater biology.

Assessing the ecological status of surface waters using biological indicators (diatoms, phytoplankton, aquatic macro-invertebrates, aquatic plants) is central to the EU Water Framework Directive, and the need for taxonomic skills in these biological groups is growing at a time when supply is decreasing. High quality *phytoplankton* identification skills are in especially short supply.

Moreover, there is increasing concern about global biodiversity loss (especially acute in freshwaters) and the future role of climate change in modifiying the structure and functioning of aquatic ecosystems. Taxonomic skills underpin both the *research and surveillance* needed to assess the impact of climate change in future, both in the use of organisms as indicators of climate change and conversely in assessments of biodiversity loss. Ironically, and as an aside, Defra have this year decided to make massive reductions to the national programme (noted above) for monitoring the ecology of upland waters in the UK. The programme has now been running for 20 years and the cuts have been made at a time when the network is arguably most needed.

We coordinate a major 36 partner EU project on "The impact of climate change on European freshwater ecosystems". As part of the project a German team is leading a major initiative to develop a new system of freshwater biological indicators for *monitoring the impacts of climate change.* In due course this system and related results from the project will be built into the Water Framework Directive allowing Environment Agencies across Europe to improve their monitoring methods. Implementation, however, will depend on the ability of staff in the field and laboratory to identify organisms correctly.

17 March 2008

Memorandum from the Species 2000 Catalogue of Life Secretariat based in the University of Reading

Species 2000 Catalogue of Life is a recent development that may not be well known to members of the HoL Science & Technology Committee. It also raises some public service and resource issues that may be of interest to the Committee.

In the evidence given below we use responses to Questions 1 and 2 to introduce the programme, and Question 4 to lay out the resource issues that the programme raises in relation to funding and sustainability.

	Acronyms used in this evidence
BBSRC	Biotechnology and Biological Sciences Research Council, Swindon, UK
CATE	Creating a Taxonomic E-science, NHM & RBG Kew, UK.
CBD	UN Convention on Biological Diversity, Montreal, Canada.
CBOL	Consortium for the Barcode of Life, Smithsonian Institution, Washington DC, USA.
CODATA	The Committee on Data for Science & Technology, Paris, France.
EC	European Commission, Brussels, Belgium.
EoL	Encyclopedia of Life, Smithsonian Institution, Washington DC, USA..
GBIF	Global Biodiversity Information Facility, Copenhagen, Denmark.
GEF	Global Environment Facility, Washington DC, USA.
ITIS	Integrated Taxonomic Information System, Smithsonian Institution, Washington DC, USA.
IUBS	International Union of Biological Science, Paris, France.
IUCN	The World Conservation Union, Gland, Switzerland.
NERC	Natural Environment Research Council, Swindon, UK.
NHM	Natural History Museum, London, UK.
NIES	National Institute for Environmental Studies, Tsukuba, Japan.
RBG Kew	Royal Botanic Gardens, Kew, UK
UN	United Nations, New York, USA.

Question 1: *Current research priorities, and barriers to delivery.*

A recent research development based in the UK and involving all of the major systematic institutions, is the Species 2000 Catalogue of Life programme, with its Secretariat at the University of Reading.

The electronic Catalogue of Life (www.catalogueoflife.org) summarises the output from fundamental research, and synthesises a simple usable standardised view of the taxonomy of all organisms. The programme has developed more rapidly than could have been predicted (it celebrated reaching one million species in its 2007 edition), and has been taken up as the primary taxonomic backbone by large numbers of national, regional, and global organisations. It provides the taxonomic backbone to the GBIF and EoL portals, and is used as a taxonomic authority file by CBOL, GenBank, IUCN and many national and regional biodiversity portals, as well as receiving very substantial usage from individuals using the website and electronic products.

Clearly the Catalogue of Life is not itself conducting primary taxonomic research, but what it is researching is the platform and product needed to deliver taxonomic knowledge to users in the outside community, either through its own services, or as an infrastructure to support other portal services such as GBIF. It uses a distributed model illustrated in Figure 1. In particular:

(i) it provides a coherent and authoritative platform through which taxonomic results (from the UK and worldwide) can be delivered to certain significant classes of users; and

(ii) the process of locating quality taxonomic coverage for all groups of organisms (plants, animals, fungi, and microbes including viruses) is decidedly helpful to the research community in that it stimulates the continuous enhancement of supplier taxon databases and it highlights the very significant gaps and shortcomings.

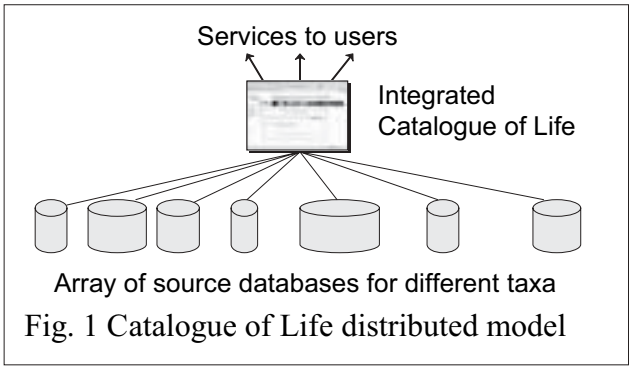


Fig. 1 Catalogue of Life distributed model

Fig. 1 Catalogue of Life distributed model.

The Catalogue of Life functions as a distributed network using peer review to select taxonomic sectors from the databases of different organisations. A skilled team at Reading connects, snips and pastes the components sectors in a complex operation to synthesise both the species checklist and the taxonomic hierarchy. The 2008 edition will be published in April, containing 1.1 million species supplied by 52 taxonomic databases around the world. NHM, RBG Kew, and CABI are among the largest partners and contributors in the UK, but smaller UK components come from the N. Museum of Wales, University of Reading, University of Oxford, private suppliers, Zoological record (Thomson Zoological), and RBG Edinburgh may join the programme shortly.

The significance of this programme may be judged from four decisions of the UN Convention on Biological Diversity at its Conference of the Parties in Curitiba, Brazil in March 2006, given below:

UN Convention on Biological Diversity

CoP 8, Decision VIII/3

Global Taxonomy Initiative: in depth review of the implementation of the programme of work for the Global Taxonomy Initiative.

The Conference of the Parties

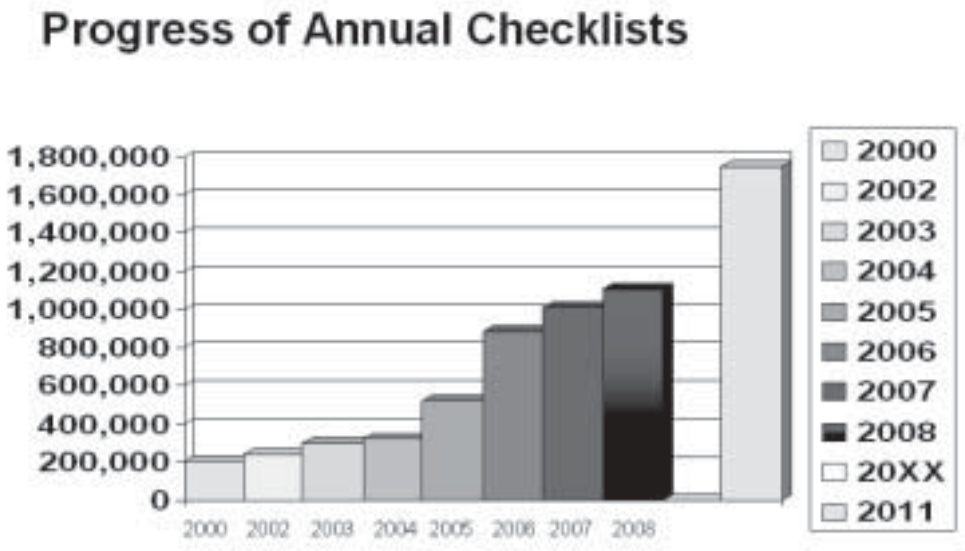
2. *Notes with appreciation* the contributions to the Global Taxonomy Initiative made by BioNET-INTERNATIONAL, the Global Biodiversity Information Facility, CABI International, the Integrated Taxonomic Information System (ITIS) and Species 2000 and *encourages* these organisations and initiatives to continue contributing to the implementation of the Convention.

6. *Recalling* target 1 of the Global Strategy for Plant Conservation ("A widely accessible working list of known plant species, as a step towards a complete world flora"), *welcomes* the progress made by Species 2000, the Royal Botanic Gardens, Kew, and collaborating partners towards the achievement of this target.

7. *Adopts* as a target under operational objective 3 of the programme of work for the Global Taxonomy Initiative "A widely accessible checklist of known species, as a step towards a global register of plants, animals, microorganisms and other organisms", bearing in mind the urgent need for timely provision of scientific names of organisms to support implementation of work under the Convention on Biological Diversity.

Requests the Executive Secretary to:

11.c. Continue collaborating with existing initiatives, including the Global Biodiversity Information Facility, the Integrated Taxonomic Information System and Species 2000, to develop the Electronic Catalogue of Names of Known Organisms and the Catalogue of Life.



Significant barriers to delivering the Catalogue of Life priorities are these:

(i) Major gaps in taxon database coverage, in many cases caused by true gaps in taxonomic knowledge.

The portion of the curve marked "D" in Figure 2 represents the fraction of the world's known species presently not available to the Catalogue of Life, either because patchy knowledge has not been assembled into a coherent taxonomic treatment, or because of true gaps in knowledge.

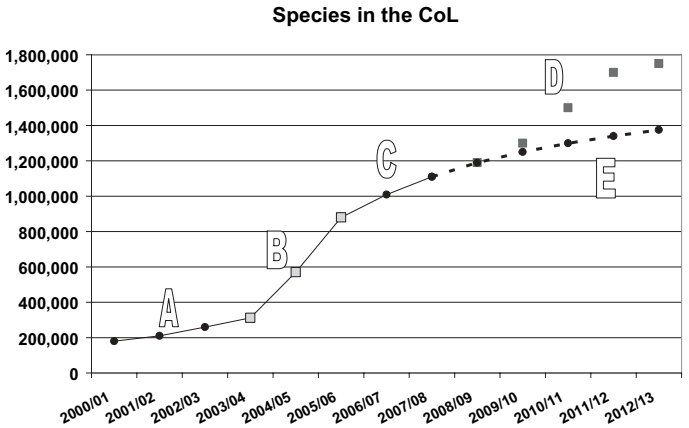


Fig. 2 Growth of coverage: A,B & C- to the present (B – increase with EC grant); D & E– projected (D with new tools, E without).

Fig. 2 Growth of coverage: A,B & C- to the present (B—increase with EC grant); D & E—projected (D with new tools, E without).

(ii) Resource limitations. Species 2000 and its US partner ITIS have demonstrated not only "proof of concept", but also that half of the task has been delivered in six years. However the operation is now

resource-limited, despite calls by GBIF and the CBD to accelerate, for instance for possible "functional completion" by 2012.

A significant start to the project came from the SPICE and LITCHI projects funded by BBSRC in the 1990's, but since then the principal resources for this programme have come largely from international sources—the EC, Japanese Government, GBIF, EoL, IUBS, CBOL and CODATA, although there is again discussion with BBSRC on UK funding. Of course, the UK taxonomic institutions make significant resource contributions to the programme by providing direct access to their taxon databases.

Question 2: *the Role of Taxonomy*

Since the last HoL review, there has been a marked change in appreciation of the role taxonomy plays in many if not all biodiversity actions. Taxonomy is now valued as the key infrastructure for two reasons.

(i) It permits the globalisation of biodiversity actions such as monitoring, regulation, biosecurity and modelling.

(ii) It provides the indexing management for biodiversity on the Internet. (The analogy is that taxonomy used to provide the "phone-book", but now it provides the "telephone exchange"—enabling access to the right data at the right time, all over the world.)

This central role for taxonomy is acknowledged in the BBSRC document "The Role of BBSRC in Biodiversity Research" (see p.7 *"development of an electronic catalogue of species names, as the means by which all biological data can be related within a coherent framework")*

The Species 2000 Catalogue of Life provides the necessary standardisation for international and interdisciplinary communication.

As examples that impact on conservation and global change:

(i) A precise Amphibia taxonomy has enabled the global conservation assessments of Amphibians, to be made comparable around the world. From the assembled data it has then been possible to provide precise quantification of the declines of certain species around the world.

(ii) An electronic synonymic catalogue of organisms (such as the Catalogue of Life), enables the selection of specimen data points from around the world (such as via GBIF) for use in bioclimatic envelope modelling. These models can then contribute to predicting species movements under climate change scenarios, and form the basis of many biodiversity prediction systems. The use of an electronic synonymic catalogue such as the Catalogue of Life, or the copy in the GBIF portal, permits synonymic amplification of the search (ie to search under synonyms as well as accepted names) so that specimens of each species can be located even in countries and in datasets where these species are listed under different scientific names. Given that many modellers are concerned with not single species, but large sets of species, the ability to automatically use synonymic amplification in the process of locating suitable data points adds significantly to the success of such searches, and the analysis of data assembled.

Question 4: *the Level of Funding*

The plan to extend the Catalogue of Life to all known species on Earth (referred to as "functional completion") and to make the continuous development a sustainable community-wide process involves four layers of resources:

(i) The ongoing taxonomic enhancement of existing taxon databases based in the UK. The cost is of the order of magnitude 500,000 spp. X £2 per year = £5 million over 5 years. There are presently 10 participating databases in the UK (largely at NHM, RBG Kew and CABI) supplying approximately 450,000 species. The number of databases and the number of species is likely to rise over the period. If it was to double—then £2 million p.a.

There is a similar order of magnitude of cost to the 20 other countries supplying the remaining 42 presently participating databases—and again if the Catalogue is to approach completion, the scale of species to be supplied may double.

(ii) The central processing facility, secretariat, and global community programme of Species 2000 has to be maintained, including a new generation of computing tools that will allow further automation of the production process over the coming 5 year period and including the ongoing development of the global programme. This is estimated at £700,000 p.a. or £3.5 million over 5 years.

(iii) Species 2000 and the national institutions are in discussion with BBSRC over a substantial research proposal to test new informatics techniques for creating proto-GSD databases for the missing groups, and to use these to close the gaps. This proposal also proposes the enlargement of the secretariat with Taxon Teams at the national institutions to target how to complete each of the major groups.

(iv) If the proto-GSD and gap-filling exercise leads to the establishment of further taxon databases supplying Species 2000 in the UK, then there will be associated costs during its set-up period (that is before the steady state of ongoing taxonomic enhancement sets in) in the order of magnitude of £500,000 over 5 years for each.

Finally, it is tempting to suggest that these costs can be borne internationally or through the UN or GEF. This programme already has very substantial support in many nations around the world, but it would be extremely difficult if not impossible to gain UN/GEF support as a UK-based programme. This is why we raise the issue as a key component arising out of the international role of the taxonomic community in the UK.

Question 5: *International Collaboration*

In our own area of activity (Catalogue of Life taxon databases) there is already very extensive international collaboration and international funding. In general the international funding has been more extensive than that in the UK.

(i) Species 2000 has Directors from the UK and 4 countries (Australia, Brazil, Canada, The Netherlands), its Team from the UK and 11 countries (Australia, Brazil, Canada, USA, The Netherlands, France, India, Belgium, New Zealand, China and Japan), and it's supplier databases from the UK and 16 countries (Ireland, Austria, USA, Japan, The Netherlands, Italy, France, Germany, Australia, Russia, Spain, Israel, Belgium, Taiwan, Poland and the Philippines).

(ii) Species 2000 has received its largest financial contributions from the EC, and from GBIF, as well as smaller amounts from IUBS, CODATA, EOL, ITIS, NIES and CBOL—all international organisations, some receiving contributions from the UK.

(iii) Significant sums have been committed to further components of the Catalogue of Life programme in the USA (via ITIS), in China, in Japan, and in New Zealand.

Question 9: *Web-based Taxonomy*

The phrase "web-based taxonomy" is used in two senses—to mean taxonomic revision process done with web-tools (something that is only just starting, as in the NERC CATE project) and to mean the presentation of completed taxonomy on the web (that is now well established).

Species 2000 Catalogue of Life is a leader in the latter process—focusing especially on taxonomic indexing, an important component for data-sharing institutions such as GBIF, SpeciesBase and EoL. However we also anticipate that revisions generated on the web by the former process may also contribute to the Catalogue of Life.

4 February 2008

Examination of Witnesses

Witnesses: Professor David Cutler, President, Dr Sandra Knapp, Botanical Secretary, The Linnean Society, and Professor Richard Bateman, President, The Systematics Association, examined.

Q127 ***Chairman:*** Thank you very much indeed for your written evidence and for the time you are willing to give us in person in some cases for the second time. We appreciate that very much indeed. Can I remind you that we are on air and that the proceedings may well be broadcast or webcast, so what you say will be available to the wider world directly. May I also invite you initially to state who you are so that this can be recorded for the record and indicate what allegiance or affiliation you have.
Professor Cutler: I am David Cutler. I am the President of The Linnean Society.
Professor Bateman: Richard Bateman, President of The Systematics Association.
Dr Knapp: I am Sandra Knapp and I am the Botanical Secretary of The Linnean Society.

Q128 ***Chairman:*** Thank you very much indeed. The evidence that we are receiving and certainly the comments that we are receiving is about a continuing decline in taxonomy in the UK. Can you tell the Committee whether this is reflected in your

own organisation, whether in the membership or the amount of time or resource that is available to you?
Professor Cutler: Interestingly enough, last year when we were celebrating a tercentenary of the birth of Linnaeus interest in taxonomy was obviously revived in the Society and we actually had 121 new members. I think this is indicative of the interest that people can find in taxonomy. Over the past ten years, because we do not only have taxonomists, and have a wide range of people in the Society with a range of interests, our membership numbers have remained more or less constant.

Q129 ***Chairman:*** We cannot arrange an anniversary for you every year, of course! Are there any other factors than that?
Professor Cutler: I think there are still taxonomists who are not Fellows of the Society, but it may be that the Society is now doing things that would be useful in coordinating the taxonomic world.
Dr Knapp: One important thing about The Linnean Society is that it is devoted to the study of natural history, which is much larger than taxonomy. Taxonomy only forms a part of what The Linnean Society does. We found that people were very interested in meetings about taxonomy that have a taxonomic slant and that has not changed over the years. So the interest is still there. How many people are taxonomists is difficult.
Professor Bateman: I am sure you have already had several different versions of the relationship between taxonomy and systematics. You will note that we are The Systematics Association and taxonomy is a subset of systematics concerned with the naming and identification of organisms. I think it is important to state at the outset that it is taxonomy that we are particularly concerned about the decline of. The other aspects of systematics such as phylogeny are in a much healthier condition. If we focus just on the naming and identification of organisms, then only a portion of our membership are involved in that side of systematics. We are mainly a professional society, we bring in active professional systematists and consequently we have a desirably low average age and a considerable percentage of activism. That also means that our membership numbers are smaller—they are round about 450, and like Linnean numbers, they have been relatively stable for some time. What I would comment on is two trends. One is that the ratio of British to non-British members has shifted substantially in the last few years. The European contingent, the North American contingent and the Australasian contingent in particular have increased in number. The second trend is as I said a few minutes ago that we are a very active society, but it is becoming more difficult to persuade people to put substantial amounts of time into promoting the objectives of the society. My impression is that professional systematists, just like many other groups of academics, are being asked to do more and more with less and less, and they are finding it difficult to maintain commitments to independent societies such as ourselves.

Q130 ***Chairman:*** The Committee has looked at this topic not once but twice before, but after the last report, chaired by Baroness Walmsley, we thought there was some evidence of an increase in attention that the organisations paid to their membership and also to looking out to the user community. I wonder if there is anything specific any of you would like to say on that?
Professor Cutler: I think the development of the website for the Society has meant that we have much better communication. We are able to inform people more readily of the activities and interests and we also report the contents of our meetings in an abbreviated form and this does attract people. We are looking forward in our forward planning to have much more involvement of our Fellows in the day-to-day activities of the Society. So we certainly have paid attention to that aspect.

Q131 ***Chairman:*** To the user community as well?
Professor Cutler: Yes, to the user community too because by digitising many of the specimens and putting those images on the web freely we are providing a wealth of information to the user community in this way.
Dr Knapp: In direct response to the last report The Linnean Society set up an annual systematics debate which brings forward issues of contention in the field to which everyone is invited and it involves voting and people having pros and cons. It is hugely well attended every year. That was something that was established in direct response to the last report.
Professor Bateman: I guess I would give a slightly different slant on this. I would say that the main effect that the last review had on The Systematics Association was to increase its political interest and awareness. We have always done our best to look after our user groups. The previous review helped to identify gaps in coverage that we were already aware of. When it became clear that the Government's response was effectively a response of no action we did what we could within our available resources to take action ourselves. For example, The Systematics Association got together with The Linnean Society to create two grant schemes—a small grants scheme and an intermediate size grants scheme—for which we found independent funding. These were designed to produce pump-priming data so that when full systematics proposals were sent to the research councils they would have greater credibility and a better chance of success than previously.

Q132 ***Lord May of Oxford:*** Prompted by the earlier Dainton inquiry I got interested in just how many taxonomists there are in the UK and how they are distributed among different categories of research. As some of you will be aware, this led me to the conclusion that the taxonomy of taxonomists is itself an understudied thing in that nobody could know. I wrote that paper with Kevin Gaston. Since that time has there been—whilst for ten years I have not really kept in touch—a more deliberate effort to document just how many taxonomists and systematists there are, both professional and amateur, or is it still in as amorphous a state as it was 15 years ago?
Dr Knapp: In response to the Dainton inquiry there was a UK Systematics Forum which set out to compile data about how many systematists there were, but it was a largely voluntary exercise. The only place where there has been very good data compiled about the numbers of taxonomists is in Australia.

Q133 ***Lord May of Oxford:*** Of course!
Dr Knapp: I fell into that!
Chairman: We fall into it regularly!

Q134 ***Lord May of Oxford:*** It is Ebbie Nielsen, right?
Dr Knapp: It is Ebbie Nielsen. I tried to get a hold of those data to look at whether there had been a change in the last decade. One of the interesting things that I discovered in talking to people in Australia is that they tend to exclude anyone who is not working in a nationally funded institution in their data gathering exercise because there is no way of knowing whether everyone has responded. So the error factor is huge even in a place where this has been established long term.

Q135 ***Baroness Walmsley:*** As you will know, we have had evidence from both Defra and the research councils and neither of them will claim ownership of taxonomic research as a discipline *per se*. They both describe themselves primarily as user groups and, as Professor Lord May said earlier, it is as if we were talking about a particle accelerator rather than an area of pure research. Is it possible for taxonomy to survive as a user-led science? Do you think there is a tension in NERC's attitude given the fact that they do accept responsibility for training and maintaining the expertise base in taxonomy as in other areas?
Dr Knapp: I guess my answer to that would be no, that no truly dynamic science can exist entirely led only by its users because users do not lead developments in science, they use developments in science. I also think users are very, very important to the long-term survival of any science. One of the things that is really important is to begin a conversation between users and producers which both of those people own because often, being a producer of information, people come and say, "We want you to do this," but in fact what you need to have is a conversation about what might be possible or what might be needed. The conversation is perhaps because no one feels as though they own it except the big taxonomic institutions like the Royal Botanical Gardens Kew or Edinburgh or the Natural History Museum. Those institutions do own taxonomy and do spend their money doing taxonomic research, but until it is owned by both users and producers I think the conversation will continue to eddy around.
Professor Cutler: We are not primarily a service industry. There has to be continuity and a tremendous background of collections and resources which have to be maintained. If people dip in and out when they require the services, I could not visualise a system which would support that sort of activity. I think we need to look at proper succession training and obviously maintain the wealth that we have in our collections and our libraries which are part of the total picture for this. The taxonomic community itself has to be responsible to quite a large extent for its activity and its survival but also in conversation, as has been said.

Q136 ***Baroness Walmsley:*** It is a very diffuse body of people, is it not?
Professor Cutler: Yes, it is.

Q137 ***Baroness Walmsley:*** Is it either possible or desirable for any one organisation or government department to take ownership and responsibility for taxonomic research?
Professor Cutler: I think it would be very difficult to do. I think the Society itself could offer some facilities for this. Obviously it is a question of people and resource. We have a very broad spread spectrum of interest both in users and in producers in this case. I think the Society could be helpful in a situation like this.
Professor Bateman: I think it is worth looking at the complexity of the situation. You have alluded to that already. We tend to draw little diagrams where we are the producers and out there are the consumers and the whole thing is subject to market forces. There is some truth in that, but in this particular case the range of users, as you have implied, is extremely great, but a lot of them are using our information second, third and fourth hand. It is a question of how far you trace that information. The problem is that, with so many middlemen, the credit that goes back to the original generators of the data gets smaller and smaller. I have found it is very difficult to get either political credit or financial credit for the actual generators of the data. It is often the middlemen who benefit relatively substantially from these kinds of systems. That is probably the biggest problem that faces any enabling science—it is not just taxonomy.

As you will have seen, the Association is desirous of broadening out this discussion to cover other long-term research programmes, not least being climate change, but even there you often find that the owners of large databases who are recycling old data are the ones who are currently having the most impact, and a relatively small amount of the total available funding is going into generating genuinely new data. I think that is the primary challenge that is facing taxonomy at the moment. It is possible to muddle through and we already are muddling through mostly on old data and recycled data. The trouble is that there is no obvious point where the system will totally collapse—it will just become less and less effective.

Dr Knapp: We often talk about the multiplicity of users of taxonomy as being a negative point, but I actually think that the multiplicity of users is a very positive point about taxonomy and it is one of the reasons that there is this resurgence of interest in the subject, it is because more and more people are realising that it is important and necessary. Rather than worry about having too many users, I think we ought to be rather pleased that so many people want us and we should just figure out how to talk to them a bit better.

Q138 ***Chairman:*** Has the character of the range of users changed dramatically or is it pretty well the same constituency but more of them?

Dr Knapp: As a practising taxonomist—and I am still practising—I think the character of users has changed enormously. I have contributed in a large way to the Encyclopaedia of Life. The users of the Encyclopaedia of Life are enormously wide and very big. One of the good things about these web-based applications like the Encyclopaedia of Life is that they are designed at their outset to connect into many different types of user groups. The really interesting user groups are possibly the ones that we have not found yet and those are the ones that are really interesting, which means that one has to be relatively nimble on one's feet to be able to identify that as an important place to look in the future. With these new big initiatives like EoL they will be different. When I started out the people who used taxonomy were other taxonomists.

Q139 ***Lord May of Oxford:*** Would it be fair to say that as more problems are more clearly realised, beginning with climate change, that defines more new user groups?

Dr Knapp: Absolutely. Taxonomy, like any science, is an iterative process of discovery, so making one discovery allows you to make another and establishes the baseline for yet other things. It is this iterative process which means it is not a one-off task. Doing the taxonomy of the Earth is not something you do once and then put away in the cupboard; it is an iterative process.

Q140 ***Lord Haskel:*** We have had evidence about the innovative technological advances offered by web-based applications to improve the efficiency and the effectiveness of dissemination. Professor Cutler has just referred to the development of the Society's website as "leading to more involvement". There is clearly a need for a roadmap both for the development of the field and for the roll-out and funding of new information technologies over the next decade. Who is or should be producing this roadmap?

Dr Knapp: I have been very involved in these web-based developments and one of the things that is becoming abundantly clear to me in being involved in these initiatives is that the community itself is building the roadmap through experimentation and through looking at different ways of doing things, different methodologies, just trying things out in a different way. I think this roadmap is emerging from the community. The appearance of the Encyclopaedia of Life on the scene very recently, it was launched on 27 February this year, means that that is pulling people's minds together in a way that I think is proving extremely positive. Whether the Encyclopaedia of Life will be the roadmap remains to be seen. I think we need to see how it works and how the community itself fits into this. The web-based developments are being tried in several different ways. There are few enough people involved in these projects that they all communicate with one another. For example, CATE, which is a project funded by NERC here in the UK, is collaborating with my project, which is funded by the Planetary Biodiversity Inventory from the National Science Foundation in the United States, which is also collaborating with EDIT, a project funded by the European Union. So all of these projects talk to one another and are taking the best from each one to see how we can go forward. One project on its own would probably not find the best.

Professor Bateman: Can I twist your question slightly because I think underlying it is envisaging databases providing identification aids. You will have had several presentations on these topics. The area that interests me equally—and I think Lord May too—is the question of the pocket sequencer, and whether we can switch from a morphology-based taxonomy to a DNA-based taxonomy. This is a topic that brings in issues such as GenBank, where you do have an initiative that is widely respected across the globe and where most of the relevant information available is being put into a single dataset, which is a situation that most of us studying morphology would give our eye teeth to see happen. Also, I was always very sceptical of Lord May's advocacy of the technology

that would allow us to do this. I am sceptical no longer. I have seen the presentations from the American military showing us these devices already exist. The only interesting question is how long it will take before they become affordable to the average systematist. Then the real challenge is going to be the quantity of data available on that database. I applauded GenBank and said that is what morphologists should aim for. However, there is a lot of poor data in GenBank, even though there is an element of quality control, and it is not going to be a magic bullet—it is not going to solve immediately our ability to identify organisms for a whole bunch of different reasons. Even though we have the one unified database, the way that we approach using these devices and the way that we collate the resulting information from that has not been properly discussed, so there is a need to discuss that kind of web-based information as well as the morphological web-based information and all of these have to be made to communicate with each other. It is not an easy task, especially when you consider the different levels we are operating at—global, European, national and regional. It is finding a solution that is satisfactory to all of those different levels that is the challenge.

Q141 ***Lord Haskel:*** Who should be providing the strategy? Who should be looking for the solution?
Professor Bateman: The organisation, if you saw its remit on paper, that would best fit that would be the Global Biodiversity Information Facility, but Britain has a rather unfortunate history in that regard, since as a nation we refused to pay our subscription to that international organisation and in the end the Natural History Museum and Kew went ahead and paid the subscription on the nation's behalf. The theory of GBIF is a very good one. The practice has not yet reached the levels where I would be a strong advocate of it. We have many different organisations that in theory could address these issues. It is a question of picking which one is going to be most appropriate and then resourcing it at an appropriate level. I think this is something that this nation alone cannot do—it has to be done at an international level.

Q142 ***Chairman:*** Can you give us some idea of the size of the subscription?
Professor Bateman: It was about ten thousand pounds.
Dr Knapp: It was £12,000. Going back to this issue of who should be responsible, understanding biodiversity and using taxonomy to understand biodiversity is a problem of global proportions and so the roadmap needs to be global as opposed to national or even regional. I do not know if you were given a document as part of your written evidence done by the European Distributed Institute of Taxonomy as a Foresight report which looked at what taxonomy might look like in ten and 20 years' time. One of the very interesting things about that that the group identified was how technology would be different for different groups of organisms. A roadmap for one group of organisms may look quite different to a roadmap for another group of organisms.

Q143 ***Earl of Selborne:*** I wanted to follow up on these international initiatives to try and understand what the end plan might be. Perhaps I should preface my remarks by putting on the record that I am a member of The Linnean Society and Chairman of the Trustees of Kew. Dr Knapp has reminded us of organisations like the Planetary Biodiversity Inventory, Creating an E-Taxonomy and the Encyclopaedia of Life, which sounds to me to be the most global initiative of all. Do they really all feed to each other? Is there a possibility that eventually the international community of systematists will resolve which of all these organisations they should give their priority to or are they complementary?
Dr Knapp: I think they are complementary. Some of them are organisations and some of them are grants which will end after five years or three years. So everything except EoL is a grant—funded project which ends at the end of five years. For example, the Planetary Biodiversity Inventory, which is funded by the National Science Foundation in the US, is part of a big grant to supply information and we have given that information to the Encyclopaedia of Life. The Encyclopaedia of Life has as its aim to provide a page for every species of described organism on earth. One of the things that will make the Encyclopaedia of Life work is if there would be credit given by institutions and the scientific community to taxonomists who would contribute to initiatives like this. A young taxonomist starting out is unlikely to devote much of their career to something which will give them no credit in terms of the Research Assessment Exercise or career advancement in a sense like that. How to make those work together goes back to depending on how we assess science in the scientific community, not just in the UK but also in other countries. I think it is a little bit different in the United States where this sort of science—descriptive taxonomic science—is highly valued in universities and in institutions like museums and botanic gardens.

Q144 ***Baroness Walmsley:*** I think that last suggestion is a very, very interesting one, giving credit to people for putting the information on. It takes me to something that has been concerning me and I go back to what Professor Bateman has just been saying about GenBank, that he is concerned about the quality of some of the data. Surely that genomic information database shares that problem with many

databases based on morphology where some of the information on the database is dubious to say the least. You will get an organism where you have several examples and it is all the same thing with several different names and, conversely, you get a lot of different things with the same name, but something that Dr Knapp has just suggested presumably would be peer review and therefore you would be sure of the quality of that sort of information for which a student got credit. What is the answer to this problem of the quality of some of the information, especially as it is passed from hand to hand to hand?
Dr Knapp: I think peer review is key in this. There is an ongoing discussion within the Encyclopaedia of Life project, which is something that was launched in what they call an alpha form, which is even less put together than a beta form. Most software is released in beta form. There is a large community of taxonomists who feel that there needs to be a core which is peer reviewed and then lots of added on bits which will allow anybody to contribute, but there is a peer reviewed taxonomic core which is authoritative. Because web-based technology is becoming incredibly sophisticated with Web 2-type technology you can mix and match a lot of these things in a way that you could not do two or three years ago. In the end technology will be our friend!

Q145 ***Earl of Northesk:*** Dr Knapp has already referred to the National Science Foundation in the United States. It supports basic taxonomy programmes, for example, the Planetary Biodiversity Inventory programme. What are the benefits of such a programme and would the concept translate into a UK sector?
Dr Knapp: The Planetary Biodiversity Initiative is something that was inventory. It was something that was started by the National Science Foundation in order to set up groups that were international and global in scope to tackle groups that would otherwise never be tackled taxonomically, so these are large complex groups. A friend of mine has analogised it as one or two workers doing one of these endless tasks like painting the Golden Gate Bridge where by the time you got to the end of it you would have to start over again at the beginning. That sort of huge international-type programme we probably do not need in the UK because we can use it. Something else that the National Science Foundation does is called REVSYS, which stands for revisionary systematics, and what that is is a programme that is dedicated to funding three year grants for individual researchers or groups of researchers at a single institution to do taxonomy, both biogenetics and descriptive taxonomy, in groups that are of manageable size. Something like that could easily be translated into the research council funding-type scheme. PBI might be slightly more difficult because they are very large grants, they are in the millions of dollars grants and they last five years and they involve global teams of people from many, many institutions. I am just reviewing grant proposals for the third round of Planetary Biodiversity Inventory grants right now.

Q146 ***Earl of Northesk:*** So at the web-based level PBI demonstrates the potential worth of a wiki-type structure?
Dr Knapp: I had one of the very first grants that was given. What we were tasked with was doing the descriptive level, species level taxonomy of a large group and the group I work on are the nightshades, things like potatoes and tomatoes. We were supposed to do that and make it available on the Internet. When I started this project five years ago the Internet was very different to what the Internet is like now. We have changed the website that we have to reflect some of these changes in technology. The money was not given to establish a website, it was given to do the taxonomy, which is one of the great strengths of the Planetary Biodiversity Inventory programme, that the money is given to generate new data, not just to recycle old data in new packages.
Professor Bateman: For me the great strength of the NSF initiatives we are discussing at the moment is that they were custom built. They did not evolve from anything else. They were not constrained unusually strongly by resource allocations. They were custom built by people who knew what they were talking about. Consequently, they are the most effective set of schemes that have been launched in a long time. If you asked me how they could be improved my answer would be that they become fully international schemes rather than US-based schemes. I see no reason why PBI could not be a fully international initiative that received funding from the NSF equivalent bodies in a range of different countries, and then we would have some chance of reducing a number of initiatives that take place. The acronyms must have caused all of you difficulties in your reading for this topic. It would allow us to combine the different nomenclature codes within taxonomy, it would allow us to have a registration scheme for names and it would allow the international aspirations of taxonomy, which have been there for a very long time, to be properly realised. It is a great scheme but if it was truly international it would be much more powerful. It would drag all sorts of other key decisions along with it and force us to take them.
Dr Knapp: One important thing about the National Science Foundation is that schemes like this originate from the community of scientists who work on that topic and then that is taken up to staff in the organisation who then sell it to the NSF management. Having staff in the National Science Foundation that are committed to biotic surveys and inventories, which is where this topic lies, has been a

long-term resident in the National Science Foundation but is not true in the research councils in the UK.

Professor Bateman: And as a result of that there is no question about where ownership of taxonomy in the US lies.

Q147 ***Lord May of Oxford:*** I just want to correct what otherwise could possibly be a misapprehension here. I lived and worked for 20 years in the States before I moved here at the end of the Eighties and during all that time I was funded from the NSF, which I think is much better organised than our research councils, with much fewer silo compartments. I was funded out of one of the basic boxes which was called Population Biology and Systematics—to the best of my knowledge it still is—and it funded responsive-mode research across the entire field of ecology systematics. It was not talking about who were users and who were producers; it was looking at research proposals across that whole waterfront. It was also more notable because the whole thing was unitary, so in my case somebody took it upon themselves to divide it half between that and half between applied mathematics in a manner you could not do here. All our discussion up to this point has been about particular initiatives of the kind that we also have here including the Planetary Biodiversity Inventory and that is good too, but we should not run away with the fact that one of the biggest differences is a research programme in basic taxonomy or systematics can go to the NSF and be funded. Here it would appear to me, from what I have read and what you said earlier, it cannot.

Dr Knapp: I think that is important and why I mentioned the Biotic Surveys and Inventories, which is a programmes like Population Biology and Systematics which has resided in the National Science Foundation since I was a graduate student, so since the 1970s. I know there has been dedicated money to describing organisms on Earth.

Q148 ***Lord May of Oxford:*** Another difference, which takes us much wider, is that much of the staff at the NSF are academics coming in and going out rather than a bunch of career apparatchiks.

Dr Knapp: I think the NERC theme leaders are a very positive step.

Q149 ***Lord Colwyn:*** Despite some of the major UK research establishments being widely recognised as playing a globally significant role and the encouraging remarks you are making this afternoon, we still continue to hear of a decline in the UK capacity for systematics and taxonomy. What in your view will appear as the first key limiting factor in this? I am grateful for The Linnean Society's very helpful paper where you say, "The single biggest barrier to delivering research priorities in taxonomy and systematics is the static (if not declining) population of scientists with expertise in the taxonomy and biology of organisms." Is this going to be the limiting factor that is likely to appear? Will this serve as an indicator that some critical points have been reached, and what can you do about it?

Professor Cutler: I think certainly it will be the main indicator as we have fewer professionally trained taxonomists. The outcome of this will not be in counting taxonomists but in looking at what we cannot achieve and do. I think we shall have problems in monitoring climate change, for example, when we lose the expertise in a lot of the disciplines, notably the fresh water biology side. Forensic science services which rely on the identification of material in various forms, material coming into the country, medical identifications and the ability to make use of our existing resources I think will all be indicators. We shall see this first when we cannot find the expert to do a particular job. What is leading to this is the fact that most of the money which is put into taxonomic training these days is rather on the cutting edge side and that is extremely valuable, but I think that students who might have been encouraged in the past to take up whole organism studies and to look at the aspects of training to be taxonomists in specialist groups are put off by the fact that there is no real long-term employment for many of them in prospect and that they have to live on short-term projects. These in themselves are limiting for taxonomy, and short duration projects are unsatisfactory. The possibility of getting a job at the end of the day is very difficult. I think we have got to look at various points in this big chain, right from primary school nature tables, up to how we train taxonomists. It can be addressed to some extent by having a basic training for taxonomists and equipping them with tools which cover a very broad spread of facilities these days. Then I think it is normally possible to take individuals and train them in expertise in particular groups, but we do not do that at the moment apart from our major institutions and some university links. To go back to the beginning, we shall find we do not have trained taxonomists, the succession will have been broken and to re-establish that is going to be extremely difficult.

Professor Bateman: I would say we have already reached that point. The second part of your question was about a tipping point. I do not think we will spot the tipping point when it happens. What we are discussing is a very gradual decline and there is not going to be any particular threshold, in my opinion, where the entire system collapses. What I did find during my year as Head of Policy at the Biosciences Federation was that of all the other biological societies who were members of the Federation, many of those societies listed taxonomy as one of their top

three concerns and these are societies that are not directly involved in taxonomy. They are already finding that the taxonomic support they are looking for just is not available and it is not available for a whole range of reasons—partly because we now have very patchy taxonomic coverage, partly because we are, quite rightly, being asked to cover new groups that have not even had taxonomy done previously, and partly because we are being asked to feed information into many of these dissemination schemes that we have talked about earlier. Each time you are adding information to something like the Encyclopaedia of Life, for the most part you are not generating new information—you are presenting existing information in a more digestible package. The workload on the remaining taxonomists constantly increases and the number of effective taxonomists declines. You will not really see this in effect until, and indeed after, the bulk of Britain's taxonomists have retired, because the moment they retire their productivity generally increases. They are no longer under a bureaucratic constraint.

Q150 ***Chairman:*** We like to think of ourselves in the House of Lords in that way!
Professor Bateman: I am not joking—their productivity does increase because they are freed of all of these bureaucratic loads. They move into the amateur societies and make tremendous leadership contributions there. Basically you are not going to see the full effect of the phenomenon that we are concerned about until we are all dead, and I am relieved to say that that is going to take a little time!
Dr Knapp: I am an example of this tipping point being reached slightly. In a recent hiring exercise in the Natural History Museum we had advertised for research leaders, so people who were to come in and set up research groups and help lead the science in the future. Only one of the six people that we offered jobs to was British. When I first came to the Museum I was a bit unusual in not being British whereas now being British is the unusual thing. I think you could make an analogy in a way to the National Health Service. You would not think that not teaching the cranial nerves in medical school would cause the collapse of the National Health Service, but in several years' time an entire generation of doctors who have no idea about how the human body was put together will cause the National Health Service to cease functioning and it is similar for the environmental health of the globe in a way.

Q151 ***Lord Colwyn:*** During our last evidence session, after they had turned the broadcast button off, I admitted that, having done biology at O level and zoology and botany at A level and then a medical education and a dental education, I had never heard the word taxonomy until I came to this Committee. How do you get people interested? Where do you find them? At what stage?
Dr Knapp: I think people are born taxonomists! Anyone who has had small children knows that they spend their lives sorting things on the ground into things you can put into your mouth and things that you cannot. One of the things that taxonomy could use is more people to go out and be enthusiastic about what an exciting thing it is to study the diversity of life on earth and there are people like that. There are definitely people who are passionate about the subject. The Linnean Society really serves a very useful function in the fact that the Society is open to anyone who wants to join who has a passion for natural history, so as a result we have meetings at which there are amateurs and professionals and sixth formers. As part of our strategic plan we are looking into how we can take the interest in organismal biology, natural history and by extension taxonomy further down in the age structure.
Professor Bateman: Most begin as children. It is incredible how many of my colleagues who I have spoken to cited the Natural History Museum, Kew or the London Zoo as being the awakening of their interest in taxonomy at the typical age of five. So if they are not born they learn very, very quickly. There might be some broader issues out there. We have rightly focused on taxonomy. I had a look at the list of A level applicants and which particular undergraduate courses they were applying for. The number of applicants for single Honours Biology this year has decreased quite substantially and it appeared on the list immediately above cinematography at just 20,000 applicants, whereas Sport Science received slightly more than twice as many applicants. Taxonomy may be at the vanguard of some broader issue that should give us some concern.
Chairman: We do look at these wider questions.
Lord Haskel: You were talking about enthusiasm. One of the things that the present Government did, Lord May will remember this, is that we started a system of ambassadors for science and that has turned out to be extraordinarily successful and there are now two or three thousand of them. Maybe that is a scheme which you could latch onto.

Q152 ***Chairman:*** How important are mathematical skills to the analysis of the information and the building of pictures and hypotheses and so on? Does the community have enough access either through its own members or to others who have an interest in this? Is this an issue for you? In some sciences this has begun to be a problem.
Professor Bateman: I would say not, to be honest with you, particularly if you roll up statistical skills with mathematical skills. There are aspects of modern mathematics such as Bayesian analysis that

are being driven by systematics. In fact, one of the concerns that is expressed by phylogenetic systematists is the way that their techniques and their concepts have been appropriated by a whole range of other disciplines and sometimes are misapplied. In terms of our actual access to appropriate mathematical skills, I would say for the present time it is adequate, but I do also notice that the interest in the number of applicants for mathematics is falling, and I would not like to say that mathematics is safe or that we will have access to those mathematicians in the future. They might have the same degree of decline as ourselves.

Chairman: I think the evidence is there for that, which is why I raised those questions.

Q153 ***Lord May of Oxford:*** I have just spent the better part of the last month writing a short book, which is the biographical memoir of Sir Richard Southwood, a major entomological ecologist of his generation. The greatest evolutionary biologist in the last half of the last Century was Bill Hamilton. Both of these are people who by the age of three to six had decided they were going to be essentially, though they did not know the words, entomological taxonomists. Only later did Southwood widen his vision and become one of the founders of ecological entomology just as Bill Hamilton widened his vision and became the most influential evolutionary biologist in the last half a century. As you have just said, Sandy, many kids are like this. I am told by Charles Godfray that the number of younger people in their teens in amateur entomology botanical societies has not decreased but that once they go to university they see this as becoming a stodgy thing and not so exciting. How do The Linnean Society, of which I am a member, and The Systematics Association see their role in working with this diversity of amateur societies, which still exist and still are healthy, partly to make sure that the Southwoods and Hamiltons of tomorrow, neither of whom were any good at mathematics incidentally, will be there and so that the amateur entomologists and the amateur botanists, the people who provide the database for the RSPB on which Defra bases its biodiversity action plans, would still be flourishing? How do you see your role in doing that? Do you think it is true that there are still as many teenagers in these societies? If there are not, that is really important and it is a failure on your part or your organisations' part.

Professor Cutler: The Society has a very keen interest in the amateur element. We provide free access to our library and our resources to bona fide enthusiastic natural historians no matter what their age. We fund people through some of our grant schemes, 17 or 18-year old people undertaking African research and so forth. We have the elements of this and we have recognised that there is a lot more that needs to be done. During our tercentenary we were looking at the future of the Society and we have now got a fairly effective plan going which is addressing these very issues, particularly that of education. We have already initiated a series of sixth form lectures again which died the death some time back largely because it was difficult to get teachers at the time to take groups of students out of normal hours. By taking lectures to different parts of the country we hope that we are going to revitalise this. We are in the middle of a series of three lectures at the moment for sixth formers to open their eyes to the impact and the interest and the spread of natural history. I think the Society is very willing and the membership is very willing and has appreciated its responsibility at last, which has taken some time to come!

Professor Bateman: Obviously the Association itself is a dominantly professional society. I would rather comment in my roles as Vice President of the Botanical Society of the British Isles and President of the Hardy Orchid Society. Since we have the President of the Botanical Society present, I think I will talk about the Hardy Orchid Society if I may, which is another organisation of about 500 people. It is funny how specialist organisations often stick at 500. I actually censused the entire Society, and we have got roughly equal numbers in every age bracket above ten. They start early and they finish late. It covers horticulturalists, it covers some with scientific interests and it covers people who like showing plants. I have spent some years educating this group of amateurs about relatively high-tech science—molecular systematics, for example—to the point now where I can use them as a field team and I can ask the Association to go out across Europe sampling on my behalf, measuring flowers and sampling for DNA analysis. I maintained such a programme this summer, and I was so delighted at the results that I wrote them up straightaway and they are already published in a peer—reviewed journal. People tend to see the amateurs as the best sources of identifications and we will hear later about the BSBI's work in that area. I honestly, genuinely believe this concept of citizen scientists has a reality to it. We can go further still when the technological innovations that have been predicted by Lord May come to pass. I noticed the written version of this question said are these amateurs going to be marginalised by the technological innovations? No way! They are going to be out there in the field with their hand-held sequencers linked to GenBank, capturing images of the plants that they are sequencing. What they actually represent are a serious challenge to the relatively small number of remaining professionals, who are going to be asked by these amateurs to interpret the results of their analyses.

Dr Knapp: I think Lord May is referring to a certain extent to the younger generation of amateurs. There are many younger generation amateurs who are very interested in natural history. Whether they go on to make natural history their socio-economic profession as opposed to their profession in the Victorian sense, ie what their vocation is, is another thing entirely. We should not worry too much about whether they will become professional taxonomists to a certain extent because if we have a set of people who are enthusiastic about natural history and enthusiastic about diversity then that provides a constituency. There are two issues in that, it is maintaining the profession in a socioeconomic sense and maintaining the profession in a cadre of people who care about the natural world. I work at the Natural History Museum, which is where my day job is when I am not the Botanical Secretary of The Linnean Society, and I think that places like the Museum and Kew are looking very much at building that vocation for natural history, but we also need to think about training those professionals. In the late 1990s I taught Introductory Biology at University College and I devoted half of a term to covering all kinds of different groups and we looked at diversity on a DNA scale and what different things did, just the diversity of life. That has gone now from the curriculum at University College.

Q154 ***Lord May of Oxford:*** But not at Oxford.
Dr Knapp: Oxford might be unusual in more ways than one! This comes back to something that Professor Cutler said earlier about whole organism biology. When that drops out of what is perceived to be a career path then I think you get people discarding it because students, let us face it, are not stupid.
Chairman: By and large that is true, yes.

Q155 ***Baroness Walmsley:*** Lord Haskel mentioned the scheme of ambassadors, which I think is probably SETNET. I believe there are about 6,000 ambassadors now. The problem is that most of those young scientists and engineers are employed by commercial companies and their companies give them credit, support, time off and all the rest of it for going into schools and enthusing young people about their particular scientific discipline. The problem with the taxonomists is that many of them belong to companies that cannot afford to spend the money that they need to back them up to go and do that. I do not know how many of the SETNET ambassadors are systematists or taxonomists but perhaps some of you know. This is a problem. I do not know if you have any solutions because research groups cannot afford to release their people. It is yet another job for people to do, is it not?

Dr Knapp: I think that is true to a certain extent. Speaking as a person who works in a publicly funded body, institutions like ours, like the Natural History Museum, Kew and the Royal Botanical Garden Edinburgh, have as part of our institutional goals to interact with the public in particular sorts of ways. I do a lot of going into schools.

Q156 ***Baroness Walmsley:*** Clone yourself!
Dr Knapp: People in my research group do as well. The Natural History Museum gives a lot of credit to people who do that sort of thing.
Lord May of Oxford: That is a really good question. If you are in a private company then the corporate social responsibility report will give you credit. If you are in something like the Natural History Museum you will get credit. If you are in a university the RAE will not and that is one of the many problems with the increasingly bureaucratised Research Assessment Exercise.

Q157 ***Chairman:*** This is becoming a discussion. We need questions!
Professor Bateman: I think that is a really important point that is being made here. It is time for me to enter the confessional! In the two senior management positions I have held, one as Director of Science in Edinburgh and the second as Head of the Botany Department in the Natural History Museum, I shifted the centre of gravity of the research focus away from taxonomy into other areas of systematics, and I did so for the reasons that Lord May is stating. He is correct to say that people in the university sector live or die by a very narrow set of criteria, but those criteria have had their impact on institutions like the Natural History Museum as well. If you are being assessed on the number of high—impact papers you produce and the amount of overhead on grants that you bring in, you would not advise anyone to pursue taxonomy—you would advise them to pursue other areas of systematics. That has very much been the nature of the decision making in all of the major systematics institutes.

Q158 ***Baroness Walmsley:*** In our last report we had a recommendation to establish a co-ordinating body bringing together all the users and producers. I think the reasoning behind it was that we did not want to decide what the priorities were. We felt that there needed to be a group of experts to decide what the priorities are, to identify the gaps and to organise the profession to fill the gaps. That was our recommendation, which had a mixed reaction, and nothing was done. Given that we have the UK Biodiversity Research Action Group and we also have the Global Biodiversity Sub-Committee, do you feel that now, five years down the track, another

entity is required? Can I also add to that question that Defra seems to see a separate need for co-ordinating the systematics and taxonomy research community as opposed to the need for co-ordinating these disciplines within their different fields of application, so two different sets of co-ordination. Do you think that separate co-ordination of research and application is a workable concept? It is a bit of a long question I am afraid at the end of our evidence session.

Dr Knapp: One danger in co-ordinating bodies is that they are occasionally populated by people who co-ordinate and therefore have no sympathy or ownership with the discipline that is being co-ordinated. Earlier on, My Lord Chairman, you identified the fact that nobody was owning this and so if a new co-coordinating body were made it would co-ordinate what? Co-ordinating application and research is like cutting off research from a functioning National Health Service because these two things have to go hand in hand or it is not healthy. I am not sure that another entity is required because without substantial funding behind it people will not buy into it. It is this business of ownership and not only users owning it but producers owning it, so I will come back to my idea about a conversation. Before we need a co-ordinating body what we need to do is to have a meaningful as opposed to just an empty conversation about what it is we actually need to talk about. The Linnean Society is a place where this could begin to happen, given the financial support to be able to enable it to happen because those kinds of things cannot be just plucked out of the air. I on a personal level feel that the more you set up bodies to co-ordinate things the less co-ordination that actually happens because when it arises from the community is when it is effective.

Q159 ***Chairman:*** Do either of the other two want to respond?

Professor Bateman: My answer is that I am sympathetic to what Sandy has said, in the sense that my opinion is that there are far too many initiatives and far too many bodies already, and the reason is that it is much easier to get momentum and funding to set something up and to maintain it, which I think is actually what we are here discussing. However, having said that I do think there is some value in the new body. We have already talked about the UK Systematics Forum; perhaps the greatest achievement that that arguably under-achieving body managed was to survey the taxonomic base efficiently and effectively and that gives us a yardstick from 11 years ago now that we could if we chose measure the current situation against. It is a black mark against the systematics community that it has not found the co-ordination to do that. I therefore think there is a need for some new body, but should it be a permanent body or just something set up temporarily in the wake of this inquiry to move recommendations forward, which I would very strongly favour. Having said that, we are all so busy that it will not happen unless there is a good, clear reason and motivation for having that body, and I think the motivation I have just given is not going to be perceived as sufficient. The Government has a very clear approach to encouraging research in particular directions these days, which is to set some fairly simple targets and then allocate resources to meeting those targets. If the body that was set up had some influence over that level of activity then it would meet—it would have no choice—and the most useful thing it could do, apart from surveying the current situation, would be to address some of the issues we talked about earlier, in terms of having registration of names and having an agreed format for placing information on the web. If Britain really got its act together it could possibly still show a lead to the rest of the world, which is what we used to do.

Chairman: Thank you. We are virtually out of time but I wonder if we could perhaps take one more question from Lord Methuen.

Lord Methuen: Is the apparent fragmentation of the systematics community a significant factor in its decline?

Q160 ***Chairman:*** Obviously a very pointed question.

Professor Bateman: I am afraid I feel I have to answer yes, it is, and it disappoints me that we have not been able to present a more cohesive front. We have made progress, but I do not think we have made sufficient progress. We have addressed many of the reasons why this is the case already and we have to some degree expressed concern about the fact that so much of the taxonomic activity is now just based in three or, at the most, half a dozen institutions, but what we have not commented on is the fact that each of those three institutions is responsible to a different government department and each of them is set very different policy targets to address, so apart from setting standards—which is what I just suggested this co-ordinating body might do—it is not very practical for these organisations to get together because they are addressing different sets of policies. So we are fragmented. We could possibly do more about it than we do, but a lot of the pressure causing that fragmentation is coming from outside.

Dr Knapp: If I could just add one thing to that, the fragmentation in part comes from something that Lord May referred to earlier about funding basic research. If you think about taxonomy and its three methods—phylogenetics, description and

identification—phylogenetics in part gets funded by research councils; descriptive taxonomy is funded by the great taxonomic institutions of the country and identification gets funded by the Darwin Initiative, a bit by Defra and by the user community. That means that the funding structure is fragmented and that in a way drives the fragmentation and the discipline which is a vicious circle.

Q161 ***Lord Methuen:*** The RAE does not help either.

Dr Knapp: Exactly.

Chairman: Thank you very much, that is a very helpful and lively conclusion to this stage in the proceedings. I have thanked you already for your written evidence but may I add that if there are points that have come up in the discussion that you would like to amplify in written form, or other points where you feel that you could amplify what you have already produced, that would be received with great thanks. Thank you very much for your presence today.

Examination of Witnesses

Witnesses: Professor Richard Battarbee, Environmental Change Research Centre, University College London, Professor Richard Gornall, President, Botanical Society of the British Isles and Dr Alastair Culham, Centre for Plant Diversity and Systematics, University of Reading, examined

Q162 ***Chairman:*** May I welcome you. You probably heard a little about the sort of proceedings that we hope to follow for the next hour or so. We are on air, you will keep that in mind I dare say, and I thank you for the written evidence that has been submitted, it is very much appreciated, and as you will have gathered we do pay very close attention to it. Could you please start by introducing yourselves, just for the microphone, indicating your allegiance or your home base or whatever seems appropriate. Can we start at this end?

Professor Battarbee: I am Rick Battarbee from University College London.

Dr Gornall: I am Richard Gornall from the University of Leicester, but I am here also on behalf of the BSBI, the Botanical Society of the British Isles.

Dr Culham: Alastair Culham from the University of Reading.

Q163 ***Chairman:*** Thank you very much indeed. To start with a general question that tries to relate to what was done in the last report that we produced in 2002, much of the focus of the thinking of that group was based on the link between taxonomy and conservation as the base science that it seemed to be serving, but of course in the wider world the whole issue of climate change has very much magnified its impact and I think it would be helpful for the Committee if you were to expand a little on that and perhaps draw any particular lessons out about the importance of your area of study for the whole discussion of global warming. Who would like to start on that?

Professor Battarbee: I could start if you wish. I think that is true and when I put my submission in I also suggested that we should think more broadly than just global change but also consider environmental change in general, as it is often I think a mistake to think that the only problems that we are facing are from climate change as there are many problems of pollution and human impact on the environment that we also need to be concerned about. In my research group of the things which we are focusing on is the interaction between climate change and its impact on land use change and pollutant change, so there is a real complexity of interactions there that we need to be concerned about, and it is global change in the broader sense I think. In that context, understanding how plants and animals will respond to those interacting stresses, and conversely how we can use the response of plants and animals to actually indicate change is absolutely fundamental and, clearly, taxonomy is central to that endeavour.

Dr Gornall: Species are the currency of understanding or measuring environmental change. Environmental change happens in a biological context and what species are, where they live and where they have gone extinct and so forth is one way of how you measure its impact, so unless you can answer those questions you cannot really do much about it.

Dr Culham: The basis that taxonomy provides for evolutionary studies is really fundamental to the longer-term understanding of the change in species or the change in climate, so if we do not have an underpinning taxonomy system of reliable, authenticated identification of species we do not have phylogenetic studies, we do not have evolutionary studies and therefore we do not have the ability to link those into broader questions. I think the next question might deal with this in more detail.

Q164 ***Chairman:*** Just a supplementary before we get to that, NERC's new strategy seems to be paying more attention to these connections; is it a bit late in the day for such a forward-thinking group of scientists and administrators to be preaching that point? Sorry, I will rephrase that question so you find it more diplomatically put: have they been a bit slow to react?

Dr Gornall: In some ways I suppose they have; better late than never of course, but on the other hand you could argue that perhaps the taxonomy community has been a bit slow to react as well in not picking up that climate change could be such a major issue to which they could contribute useful data, so to some extent it is a two-way process, a two-way criticism if you like.

Q165 ***Chairman:*** Does anyone else want to venture into the discussion?
Dr Culham: NERC have been quite proactive in funding studies of climate change from a physical point of view. The University of Reading is part of a group including an internationally famous meteorology department who have been working for many decades on the climate models needed both to predict climate change in the future but also to look backwards and model past climate changes. The detail of those models and the complexity of those models has only recently got to a stage where we can tie it into systematics and taxonomy, so climate change is happening, we accept it happens and the level of detail and the complexity of the computer models has been dependent on very expensive and very time-consuming research, and it is only now at that stage of completion where we can use it.
Professor Battarbee: There are two aspects to that: one is where we are now in terms of understanding the impact of climate change on biodiversity and the structure and function of ecosystems. We are only just reaching the point where there is a general acceptance that we will have climate change in the future. The models seem to be robust and there has been a major emphasis and a lot of money spent on modelling. It is right that we should now be looking very, very carefully at impacts, and to a certain extent we need robust models to project the future, to actually then ask the question how might ecosystems and how might plants and animals respond. So it is timely in that sense and perhaps not too late. We can see that changes are already taking place and have been, perhaps, for the last few decades. The second part of this is that there has been some contribution already by taxonomists and ecologists in looking at the changes in plant and animal distributions in the past in an attempt to reconstruct past climate change through time and by so doing to try to test General Circulation Models. So there has been a role if you like of taxonomy in a fairly ecological sense already, but now is the time to move on and begin to look at ecosystem impacts in the future.

Q166 ***Chairman:*** In the discussions between different groups of scientists has there been an adequate discussion between environmental scientists and taxonomists about the need to have a capacity in taxonomy? Are both sides aware of their need for each other?
Dr Gornall: To some extent the two groups tend to operate independently. It is good when it happens when you get the people with disparate disciplines coming together with a holistic view of something, but I would have to say it tends not to happen, unfortunately. There are exceptions but on the whole the people who are interested in grassland communities, for example, may not talk directly to a taxonomist for their actual input into that. They may use taxonomic products and they may perhaps chat over coffee on some specific points, but the taxonomists will not be present on the research team as an integral part of the investigation, that is probably true.
Professor Battarbee: I come at it from the environmental science perspective and environmental scientists who are ecologists tend to have taxonomy as part of their trade. They are often trained in taxonomy, or are self-trained in many cases in taxonomy and use taxonomy as the research question demands. To a certain extent, therefore, ecologists may not need to have an interaction with taxonomists until problems arise or there is a need to do some fundamental research. There is certainly the need to have that professional taxonomic base available so that when questions are asked that require that interaction can take place, and there are numerous examples of that.

Q167 ***Lord Methuen:*** We have to some extent already touched on this: what does the taxonomy and systematics-based evidence from past climate change tell us about the possible biological impact of the climate and environmental change that we are now seeing around and about us?
Dr Gornall: Historically there is a lot of evidence that environmental change greatly affects the biological environment. If you go back to when the land flora and fauna first emerged from the primeval swamp, for example, about 460 million years ago, there have been intervals where we know that the environment has changed quite directly and, correlated with that, there have been some quite dramatic changes in not only species distributions but also species composition, with speciation events occurring and also extensions occurring.

Q168 ***Lord Methuen:*** Obviously some of these are due to cosmic events rather than more naturally occurring.
Dr Gornall: Some of them have been linked to plate tectonic movements, some have been linked to atmospheric conditions, the most recent one of course was the last Pleistocene ice age and it is obvious that those wrought havoc amongst the

populations of Northern Europe, so it is clear that environmental change and climate change can have dramatic consequences.

Dr Culham: This is an area I have been focusing on in the last five years, initially funded by e-science money from BBSRC—another case of disguising taxonomy in another hat to get funding. The use of molecular phylogenesis in evolutionary trees based on DNA sequence and the dating of those trees based on fossil evidence has allowed linking of plant evolutionary trees with paleo climate models, models of ancient climates. Those climate models are validated by running them through to the present to see if they correctly predict what we have now and the linking is very much a taxonomic point, it is taking a particular group of organisms, a taxonomical group of organisms, looking at their relationships in an evolutionary way and then tying in the pattern of diversification of lineages to model patterns of climate change, and those models of course are linked to geological evidence and fossil evidence, but only slimly. There are not many fossils although there are bits—all over the world there are some fossils but the fossil data is more gap than evidence. Bringing together very modern techniques of DNA sequencing and taxonomic sampling techniques has allowed novel compilations that have given a new insight to the way in which plants might have reacted over millions of years to climate change, and some of those results suggest less change than might be expected.

Professor Battarbee: If I might be a bit more specific and talk about more recent times, traditional taxonomic techniques applied to fossil material have revealed very, very clear evidence of naturally varying climate on lots of different timescales as has just been alluded to. The question is which is the most relevant timescale for our current issue? We can look at the interglacial cycles, of which there have been many, and they tended to be cooler than the present time; the previous interglacials tended to be about the same temperature—we can see that from interglacial after interglacial. Many of them have occurred with more or less the same temperature and more or less, in Europe, the same flora and fauna for the last half a million years or so. What is interesting is this recent period that we are living in; we call it a warm period and it is the equivalent of an interglacial and until recently, until global warming, we were convinced there would be another glacial period coming, but now we are not so sure. But we do know from the fossil evidence, from using standard palaeoecological, taxonomically-based techniques, that, North West Europe, was warmer by about two degrees centigrade than at the present time 8,000 to 10,000 years ago, for astronomic reasons, and there has been a general cooling in that timescale. We can now see we have had a recent warming and so one of the questions is the extent to which the recent warming we see is due entirely to greenhouse gas emissions and concentrations and to what extent there is natural variability in the system as well, and the evidence suggests that it is mainly greenhouse gas forcing it, but we are still not as warm—despite the scaremongering we have had—as we were in Europe 8,000 years ago when July temperatures were about two degrees centigrade higher than they were on average between 1960 and 1990. That is interesting because it tells us that at least the in northern hemisphere, the world can function at two degrees centigrade warmer, and we are heading very much towards that two degrees centigrade increase. The European Union has taken two degrees centigrade as being the level at which it would like to cap the temperature; as far as I can see the community would actually agree that there is no analogue for any warming greater than two degrees centigrade in the past, so once we get beyond two degrees centigrade then in fact we will be into a new world.

Q169 ***Lord May of Oxford:*** Is the two degrees centigrade eight thousand years ago that you were talking about the global average or Northern European?

Professor Battarbee: This is a European inference in fact.

Q170 ***Lord May of Oxford:*** That was issued in a way that may have misled some. The temperature he is talking about is typically two to two and a half times the global average of warmness, so on that basis we would be talking about five degrees by the middle of the century; I just thought people should be clear.

Professor Battarbee: We know from that time that the plants and animals, for example, were more widely distributed to the North and since then there has been a relocation. This is very interesting in terms of biodiversity conservation because it shows that plants and animals do migrate with the climate, but 7,000 or 8,000 years ago of course there were very few people and we now live in a polluted, fragmented landscape and the plants and animals will probably not be able to migrate to the same extent as in the past, so with this warming that is taking place now and likely to take place more in the future there is much more chance of extinctions and species loss.

Q171 ***Earl of Selborne:*** I would like to address my question to Professor Battarbee who has given us very interesting written evidence about the role of taxonomy in monitoring the aquatic environmental change and the implication on classification of the effects of climate change, My Lord Chairman, and in your written evidence you refer to the fact that Defra proposed a massive reduction in the 20-year

programme of monitoring lakes, rivers and streams with which you have been concerned. We heard from the Scottish Environment Protection Agency that they are also concerned about the capacity in aquatic taxonomy and they take the view as you appear to that the taxonomic requirements in this area are expanding. We hear from Defra a rather different story, they refer to "short-term demands" and they submit that it "has not identified any specific major impediments to delivering our priorities deriving from the spheres of systematics and taxonomy". I wonder if Professor Battarbee would like to give us his comments on that.

Professor Battarbee: I was really quite surprised to see that. I am not quite sure who was giving the evidence and where that statement came from, whether they were thinking about the problems for freshwater ecology, freshwater taxonomy, or not. I think the SEPA view would be widely held, not just in Scotland but certainly by the Environment Agency, by Natural England, by CCW, by all the agencies that are charged with freshwater protection. The environment agencies in the UK now have to respond to the needs of the Water Framework Directive which requires that all surface waters are restored to good ecological status by 2015, and this is defined ecologically and biologically. The Environment Agency, SEPA in Scotland, are now doing their very best to try to characterise surface waters in the UK with respect to phytoplankton, to macro-invertebrate populations, and to aquatic macrophyte populations, the main constituents of the freshwater ecosystems, and they are having great difficulty in finding the right consultants to do that. They do not really have sufficient taxonomic and ecological expertise within their own ranks to do that, and I know from even very recent experience the great shortage of people with phytoplankton identification skills is serious, to the extent that I know one colleague in the Environment Agency is looking to Scandinavia to let contracts because these kinds of skills are still strong there. If I could influence you in any way I would urge you to either go back to Defra and ask for some clarification or perhaps even discount it. I brought with me a review of freshwater ecology in the UK because we are concerned that freshwater ecology as a science in general is actually decreasing and fragmenting and taxonomy for freshwater systems of course is part of that concern.

Q172 ***Earl of Selborne:*** Could I specifically just follow up the point about the Water Framework Directive; I understand that for every river it has to be determined what is meant by good ecological status, and that is something on which we are already, apparently, falling behind the timetable. Presumably aquatic taxonomy here will have a role.

Professor Battarbee: It is absolutely fundamental.

Q173 ***Earl of Selborne:*** Would you think you could achieve good ecological status while at the same time reducing the expenditure on this monitoring?

Professor Battarbee: The monitoring I am talking about refers specifically to acid rain and the impacts of acid rain, and Defra have significantly reduced the network that we have been running to look at the responses to that reduction in acid deposition. The answer in short is not as much as we would have done had they continued to fund. There are 22 lakes and streams that we have been monitoring for 22 years and that has been reduced now to a handful, so it is no longer a network, and in that network it has been the monitoring of chemistry and biology and different biological groups, and after 20 years now we are just beginning to see some signs of biological recovery, and so this network has now been reduced, just at the time where we are beginning to see some success in fact with the government policy. My concern is partly the loss of it from the point of view of monitoring recovery from acid deposition and acidification, but mainly from the fact that we have 20 years of excellent, high quality chemical and biological data for lakes and streams across the whole of the uplands of the UK just at the time when we need to have those kind of long-term data sets to monitor the future effects of climate change. No thought has been given to that, in fact, in the decision to reduce the funding for this particular network because the decision was taken by the air quality division in Defra and not by the division that was concerned with climate change. In our dealings with Defra we find there is very little joined-up thinking in fact which allows one department—Lord May mentioned silos in the past in a different context but there seem to be silos in Defra and a decision in one part of Defra was taken without any real regard to the wider need in fact to keep this network going. I speak with a vested interest but we have plenty of evidence to show that other people and other parties in the UK would actually support that particular remit, and in fact the Joint Nature Conservation Committee has just written Defra a long letter saying how much they think this is a wrong decision.

Chairman: We have an interest too although I hope not vested in monitoring what is happening in the watercourses of the country. Lord May.

Q174 ***Lord May of Oxford:*** We have heard quite a bit of evidence from people in the taxonomy and systematics community that their subject is in a worrying state and yet, rather oddly, the BBSRC—I was not at the meeting but read the minutes—and NERC have suggested that they just do not see a

problem, partly because they do not see basic taxonomy systematics as part of their business; to quote from the minutes "it is not a hypothesis-driven science" which I find rather bizarre. More importantly, they say "these concerns are not reflected from the user community". We see you as perhaps representing the user community, is it your experience that the user community is perfectly happy with the health of taxonomy and systematics in the UK at the moment?
Dr Gornall: I wonder who they have asked.

Q175 ***Lord May of Oxford:*** It is not clear that they actually asked anyone.
Dr Gornall: I will give you at least one example from one area of the user community which is ecological consultants, who are widely employed by councils up and down the land to do ecological surveys of various plots of land which are subject to planning permissions and so forth. They are really struggling for properly qualified people with taxonomic identification skills, so at least some of these surveys—goodness knows how many—will be substandard because the people employed are not properly qualified. Some reference was made in an earlier session to at what point is this tipping point. One of the panellists suggested we might have already got to it and I suspect that in terms of ecological consultancies we might be there now because it is certainly true that if you have got taxonomic skills you will be snapped up like that by these ecological consultants because there is a real shortage currently.
Dr Culham: Perhaps I could come in here as somebody who is both a user and a trainer of this group, I run an MSc that has been running continuously now for 38 years on taxonomy in various guises, but we lost one of our plant group ecologists recently through retirement and for low impact RAE work the university were not interested in replacing him; we gained a replacement through industrial funding, one of the ecological consultancies paid 50 per cent of the salary for a new member of staff, just for a basic replacement. We train and we provide those trained individuals that Richard has said are in such short supply, we train students every year in the identification of the British flora. It is specialist knowledge but it is now in huge demand from a number of consultancies. We have no research council-funded studentships for the Masters course, we have a small number of places funded again by consultancies and one place in fact funded by the Royal Horticultural Society as a result of the last House of Lords inquiry into systematics, they came forward with the money for one student placement. Money is tight.

Q176 ***Lord May of Oxford:*** It sounds like it would be a fair summary of your response to say that from your perspective as users the statement that we heard from the research councils is daft.
Dr Gornall: Absolutely.

Q177 ***Lord May of Oxford:*** On the other hand, the user community is a very diverse and varied community. Might it be that there are other sectors which do not see a problem and, if so, what might they be and why is it that the research councils are different from them and what can we do about it—or maybe they just did not ask anybody.
Professor Battarbee: We need to know who they asked really and who gave the answers.
Dr Culham: Yes, we do. Looking through scientific publications that are predominantly on molecular biology it is not unusual to refer to organisms by their common name, it is not unusual to have no substantiated taxonomic back-up on those papers to prove that the organism that is claimed to be in use was used. Part of the increase in research quality controls surely should be a requirement for editors of journals to check that organisms that are claimed to be in use in research are those organisms.

Q178 ***Lord May of Oxford:*** Of course, if we had full bar-coding that would work.
Dr Culham: Yes, but we need to get through the expertise gap to get to the barcode database; we need the morphological taxonomists I think to link molecular data to the morphological data.
Dr Gornall: Can I just add one more thing, and that is that there is a reservoir of taxonomic expertise out there. It is found amongst the amateur community, people who do it for fun. They are not employed, by and large, as ecological taxonomists, they are not by and large academics, they are just keen naturalists and they derive their skills from each other and from the very few academics whose paths they might cross. The Botanical Society of the British Isles, for example, has a network of over 150 people who look after what are called vice-counties—that is old-fashioned counties or sub-divisions thereof—and for particular projects the society can put out into the field something like 2000 people all with various levels, medium to high levels, of botanical expertise.

Q179 ***Lord May of Oxford:*** We already know that Defra is delivering part of the action plans largely through organisations like yours and the RSPB, they are dependent on it, but do you think the future is as secure as today, do you think those amateur societies are going to continue to attract young people who will go on in adult life?

Dr Gornall: It is very precarious, because it relates back to some of the questions you asked in the previous session about encouraging young people into the field. Although there are initiatives taken by various bodies there is not a national effort to try and get people back into whole organism biology, which is what is actually suffering and, as has been referred to earlier, taxonomy is one component of that, perhaps at the sharp end.

Professor Battarbee: It also differs between organism groups. I can imagine that the more charismatic groups will attract interest and amateurs will remain attracted throughout all age groups, as we heard again in the previous session. The groups that we work with are not so charismatic perhaps—we work with algae, particularly diatoms, which are beautiful organisms but you need a really high quality microscope just to see them; 20 or 30 years ago there was a thriving amateur community but they have all died now. We have a British Diatom weekend every year and gradually, over the last 20 years, the amateurs stopped coming, mainly because they had died. They have not been replaced at all, so there are lots of important groups, perhaps among the indicator groups rather than the groups that are very attractive, where expertise is gradually being lost and, as someone said before, there is a tipping point but it is a very slow and gentle decline as experienced professionals have retired or gifted amateurs have slipped away and not been replaced.

Q180 ***Baroness Walmsley:*** Could you tell us how accessible is Research Council UK funding for taxonomic and systematic studies that underpin climate change research? We have heard from NERC and they say they fund a lot of taxonomists as part of responsive mode research grants, and they say that if taxonomy is needed they will pay for it, but it strikes me as a very patchy way of doing it. We were wondering is this your experience and, if so, do you think this approach is sustainable and what impact might it have on the discipline?

Dr Gornall: I looked at the NERC website before I came and typed in "climate change" and there was a whole list of the grants that have been awarded in the last ten years, with climate change somewhere as one of the key words, and none of them was for taxonomy. Of course, I do not know what the applications were but it does suggest that taxonomy is not funded to the extent that it perhaps ought to be. If you however look at what taxonomic projects they have funded, they all relate to various aspects of evolution or conservation, none of them is for what you might regard as alpha taxonomy, that is the writing of floras or the preparation of monographs, none of them. Of course, that is because, presumably, that sort of research is not innovative, certainly, there are no new methods, there is no novelty, it is derivative and therefore it is unfundable and probably even ineligible for funding under some criteria. That aspect of taxonomy, what you might regard as alpha taxonomy, floras and monographs, does not stand a chance. Yet that is the stuff which people who monitor the environment, species compositions of floras and so forth, need; they need these products, the identification keys, the species descriptions and so forth. It is not being funded in this country outside major taxonomic institutions I should add.

Dr Culham: I will add a little to that as someone who has applied to NERC for research funding over the years and occasionally received some. Taxonomic funding is not built-in, you cannot get money into taxonomy. The way taxonomy has been achieved is through building it in as a small part of the larger projects with sexier titles, through conservation or through climate change. A positive side effect is that it does encourage taxonomists to collaborate with other environmental researchers and that is a very positive side effect; the downside is that the basic funding is not there to actually do adequate pieces of taxonomic work, it is simply patching gaps.

Professor Battarbee: Again, coming at it from the other side that is a perfect answer in a sense because when we have questions about climate change and its impact upon ecosystems we are confronted by taxonomic issues immediately, and most of our community will have those routine taxonomic skills so it is not important at that particular point. It always becomes a problem, however, when you are faced by a taxonomic question, a taxonomic problem, and you then need some professional taxonomic expertise to resolve that, to make progress, a separation perhaps between two species that are pretty much the same but might have really quite different ecological preferences or respond differently to climate. At that point you then really need to have some professional expertise to start to say are these two species, how are they related, can we separate them, do they live and grow in different environments? What we try to do is move in that direction and we always depend upon the availability of more expertise in a university or, more than usually, in the NHM or somewhere like that. That reservoir of experts is therefore absolutely essential when that point comes where we need that extra, very high-level professional skill to separate between specific species. One final point on that is what we try to do when we are applying for research money, when we know there is some taxonomic needs involved with that, we disguise it and we often call it taxonomic quality control between labs. Just as it is very important in chemistry to be able to measure things absolutely accurately and to have the same

accurate measurements between laboratories, we transfer samples and different machines are then used to see if we come up with the same answers. We can do that with identification of specimens as well, so we send microscope slides around and people have to identify them blind so to speak, then we can compare results and see whether we have consistent approaches to splitting and lumping in taxonomic divisions. We disguise it because we do not think it will enhance our research proposal.

Q181 ***Baroness Walmsley:*** That seems terribly sad to me. Can I ask a follow-up question? Professor Georgina Mace told us that for the purposes of the RAE outputs are measured not just on their scientific merit but how well they correlate with policy. Have you noticed that?
Dr Gornall: With whose policy?
Baroness Walmsley: I presume she meant government policy; it must have been. This might be helpful to taxonomy given the Government's concentration on the effects of climate change for example.

Q182 ***Chairman:*** If it has not crossed your horizon then just say so.
Dr Gornall: The way people work at universities is wonderfully anarchic. To some extent we are market-driven in that we know what is flavour of the month in terms of the research councils and what they are likely to be funding, so you will try and angle your research in that direction and, as Alastair says, dress up your taxonomic project as something else perhaps. You really do follow your own nose and you make your collaborations with other institutions as and when you see fit, so I am not certain that anybody really pays much attention to government policy other than as a reaction to where the money comes from.

Q183 ***Baroness Walmsley:*** Is it not government policy that drives the RAE and then therefore that drives the applications?
Dr Culham: There is another step involved there. Government policy drives what the research councils will fund and what research councils will fund governs what grants we can get and therefore what outputs we can produce, and of course the quality outputs are what is measured in the RAE. Without funding we are stuck, but funding does follow government policy in as much as research council funding, particularly specialist initiatives, follows that policy.
Dr Gornall: As taxonomists the RAE is an impediment in a way, we cannot do what we are trained to do to our fullest capacity. It has to be almost subverted so that it gets incorporated into another project basically.

Baroness Walmsley: This is all depressingly familiar having chaired the last report five years ago.
Chairman: And in other areas too. Lord Northesk.

Q184 ***Earl of Northesk:*** In written evidence the BSBI comments that the leading UK systematic research institutions do not take on a leadership role in the national context in terms of setting research priorities and facilitating training. What in your view needs to be done to rectify this?
Dr Gornall: I have to say I found it a rather loaded question actually, so in my response I said that these institutions do not take on a leadership role in the UK context, at least the ones that I am aware of. They all carry out their roles in these different activities, both in research and in facilitated training, and they do that as part of their own internal policies and they do it excellently, but there is not to my knowledge a national consensus or body that has set any kind of agenda as it were. These national institutions may collaborate and they do collaborate with bodies on an ad hoc basis as the need arises, but I would hesitate to say that there is a leadership role being taken by any of them and I would actually question, before you say how do we get one, I would like some sort of forum at which we could discuss whether we need a leadership role. This relates back to the co-ordination issue which was discussed earlier; the presence of yet another body—we should be cautious before jumping into that one. Having said all that of course there are areas where a bit more of a co-ordinated approach would be beneficial. I am hesitant to say at the moment that I would certainly love to see a leadership role being taken by, say, the likes of Kew or the Natural History Museum or Edinburgh or whatever.

Q185 ***Lord Haskel:*** The regional botanic gardens and museums we have been told house important collections but some evidence from the Botanical Society of the British Isles highlights the widespread transfer of collections to larger institutions, perhaps for safety but even for destruction of the collections. What are the drivers, what are the reasons for this?
Dr Gornall: The transfer is to avoid the destruction of the specimens.

Q186 ***Chairman:*** That is a relief.
Dr Gornall: The drivers are largely just the exigencies of local authority funding because many of these collections are in local museums, some of these collections are in schools. In the past many schools actually had or developed herbaria as part and parcel of the biological education of the students and nowadays the GCSE and A-level syllabuses have changed to such an extent that school herbaria in particular are surplus to requirements and in many cases these have actually just been put in the skip. I

know of one recently which was saved from a rather dank London basement; it contained some enormously valuable historical material and I am glad to say that it is now being well cared for at the University of California in Berkeley, so it had a reprieve and I hope that we will learn more about the collections that are in it in due course. The main drivers in schools are the GCSE and A-level syllabuses which no longer support whole organism biology to the extent which they used to and therefore the students no longer collect specimens; in local authorities the driver is simply one of money. Many museums no longer can afford to have a zoological curator as well as a botanical curator so one of them has gone; sometimes the zoological one has stayed and so the botanical specimens are just put in a box and archived and nobody ever looks at them. Yet they contain extraordinarily valuable historical data; it is unpublished but it has been collected by individuals over 200 or 300 years and it is there in our archives. The BSBI actually has an initiative at the moment to go around photographing these specimens, the material is then put up on the web and members of the public are invited to transcribe the data so we actually can recall the records. I know this is not a systematic scientific survey of what was present or not present in the British Isles 150, 200 years ago, but it is better than nothing.

Q187 ***Lord May of Oxford:*** In so far as this is going out of syllabuses, do you not think that is likely to have an impact on the amateur societies that we were talking about earlier?
Dr Gornall: Absolutely. The children will no longer be exposed to the enthusiasm and the joy of natural history and it will just pass them by, they will be lost to us.

Q188 ***Lord May of Oxford:*** Are they falling out because of the prejudice against taking kids outside the school grounds on health and safety grounds or are they falling out because they do not seem to be hypothesis-driven science, or both?
Dr Gornall: My knowledge of the GCSE and A-level curricula is not brilliant, but I know something about it. A lot of it seems to be focused on human biology and a lot of it is bent over backwards to include quite up-to-date science in it and, given that you have got to have X amount in the syllabus, you cannot have it all in, to some extent the less fashionable stuff has been squeezed out. I also question to some extent the decisions of the people who actually include the topics that they do include, so speaking with a botanical hat I know from interviewing students year in year out in my first year biology class when I ask "What botany did you do at school?" the only thing they have in common is photosynthesis and they did a little bit else as well, but it is basically photosynthesis. I cannot think of a bigger turn-off at that age than the biochemistry of photosynthesis. Come on people, there is a better way of enthusing our young people about natural history and the scientific world than reducing plants to photosynthetic metabolism; they are much more than that. It is important, I acknowledge, but you get all you need to know at primary school and you do not actually need to touch it again until you get to university, there are lots of other really exciting things that you can do. I am digressing here.

Q189 ***Chairman:*** It is very interesting.
Dr Gornall: That is one of the reasons why kids are not taking it up, botany in particular.

Q190 ***Lord Haskel:*** Are you trying to do something to get this situation reversed, for instance to get the local museums more involved and this sort of thing?
Dr Gornall: There is a network called the Botanic Gardens Education Network—this is just about plants of course—but botanic gardens around the country are trying to address this problem by having schools programmes. At Leicester we have one and last year we had over 9,000 kids through the gates where we did basic biology of plants and evolutionary biology as well, and the age range was from 5 up to the age of 18, so right across the primary and secondary school spectrum; but these initiatives are local, nothing compels a botanic garden or a museum to do these sorts of things. Where they have an education officer of course they try, but there is no co-ordinated response, it is all very ad hoc. The advantage of that is that you can actually do what you like, there is no set syllabus, although obviously to get schools to come you have to look at what is on the syllabus but we try and enrich that by producing material which is on the syllabus but which we regard as extension work, enrichment work. It is a problem with the school syllabus.

Q191 ***Earl of Selborne:*** We heard that Defra's Central Science Laboratory houses a bar-coding unit with a strong focus on plant pathogens, including fungi. The University of Reading is also active in searching for molecular markers for fungal pathogens. Are there synergies between academia and the Central Science Laboratory?
Dr Culham: Another difficult question. Superficially, yes, there are some synergies; we have links mainly with our plant pathologists and the CSL but recent experience, again funding driven, is that a very promising employee at CSL who completed a PhD on rysoctonia, a disease of cabbages, part-way through her PhD was then transferred onto a project on bees, to study varroa, using the same molecular techniques

but losing effectively the taxonomic knowledge she gained on the infective fungi. Both groups are developing molecular markers, the technology is there and it is something that most universities have access to. Links are maintained really by availability of funding, particularly on PhD projects between CSL and Reading.

Q192 ***Baroness Walmsley:*** Dr Culham, your university, the University of Reading, benefited from the NERC taxonomy initiative in the 1990s and we know that that left a real footprint, a real heritage which still survives in your university and elsewhere. Is it time for another one?
Dr Culham: I was quickly doing some sums as to where those footprints had taken the people that worked on that initiative; I was one of the people who received grant money from that. Of the four post-doctoral research fellows we had one is now in the Netherlands, one in South Africa, one in Canada and one in the US because the career paths there were much stronger. Of the ten PhD students, two are still in the UK, one working for Kew, and most of the rest are now in the US. In fact, one of them is curating the herbarium that took on the UK school collection that Richard referred to.
Lord May of Oxford: Clearly we need a transfer fee system.

Q193 ***Baroness Walmsley:*** Does that mean that you are saying we would be wasting our money having another such initiative unless we have career options to keep them here?
Dr Culham: Yes. Reading hosted what I can only call the closing conference of the NERC taxonomy initiative and it was evident certainly three years into the five years of the initiative that there was no serious intention by the NERC to fund basic taxonomic research after the end of the initiative. They were very open about it, the head of NERC at the conference stood up and said words to that effect and career-minded taxonomists, of which we developed many during that initiative, felt that they had seen the writing on the wall and they went to countries where there was a career in taxonomy. In fact, most of them now have been promoted well beyond my status at Reading, having trained many of them. There is a need for another initiative but it must have core funding to follow it up and there must be a career path for those people who are trained.
Chairman: Thank you very much, that is very helpful.

Q194 ***Lord May of Oxford:*** That is tricky; it cannot be dedicated core funding just for that, it has got to be a vision of science that is more generous and saner than that which is currently animating NERC.
Dr Culham: Yes, and BBSRC. They need a remit that should include taxonomy; both of them I have received funding from over the years but the taxonomy has always been disguised, there has been no core taxonomy funding, which is different in other countries.
Chairman: You can see that both sessions this afternoon have engaged the Committee very firmly and we have responded as you have responded. Thank you very much again for the written evidence and may I repeat the offer, that if there are matters that you would like to clarify further in writing we would be very happy to hear from you, or if there are points that have occurred to you because of the session, again we would be very happy to receive anything in writing that you would like to submit. Thank you very much for your time and for the interest you have provoked.

Supplementary memorandum by the Systematics Association

Opening Statement

The Systematics Association welcomes the ongoing interest of the House of Lords in the UK's systematic biology community, and acknowledges the patience shown by the Lords in their willingness to continue to monitor what might conceivably be regarded as a minority discipline, of tangential importance to the UK's science base. Obviously, this is not the view of the Association. However, we do believe that taxonomy is currently operating at the sharp end of a broader malaise that is slowly but steadily eroding the cohesion of the UK's science base—specifically, the piecemeal dismantling of the infrastructures surrounding a wide range of enabling, baseline sciences that are best represented by taxonomy in the present round of parliamentary reviews.

In our opinion, the most critical challenge that we are facing is the broader question of how the UK maintains—or perhaps fails to maintain—sufficient fundamental research in disciplines that require continuous, long-term activity but that feed only indirectly into the needs of society—and so contribute only indirectly to explicit policy-related targets and government commitments. The way the UK's science is currently funded strongly emphasises short-term research projects addressing more focused, and so more

tractable, problems. Also, the government's long-standing predilection for setting a few simple performance targets to encourage development of particular areas of research inevitably forces research leaders to prioritise immediacy of impact above the maintenance of permanent infrastructures—in this case, of both taxonomic researchers and the collections that provide much of the basis of their work.

This trend of instant gratification has been epitomised by the Research Assessment Exercise, which has dictated research planning in the universities and has strongly influenced policy in all other public sector institutions. The RAE in effect boils down to just two linked criteria—bringing into the host institution the maximum amount of overhead funds, and publishing a small number of scientific papers of high immediate impact—an approach that is, in truth, highly inefficient, and certainly one that seriously disadvantages taxonomy, which has at best a modest initial impact but retains its full relevance thereafter.

At this point, I would like to make a personal confession—in my past roles as Director of Science at the Royal Botanic Garden Edinburgh and as Head of the Botany Department at the Natural History Museum, I have knowingly and deliberately contributed to the decline of the taxonomic research conducted under my proctorship. I have done this by encouraging staff to evolve their research programmes to better fit the RAE-inspired criteria by which they, and their institutions, are currently measured. In making this decision, I have been in accord with the policies promoted by the senior managements and Boards of Trustees of these institutions. Moreover, I remain unrepentant—in the current environment, taxonomy simply does not bring adequate benefits to either the individuals or institutions that pursue it. Thus, to maintain a strong taxonomic base in such an environment is an act of altruism that can only accurately be described as reckless.

Suggestions for making taxonomic data more widely available are similarly altruistic, since one of the main features of taxonomic data is the willingness with which we share those data for free. Placing such data on the Web is simply the latest manifestation of a long and honourable tradition of freely distributed biodiversity information, borne out of Victorian philanthropy, and encouraged by the continued substantial contribution of amateur organisations to the surveying and monitoring of organisms.

The truth of the matter is that the taxonomic community has become increasingly influenced by market forces, and the market price for taxonomic data has historically been next to nothing. Ironically, this collective generosity now decreases the influence of taxonomists in the wider world. Yet it remains a highly desirable feature of our community, because the data are valuable to an exceptionally wide range of users—but often indirectly, through complex chains of intermediaries. This mode of usage reduces the value that anyone user places on taxonomic data, and makes it all but impossible for the originator to recoup the costs of generating that data, even though those costs are remarkably modest. It is equally difficult to persuade funders or users to view preserved or living natural history collections as being analogous, to the concentrations of DNA sequencing technology that permitted successful completion of the Human Genome project. In short, the Association believes that taxonomy is too far removed from "the market" to allow its future to be dictated wholly by market forces. The negative consequences of doing so have become painfully evident, and lie at the root of the present review.

The declines in long-term infrastructures such as taxonomy are occurring slowly, so that their consequences are not immediately obvious. However, we note that reversing the decline in taxonomy will of necessity, also be a slow and tortuous process (the oft-used popular super-tanker analogy is particularly apposite here). The Association concludes that Britain needs to develop a simpler and more responsive science infrastructure—one that is expressly designed to operate over much longer time scales. The shorter term, more overtly charismatic research programmes that are the current focus of British science could then be firmly fixed onto that robust framework, thereby improving both cohesion and communication in our science base and better placing UK researchers to address major interdisciplinary challenges, not least climate change. The association believes that the broader topic of Britain's long-term research base should be regarded as a high priority for future parliamentary review.

TUESDAY 29 APRIL 2008

Present	Colwyn, L	Selborne, E (Chairman)
	Krebs, L	Soulsby of Swaffham Prior, L
	Haskel, L	Walmsley, B
	Methuen, L	Warner, L

Memorandum by the National Biodiversity Network Trust

1. Background

1.1. The National Biodiversity Network Trust (NBN Trust) is a charity set up to oversee the development of a National Biodiversity Network, and to encourage participation in its objective of making UK biodiversity data and information available through the internet (see Annex).

1.2. As such, the NBN Trust feels that it has a particularly relevant overview of some aspects of the topic covered by this Inquiry and wishes to make the following submission, in particular, relating to the role of systematics and taxonomy in generating and using biodiversity observational data. We have therefore addressed questions 2, 7 and 8.

2. Responses

Question 2.

2.1. The role of systematics research in relation to biodiversity conservation etc. in the UK, varies greatly across taxonomic groups, depending on whether these groups are well-understood already or not, and on the perceived relevance of particular groups to overall ecosystem function. For example, taxonomic research on fungi found in the UK is currently very active, owing to the increasing realisation of the role of fungi in ecosystems; while taxonomic research on groups such as the mammals of the UK is limited since they are already well-studied. Looking at issues of biodiversity conservation globally, taxonomic research plays a crucial role, since if one cannot identify and monitor the planet's living organisms one cannot assess the impact of climate change on biodiversity. The UK has a leading role to play in this field.

2.2. The role of basic taxonomy, however, remains highly important across most groups, because of the need to maintain and enhance understanding of the role and inter-relationships of specific taxa in the environment. This applies both to the definition of taxa and also to their identification in practical situations. The role of taxonomy is fundamental to all other activities involving the study and management of the broader natural environment. Without an ongoing process of developing and maintaining taxonomic knowledge, both in terms of current scientific understanding, and the application of that knowledge in practice, our ability to properly appreciate and react to the needs of conservation would be seriously impaired.

2.3. As far as the level of recognition of this contribution is concerned, the NBN Trust has only tangential evidence, but its contacts with a broad range of organisations covering a wide range of taxonomic groups would suggest that the importance of taxonomy is still very under-estimated, despite reports on problems with taxonomic support going back to the 1980s. For example, few universities now address whole-organism biology or taxonomy within their curricula (although very recently this has slightly improved). Also, many other institutions, such as museums, that formerly had natural science staff with taxonomic expertise in various fields have now lost them. The result is that many subject areas witness difficulty in recruiting and developing new participants, and, in a substantial number of cases, the country is now lacking paid personnel with specialised knowledge in a particular group. Given the mainly volunteer-based nature of biodiversity recording and documentation in the UK, this is increasingly a concern. The Trust also understands that there are increasing difficulties recruiting even professional staff proficient in species identification across a broad range of groups by, for example, ecological consultancies and local authorities. Much of the problem stems from the dispersed nature of the taxonomic endeavour and its sources of funding, sometimes quite divorced from either mainstream academic funding or that directly related to biodiversity conservation. For example, funding of regional museums, with a vital role in supporting taxonomy, is usually unrelated to research or conservation funding streams.

Question 7.

2.4. The NBN Trust has wide and substantial experience in this area, having supported processes of biological recording across all sectors since its inception.

2.5. Taxonomic data consist of a number of discrete components:

- Data concerning the description, biology, genetic make-up and evolutionary relationships of the taxa themselves.
- Information on the ecology and interaction of taxa.
- Data on the geographical and temporal occurrence of taxa.

2.6. Strict taxonomic data concerns primarily the first of these, but its application is fundamental to effective work involving the other two components. In turn, data collection in these other areas provides essential feedback to the processes involved in the first area, as well as providing data to other users in conservation and land management etc.

2.7. At present, data collected and generated in relationship to the first of these areas is patchy, depending on the taxonomic groups concerned and the organisations or individuals involved in its production. As noted in the answer to Question 2, above, quite a few taxonomic groups now have few, if any, people actively involved in their description and study in the UK, and funding for this role is often insecure. Several insect groups, for example Diptera and Coleoptera, rely in part at least on purely voluntary expertise, often from a very few retired professionals.

2.8. Collection of data in relation to the second area is largely the affair of professional organisations, such as the Centre for Ecology & Hydrology in NERC, Rothamsted Research in the BBSRC, or some universities. As such, it is probably better funded and supported than most areas, although basic data from such sources is sometimes not readily accessible by others.

2.9. The principal area in which biological recording schemes at the national and local level are engaged is with the third area—the broader collection of data on the occurrence of species. This sector is extremely varied and dispersed. There are about 80 existing taxonomically based national recording schemes, ranging in size from one-man-band, volunteer operations with few or no resources; through to large biodiversity organisations focused on a specific group, such as the British Trust for Ornithology. In addition to this, there are large, but unknown numbers of local voluntary natural history organisations that may or may not feed data into these national schemes. At the local and regional level, there is also an incomplete network of some 74 local records centres, run either by local authority based partnerships or by voluntary bodies etc. that collect biodiversity data especially in relation to local planning and land management needs. These also may or may not collaborate with respective national recording schemes over the collection and validation of data.

2.10. The primary mechanism for the support of most, especially the smaller terrestrial national recording schemes is through the UK Biological Records Centre, currently at CEH Monks Wood, and due to transfer shortly to CEH Wallingford. The resources of the BRC are relatively limited, although improving, especially through its partnership role in the development and use of the NBN Internet Gateway as a mechanism for data communication. Larger recording schemes are increasingly being supported directly through voluntary societies, although funding support for this activity is often patchy and short-term, either coming from government bodies of one kind or another, or from charitable sources. Lottery funding has sometimes been available, but the criteria for receiving these funds often do not relate to the needs of the biological recording organisations. Marine biological recording is supported by a separate network of organisations, focused through the Marine Biological Association. The Freshwater Biological Association also lends some support in its area, especially through recently acquired short-term funding from charitable sources.

2.11. Local records centres are a non-statutory function at the local level, and therefore suffer from insecure and often very inadequate funding, although this is improving through increased support from the Conservation Agencies recently. Their role is largely to focus the collection and use of data towards biodiversity conservation and related needs at the local level, but they also play an important (but varying) role in support of biological recording by local voluntary groups on the ground, and are therefore an important element in supporting the overall capacity of national recording schemes as well.

2.12. As regards the effectiveness of the current system to generate and make data available to potential users, the NBN Trust and its partners have recently carried out a review of this area, and it is evident that, while broad-scale understanding of most groups is reasonably well catered for through the majority of existing recording schemes, the level of detail and frequency of survey that are now being demanded by key data users is putting a severe strain on the existing recording system. Many voluntary recording schemes are just not well-enough supported, either in terms of people involved or practical resources, to carry out the level of recording that is increasingly needed for uses such as Biodiversity Action Plan work or development planning control.

Meanwhile, local records centres, that might be in a position to fill this need, are not securely funded, and often do not have sufficient staff with wide enough knowledge to carry out this work either. The NBN Trust, through its partnership, is now seeking to co-ordinate what resources may be available from existing sources to do what it can to improve both the flow of data and its quality. However, much more is needed to be done to support both the volunteer recording network and local records centres if users' data needs are to be met.

Question 8.

2.13. As has been mentioned in relation to Question 2, above, museum collections are a vital resource underpinning taxonomy and also recording in the UK, but tend to be under-resourced, partly as a result of not being seen as a high priority within the museum, especially at the local level.

2.14. The taxonomic support provided by museum biological collections involves more than one aspect. National and major regional collections have an obvious and direct role in support of descriptive taxonomy *per se*. Their collections will have important UK type specimens necessary for nomenclatural work, as well as for research. However, the role of larger local museums also in providing resources for identification and the maintenance of necessary reference material from recording work, both by their own staff and from voluntary sources, must not be under-estimated. This latter role is often badly neglected by local and regional museums, especially if they have lost specialist skilled staff through lack of resources. The tendency for many museums to employ generalist collections managers, while being administratively efficient, may not enhance their function as centres of local or regional expertise, or as effective resources to support local recording.

2.15. The role of independent university and other research centre collections should not be forgotten, although these are increasingly seen as irrelevant when molecular biology becomes the sole interest of their institutions. While the university itself may have moved away from whole-organism biology, the collections in their care may be vital for ongoing taxonomic understanding generally because they may house important material from earlier workers. Recognition of these roles through funding mechanisms needs to be examined and enhanced.

2.16. Finally, the interdependence of smaller museums and larger institutions also needs to be recognised, where collaboration with the professional expertise of larger institutions can be vital in maintaining local capacity.

Annex

THE NATIONAL BIODIVERSITY NETWORK TRUST

1. The National Biodiversity Network Trust (www.nbn.org.uk) was established in 2000 as a company limited by guarantee and a registered charity

2. The full members of the Trust are drawn from non-governmental organisations and government agencies, namely:

Scottish Natural Heritage	Scottish Environment Protection Agency
Natural England	Environment Agency
Countryside Council for Wales	Natural History Museum
Joint Nature Conservation Committee	Natural Environment Research Council/ Centre for Ecology and Hydrology
Marine Biological Association	The Wildlife Trusts
Freshwater Biological Association	British Ecological Society
National Federation for Biological Recording	

3. The Board of the Trust is drawn from nominees appointed by these full members and presided over by an independent chairman, Sir Neil Chalmers.

4. The Trust is a non-advocacy organisation whose principal objects are:

- to improve and ensure the accuracy and verifiability of collected biodiversity data and to promote its effective collation and interpretation.
- to develop an electronic network connecting all known data holders through the Internet, and to promote public access to the network, with appropriate safeguards for sensitive and personal data.

5. To this end the Trust operates an internet "Gateway" (www.searchnbn.net) which presently (January 2008) gives rapid access to 27,920,319 species distribution records from 229 different datasets, many of which are available at a resolution of 100 metres square. The majority of these data derive from voluntary recording organisations, or from local records centres etc., that participate as partners in building the Network. Interpretation of these data is aided by a mapping interface which also allows access to geographical boundary datasets including SSSI, SPA, SAC, National Nature Reserve and Watsonian Vice-county boundaries.

6. The NBN Gateway is also the UK node of GBIF, the Global Biodiversity Information Facility through which it is possible to access species data sets from around the world.

Memorandum by the Joint Nature Conservation Committee

JNCC is the statutory adviser to the Government on UK and international nature conservation. Its work contributes to maintaining and enriching biological diversity, conserving geological features and sustaining natural systems. JNCC delivers the UK and international responsibilities of the four country nature conservation agencies—Council for Nature Conservation and the Countryside, the Countryside Council for Wales, Natural England and Scottish Natural Heritage.

The state of systematics and taxonomy research

Q2. *What is the role of systematics and taxonomy and, in particular, in what way do they contribute to research areas such as biodiversity conservation, ecosystem services and climate change? How important is this contribution and how is it recognised in the funding process? How is systematics integrated in other areas of research?*

1.1 Biodiversity conservation is concerned with sustaining the full variety of life, from biomes containing many species down to the genetic variation that is present within individual species. Systematics is an essential tool that underpins biodiversity conservation by providing a logical classification and framework for describing and studying living organisms.

1.2 Biodiversity conservation depends upon the accurate definition of species, but it is increasingly becoming realised that each level in the hierarchical classification of living organisms is of value for conservation. Higher levels (genera, families and above) group together related species that share common ancestors and many biological properties. These shared properties can be used predictively to investigate how related species can best be conserved. At lower levels (for species, and segregates within species) inter-breeding organisms contain much genetic variation, which is essential for their long-term survival. Discovering the extent and nature of this variation is important when attempting to conserve threatened species with small populations.

1.3 The accurate identification of species is fundamental to current biodiversity conservation programmes in the UK, including in particular:

i. in the selection of Sites of Special Scientific Interest (SSSIs) in Great Britain and Areas of Special Scientific Interest (ASSIs) in Northern Ireland. SSSIs and ASSIs are the primary mechanisms for protected area-based nature conservation in the UK, and are at the core of the UK's nature conservation strategy;

ii. species recovery and action programmes undertaken under the UK Biodiversity Action Plan, where the accurate identification of species is necessary to implement needed conservation action (including legal protection and enforcement);

iii. measuring progress towards halting the decline in biodiversity by 2010, which is a key international obligation for the UK;

iv. reporting on the conservation status of UK species of European Community importance, which is an international obligation for the UK under the EC Habitats Directive.

1.4 In addition to traditional taxonomy, there appears to be significant potential in applying the rapidly-expanding field and knowledge of genomics to nature conservation, and to our understanding of ecosystem services.

1.5 DNA sequencing has already proved to be of considerable value in the understanding of the evolutionary relationships between organisms, including determining which organisms are closely related, and their relative position on the evolutionary "tree". The study of DNA characteristics has already revolutionised ideas about the nature and categorisation of life-forms and is proving a considerable aid to traditional taxonomy in the identification of species having otherwise very similar characteristics.

1.6 Potentially, DNA sequencing also provides a way of identifying different microbial species, 99 per cent of which cannot be grown in laboratory cultures. However, given that there are estimated to be very large numbers of "species" of micro-organisms (probably millions), the technique could be problematic to apply in practice. Another approach currently being explored is to characterise the DNA of small samples of seawater and soil, treating the whole sample as if it were an organism and endeavouring to predict its ecological and environmental role. The facilities made available as a result of the human genome project are helping to drive this work forward, but its potential may be some way from being realised.

1.7 Perhaps more prosaically, genomics may help us to prioritise conservation action by concentrating effort on taxa which are genetically quite distinct from others, as opposed to endeavouring to conserve numbers of taxa which are genetically quite similar. It would be regrettable to fail to take action to conserve species which were genetically quite distinct from others, simply because we failed to recognise the fact.

1.8 JNCC considers that, in the future, there will be a need for both traditional taxonomic expertise and also new approaches such as those referred to in 1.5 to 1.7 above.

Q3. *Does the way in which systematics research is organised and co-ordinated best meet the needs of the user community? What progress has been made in setting up a body to lead on this? What contribution to the leading systematics research institutions make both nationally and internationally?*

2.1 Traditional systematics in the UK is marking time; it is not competing effectively for funding with other biological sciences and is dwindling in relation to the needs of its users. There is a declining population of professional systematists and funding is probably also declining overall; new initiatives that have been attempted to improve the situation have been inadequate for the task.

2.2 UK systematics has a complex organisational structure, with no single body responsible for leading and developing the subject. The multiple users of systematics in the UK are too diverse in their needs to be able to act effectively together in giving the leadership and direction required. These users include biodiversity conservation, ecological research, trade and industry, medicine, agriculture, forestry and education.

2.3 JNCC considers the fundamental problem lies in the lack of overall direction and responsibility for UK systematics. JNCC is not aware of significant progress being made to provide overall direction and responsibility for UK systematics since the Select Committee's last report into this matter, and remains of the view that a single Government Department needs to be given responsibility for this. Its responsibilities should include: considering the range of taxonomic skills that will be required in the future, identifying areas of projected shortfall in the supply of these skills, and initiating action to ensure such shortfall is addressed. Co-ordination mechanisms, however well-intentioned, are unlikely to meet this requirement.

2.4 JNCC and the country agencies assess the changing status of UK biodiversity, working in partnership with research institutes, universities, national societies, non governmental organisations and expert individuals. The JNCC and country agencies commission little systematic research, but instead seek to work in partnership with professional and volunteer systematists to deliver checklists of UK species and higher level taxa, as well as reliable ways of identifying these, to enable their detection and effective conservation. These activities should be seen in both their national and international contexts, because, increasingly, biodiversity conservation is working via international conventions (such as the Convention on Biological Diversity) and Directives of the European Union (the Birds Directive and the Habitats Directive).

2.5 Systematics enables effective sharing of information about species by establishing an internationally-recognised system for describing, naming and classifying taxa. Both biodiversity conservation and systematics rely upon networking and sharing information, using checklists of named species to ensure that dispersed sources of information can be located and used reliably. JNCC is a partner in the development of the UK biodiversity information network, the National Biodiversity Network (NBN), to share information about UK flora and fauna. There is a particular association between JNCC and the Natural History Museum to deliver the species dictionary for the NBN. It is important that UK biodiversity is understood in relation to the changes taking place in the status and distribution of species in other countries, which depends upon extensive sharing of information via networks.

2.6 UK research institutions and user bodies are attempting to fill the gap left by the absence of clear direction and oversight by coming together to achieve improved co ordination and greater efficiency of effort, and the better direction of available resources to meet needs. However, these endeavours tend to be somewhat *ad hoc* and piecemeal.

2.7 JNCC considers that the UK contributes considerably to global systematics, via its extensive collections, libraries and expertise. We are aware that many UK institutions, including the Natural History Museum and the Royal Botanic Gardens, Kew, make substantial contributions to biodiversity conservation

internationally, including through programmes such as the Government's Darwin Initiative. By far the major part of UK biological collections and information, and associated expertise, relate to species of overseas origin. UK institutions are actively engaged in supporting biological conservation overseas by facilitating access to their collections, contributing their expertise and assisting in knowledge transfer. The potential to increase this contribution is enormous, were resources for that to become available.

2.8 UK institutions are aware that the development of innovative and cost effective ways of achieving knowledge transfer in the fields of systematics and taxonomy to developing countries will be required if these countries' conservation and other needs are to be met.

Q6. *What impact have developments in DNA sequencing, genomics and other new technologies had on systematics research? In what way has systematics embraced new technologies and how can these research areas interact successfully and efficiently?*

3.1 JNCC is not in a position to comment substantively on this question, but we would refer you to our response under paragraphs 1.5—1.7 above in relation to the future potential significance of these research areas to nature conservation.

Q9. *What progress has been made in developing a web-based taxonomy? How do such initiatives fit in with meeting demand for systematics and taxonomy information? How do UK-led initiatives fit in with international initiatives and there is sufficient collaboration?*

4.1 JNCC considers that web-based taxonomy has enormous potential to transfer taxonomic knowledge to the user community worldwide, to communicate innovative and cost-effective taxonomic techniques to a dispersed audience, and to update information rapidly.

4.2 Web-based taxonomic initiatives are developing rapidly, but as there is no effective co-ordination of these there is no means of ensuring resources for this work are directed cost-effectively, and there is a risk of proliferation, duplicated effort and important areas not being addressed. To the end-user, the large scale European and International initiatives appear competitive when in reality they are, in the main, tackling different but related problems. For example, the Biodiversity Heritage Library is digitising historical literature, the European Distributed Institute of Taxonomy is mainly developing tools, while the Global Biodiversity Information Facility is concentrating on joining digital data together.

4.3 The real constraint to ensuring web taxonomy delivers information that is readily and easily used for conservation and other purposes is the absence of clear mechanisms to support this. The current (mainstream) way taxonomic information is disseminated is via a very fragmented base of institutional publication mechanisms, and subscription journals. To make web based systems work, and become the mainstream, adequate incentive mechanisms are needed to encourage this. These are not yet in place.

Q10. *What needs to be done to ensure that web-based taxonomy information is of high quality, reliable and user friendly*

5.1 The quality of information in web-based systems is generally of good quality and it is possible to build peer review, and other quality assessment measures, into web-based systems. For example, both UK National Biodiversity Network, and the Global Biodiversity Information Facility have developed standards for describing web delivered data content. They have also produced tools that enable data to be fitted to their intended applications.

5.2 The methods for ensuring quality can be developed. The issue is how to sustain the resources for the web-based publication mechanisms so that they can run the quality assurance processes once these become available.

Q11. *How does the taxonomic community engage the non-taxonomic community? What role do field studies play?*

6.1 Taxonomy is specialist in character and not always easy to communicate effectively to a non-specialist audience, but this is an important challenge that taxonomy needs to address if its tools are to be used effectively, and if the resources needed to maintain taxonomic expertise, and to develop new, and potentially easier-to use, tools are to be forthcoming.

6.2 In general, we do not consider that the taxonomic community has been successful in communicating the value of its work to the non-taxonomic community, and outreach activity needs to be developed considerably. Nonetheless, there are examples of institutions with good outreach programmes, for example the Royal Botanic Gardens, Kew.

Q13. *What is the state of training in systematics and taxonomy? Are there any gaps in capacity? Is the number of taxonomists in post, and those that are being trained, sufficient to meet current and future needs across all taxonomic subject areas?*

7.1 JNCC is not able to give a comprehensive response to this question, although we would anticipate that the answer would be that there are gaps in current capacity and that we would be very surprised (though pleased) to hear that future training needs in systematics and taxonomy have been investigated and plans to meet these needs put in place.

7.2 JNCC is aware that gaps can arise in expertise in the UK or in parts of the UK. For example, although Scotland is of international importance for lichens, five years ago there was a dearth of lichenologists working in Scotland and this caused significant problems for lower-plant conservation there. Action was taken to address this but the potential for gaps in expertise to emerge is always there.

7.3 It is necessary for specialists with taxonomic expertise to be deployed in the field and the need for identification of species on sites cannot always be met by sending samples to distant centres for identification purposes. The same issue applies in implementing *in situ* species recovery programmes effectively, with lower plant and invertebrate groups being those where lack of specialist taxonomic expertise is felt most. Increasingly, as conservation effort addresses the needs of marine biodiversity, an increased demand for taxonomic expertise in marine organisms can be expected.

4 February 2008

Examination of Witnesses

Witnesses: Sir Neil Chalmers, Chairman, and Dr Jim Munford, Programme Director, the National Biodiversity Network Trust; Dr Mark Hill, Head of Biological Records Centre, Centre for Ecology and Hydrology; and Dr Ian McLean, Head of Targets & Standards, Joint Nature Conservation Committee, examined.

Q195 ***Chairman:*** Welcome to our witnesses; we are most grateful to you. I apologise for the fact that I am deputising for the Chairman but, as I explained outside, he has been delayed in Scotland. There is an information note available for the public. This sets out the Members' declared interests, and I think I should at this point remind you that I was once Chairman of the Joint Nature Conservation Committee and that is not totally irrelevant to today's proceedings. Indeed, I get a pension from Natural England, I am glad to report! Would you like to introduce yourselves.
Sir Neil Chalmers: Thank you, my Lord. My name is Neil Chalmers and I am the Chairman of the National Biodiversity Network Trust.
Dr Munford: I am Jim Munford, I am the Programme Director of the National Biodiversity Network Trust.
Dr Hill: I am Mark Hill and I am Head of the Biological Records Centre at Monks Wood.
Dr McLean: I am Ian McLean and I work with the Joint Nature Conservation Committee at Peterborough.

Q196 ***Chairman:*** Thank you very much. Would any of you like to make an initial statement or would you wish us to go straight into our questions?
Sir Neil Chalmers: May I make a very brief statement. I think that taxonomy in the UK is massively dependent upon a large band of enthusiastic amateurs and that this is underpinned by professional taxonomy. The National Biodiversity Network Trust brings these two together and we see the value of this. What I would say in relation to that is that the amateur enthusiasts have always been a very important part of British natural history and understanding of biodiversity and that, if one is to address the problems that face UK taxonomy today, one must recognise that one must put money into the professional base but that will have a very strong leverage effect as it filters out and interacts with the amateur community out there.

Q197 ***Chairman:*** Thank you very much. Would anyone else like to add anything at this stage? I think my first question leads very neatly from Sir Neil's opening statement and that is that we have heard time and again of the breadth of amateur expertise in this country and of course of the long historical professional expertise, but professional expertise, as in your own evidence you have stated, suffers from retirements and lack of replacement and therefore presumably the interaction between professionals

and amateurs is at risk. How will the decline in numbers of professional taxonomists affect regional and local biological recording and what needs to be done to maintain the general level of skills to sustain field studies?
Sir Neil Chalmers: I will start with a general answer, if I may. I think this decline will undermine the effectiveness of the UK taxonomic effort, particularly in lesser well-known taxonomic groups. With birds and butterflies there is not such a problem but as soon as you get into the soil arthropods, let us say, you are in deep difficulty. I think there is a very major damaging effect that will result from this decline in professional expertise. The answer must be, as I think has been argued by a large number of people within the systematic community, a very strong recognition of the importance of professional systematics in this country and a much better method of supporting it.

Q198 ***Chairman:*** One of the pieces of evidence that we have seen time and time again is that the user community of the data which is generated both by amateurs and professionals seems to get ever more insistent. There are new biological action plans, water level management plans, biodiversity action plans and all the rest of it. Is there any likelihood that lack of relevant data is going to impact adversely on these user communities?
Dr Munford: I think first of all it is important to recognise the new trend in professional taxonomy which is away from whole animal taxonomy and more to do with molecular science and so forth. It is the whole animal taxonomy which underpins recording activity particularly in the UK. The other important point to make is that professional taxonomists do not come alone; they also are involved or use collections, particularly at the regional and local level, and these are very important for underpinning enthusiast, volunteer-based biological recording in the UK.
Dr Hill: I would say that there was very much extra value to be obtained from those professional taxonomists who engage strongly in the community. I think they contribute absolutely enormously but this is something perhaps which may not always be sufficiently rewarded.

Q199 ***Lord Krebs:*** Could I just pick up on that point from Dr Hill. I was wondering how for example the NBN facilitates the interaction of amateurs and professionals and, to pick up on your point, how one can extract the most value out of the existing professional community, and also perhaps as a supplementary to that, how the NBN through its member groups engages with young people?
Sir Neil Chalmers: If I give a general answer to that, my Lord Chairman, and perhaps ask the Programme Director to speak more specifically. The NBN has various components and a very important component is the group of people who collect data and feed those data into the databases of the National Biodiversity Network. They are sometimes individuals and they are often important natural history societies and groups around the country. In interacting with the NBN, we have a very clear way of ensuring that their data are input into the databases, that their input is recognised and that its quality is validated. It is this interface between the data donor community and the professionals who validate the data and add to its value that I think is a fundamental part of the NBN's work.
Dr Munford: I think it is important to stress that certainly biological recording is probably as strong now as it has ever been, but there are important differences, so that, for example, if you look at the membership of the Botanical Society of the British Isles, I think it would be fair to say, if you went back to the 1950s for example, that a large proportion of their membership would have been professional taxonomists. That is no longer the case and a much smaller percentage of the membership of that learned society is made up of professionals but the society itself has never been bigger, so there is an interesting drift towards a preponderance of what might be called amateur (although we prefer the word "volunteer") recorders. The other part of the question was to do with our engagement with younger recorders and indeed the public in general. The data that we make available through the NBN is not just dependent upon quality; we will take any biological data, biodiversity data, spatial or distribution data and make it available, but we lay great stress on the metadata associated with that data so that end users can distinguish between high-quality and low-quality data. I think that is quite important because if you look at some of the most well-subscribed recording initiatives, for example the Big Garden Birdwatch run by the RSPB, in 2007 they had over 400,000 participants generating six million records. Most of those will not have been professional ornithologists, they would just have been members of the public, but it is easy to recognise garden birds, they are not subject to mistakes, and so we are placing great emphasis in the NBN on recognising those taxa which are by their nature difficult to identify and putting in place measures to assure the quality of those records.

Q200 ***Chairman:*** Are you confident that everyone can tell the difference between a chiffchaff and a willow warbler?
Dr Munford: I think given appropriate support, keys and so forth, that mistakes are few but mistakes will exist.
Lord Krebs: Particularly those from Selborne!

Q201 ***Lord Colwyn:*** Could I be reminded how many professional taxonomists there are roughly and the decline, what sort of percentage are leaving?
Sir Neil Chalmers: Across the whole country?

Q202 ***Lord Colwyn:*** Yes?
Sir Neil Chalmers: That is a very difficult figure to quantify. If one looks at the major institutions then one is talking in hundreds of professionals, I think we are talking low thousands probably. I would not like to mislead the Committee but I think it is that order of magnitude.

Q203 ***Lord Haskel:*** I think it was Dr Munford who said that taxonomy is more to do with molecular science. Are the volunteers acquiring these skills?
Dr Munford: No, I think that is really the dichotomy that professional taxonomists are more attracted to the new sciences, the molecular sciences, whereas the taxonomic skills required for, as it were, naturalist recording are of a different nature, and there is this dichotomy between what professional taxonomists are interested in and those coming from the volunteer community.

Q204 ***Baroness Walmsley:*** That leads us very nicely to the next question. The National Federation for Biological Recording actually referred to this very thing in their evidence and they called it the inevitable pitfall of sectoral separation where the professionals are increasingly using the molecular systems whereas the amateur in the field requires a morphological definition, and perhaps a few other factors as well, so as we have this split, is there any danger of the amateurs being marginalised? After all, they do not have access to the equipment to do the molecular tests and they do not have access to the recording databases because that has got to be done finally by professionals. If so, is there anything that can be done to further integrate the two groups? Can I also add to that, is the situation worse in the case of the less-studied groups, perhaps the fungi, which rely quite strongly in the professional side of things on molecular studies to differentiate them?
Sir Neil Chalmers: Perhaps if I could again start, I think that it is true and welcome that there is a strong growth of molecular systematics but my view is that morphological systematics, that is systematics based upon the appearance, the anatomy of organisms, remains and will remain very important indeed. After all, what one sees walking around on this planet or growing in it are plants and animals and they need to be recognised. Indeed, if you are going to collect molecular data from organisms you have to be sure that the organisms you are collecting them from are of a particular sort and they are not a mix. I think some of the most interesting questions that face systematics today are to do with the relationship between morphological data on the one hand and molecular on the other. I do not see a decline in the importance of morphologically based traditional systematics. I think, to answer your question, there is going to be a very clear need to ensure there is a good interface between the enthusiasts who will be almost always dealing with the morphological, the traditional, and the molecular which is going to be done by the professionals.
Dr Munford: We are in the process of giving access to something like one million records from the British Mycological Society so we are very aware of this debate, particularly amongst mycologists, on the change in taxonomy. It is really not for us in the NBN to resolve, it is for professional mycologists to resolve in the fullness of time. The one assistance, as it were, we give to this process is that there has always been a problem with nomenclature from way, way back, so the Natural History Museum run for us the NBN species dictionary which is our key tool for dealing with these issues in relation to nomenclature, and that contains within it a system for resolving synonymy between species. In the worst case at the moment for plant names the synonymy is something like nine to one of the well-formed name and the number of synonymic names that you find, but that is pretty exceptional, in most cases the problem is not as great as that, but we do have a mechanism that deals with that issue.

Q205 ***Baroness Walmsley:*** Can I just follow this up and take us back to what actually happens in the field. If an amateur identifies or thinks they identify something which may or may not be that something but perhaps something closely related then it is important that that item, or part of it at least, is collected to take back to the professional for confirmation of the identification possibly through molecular means. That means that the recording of where it came from and the condition of the original organism is terribly important, and also the quality of the sample and the fact that it has got to be fresh when it has got to the professional, that is also very important. If you are going to do that, you need really close co-operation between the two groups, do you not, and perhaps we could hear what arrangements are made to ensure that that can happen.
Dr Hill: Can I say something about the plant world. There is quite a lot of collaboration in the matter of the Spanish bluebell at the moment, an object of great interest, and the thing is that this obviously is a very interesting question because these things are invading the British populations but the question is how much and where they have come from and so on, and I think the molecular community and the volunteers can work together very much to try and solve this

problem and find out whether it is actually a menace or not.

Q206 ***Baroness Walmsley:*** Could we just pull them up from my garden!
Dr McLean: Perhaps I could just add from the perspective of an entomologist, which I am, I have also seen good examples of collaboration between professional researchers and volunteers who go out and cover the ground. We tend to have a situation where the professionals are in laboratories with very expensive equipment but the volunteers are the people out in the field who walk the ground, and I firmly believe that we need synergy between those two communities, just as we have synergy in organisations like the British Trust for Ornithology between professionals who co-ordinate bird surveys and the volunteers who go out and gather the data so I think the nature of the collaboration may change but the synergy should be the same.

Q207 ***Lord Krebs:*** If I could just come back to this question about the concern that there might be separation between the professionals using molecular techniques and the amateurs using morphological techniques for identification. In a previous session we heard from Professor Bateman from the Systematics Association a rather different view. He said about the amateurs: "They are going to be out there in the field with their hand-held sequencers linked to GenBank capturing images of the plants that they are sequencing. What they actually represent is a serious challenge to the relatively small number of remaining professionals who are going to be asked by these amateurs to interpret the results of their analyses." Do you see that, as the co-ordinators of the vast army of amateurs in many areas, as a plausible vision for the future?
Dr McLean: I would say that some volunteers might well be interested in collecting those sorts of data and collaborating with the professionals essentially. The issue though is whether they are going to have the technical means to do so at a cost that is reasonable for them. At the moment I think that is rather unlikely. It might come in 10 or 20 years' time but I think the immediate issues we are dealing with are rather more pressing in that I think we need to get more collaboration now based around the model of the volunteers collecting material and transmitting it in suitable condition, as you have indicated, to the professionals to work with. I think that is the immediate challenge rather than the next generation which may well come but I do not think we are there yet.
Sir Neil Chalmers: I think that it is a more plausible scenario if one is looking at information technology and the application of that rather than molecular technology. One can certainly go around as an amateur with a hand-held palm-top GPS facility and record very accurately where you have collected something and when and what it is, if you have that knowledge, which can then get fed into main databases very quickly and very easily. Those are in operation now and developing very fast and I think that is one real growth area.

Q208 ***Lord Methuen:*** In its written evidence, the JNCC considers that "the fundamental problem lies in the lack of overall direction and responsibility for UK systematics", and "that a single government department needs to be given responsibility for this". Where do you think this responsibility should lie and why?
Dr McLean: We believe at the moment that, as far as we can see, the responsibility at departmental level lies firstly with Defra, who are the sponsoring department for Kew, the Department of Culture, Media and Sport, which sponsors the Natural History Museum and other museums, and in fact has increased their investment in those museums recently which is very welcome, and then there is the Department for Innovation, Universities and Skills which deals with research and training. None of those, as far as we can see, has a lead role and there is no lead role either from the research councils or from the Government Office of Science. For a fundamental discipline, which systematics and taxonomy is, we believe that lack of a lead department is a severe handicap. After your last inquiry, it was our impression that the Environment Department was going to take a lead role and really try and develop a focal point for developing the discipline domestically, linking internationally, but that has not happened for whatever reasons. At this stage I think from the point of view of our agency we find it difficult to judge between the departments, to be honest, because we do not have the information that would help us to discriminate between the departments that is going to have the greatest interest and the greatest ability to solve the problem, so I am afraid at the moment I do not think I can answer the second part of your question in terms of who should it actually be because I do not think we have the information to judge that. We still believe that it would be a very big advantage to this discipline if such a department were to be identified.

Q209 ***Chairman:*** Did you want to add anything to that Sir Neil?
Sir Neil Chalmers: If I may, my Lord Chairman, yes. I think there is something that has to be recognised about systematics as an activity which is that it is a data-rich activity in which you accumulate data over a long period of time to build up big pictures about animal and plant life on this planet. That form of activity is very important but it is ill-suited to our

current method in this country of funding science which, if you look at the Research Assessment Exercise in universities and all of the consequences of that, is focused upon relatively short timescale projects, three to five years typically, to answer specific hypotheses; problem-solving science is the major mode of operation. Systematics is one of a group of sciences which is not like that where it can take decades to build up a picture of the entire plant and animal life of, let us say, central America, and I think that it requires a lead from a government department, possibly DIUS, to recognise this and set up a funding mechanism which is appropriate for that kind of science.

Q210 ***Baroness Walmsley:*** I absolutely agree with Sir Neil about the problem of short-term funding for long-term projects but we might be excused for feeling a bit frustrated on this Committee because this is the third report in which we are being told, and we had all concluded ourselves, that we need some leadership and we are simply not getting it over and over again. Sometimes when you have three departments interested in an issue you get a kind of useful creative tension where they are all competing to do something. In the case of taxonomy, it strikes me they are all competing not to do it. What can this Committee recommend that might bring it to the attention of government departments that this is something terribly important for the future of the planet, that their department really needs to take ownership of it and grab it from the other two departments and run with it and really do something worthwhile? What can we do to inspire them?
Sir Neil Chalmers: My personal view is that you have to show that systematics underpins activities which are vital to the economy of this country, to the education and well-being of this country, and to government objectives relating to sustainability, let us say, and there is work to be done there to get those messages well defined so that they can have a powerful impact.

Q211 ***Lord Warner:*** Could I go back to Dr McLean's point, that was an extremely elegant answer about the kind of fog around the government departments which makes it difficult for you to identify where leadership could come from, but picking up Baroness Walmsley's point if the government departments are not themselves fighting to have this leadership role, let us turn it round the other way, what do people in the field think about this, who would they like to see have the leadership role despite the fog?
Dr McLean: Perhaps I could just start by saying that part of the issue for us is because we are sponsored by Defra we understand that department better than the others so we have a closer view of that than we do of the University department or Culture, Media and Sport. I would suspect from what I know of taxonomists in my own discipline, invertebrates and entomology, that it would be the university area and the research area that they would probably feel greatest affinity for because that is, if you like, a department which is responsible for developing our knowledge whereas, in a sense, the Environment Department and the Culture, Media and Sport Department are users of that knowledge rather than actually responsible for generating it. So, I think the view from the field, if you like, which I sense is what you are asking, would be very much for the universities and the knowledge base because I think people would feel a greater affinity with that and I think they would trust it with their interests to actually see them promoted and developed in the way that we have been arguing.

Q212 ***Lord Krebs:*** That would certainly fit very much with my own thinking but when we spoke to NERC and BBSRC, they both describe themselves as users of taxonomic research rather than generators of taxonomic knowledge. Does that seem slightly odd as a position for you?
Dr McLean: No, I think it is understandable in terms of their individual research council roles, but I think we are coming back to the point again, the frustration of the Committee that there is not something above that level that is taking the lead role and unless we had a research council that was primarily responsible for investigating the evolution and identification of living organisms, it is quite unlikely that any of the others would go for it. That sort of research council is unlikely and so I think one has to look at the higher level of the departments to see where it might be brigaded best.

Q213 ***Lord Warner:*** Can I move us on into mechanisms. In the effective implementation of species recovery programmes, the JNCC identifies lower plant and invertebrate groups as those affected most by the lack of specialist taxonomic expertise and elsewhere the JNCC has commented that an increased demand for taxonomic expertise in marine organisms can be expected. One of the things we have wrestled with is trying to understand what mechanisms exist for communicating increased demand. Could you give us your sense of what these mechanisms are and how effective you think they are.
Dr McLean: I will certainly try and help you with that. There is not, as far as I can see, any current mechanism for directly joining up those areas where we recognise there is an increased demand and need with the providers of taxonomy, but I think there are two options: we could either use an existing group which has a general overview which might be adapted to take on that function or we could create a new

group. The existing group that we feel is closest to it would be the UK Biodiversity Research Advisory Group, which I think some previous witnesses have told you something about, which is designed to identify the research needed to underpin biodiversity conservation, so that is very much our sectoral interest and responsibility as an agency. The UK BRAG could conduct a piece of work, as they have with other areas, to draw together the requirements from biodiversity conservation for taxonomic support and identification guides, so that would be our first option. Our second option would be to establish a separate programme in order to carry out the same function, but this would need to be linked to a government department which was taking a lead role for systematics and taxonomy in the future, so if we did actually solve the problem of getting a lead department, then having a programme board responsible to that department would probably be a stronger solution rather than having the UK BRAG (which is linked into ourselves and into Defra) responsible for it. We would like to see the solution fit the bigger picture, and I have tried to offer two options there.

Q214 ***Lord Warner:*** Can you give us some sense of how much you think anyone is listening to the voices of unease that are coming from the ground level and do you see some sense of anyone acting on those voices?

Dr McLean: My personal experience with field naturalists and taxonomists is that there is a considerable frustration at the lack of progress. I think people feel that there are some very good individual initiatives and a lot of good individual things happening, new identification guides appearing and so on, but there seems to be no game plan and no top-level agenda and I think the people on the ground sense that and are frustrated by it.

Q215 ***Lord Krebs:*** We talked a bit earlier about the lack of taxonomic expertise in certain areas, and again this links to the point about who is making a noise. If you had to make a noise about the areas that are particularly vulnerable, do either you or the NBN have a list of the top 10 taxonomic groups where expertise is threatened? We heard earlier on from Sir Neil that birds, my area, is sadly not within the threatened groups so I cannot bid for more money, but what are the threatened groups?

Dr Munford: Following on from some of the comments that have been made in previous questions, I think it is important to recognise the difference between international taxonomy and national taxonomy, and I think that professional taxonomists are bound to be attracted towards international taxonomy, bigger science, and I think that national taxonomy is reasonably well supported by volunteer effort, although there are definite lacunae, for example we have already talked about the mycological issues. The groups that concern me as being where I do not see any activity at the moment within the UK are some of the soil organisms, Collembola for example, which seems an odd vacuum, and some of the smaller organisms, like rotifers for example, and then it gets patchy and it is very difficult to come up with a definitive list because you could look at things like Coleoptera and you can see gaps there and so on and so forth, but the two major ones where I see a distinct lack of activity would be towards the Collembola and small organisms such as rotifers.

Dr McLean: Could I add to that from a six-legged perspective. I think there are about 24,000 or 25,000 species of insect in Britain so in world terms that is not very big but it is still quite a challenge. The major orders where there is the greatest taxonomic impediment are the Hymenoptera, particularly parasitic Hymenoptera, which are very significant ecologically and fascinating in evolutionary and biological terms, which are quite difficult to study because there are no accessible key works to get you started. There are some very good key technical works if you really understand them but it is getting people into them at a reasonable level. Some of the other major orders like beetles, the Coleoptera, which have already been mentioned, and the two-winged fliers, the Diptera, there are over 6,000 species where there is a substantial number of families where there is no recent taxonomic revision or treatment. So just there I think that is illustrating there are some quite significant problems. The Royal Entomological Society started its "Handbooks for the Identification of British Insects" back in the late 1940s/early 1950s with a game plan to cover our fauna. Many of the volumes are old and hard to use and the rate of production is one or two a year, which is quite inadequate to ever cover the entire British insect fauna within the foreseeable future, so that seems to me a very major challenge from the insect point of view.

Q216 ***Lord Warner:*** May I move on to a related point which is about the quality assurance, and you did touch on that earlier on Sir Neil, in an earlier answer, but I wonder if you could recap for us what the NBN has by way of mechanism both to quality assure the recording but also what is the mechanism for continuity of funding to underpin that quality assurance?

Sir Neil Chalmers: I will ask the Programme Director to speak to that.

Dr Munford: I have already mentioned some of the key aspects. Firstly, the NBN is not selective in terms of data quality but all data that can be accessed through the NBN carries extensive metadata which

describes its quality and we have issued guidance on that. Most of the records that we receive come from national recording schemes or local record centres and they have in place procedures and protocols for assuring data quality. We separate two aspects, data validation and data verification. The validation is more to do with the correctly formed record in terms of its geospatial references and so on and so forth. The verification is whether the species reported is in fact the species in hand, as it were. There is a whole variety of mechanisms which are used by national recording schemes and local record centres to assure the quality of the data. What we are doing in the very near future is to publish two guidance manuals, one is on the setting up of a recording scheme, which addresses some of these issues, in particular the requirement for training and mentoring of biological recorders, and another piece of guidance is on verification and validation of data. It is best practice guidance; it is not us laying down the rules; it is just us publicising best practice. We have also got another initiative in its early days which is trying to separate out those taxa which are inherently easy to identify and those taxa which are inherently difficult to identify, and there might be different procedures and protocols associated with both, so you might be quite willing to accept a record of a green woodpecker from a novice recorder but you might expect for rare or threatened or just difficult taxa more expert input into the founding of that record. That is how we basically assure data quality.

Q217 ***Lord Warner:*** And the funding point?

Sir Neil Chalmers: I think it is fair to say that the funding is fragile. The NBN itself is an umbrella organisation and you will have seen from our submission the organisations which are members of that, and the NBN's budget is tiny and it is a facilitatory body. Much depends, in my view, upon the willingness, which I am glad to say is quite significant, of these member organisations to put biological recording into their own programmes and to ensure that this work is done well. The NBN's job is to try and bring this together in a way which gives added value to the country. It is fragile because each of these agencies has to decide where that is going to fit in its own priorities. During the last 18 months I have gone around and talked to the chief executives or chairman of virtually all these organisations, and I have noticed a very big difference amongst the organisations in their willingness to give a high priority to this work. For some it is very high, and that is very welcome; in others it is distinctly low.

Dr Munford: If I might add something, Sir Neil has referred to our funding base which is very fragile, but the staff directly associated with the NBN Trust is a very small group of staff. So we are always looking for multipliers; for example we are engaging in dialogue with the Institute for Ecology and Environmental Management who run training courses so that we might piggyback on that and coupled, with the best practice guidance that we are producing, organise training courses around these aspects related to data quality.

Q218 ***Lord Soulsby of Swaffham Prior:*** Can we come to the NBN, in addition to morphological and biological input that might be on that network with regard to species, what else do you think would be useful to have on that network? Let me explain what I think would be useful and then you can comment on it. With global warming, and all the rest of it and exotic diseases coming in from overseas, I am interested to know the vector potential of various arthropods. Would that be a useful thing to have on this network, the vector potential of the culicoides tribe of blood-sucking insects for example, so that workers could go to it and discover what the vector potential of a given species or strain of culicoides might be?

Sir Neil Chalmers: If I may kick off and then perhaps each of us can give a different answer. I think one of the most useful things that you could have on this database is a time series of records so that you can show changes over time. You can for example plot invasions of invasive species very effectively through this method, and I do think that that is one of the most useful dimensions, if you like, of this sort of database.

Dr Munford: As I mentioned earlier on, we are severely limited by funding and the staffing available to us, however we have focused over the last few years on species distribution data. We have now received a block of funding through the Big Lottery Fund which will allow us to develop our ability to hold attributed Polygon data, such as sort of habitat-style data, we intend to move into the area of habitat data fairly rapidly. We have also been working very closely with the recent invasion of the harlequin ladybird and we have demonstrated, I think quite adequately, that we can use the network of biological recorders and the public in the UK to accurately monitor the spread of this invasive species, and we would wish to do more of that. We have had it inmind to visit for example the Royal Horticultural Society. Gardeners are clearly very interested in invasive species, the lily beetle and so on and so forth, and I am sure the NBN could rise to the challenge of monitoring the spread of invasive species. Another area I need to mention is that we provide data to a global initiative, the Global Biodiversity Information Facility, and by using that facility one is able to plot, as it were, the ecological envelope of potentially invasive species. So for example they were able to plot the ecological envelope of the Asian tiger mosquito before it arrived in the United States into Galveston and they were

able to accurately predict the area of the US that would be covered by this invasive species. They now have the ground truthing that shows that model worked well. Interestingly, when they developed that model it showed that certainly Kent, Essex and southern Suffolk would also be within the ecological envelope for that mosquito and recent data confirms that it has in fact arrived it is a vector for dengue fever.

Dr Hill: Just to add to the matter of what is done by the NBN Gateway and how the NBN themselves distribute data. We have been working with Defra on preparations for what we hope will come off on a non-native species portal for Britain, and the point about this is that it will use data through the NBN but it will actually present the information through a separate portal, and I suspect that might be the model that would be good for having vector potential and that sort of thing, but there would be a disease vectors special website which would use data from the NBN but would be actually a separate entity with its own individuality.

Chairman: We will move on, Lord Haskel?

Q219 ***Lord Haskel:*** I wonder if we could move onto the care of long-term data sets. In oral evidence the NERC identified the care of these data sets as part of the national capability role of their research centres. Given the transfer of the Biological Records Centre at Monks Wood to another location, has there been adequate consideration of the impact of these changes on major stakeholders such as the JNCC or the NBN?

Sir Neil Chalmers: There have been extensive discussions between NBN and the Biological Records Centre, and indeed the Biological Records Centre is an important part of the NBN because it is an umbrella organisation which involves the Biological Records Centre, so I think there has been a good deal of consideration of the impact of these changes. We expressed our concern at the time the changes were first mooted and we were assured that the Biological Records Centre was of high priority in these changes, which is encouraging. We must be vigilant of course in the months and years to come to ensure that the Biological Records Centre continues to be able to give the very good service that it has given in the past.

Dr Hill: May I add something, my Lord Chairman, just to say the sort of effect this is having on us; it is making us do one thing we had never even thought of before which is to scan all our cards and get them digitally into a form where they are available. Previously we had this vast supply of paper data but it is now physically possible to scan it, so that will be an improvement, I hope, to the availability of data at a national level.

Dr McLean: Could I just comment briefly as a previous nominated officer for the BRC contracting chain, which is not currently my responsibility but previously I did work very closely with Dr Hill on ensuring that we did get a good transition to the new arrangements, so I think organisationally we put a lot of management time into making sure that the process worked well.

Dr Munford: I would like to point out that the Director at the Centre of Ecology and Hydrology, Professor Mark Bailey, is in fact one of the trustees of the NBN Trust. The Centre for Ecology and Hydrology houses the servers which drive the NBN, and I sit on the Biological Records Centre Management Advisory Group, so there is a good deal of contact, and a good deal of debate and discussion, about the issues that you have pointed out. I am reasonably happy that all is being done to safeguard the continuity of those long-term data sets.

Q220 ***Lord Krebs:*** My Lord Chairman, if I could just follow up by asking about the continuing collection of long-term data sets, whether at Monks Wood itself or in universities. From your perspective, are arrangements in place to ensure that long-term records that have huge value, particularly in light of understanding the impacts of climate change, are being stewarded and collected and archived properly?

Dr Munford: I think we have made the point clearly that most biological recording in the UK is run by volunteers. A report produced in 1995 by the Co-ordinating Commission of Biological Recording, which was chaired by Sir John Burnett, reported that at least 70% of recording activity is by volunteers, and they are volunteers who do it for their own reasons; so in terms of long-term data sets there will always be an army of recorders interested in vascular plants or birds for example. If you were to look at the British flea recording scheme, that is one man who is in his 80s, so if there is an importance associated with long-term records—

Q221 ***Chairman:*** There was a well-known lady, was there not!

Dr Munford: The point I am trying to make is there is a huge variety. There are some taxa which are fairly well safeguarded in terms of long-term continuity in the data sets; there are other taxa with fewer participants in the recording activity which I would have to say would be subject to death or other variation which is really beyond our control because it is a volunteer community.

Dr Hill: Can I say that I think this is where the Biological Records Centre has a very definite function. We have actually received flea data from this octogenarian and we are about to publish a volume showing where the things are and these data

will then be maintained on a NERC server at Wallingford, I hope indefinitely, and I would have said that the aim is that this will be seen by NERC as what they call a national capability element which they will just maintain on a long-term basis, and there is no evidence that I can see that that is not an absolutely firm plan.

Q222 ***Chairman:*** At an earlier point in this meeting, Baroness Walmsley reminded us that the House of Lords Select Committee had visited this area before, twice in fact and I have been on both those previous committees, and on every occasion we have heard from the taxonomic community itself that they do not feel they have been successful in communicating the value of its work to the non-taxonomic community, and this is a point that the JNCC in its written evidence makes. Is that still true and, if so, is this not an odd contradiction when you think that we have heard there are so many volunteers or amateurs who are contributing to this data collection and yet the value does not seem to be understood by the wider scientific and non-scientific community?
Dr McLean: Yes, it seems to me that the gap is relatively small but it is nevertheless a gap. I think we are all aware of the huge contribution that David Attenborough has made to the wider understanding of the variety of life on Earth, and that has been an immense achievement. An awful lot of the world's biodiversity has now been seen by people which would not have been seen without that person's huge single-handed effort. What people probably do not grasp, though, is all the work that is necessary to understand, classify and work with it, and it is a relatively small gap but we do not yet have an Attenborough advocate who has spelt out the message to people that this is what we need, and until it actually is done at that sort of level and engaging with that breadth of the population, we are still going to have the shortfall.

Q223 ***Chairman:*** So you have identified leadership which is needed within government. Is leadership needed within the taxonomic community as well?
Dr McLean: Yes I believe that it is. Possibly part of the issue is that it takes a long time to become familiar with a group of organisms and when you have invested that effort you want to recoup it and bring it back by publishing on it and by selling your expertise that way. It can be a distraction to spend the time trying to publicise the broader requirements of taxonomy. There are some very good taxonomists who do it though within their own areas, but I think it is only a minority of the community that actually has the capacity to do it.
Sir Neil Chalmers: I believe there is a need for strong leadership and powerful messages to go out in Britain about systematics and its value. I think at the moment too many of us think about systematics and about wildlife, if you like, in the UK, as something that is nice to have but not absolutely vital to the country, and therefore people who study butterflies or flowers are doing interesting things and having a nice time but it is not really of fundamental importance to the future economy of the country. Somehow one has got to change that perception, and I think that the systematic community, certainly during the time that I have been associated with it, has made from time to time some quite serious attempts to promote the value of systematics, but I do not think it has done it, looking back, with a consistency and political drive that is really necessary to move the systematics issue up the agenda, if you like. I think this is perhaps one of the most frustrating things of working in the field of systematics and one of the areas which I would hope one could work on in the years to come to make sure that this difficulty is overcome.
Chairman: Thank you very much. I think that exhausts the questions that the members of the Committee wanted to ask. Thank you to all our four expert witnesses for a very interesting session. It has been most helpful to us, thank you.

Examination of Witnesses

Witness: Dr Richard Fortey, President, the Geological Society, examined.

Q224 ***Chairman:*** Now I welcome Dr Richard Fortey. I know you were able to hear the earlier session so I do not need to repeat myself. Is there anything you would like to say by way of introduction?
Dr Fortey: Just about myself. I am that rarity of a practising taxonomist and I have worked at the Natural History Museum for more than 35 years. I have been President of various societies that deal with the palaeontological side of taxonomy. I am currently President of the Geological Society of London and as well as working on trilobites, my own particular theme, partly in response to some of the things we have been talking about earlier, in the last decade I have devoted a lot of time to writing books for the general public most of which are designed to explain why taxonomy matters.
Chairman: And that is a subject we would like to return to in a moment but I would like to ask Lord Soulsby if he would like to start.

Q225 ***Lord Soulsby of Swaffham Prior:*** Good afternoon. I was interested in your comments about taxonomy. Some nearly 50 years ago I started cutting

my teeth in taxonomy and enjoyed it thoroughly but then moved away from that. My question basically is, in your summary of your 2006 Michael Farraday Lecture you stated: "The business of taxonomy and systematics remains the shop floor of biology research". Do you think that that view that you expressed in 2006 is widely held still amongst the biological research community and the environmental policy people?

Dr Fortey: I think widely, not actually. Quite a lot of what we might describe as cutting-edge scientists are interested in what they do. A lot of them, as we have heard earlier, these days deal with various kinds of molecular techniques. The shop-floor taxonomists relying, as we have heard already, more and more on an amateur community are not regarded in general as, what shall we say, the kind of people that the research councils like to fund. People who do taxonomy who do the basic stuff find getting external funding progressively difficult, and so to that extent I think there is a feeling that it has moved from centre stage.

Q226 ***Lord Soulsby of Swaffham Prior:*** What in your opinion needs to be done to give it a higher profile and make it more readily fundable by research councils and the rest?

Dr Fortey: I think there are two issues here which we have also heard about briefly and there are two sides to thinking about taxonomy. The first is, what you say, the national interest and the other one is the international issues about taxonomy. It is true that there has never been a more desperate time to have taxonomic expertise on a global scale simply because we are losing habitat at quite an astonishing rate particularly in places like Indonesia where deforestations continues apace. We do not even know what organisms there are there. This is not a luxury; this is a necessity. We have to know what these animals are. There are things that are probably going extinct that have not even had the blessing of a scientific name, we have not really identified them, let alone doing the interesting stuff, the Attenborough stuff, which you might describe as writing the biography of those organisms. Any species you like to look at will have a history as interesting as a tiger if you only knew about it. I saw a wonderful TV documentary about the tiny wasps that live inside figs and the wasps that live on those wasps and so on, marvellous stuff, really dramatic, and we simply do not know enough about organisms yet to get to that stage, so I think it is urgent, really I do, that taxonomy is focused on these areas where otherwise we might lose species. I think that is an agenda which can appeal to a lot of thinking people.

Q227 ***Lord Soulsby of Swaffham Prior:*** From the last witnesses there was a very nice example given of projecting from a potential model of transmission by insect vectors, especially given the point we were hearing about in the United States, and it does seem to me that it is important being able to say sooner or later that one is going to have a problem of whatever it is, based on the ecology and the knowledge of species and of the species that might occur because, as you say, half the species we do not know exist, and it is the projection forward of the potential problems that I think is very important in the whole field of taxonomy.

Dr Fortey: I could not identify that particular mosquito you were talking about. It is very important that you have people who can. A lot of insects in particular and fungi have been mentioned, and I have long been an amateur mycologist so I know about the fungal field, these are difficult organisms which require expertise. They do not necessarily require a home-made molecular sequencing kit. I know one or two amateur mycologists who are so enthusiastic about finding the answers about their particular organism that they actually pay out of their own pocket to have the sequencing done—and it can be done—but most taxonomists most of the time work on morphology, and you can do that these days, you can have a microscope at home (I have got one myself), you can acquire literature, and the web is a fantastic resource. This allows us to get at literature which was formally the province of only people that worked in the national museums. There is a much greater facility for getting out there to get at the more esoteric literature so amateur taxonomists can be better and more professional. That is important but of course it is equally important that there should be ground truthing, a real body of expertise, who can check the veracity of records, otherwise standards could slip and there will be nobody to notice that they are slipping. We have heard about the last remaining flea recorder. Would it not be good if there were a second person who could actually back up those identifications? That is not unusual. There are some groups of organisms which have hardly any or even no experts at all on them. I think this is wrong; it is not how it should be.

Q228 ***Lord Colwyn:*** The current interest in climate change issues has focused attention on the fossil record as a source of knowledge on responses of organisms to past change. Obviously from your self introduction I imagine that this is something that is of great interest to you, but is taxonomy generally relevant to this and has it benefited from this increased interest?

Dr Fortey: I am not sure it has benefited but is it relevant? Absolutely. For example, if you go through the changes of climate in the Ice Age and so on, you have climatic oscillations which are recorded in changes in the beetle fauna, they are cold beetles at some stage, warm beetles at others and they move backwards and forwards. They are a thermometer

which tells you what is going on. It takes tremendous skill to be able to identify a beetle from its elytra, the hard wing cases that are the only things preserved as fossils. That is a real skill. There is a man called Russell Coope in Birmingham who practically alone is able to do that work. I think he is still going strong even now but as we were talking about before, when he goes I do not think there is anybody who will that have very specific skill with that particular group of organisms. We have somebody in the Natural History Museum who works on chironomid midge mouth parts and is doing extraordinarily important work on the climate oscillations that are happening in Scandinavia now and have happened in historical times from lake-bottom sediments, so taxonomy is absolutely vital to understanding past climatic change and I suspect will be just as vital in predicting the future.

Q229 ***Lord Colwyn:*** Your examples sound like professional taxonomists; what about the amateurs?
Dr Fortey: There are some amateurs that do this but the examples I know about are actually professionals.

Q230 ***Baroness Walmsley:*** That takes us nicely to the next question because we have had evidence of the decline in the number of taxonomists in university biology departments. In your experience, is the same thing happening with paleotaxonomists in geology and palaeontology departments?
Dr Fortey: Yes it has been a slow and rather relentless decline. There are reasons for it. The principal reason I guess is that university academics are hired more and more for their grant-raising potential and bodies like NERC, with respect, do not hand out money for grant proposals that are primarily taxonomically aimed. I can speak from personal experience here. The grants I have been successful in getting have got taxonomy in them hidden away or rather cunningly concealed under a scientific hypothesis—perfectly genuine I might say—which needs the taxonomy to solve it. It is not duplicity; it is a certain measure of cunning. When I have put in a grant which is pure taxonomy I am afraid it has got bounced. I have done it several times so I can speak from my own personal experience and I am sure it measures up with others. To return to your point, if you have got a hiring situation in a university department you are going to have somebody who is going to cover the lecturing base but also is going to be a glamorous grant raiser and that will not be somebody whose PhD was primarily taxonomically directed; that is just the way it has gone.

Q231 ***Baroness Walmsley:*** So the finger points at NERC again or BBSRC?
Dr Fortey: Yes it becomes self-fulfilling in a way because, after a while, the people—I have sat on the boards myself and I know they strive to be fair, they really do, but once you have got a university department of the kind I have described the people you recruit to the NERC committees will of course be scientists who are not taxonomists, so even though they may make friendly noises occasionally at taxonomists when they come across one in the street, they are not dealing with them on a day-to-day basis and they will tend to favour the kind of research they do, which these days, as we heard, is increasingly molecular or theoretical.

Q232 ***Lord Krebs:*** If I can just come back to your point about cunning concealment, one could actually put that as a rather positive feature given all the interest in climate change and the research councils, particularly NERC, do fund a lot of work on climate change, surely that gives a window of opportunity to the skilful grant writer who wants to do taxonomic research to increase funding in the area under the badge of understanding past (and therefore future) climate change. As a supplementary to that, some of the people who do this kind of work are actually not in geology or palaeontology departments but in geography departments for example. We have heard from Rick Battarbee of UCL and Kathy Willis in Oxford, who will be doing similar kind of work, so are there people benefiting from the new relevance of palaeotaxonomy to climate change?
Dr Fortey: There will be a few beneficiaries of course. Maybe Russell Coope has a successor and I hope he does, but of course that will not deal with the totality of the fossil record, it will not go back to the part of the geological column I am interested in hundreds of millions of years ago. The kind of people who would work in a geography department are those who can top slice the last million years at most, or maybe two million. That still leaves 3.5 billion years of very interesting fossils records to look at. If you were very, very cunning indeed, perhaps you might compare the Ordovician Ice Age and what happened afterwards with what might happen over the next century or so, but I suspect that would be a step of ingenuity too far which the panel would probably see through.

Q233 ***Lord Krebs:*** Is your point that in terms of palaeotaxonomy, it is taxonomy over the last million years that is relevant to the climate change agenda in terms of research?
Dr Fortey: Yes exactly, and there are certain groups of course that you can name, obviously palynomorphs, diatoms, beetles, midges and so on which will be important to that particular issue, but of course that is a minute part of the natural world they are concerned with and is it right, should there be one national expert on, let us say, ammonites, a

group of organisms that lived for a couple of hundred million years with tens of thousands of species and wonderfully varied, is it right to have one person paid out of the public purse even though they are not necessarily relevant to climate change? My view is of course yes it is right, but if you are going to justify everything in pragmatic terms then you let the ammonite expertise go, which is exactly what is happening.

Q234 ***Lord Haskel:*** You spoke of the web being a great resource. Others have told us about significant progress towards creating a new e-taxonomy on the web. Have there been any particular advances in the web-based taxonomy of palaeontology?
Dr Fortey: It is in its infancy. There are good web resources. For example I have been terribly impressed by my own speciality, trilobites. There is a very, very good website set up by somebody, of all absurd places, who lives in Hawaii, which is the furthest you can go on this planet from any trilobite. Maybe that is why, I do not know, but the people that log into that site swap literature and they are tremendously up-to-date. They exchange views, they exchange photographs, an expert will occasionally chime in and say, "This is something I really know about; I think it is that." It is an extraordinary thing and it was not happening a few years ago. If you think back to the great days of Darwin and his friends when they would despatch a letter on the Friday morning and it would be received 150 miles away perhaps the following day and then a reply would come back, it is almost as intimate as that. I think it is a tremendous thing. On the mycological side, the number of macro fungal taxonomists in this country has dwindled to the fingers of one hand or maybe less. I can speak from experience here because I take out an Oxford University party into the woods around Oxford because as an amateur I can identify the macro fungi, and the specialist in the department cannot do it, and then they do very, very clever things with the microrisal DNA and other molecules that they collect from the soil, but I am the person that has to say what the fruit bodies are. However in the mycological community there is a network at a national level of people who are amateurs in correspondence with one another who I think get pretty good identifications and, significantly, when they do not know what something is they know who to send it to, so they are not endlessly bombarding the world authority on some genus or other with rather unpleasant dried specimens. They will send the person something when it matters. I have named my first fungus last year—I have named many, many trilobites—having sent a specimen to the expert on this particular group who happens to be Norwegian, and one of two people who could have probably told the world it was a new species, so, yes, is the short answer, it is working very well.

Q235 ***Lord Haskel:*** But you say it is in its infancy. Is there anything holding it back, is it developing?
Dr Fortey: I think there is enough amateur interest to drive it. The thing which concerns me is that it would take off all by itself and there will not be the equivalent of my friend in Norway or the man in the Natural History Museum who knows about the group and can be critical about taxonomy. The trouble with amateurs if they are working with a difficult group is that they tend to like to make a species, there is something rather glamorous about it, which means that they might tend to overemphasise certain rather trivial features which might, if you really knew the organism, just be a matter of variation within a species. The shell world for example, my friends in the Museum tell me has been troubled by this for many years. Cowries, those wonderful shells, have an infinite variety of colour patterns and it is very easy to convince yourself that you have a new species in hand. There has to be somebody that acts as quality control. This is part of the problem with para-taxonomy which I suspect you have heard about or will hear about. This is training people from a base of expertise like the Natural History Museum to go back to Paraguay, or wherever it happens to be, to do their own taxonomy. It depends on the talent of the people in the first place, it depends on the quality of the teaching, but still the reference collections, which are the ultimate ground truthing, will be held in somewhere like the Natural History Museum and the comparisons need to be made back again if you are not going to start creating nonsense taxonomy.

Q236 ***Lord Methuen:*** As a well-known author of popular science books, how do you think the role of the taxonomist is perceived by the general public?
Dr Fortey: My own mission has been to slightly improve it, I should say. There is an image which might be a 19th century hangover which is a slightly dusty one which is somebody peering over a drawer and blowing the dust off a tome published in 1843.

Q237 ***Lord Methuen:*** You should have been to Calke Abbey!
Dr Fortey: That is the image I would wish to dispel because I think it is far too important. What we have to do, and one of the previous speakers is absolutely right, is we have to release the image of taxonomy from any hint of antiquarianism for example. David Attenborough has been a spokesman for taxonomy but it would be nice to think that there would be somebody, perhaps it should be a future Director of the Natural History Museum, to whom the world would naturally turn if any taxonomic question was

going to be discussed. In other words, you want to invest it with a certain amount of glamour. It should have glamour because it has urgency for the reasons I have explained about wanting to know what is going on in the parts of the world which are under threat. I would have thought it should be extraordinarily glamorous and important but it has not got there yet.

Q238 ***Lord Haskel:*** How would you encourage the next generation of amateur naturalists and taxonomic enthusiasts? Do you go out to the schools and talk to them?
Dr Fortey: I speak to a lot of people, yes. Mostly I speak to amateur clubs, though, people like that up and down the country. There is an astonishing number in palaeontology. Somebody else will know this better than I do what part taxonomy plays in the school curriculum. Do people explain what it is about? Do people explain the urgency of it? I think it should be on the school curriculum.
Baroness Walmsley: It is not.

Q239 ***Chairman:*** I think we have been advised that it is very rarely in the undergraduate syllabus let alone schools.
Dr Fortey: This is one of the problems, again for reasons which have now become self-fulfilling, that if there are fewer taxonomists in the department, there will be fewer people to teach it. In particular, one of the hangovers from this previous era of taxonomy was there was a rather dreary flog through the natural kingdoms or "go up the geological column" way of teaching taxonomy which was pretty deadly honestly. I would like to think that when I teach about trilobites that I bring them back to life and I engage with their biology. The interesting scientific challenges that you can do with dead organisms, or climate change; approach it from that angle; not "there are 72 genera in a particular family and you will now learn them", that is not the way to enthuse people about taxonomy, but that just requires a little creative thought about teaching and getting the right people in place to do it.

Q240 ***Lord Krebs:*** If I could just build on that and ask you to talk a little bit about how the taxonomic community is appreciated by other scientists in related areas. You talked earlier on about a caricature of a scientist on one of the grant-awarding committees who is nice to the taxonomists in the street but not nice to them when it comes to awarding grants for taxonomic work. Do you think, just as there is a job to do to present to the public the significance of taxonomy, taxonomists could be more effective in making their case to the rest of the scientific community as they jockey for position in terms of obtaining research funding?
Dr Fortey: Yes they could have been more effective. I could have been more effective myself. Quite how you do it is another question. I would like to think you could get primary taxonomic studies funded. Quite a lot of projects that I have had before me as a referee have a taxonomist written into it somewhere as a co-worker. Taxonomists are, without being in the least pejorative, generally quite cheap. Nowadays molecular sequencing costs something but a lot of the equipment we use, the old-fashioned binocular microscope with a few new widgets, you can do quite well with that. So a lot of grants that get approved, as I am sure you know, are ones that apply a major new technique to a problem which requires the designing and manufacturer of expensive new equipment. I could mention that some of the taxonomic and palaeontological grants that have been successful are just like this. For example, quite recently people have been using the CERN Accelerator to look at insects hidden inside opaque amber, with tremendous success I might say. You can practically see the hairs on the legs and you can apply traditional taxonomy to these creatures. It is quite expensive because it uses a very expensive piece of kit. The taxonomy at the end of it is not unimportant, it shows that a particular family of ants went back to the Crotatius which was not known before, but if that were the end product of something that I had applied for as a direct research grant without the CERN Accelerator coming into it, I do not think that grant would have got very far.

Q241 ***Chairman:*** It sounds as if expensive taxonomy is easier to get funded than cheap taxonomy.
Dr Fortey: That is probably quite right.
Chairman: I think we have come to the end of our questions. Thank you, Dr Fortey, you have covered a very wide spread both in your professional capacity as President of the Geological Society and the way you describe yourself as an enthusiastic amateur as well. Thank you very much.

TUESDAY 6 MAY 2008

Present	Colwyn, L	Selborne, E
	Krebs, L	Soulsby of Swaffham Prior, L
	Haskel, L	Sutherland of Houndwood, L (Chairman)
	May of Oxford, L	Walmsley, B
	Methuen, L	

Memorandum submitted by the Department for Innovation, Universities and Skills

The Department for Innovation Universities and Skills (DIUS) provides funding to Research Councils through the Science Budget to support the whole range of their activities. It is up to each Research Council to set its priorities in a Delivery Plan agreed with DIUS.

DIUS monitors the activities of the Research Councils and Research Councils UK (RCUK) through a performance management system. All the Research Councils and RCUK have agreed annual delivery plans which set out targets and milestones, monitored and reviewed every quarter by DIUS and fed into the business planning cycle.

Research Councils develop expertise in particular areas of research and associated policy issues, during the course of their work, and on this basis have responded from time to time to inquiries where such expertise is relevant. DIUS accepts that in this particular case it would be appropriate for RCUK to provide such expert input in support of Defra's lead on policy issues relating to Systematics and Taxonomy.

January 2008

Examination of Witnesses

Witnesses: Dr Alf Game, Deputy Director of Science, and Mr Steven Visscher, Interim Chief Executive, BBSRC, and Professor Alan Thorpe, Chief Executive, NERC, examined.

Q242 ***Chairman:*** May I say welcome very warmly. We much appreciate your giving us time and thank you for the written evidence; again that is very, very helpful to the Committee. You may well find that at the end of the session there are things that you may wish to amplify further and, in that situation, we would be very happy to receive further written evidence from you through the secretariat. The Committee members all have labels attached to them, equally we can see your names, but unfortunately the recording machine cannot, so I wonder if you will identify yourselves for the auditory record and then we will move on to the session.
Professor Thorpe: I am Alan Thorpe and I am Chief Executive of the Natural Environment Research Council.
Mr Visscher: I am Steve Visscher, the Interim Chief Executive of the Biotechnology and Biological Sciences Research Council.
Dr Game: I am Alf Game, Deputy Director of Science at the BBSRC.

Q243 ***Chairman:*** Thank you very much. Did any of you come with a short opening statement that you wanted to make? There is no requirement but if you wanted to amplify any points in previous evidence, there is the opportunity now. In that case, can we move to the first question. The evidence that we get about the number of salaried taxonomists working in the UK is that it is difficult to know because we know also there is a very large number of volunteers and there is very good work done by those who perhaps mistakenly are called "amateurs" and who are often very professional, and that is a very important part of the scene, but knowing how many are salaried and being paid is difficult. RCUK nonetheless has observed that the number of high-quality taxonomists is generally regarded as insufficient, and I wondered if the two research councils represented wanted to comment and amplify their view that the discipline is in a good and healthy state in light of that?
Professor Thorpe: I would like to make a comment about the health of disciplines and how we look into that because I think this is rather pertinent to this evidence. Research Councils UK produce an annual report on the Health of Disciplines. It is essentially based on evidence that has been accumulated by various sources across the community during that year, but because it covers all the research councils it is by its nature quite broad. I doubt—I would

need to check—that it has referred particularly to taxonomy in recent years as being an issue, but nonetheless that report is produced every year. I think one of the difficulties for NERC in addressing the questions that this Committee has been asking about taxonomy is just literally the range of disciplines that the NERC has to think about in this term "health of disciplines". I am afraid it just has to be accepted that it is really bewilderingly large. We start with the basic disciplines of physics, chemistry, biology and mathematics, and they feed into environmental science, and then we have marine, atmospheric, terrestrial, geology, earth observation and polar at another level, and then we have climate science, biodiversity, natural hazards, natural resources, pollution, et cetera, and then we have a whole sequence of sub-disciplines, and taxonomy and systematics would figure there as well. It is really difficult to routinely capture information about all of this whole space of disciplines, so what we try to do is from time to time, where we feel there is evidence that we need to look at particular areas, particularly sub-disciplines, we will instigate a particular investigation. We did one for example in another area, marine science, a couple of years ago, a big study with international experts who gave advice about the health of disciplines in the UK on marine science, so that is the general point I wanted to make about this. A more specific point is that at this time we have just published a new strategy for NERC going five years from now, and we have got a whole sequence of changes in the way that we are operating, but particularly we have recognised the need for a skills needs review right across environmental science. The Environment Research Funders' Forum, which gathers together all the main funders of environmental science, not just the research councils, is coming together (although NERC is leading that) under that banner to look at this whole area of the skills needs because we recognise that it has been some time since we have done a really comprehensive analysis, and this review will be started and it will report in the order of 12 to 18 months' time. It has highlighted specific areas within environmental sciences for a particular look and taxonomy, I hope you will be pleased to hear, is one of those that we have highlighted for special attention. So I think that is the way that, generally speaking, we approach looking at the health of the disciplines. We do from time to time periodically but not every year for sure take quite a detailed look at areas, and that is one, and we are taking a more comprehensive view in this overall environmental skills needs review coming up. I hope that is a helpful answer in terms of what we are actually going to do in the next few months to a year.

Q244 ***Chairman:*** You say it is a skills needs review; will it also be a review of how far those needs are being met?
Professor Thorpe: Yes, absolutely.

Q245 ***Chairman:*** And despite the difficulties you have just outlined, you think you will be able to get a handle on that?
Professor Thorpe: We are looking at both ends, if you like, the pull end in terms of employers and the need for those sorts of skills across the science base in the economy, but also the provision of expertise and availability of that expertise, so we are trying to look at it from both sides. I repeat, it is a big space to be looking at and that is why it is going to take 18 months, but it is something of the ilk of a once-in-ten-year exercise because of the nature of how big that kind of review is, but I hope it will be helpful for this area in particular. There are a number of other highlighted areas but this is one of them.

Q246 ***Chairman:*** BBSRC?
Mr Visscher: BBSRC will be working with NERC on a number of these matters, as you might expect, and the approach that Professor Thorpe has described to the health of disciplines. Within BBSRC, if one looks at the system and says does this work, or can it work in principle if there are issues arising, then there are examples and they are given in the recent Health of Disciplines Report from RCUK. Mammalian physiology was one and veterinary research was another. I would say that overall our structure does allow things to bubble up where there is a need. At the RCUK level that might be major areas like veterinary research for example, I think the work that we did with the Linnean Society and the Systematics Society on the CoSyst system of encouraging researchers to work with others, in order to develop a potential to put in grants, is one example where a small area of activity is starting to nurture new action. This has only been going a short period and I think we awarded six grants last year and nine this year. It is a small pot of money just to facilitate this and now the first grants are coming in from those taxonomists in with other parties, and I understand the first one has been funded by NERC and there is another one being looked at by BBSRC, so currently it is one out of one.

Q247 ***Chairman:*** We were a bit puzzled that RCUK did not see any obvious noises in the system about whether there was a sufficient number of people there in order to do the work and yet when we talked to the various organisations that represent the practitioners and users and so on, we are getting a different message. I just wondered if at research council level you are beginning to overcome what looks like a gap

of understanding between what is happening out there and what is thought at headquarters.
Professor Thorpe: I think I can confidently assure you that we hear a lot of noise about shortages of funding and shortages of courses that research councils can provide. For example, I hear regularly from various communities, let us take another community just to vary it, the deep earth/solid earth community, which thinks that NERC does not provide sufficient funding in their area. We get a lot of information from a variety of sources, from individual scientists, from review panels that we have, where feedback comes back about particular areas where the community feels there are shortages either in courses or in funding available, so I think it would be wrong to characterise it from my perspective that these perceptions of the scientific community are not voiced; and they are certainly heard. The question of course is how to balance that across the whole portfolio, how to deal with those representations, and those representations are being made all of the time.

Q248 ***Chairman:*** Perhaps I was not clear enough, it was not simply the worry about not enough cash—and I have never yet met a scientist who thinks they have enough cash so that is taken for granted—but it is rather the question of whether or not there are enough people in the system with the skills, and do we know that that is the case, and if it is, fine, if it is not, what are we doing about it?
Mr Visscher: Perhaps I could just add in relation to the BBSRC's structure that in our Genes and Developmental Biology Committee we have made a point of having that expertise and typically one or two people with that area of expertise. If the numbers of grants increase then we will probably start to draw in a greater number as well. We also have some expertise within our own secretariat in this area so it is not as if there is no expertise there. We also try and get out to the community to engage with them directly. I know that a member of our staff gave a talk last year to the Systematics Society on grantsmanship, if you like, and how to work the research council systems and what the priorities are and how to go about it, so we try and engage with people and listen at the same time.

Q249 ***Baroness Walmsley:*** When you have done these skills reviews in the past and identified shortages, what have you been able to do about it other than focusing more attention on the funding? In other words, are there any lessons we can learn from other disciplines in relation to the things that you have been able to do or is it just keeping a focus when funding applications come in to make sure that this particular discipline is not ignored?
Professor Thorpe: We have a number of ways of intervening to help and typically to build capacity in particular fields. The most recent one for NERC that I am familiar with is in environment and human health where we recognised that there was a lack of capacity of the scientific community addressing that issue, so we have actually looked at a range of funding interventions, right from targeted studentships through to encouraging (but it is only at encouragement level) universities so that courses are provided in that area and bringing together other funders with us to address this, in that particular case the Department of Health and MRC to work with us, so I think there is a range of ways in which we can effect that sort of capacity-building in a field that we think needs developing appropriately. It depends on the field.

Q250 ***Lord Krebs:*** If I could just paraphrase what you said to check that I understood it. I think it was this: given the breadth of your portfolio in terms of science, taxonomy as a shortage area has not come on to your radar screen, and part of the reason for that is that you hear a lot of noise from many different communities shouting for more resources or more skills and taxonomy has not stood out sufficiently in the judgment of NERC to warrant or merit particular attention. Is that what you were saying?
Professor Thorpe: No.

Q251 ***Lord Krebs:*** Then I am glad I paraphrased it! Tell us what you were saying.
Professor Thorpe: I did not comment on how strongly taxonomy had come out. The one piece of evidence where I can say that it has come out is that one of the changes that our new strategy has brought in is that we have seven thematic areas that we are supporting, and one of those is biodiversity, and we have a new layer of advice for the NERC Council, and that is an expert, a scientific theme leader in each of those seven themes. The theme leader for each of the themes is producing an action plan of actions, funding, et cetera, and this is the draft Biodiversity Action Plan I have in front of me. My council will be considering this in the next couple of months, but I can say that in this draft plan there is mention of the requirements for taxonomy as an essential underpinning of the work in biodiversity and there is mention of the fact that there are questions about developing the right expertise and there being a shortage of expertise in this area, so this is beginning to highlight from the recent work of the theme leader Lloyd Peck in this area advice to my Council about this area, so I think there are beginning to be signs. I think perhaps where I might have given you the impression that you described is that we have not done this overall skills review yet, and that is still to come, but in terms of

this theme action plan there is beginning to be evidence.

Lord May of Oxford: I wanted to go a bit beyond the discussion of what is the demand and how responsive you are to it to suggest that—and unfortunately I have missed some of the earlier meetings but I have read the testimony—both NERC and BBSRC are actively contributing to the problem rather than its solution. To start with NERC, if I may, NERC has stated in one place here that it does not fund taxonomy per se, which I find pretty weird. It is as if taxonomy was some technical thing you acquired or some hippy phenomenon whereas the house of the life sciences is built with taxonomic bricks assembled in the architectural plan of systematics. It is a discipline and I find that statement incomprehensible. When you put it together with the fact that universities are reluctant to employ taxonomists because they are worried they will score badly in the RAE, which then feeds into a decline in teaching, you have got a vicious circle that feeds upon itself. My question essentially is: why do you not fund taxonomy per se?

Chairman: Starting with NERC?

Q252 ***Lord May of Oxford:*** I have got a different question for BBSRC.

Professor Thorpe: We have a completely open, responsive-mode grant scheme and so long as it covers the environmental science mission, which in the broadest sense covers NERC, then our responsive-mode grant scheme is available to all those that apply.

Q253 ***Lord May of Oxford:*** So when you say you do not fund it you mean you do not get any proposals that you would call taxonomy per se?

Professor Thorpe: I think it is quite difficult to judge what proportion of a particular proposal you would class as taxonomy. That has been quite difficult to do. There is no doubt that it is very competitive to win grants and I think all communities need to write their proposals bringing out the environmental science frontier knowledge that is going to be generated by the proposal if they are going to be successful in those competitions. I imagine, like a number of disciplines, taxonomy-related proposals need to be written with that clear message of the environmental relevance and scientific relevance.

Q254 ***Lord May of Oxford:*** Just to interrupt because I do not want to go on and on. You say—and I do not need to be told that the grant system is competitive—that you would not discriminate against taxonomy and it is simply flatly incorrect to say that you do not fund taxonomy per se and that you would welcome it?

Professor Thorpe: Yes.[1]

Q255 ***Lord May of Oxford:*** Going on from the responsive mode, why did NERC decide not to fund taxonomy in the directed mode that it did as part of the very successful taxonomy initiative in the 1990s that was specifically in response to a much earlier inquiry from this Committee? Why did it decide not to pursue that?

Professor Thorpe: Our directed programmes, as you call them, are within the strategic priorities that we set in our strategy, and our current strategy is aligned along seven themes and one of those is biodiversity and that is relevant to taxonomy, although it is not the only place where it would appear, and we have not announced the programmes that are within each of those schemes yet because we are relatively early in the cycle but I am sure, judging from the draft theme action plan that I have seen, that there will be opportunities for that sort of research to be bid for within that theme.

Q256 ***Lord May of Oxford:*** I would have difficulty distinguishing between biodiversity and taxonomy systematics.

Professor Thorpe: I can only use the language that our strategy is couched in and that is the language it is couched in.

Q257 ***Lord May of Oxford:*** If I could move on to BBSRC, if I have read things correctly, you have suggested that research qua research carried out by employees in museums and gardens should be provided by the parent department. I declare an interest as an ex-Chairman of the Trustees of the Natural History Museum, and it was during the 1990s that I understood the rules to have been changed so that institutions such as the Natural History Museum and Kew could compete for competitive funds, and indeed have done so, at least when I was more familiar with them, very successfully, so could you perhaps give me a gloss on this statement that it is not your responsibility to provide funds for research for things like the Natural History Museum?

Dr Game: That is not actually what we have said. Our problem is with proposals that come in for what one might describe as pure taxonomy, in the sense of someone wanting to put a proposal in where they say,

[1] NERC stated in paragraph 9 of the main RCUK written submission to the inquiry that it "is not primarily concerned with systematics and taxonomy *per se*, focusing instead on using the information, particularly in the context of how biodiversity contributes to key ecosystem processes and services." In NERC's supplementary evidence in April 08, we tried to dispel the apparent misconception, voiced in earlier oral sessions, that NERC does not fund taxonomy. We stated among other things in paragraph 20 of that submission that "it is true that we do not fund alpha taxonomy in vacis. However we do fund it, and other systematics and taxonomy research, where it is required to address important environmental science questions.

"I would like to write a monograph on taxon X because that is what I do; I am an expert in this field"—

Q258 ***Lord May of Oxford:*** A bit like somebody saying, "I would like to do research on diatoms because I think they are interesting and that is what I do"?
Dr Game: Exactly. All we are saying is that in order to compete in a competitive system there has to be some reason advanced for why taxon X is better than taxon Y or whatever. If you look, we have funded taxonomic monographs and monographic studies, some put forward by the museums and gardens in the past, but relatively few of them, and I can give examples of them. For example, we funded a study of the actimomyces which followed on from the fact that the streptomyces genome had been sequenced and people needed to know more about the structural relationships between those organisms because it would help investigate potential industrial uses. We funded a study of the dictyostelids on the basis that that was a very important area in studying the evolution of early vertebrates and again genomics had offered a path. In both those cases the taxonomist offered a reason why we would want to do this in comparison with a piece of science in any other particular area, so the only trouble we have really is with people who appear not to want to try to justify their work in the broader sense of its relevance to either other scientists or to the mission of our organisation, because there is very little way you can actually rate one proposal against another unless you have some justification offered for why you want to do it, otherwise you are just dealing with a letter which says, "I am really good; give me some money."
Lord May of Oxford: I have to say I did not fully understand that. From my point of view, you write a proposal that would make an excellent contribution to our understanding of how the world works and the fact that it has to be shoehorned into some list of things I do not fully understand. There is an undertone in some of this conversation of the feeling that I thought Banks had solved when President of the Royal Society 200 years ago. Banks's presidency was characterised by a great deal of controversy because at that time people felt that science was the physical sciences and he was just doing gardening, and I do detect undertones of that: if you are going to do something on taxonomy then you had better explain how it is interesting to something else. While I am sympathetic to it, I think I have more experience perhaps than even you collectively of writing, judging and managing research grants and I fully appreciate—and we do not need to be told again of the competitive nature. What we are trying to find out is why there is this apparent disadvantage of this discipline which is a *sine qua non* for addressing biodiversity and consequent things like delivery of ecosystems services. It is immensely practical even if it looks to some people as if it is arcane and peculiar and just an enthusiasm of someone in a cubby hole.
Chairman: Do you want to respond to that? Lord Krebs, does your question amplify that one?
Lord Krebs: It is probably better to take a response.

Q259 ***Chairman:*** Let us take the responses and then we will come back.
Mr Visscher: Just briefly to respond to the funding of the grants that do get through the system. In fact, the success rate of grants with a taxonomic aspect to them within the BBSRC system is above average. Over a two-year period, if we look back at the success rate, it was just over 50 per cent against average of 25 per cent, and so I think that shows that good grants can be funded and do get funded. You have had information on the total spend that we have put through in this area which is of the order of £26 million, so it is perfectly possible for these to get through.
Professor Thorpe: In NERC about 64 per cent of its responsive-mode grants are in the area of biodiversity, so in all of the areas that you just described NERC supports a lot of grants. I do not think it is true that NERC would regard it as "gardening".
Chairman: We are pleased to hear that. Lord Krebs?

Q260 ***Lord Krebs:*** I just had a couple of supplementary questions to those asked by Lord May. Dr Game said that if you get a taxonomic application how do you know whether taxon A is more justified to be funded than taxon B. I would have thought that might be something that the research councils have a strategic view on; you take advice and you understand where there is a lack of knowledge. As an ornithologist, I would say it is unlikely there is a lack of taxonomic knowledge of birds in the UK but I can imagine other groups where there is a lack of taxonomic knowledge. Is that not something which it is your job as a research council to have a strategic view on? My second supplementary to Professor Thorpe is: in deciding not to continue the taxonomy training initiative did you or your predecessors come to the view that there was a sufficient number of taxonomists as a result of the training initiative and therefore it was no longer necessary?
Dr Game: I would accept the point that you make that it is our job to have a view about the strategic relevance of proposals that are put forward to us. I feel that we also rely on the applicants to have some view themselves about it.
Professor Thorpe: We have a strong thematic, directed programme of strategic research and so we absolutely would ask the questions that you raised. We would

have a view via the advice that we get, as I have already outlined, from our theme leaders in the theme action plans and through our Science Board on the areas of strategic priority. Set against that, we also have a completely open responsive mode for the best ideas judged via international peer review to be the best-quality science, and it is the quality of the science that is critical here. I think we have both of those methods available. In terms of picking up on the previous initiative that Steve mentioned, I think Georgina Mace mentioned when she was here that that had been influential in training up and developing expertise and it is one of the reasons why we wanted to look again in this skills review as to whether that needed to be followed up, and that is part of the reason why I wanted one of the foci of that review to be in this area.

Q261 ***Baroness Walmsley:*** Does that mean it is possible there may be a new taxonomic training initiative as a result of this?
Professor Thorpe: Absolutely.

Q262 ***Lord Krebs:*** I think this really builds on something that we have already been discussing but perhaps I could phrase it in terms of the words of another witness that we took evidence from who is a very distinguished taxonomist and who said that bodies like NERC do not hand out money for grant proposals that are primarily taxonomically aimed and he speaks from personal experience that you have got to hide the taxonomy away by cunningly concealing it under a scientific hypothesis. Do you think that is a fair comment or do you think that is going too far?
Professor Thorpe: Personally I think, as Lord May has said, when one is writing a grant proposal one tries to provide the best possible case for the science, making it attractive at the cutting edge of frontiers of knowledge so it will appeal to and be judged highly by the peer review system. Our success rate is 25 per cent or so, so it is (I come back to it) very competitive, and proposals need to be written so that they are seen to be high-quality science addressing what the peers of that area judge to be high-quality science, and I think there is clearly a skill in being able to write proposals in that way, and we are all aware of that fact. I would not regard that as covering things up, I think it is writing a good proposal.

Q263 ***Lord Krebs:*** But it does come with a problem and it relates to the question I asked Dr Game. If part of your strategic remit is to ascertain the coverage of the waterfront in taxonomy, it may be easier to conceal taxonomy under a scientific hypothesis for certain taxonomic groups than for others and therefore, inadvertently, gaps will appear in knowledge and expertise in the country. Would you not agree that it is your job to be aware of that and be proactive in dealing with it?
Professor Thorpe: I absolutely accept, and I have already said, this is why NERC is structured around having a very strong and large strategic priority-driven and directed programme so that we can target. That does not mean to say that we cover everything and our strategy actually is quite focused and definitely does not cover everything, so that is not to say that, but we do take a strategic view as well as having a scheme that is fully open to the best ideas via our responsive mode.

Q264 ***Lord Krebs:*** Do you as councils currently have a view as to which areas of taxonomy, which groups need particular bolstering by strategic investment?
Mr Visscher: For BBSRC at present we do not. We are about to enter into the development of a new strategic plan which will give the opportunity for us to look across the whole portfolio of activity of BBSRC, and we will go through the usual consultation process in that so there will be the opportunity for interested groups to put forward the case alongside other considerations.
Dr Game: I think it would be fair to say that one or two areas have emerged relatively recently which we need to look at, one of which is marine micro organisms, because of the rising interest in those from a commercial point of view. There is a great deal of interest surrounding fungal pathogens, particularly in plants, as a result of the effects of climate change, and we are aware that there is a shortage of skill in some areas of that. These are things which have come up through the community and from talking to users and will be things that will be taken into account.

Q265 ***Lord Soulsby of Swaffham Prior:*** The next question is on improving our understanding of the relationship between biodiversity and ecosystem functioning and ecosystem services provision which is central to NERC's new biodiversity thematic programme. We believe this will require new kinds of information on taxonomy of microbes, fungi, soil fauna, marine invertebrates, and so on. If taxonomy as a discipline in the UK is allowed to continue to decline, how does NERC expect to be able to generate such knowledge?
Professor Thorpe: This is exactly why we have introduced a sharper focus of advice to NERC about how to develop the priorities and the underlying skills that are needed for the biodiversity theme, so we are beginning to have much better advice in that direction and, as I have already mentioned, the theme action plan is highlighting some of the areas, if you like, state-of-the-art techniques in taxonomy, that need to be developed for biodiversity research and ecosystem function. I think we have in place the ability now to capture areas where we need to

develop further. The other area that we are working on is the significant part of NERC funding that goes into maintaining a national capability to do environmental science, so rather than in these thematic areas that I have talked about like climate change and biodiversity we look at whether we have sufficient facilities like ships, planes, instrumentation, and laboratory instruments for the community to use, so we call this "national capability", and again we are just about to introduce a new advisory committee to our Science Committee to look at this national capability that we support, and this will be another way in which we will be able to highlight areas where we think there are at the moment shortages of skills and we need to enhance those. I do think we have in place through the theme leaders and advice and also through this national capability advisory group ways that we have not had before to capture these shortages and be able to fill them.

Q266 ***Lord Soulsby of Swaffham Prior:*** Would this be on a competitive basis or would this be a non-competitive initiative from NERC in terms of you having seen the need to do some work on taxonomy and setting that in motion rather than waiting for a proposal coming forward?
Professor Thorpe: Yes, in our strategic priority area in developing these themes we will often have an announcement of opportunity in a particular area, so we would specify a subject area and ask for the proposals to be focused in that area, and then we would have a competition amongst the proposals. Sometimes if there is an obvious area where a facility needs developing or it is already in existence and it needs further enhancement, we would simply commission that to happen directly, so we have a number of ways of funding these initiatives. We use the competitive method a lot to test for quality but where there is an obvious provider that is providing a facility long term, to pick another example, running an Antarctic base for example, we do not ask for competitions for new providers but we make sure that that provision is high quality and developing in the best possible way, and that is how we direct the funding.

Q267 ***Lord Soulsby of Swaffham Prior:*** I am reminded of many years ago now the all-Union Academy of Sciences in the Soviet Union which would commission monographs on taxonomic subjects of various kinds. This might be the life's work of a scientist but at the end of it there was a monograph which was a very definitive monograph, and when they were translated—I speak Russian—into English, they were extraordinarily good in terms of quality of life cycle, vector potential, all of these things. We do not seem to have anything like that now. Is there something that would replace that because the all-Union Academy in the Soviet Union had this massive number of monographs that will tell you just about anything about the morphology of all the invertebrates in the Soviet Union.
Professor Thorpe: I am not sure that we would support or fund the long-term writing of a single monograph in the way you have described as a research council.

Q268 ***Lord Soulsby of Swaffham Prior:*** Is there anyone who could do that?
Mr Visscher: I suppose in a sense this is getting down to long-term core funding-type activities, more of a scholarship nature than research grants. I think if one looks at the way that Kew is funded for example, with a core grant from Defra, then clearly there is an opportunity for the director there to make choices about how that funding is deployed. I do not know whether he makes that choice to fund such activities but I think by its very nature it is different in character to the mainstream funding of the research councils and it is something where there is a perceived need which could be funded from such a source.

Q269 ***Chairman:*** I have to say I was mildly surprised to hear Lord Soulsby commending a Soviet-style approach to things but then I had a second look and I thought to myself, "What are we doing in Biobank?" We want to have a major reference library of some kind, if I may use that metaphor. Is there a need for any equivalent if one is thinking about taxonomy, in which case it would be partly a research council, but it may be there is no need for this, although it seems to me our inquiry is suggesting perhaps that is what is lacking?
Professor Thorpe: Research councils and certainly NERC supports long-term facilities that are enduring that go on in a number of areas. We have a large number of institutes that maintain and develop facilities on behalf of the community, so I would not want to say that we do not do long-term support. I was referring particularly to the output being a monograph at the end of a career, but certainly long-term support for facilities, expertise and data sets particularly are critically important to us.
Lord Soulsby of Swaffham Prior: Maybe I used the word "long term" wrongly. What I was trying to get at is a definitive monograph on whatever, if you wanted to get to know anything about chironimids, flies, for example you would go to this monograph and you would find everything you wanted to know there.

Q270 ***Baroness Walmsley:*** Ecosystem functioning and services obviously is a big interest to Defra and yet both of your councils and others formally report to DIUS. We were rather surprised to hear that Defra seemed to be unaware that taxonomic needs are likely to change, presumably in response to climate change

and other things, so our question really is: how do you, the research councils, communicate changing taxonomic needs to Defra and why do you think they are apparently unaware of the potential for major changes that could impact on their ability to deliver policy?

Professor Thorpe: As a research council NERC has very extensive interactions with Defra and I will not bore you with the depth and breadth of those, so I am very surprised to hear that comment coming from Defra. My perception is that they do get feedback from the basic science community via a large number of routes, not only bilaterals between myself and counterparts in Defra but also in community meetings, science research meetings where Defra-funded scientists meet with research council-funded scientists, so I am rather surprised. Also Defra support a number of activities within NERC institutes like the Centre for Ecology and Hydrology on the Countryside Survey for example which is specifically to look at elements of biodiversity across the UK countryside. I feel sure (but it is just my perception) that they are aware but I cannot really comment any further. Defra are very supportive for example of a new policy research programme that we are developing with a number of government departments and research councils called Living With Environmental Change, which is angled specifically at this issue of ecosystem services and the degrading of those services as outlined by the Millennium Ecosystem Assessment and other assessments, so we find we have very close collaboration with Defra and that is my perspective from the NERC side.

Q271 ***Chairman:*** Do BBSRC want to comment?

Dr Game: Really to some extent we look to Defra to tell us when they have requirements that change in terms of what they want from the science base. If you actually look at what has been going on in recent years regarding BBSRC, they have been good at that and they have told us very clearly that they want a shift from a production focus to a sustainability focus for example, and we have regular meetings with them about policy and they sit all over the BBSRC system. I have to say that with maybe one specific exception taxonomy has never really risen to any prominence in their dialogue with us. It has to be said that on the biodiversity side their dialogue would be expected to be more with NERC anyway but there is evidence that when specific requirements have arisen, as it did for example in mycology, they respond and they let us know what they doing and talk to us about it. I do not think there is any lack of communication; there might be an interesting clash of priorities.

Q272 ***Baroness Walmsley:*** So whose responsibility is it to look forward and anticipate the training needs? Is it the research councils, is it Defra, it is DIUS, is it individual universities? Who is it that has to look in their crystal ball and say, "We are going to have a shortage in that area; we need to do some training now"?

Mr Visscher: I think this emerges to some extent from a dialogue between the parties and certainly you have heard about across-research council discussions and many discussions both with our community and with Defra and other interested parties, and I think overall in a sense this is how our system of priorities does ultimately work and things find their way to the top of the pile through the force of the argument and showing that the need that has been made. As Alf has said, with one or two notable exceptions, such as mycology, areas have not really surfaced at the very highest level in the recent past. Whilst we look, by and large, to Defra because it has a lead in a number of areas on key committees, on the Funders' Forum and the Global Biodiversity Forum and so on, they also need support from the research councils and that dialogue is very regular.

Professor Thorpe: My answer would be that there are many people who have an interest in it and need to play a role in training—research councils, the funding councils of universities, universities themselves, all of the people you mentioned actually, and we all take a view. I would hope that we could perhaps link better together to take a collective view but there is no doubt a lot of people have an important role to play.

Lord May of Oxford: I am assuming we are near the end. I want to air a reflection, in a sense, and see what you thought of it. It is a much kinder reflection than some of my exasperated comments earlier—

Chairman: Unaccustomed as we are, I have to add!

Q273 ***Lord May of Oxford:*** I have just finished writing the biographical memoir of Richard Southward. He is an interesting person who in his early years, from the age of about three but right through his PhD and a little beyond, he was doing pure taxonomics and then his horizons broadened and he is one of the major figures in establishing what I would call ecological etymology. It is interesting that even Dick himself in his list of lifetime publications (and he continued to publish little taxonomic notes in taxonomic journals) had the numbers running one through to 245, and the little notes in taxonomic journals he would call them 30a and 30b, as if they were not quite real papers, and here is a person who was one of the doyens of the discipline. Furthermore of course, you go back in time 50 years, the world was vastly different; there was less money and fewer researchers and the competition was not as savage, and the emphasis was

more on trying to understand things and less on the necessary, but to me sometimes exasperating, codification and strategy reviews and all this stuff that sometimes seems to me to verge on and trespass into bullshit. It makes everyone's life difficult because in order to keep funding something that I really do believe is at the foundations of thinking about climate change and biodiversity and everything else, one has to deal with an idiom that even some of the practitioners feel is not quite "honcho papa"-ish science, and furthermore there is a muddle in the funding agencies between government departments and research councils, so basically I have a lot of sympathy for you but I have even more worries about where we are going. We are a bit worse than many other countries but we are not unique. I just wondered whether you think that reflection has validity or would you politely like to say you think it is nonsense?
Professor Thorpe: You call it the strategic view, sorry to say what you said, but bullshit—

Q274 ***Lord May of Oxford:*** It does shade into box ticking and stuff, you have got to admit.
Professor Thorpe: This in my view is profoundly not correct. The scientific enterprise is huge. The sort of canvass that NERC has to cover is huge. There are a lot of researchers and a lot of areas of science and if one was to apply the method that you described of supporting all of what you would regard, or a collection of your peers would regard, as the critical sub-disciplines within environmental science NERC's budget, however large it is, would never cover it. NERC Council is in the position—and it is a very real position—of having to prioritise and of having to spend the £400 million a year that the taxpayer provides, and I regard that as legitimate and absolutely critically important to do, and that prioritisition needs to build on scientific excellence and it also needs to build on where the scientific community thinks the priorities lie. We do not invent these priorities and these strategies ourselves. The scientific community actually takes part itself in coming up with what it thinks are the cutting-edge areas we should support. It is because we have to prioritise because our budget, however large, still is not as large as it might be to support all of the areas. That is the way I would characterise it.

Q275 ***Lord May of Oxford:*** I would say there is a germ of truth in this that if you do not do it explicitly then you do it implicitly. At the same time, many of the European research councils did not do a bad job of taking about 1,000 applications and distributing a sum of money similar to your total budget across all of science just trying to pick the things that are most exciting, and of course that is back to the implicit theme and you could argue—
Professor Thorpe: That is what we do with our responsive mode and the success rate of the ERC was below 10 per cent.

Q276 ***Lord May of Oxford:*** Much worse.
Professor Thorpe: Way below. That shows again that a lot of people in a lot of sub-disciplines were not going to be supported and could not be supported.

Q277 ***Chairman:*** Do BBSRC want to comment?
Dr Game: I wanted to go back to the example of Richard Southward. I do think that one of the reasons—and you are right that this is a problem for everyone—is that there has been this change in the nature of life sciences and the approach to why things are funded and so on, and it is causing a difficulty for this rather special area. I did my PhD in taxonomy but that was 25 years ago and life has changed a lot since then. One thing I do think has caused a problem here is the combination of the isolation of taxonomists out of the university system and the partitioning of funding between the different agencies and the playing between the two. The only thing I would say of the discussions that we have been having that has really worried me is the criticism of the efforts that we have been making to try to get the taxonomic community to work more closely with the rest of the life sciences system, because it seems to me that a lot of the problem is the failure of fellow scientists in other areas of the discipline to actually appreciate the value and potential of what taxonomists are doing. So the notion that by pushing this, investing money into this, which is what the Systematics Association and Linnean Society asked us to do, is trying to force these people to misrepresent themselves or shoehorn themselves into the wrong holes, I think is really worrying and is actually a problem. The rest of your analysis I would agree with totally.
Chairman: And we are looking forward to reading the memoir about Sir Richard Southwood. Thank you very much indeed. It is much appreciated, as I suggested earlier, you giving your time and your expertise, and if there are any points upon which on reflection you want to expand, do not hesitate to give us a short written note. Thank you.

Examination of Witness

Witness: IAN PEARSON, a Member of the House of Commons, Minister of State for Science and Innovation, examined.

Q278 ***Chairman:*** Minister, welcome. We very much appreciate your taking time to help us with this inquiry; it is a very important inquiry that underlies a great deal of the science that is going on. We are in a little bit of difficulty—and I will just be upfront about this—that clearly one of the things that keep coming up is the fact that the area of systematics and taxonomy is spread across government, so more than one department has a clear interest and indeed, we believe, responsibility. We had rather hoped that there might be representatives from other departments here but in one case the representatives suggested that there was nothing further to be said from Defra, and one of the questions I will ask is about splits of responsibility between, say, your department and Defra. So we are in a little bit of difficulty on that. We also understand that you may have been provided with written answers to read out to some of these questions. I think that would be wasting your time and ours.
Ian Pearson: I was not intending to do that.

Q279 ***Chairman:*** Good because clearly it is the follow-up and the discussion that lets us move on. But your presence here is much appreciated and your department has significant responsibilities and is indeed making a significant contribution. May I then begin—and we will move round the table as we have a number of questions. Taxonomy and the funding for it is, as I have just suggested, dispersed. The leading institutions receive grant-in-aid from more than one department including, clearly, your own. What we would like to discuss a little with your help is what manner of responsibility there is for taking a strategic overview. Whose responsibility should that be? What are the kinds of interchange between departments? How far is the liaison such that things will not fall between the cracks, and so on? And ought there to be a single lead department?
Ian Pearson: Firstly, thank you very much for the opportunity to appear before the Committee. I think that this inquiry can be very valuable to us as a government because it is an area where I know that you have done work in the past, and you had Baroness Walmsley's report previously and we have seen some action from the BBSRC and from the NERC as a result of that. Obviously the Committee thinks that there are issues that remain unresolved which is why it is conducting this inquiry, and I will be very interested to see your conclusions when they are complete. In terms of overall responsibilities, as you will appreciate and has been given in evidence already to you, DCMS, Defra and DIUS take responsibility for areas which fall within each of our remits and there is a clear relationship between government through DIUS, through to our Research Councils when it comes to providing funding in the field of systematics and taxonomy. I suppose my answer to you is that we have a collective responsibility here as government departments, as a government for ensuring that this area is paid sufficient attention. As you will be very well aware—perhaps far more than I—from reading some of the background briefing before this meeting today I was reading about the coordination that takes place through the Biodiversity Research Action Group, through the Global Biodiversity Sub-committee, and also how the Environment Research Funders' Forum works. That brings together a range of different organisations of those with an interest in this area and does provide coordination.

Q280 ***Chairman:*** So in the end you do not think that a single lead department would help things?
Ian Pearson: As I say, I would be interested in the Committee's conclusions on this but it does not seem to me intuitively right that there will be a single lead department that would be responsible for the taxonomy aspects of the convention on biological diversity—collections of the Natural History Museum or Kew Gardens, or indeed taxonomy research that is ancillary and related to other research that is conducted by different Research Councils. I am minded to come to the conclusion myself that it is better for each organisation to concentrate on the areas that are within its current remit rather than to have one specific lead that tries to cover such a broad territory.

Q281 ***Chairman:*** One of the issues clearly is how one relates to and communicates with the community out there, who actually do the work and see the need at ground level, so to speak, and who give us various messages. It has been suggested to us that this Committee is one of the few ways in which there is a route in, and although we are flattered and delighted and the work of the previous Committee under Baroness Walmsley helped move that ahead, it is obviously not the appropriate mechanism for the community to communicate with the sponsoring departments. Again, this is coming back to the issue of whether it is a lead department and a single point of contact and so on, because the communication with the community is an issue that has come up.
Ian Pearson: I am not aware of an issue in terms of lack of communication between the community and the Natural Environment Research Council or the Biotechnology and Biological Sciences Research Council. I cannot obviously speak for other government departments but from what I can see there does seem to be good communication between Research Councils and the relevant communities that

cover their remit. I think some of the additional evidence that has been supplied by the Research Councils, to answer your question, shows the extent of Research Council funding for research that does include taxonomy as part of its remit.

Chairman: In fact we have been discussing that with officials over the last hour and a half, and had a useful exchange. I will ask Lord Methuen to take up this discussion.

Q282 ***Lord Methuen:*** The Committee has heard of difficulties in finding UK-trained taxonomists, leading to the recruitment of specialists trained overseas for UK institutions. Why is the UK university sector failing to produce sufficient specialists with the skills to meet the UK's needs?

Ian Pearson: I do not necessarily accept that that is the case. I am informed that HEFCE—the Higher Education Funding Council for England—does not have an information base that would enable it to take an independent and rigorous view as to whether and to what extent the system is failing to produce specialists. You will have seen the research evidence that was submitted by Research Councils UK when it comes to the issue of skills from, I think, paragraphs 84 to 96, which provides some of the detail of what is going on. I would also like to quote the Director of Science from the Natural History Museum who in his evidence to you said, "In our experience it has not been difficult to hire taxonomists." I think you also heard some evidence from Nic Lughadha who has said, "We have looked to change our recruitment model and we will recruit bright people with an aptitude and provide training for them." I certainly accept that there is an issue here and Professor Mace said to you that NERC takes responsibility for ensuring that it maintains the expertise base in taxonomy. When Lord Krebs was Chief Executive of the Natural Environment Research Council he introduced a significant training initiative, which I think has embedded a lot of trained taxonomists into research groups in the research community. Of course, this is not the level of detail that I as a minister want to get involved in because I would always be conscious of wanting to abide by the Haldane Principle, and it would be up to the Research Councils themselves to make sure that collectively they are providing sufficient support to enable a thriving research community, and as I am sure you will have heard they will report annually in terms of the health of disciplines. Also it is my understanding that the Environment Research Funders' Forum is commissioning a study shortly, which will be looking at skill needs in the sector and I hope that that will be of benefit in the long term.

Q283 ***Baroness Walmsley:*** I think on that last point we are comforted to hear that but I do not think we should be deceived when we hear the Natural History Museum say that they do not have any difficulty finding taxonomists because it is a world famous institution and taxonomists from all over the world want to go and work there, and most of the ones that they are recruiting are not from this country, so it is the UK capacity that worries us particularly. One thing that worries us particularly is that when you find that you need a taxonomist and you cannot find one, that is too late because it takes years to produce a good taxonomist, and the output of work that the rest of the scientific community need. So it really requires somebody to be looking forward and taking that responsibility to do that and taking the action to train the people that we are going to need in this country, not just relying all the time on people from abroad—wonderful though they are. So who is taking that responsibility?

Ian Pearson: There are two points I want to make in response. The first one is very much the fact that you do have some figures about the number of doctorates in PhDs in this sort of research area that have been provided by the Research Councils, and undoubtedly you will want to come to a judgment as to whether that is sufficient given the circumstances, and I hope that the study that I was talking about itself will want to have a look at that. As I say, my responsibility overall as a minister is that I want to be assured that the Research Rouncils are paying sufficient detail to the health of key disciplines. It is not my role to interfere and to specify what those levels should be, or to tension the systematics and taxonomy community against other particular research communities. It is my role overall to ensure that as a government we feel satisfied that there are sufficient people. The second point I would want to make as well is that it is not only world class institutions such as the Natural History Museum that draw on the best people internationally. We do have a global labour market in these areas but in other areas as well and it is absolutely right that in the UK we should have the ability to attract the brightest and the best wherever they come from. Of course we want to train our own people as well, but I do not know what the right figure is—whether 50% should be home-grown, whether 10% or 17%, or what that figure should be. I think you have to rely on the recruitment practices of individual organisations and it is my understanding that HEFCE itself does not consider that a case has been made as of yet that there are strong skill shortages in the areas where it provides support in terms of research training. Undoubtedly the study will help to contribute to the knowledge which will enable more informed decisions to be taken.

Q284 ***Lord Krebs:*** I would like to pick up on this point about collective responsibility that we discussed a few moments ago and I want to make two

points and I would be interested in your response. We have heard from each of the players, government departments and Research Councils, at different times the comment that they are users of taxonomy rather than generators of taxonomic knowledge; so we are concerned that maybe everybody sees that they have an interest in taxonomy but they do themselves as having a primary responsibility for generating taxonomic knowledge or skills. That is point one. The other point that has come to us is that in this collective responsibility we have sometimes gained the impression that different players are thinking that another player in the collective group is responsible for an activity, and if you look at it from both sides it may be that things fall through the gaps. I will give you an example. In the written input from RCUK they say that the AHRC's remit includes maintaining collections, including taxonomic collections, their presentation, interpretation and management. When we asked the AHRC about that and those collections in regional museums, their role in teaching, AHRC said, "This is the role of HEFCE." So there are really two players batting the ball between them and then maybe it disappears down the plughole between them, if I can mix my metaphors!

Ian Pearson: My understanding is that it was seen more as a transition from AHRC funding this area to HEFCE taking over funding of this from 2009 onwards, and obviously it would be a matter for HEFCE and you might want to talk to them about the extent to which they are going to be providing funding. But I agree with you that there is always a danger that things might fall between the cracks when you have lots of different organisations involved, and that is why having coordinating groups that come together to discuss these issues and to, if you like, manage the discipline across boundaries, is I think, important, which is where things like the Environment Research Funders' Forum come in, and also where, for instance, the Biodiversity Research Advisory Group I imagine would have a role. Again, I see it very much as my role to ask the Research Councils to provide me with assurances that this issue is being addressed rather than for me to micromanage the delivery of particular solutions. I do not think that is what you would expect a minister to do and I think we need to be very careful in ensuring that we do not have ministerial decision-making when it comes to what research is conducted. We take decisions very much at a strategic level and it is really up to the Research Councils and the peer review process to decide what is the best research and what should be funded within the funding envelope that the government provides.

Q285 ***Chairman:*** I think we do understand that and clearly it is essential that ministers do things strategically. The question that has troubled us is where does the buck stop if there is a gap, if there is a problem? And inevitably if there are two or three departments involved there is a sudden absence of those who will stand up and say, "It stops here". I think we are quite likely to ask that that be thought about again because it is always a potentially dangerous situation. But we do understand that ministerial responsibility is as it is writ.

Ian Pearson: I think it would be a very valuable exercise if, as a result of your conclusions, you came up with an analysis of where you think the cracks are and where you think the problems are, and that at least would give us an agenda to work on and to see, firstly, whether we agree but, assuming we do, how we fix those.

Q286 ***Lord Haskel:*** Minister, the nub of our concerns is that in the past the delivery of UK conservation priorities has been supported by a wealth of existing taxonomic knowledge. However, deepening our scientific understanding of the emerging field of providing ecosystem services is going to require a vastly improved knowledge. We are going to have to learn a lot more about microbes, fungi, soil fauna, marine invertebrates, and our concern is how is the government responding to these new scientific priorities, and specifically, of course, the demand for new taxonomic knowledge?

Ian Pearson: As I say, the role of government is very much one of acting at a strategic level and when you look at how the decision process worked during the last spending review period, where we made decisions on support for funding for the Research Councils, we essentially made some broad strategic decisions; firstly, about the importance of full economic costing to the university sector to ensure that we have genuinely sustainable long term research being conducted in the United Kingdom. We made a decision that we wanted to see cross Research Council priorities and we set out four major priorities, which were Living with Environmental Change, Energy, Aging and Security and Counterterrorism. We believe that those are big challenges facing the world and facing the UK as well, and we wanted to make sure that sufficient resource was going to be directed into those areas. We also made decisions on the balance of funding between different research councils. One of our big priorities in the decision that we took was that we wanted to see full implementation of the Cooksey Review. That is one of the reasons why the Medical Research Council had their biggest increase in the funding councils. Of course it is always the case in these sorts of areas when you are making those big strategic decisions that some Research Councils will do better than others, and that they will have to make some fairly tough decisions. As you will be aware, the issue of the Science and Technology Facilities

Council, there have been various issues and concerns raised within that community about its overall settlement and about how the process of consulting with the community had actually worked. We as a government most clearly do not get involved in the detail of the decisions that individual Research Councils take within their funding envelope. Again, I would go back to the importance of Haldane as a principle and the need for Research Councils to conduct peer review research and to tension between research groups in one particular area and in the other areas of its remit. That clearly is best done by the individual research communities rather than government. So the short answer to your question is that it would not be right for me as a government minister to say, "You have to provide this certain level of funding and research to systematics and taxonomy." That has to be a decision that Research Councils take for themselves, but overall I would point out that when you look at the science budget it has been increasing over the last 10 years and will continue to increase over the next three years; and we have seen sustained investment in UK science and it is up to the scientific community to decide on the detail and the balance of priorities.

Q287 ***Lord Haskel:*** The key that we are concerned about of course is biodiversity. Are you satisfied that these strategic arrangements you have just described to us are going to deal with biodiversity as we need to deal with it?

Ian Pearson: I certainly agree with you, particularly as a former climate change minister as well, on the importance of biodiversity as an issue. Within, for instance, the Living with Environmental Change policy there is a lot of research that will be funded into the issue of biodiversity. Again, the priorities within that field will be very much something for the Research Councils themselves to determine and NERC will lead on this. But I am confident that there is significant new research that is going on into this area in the future, and it is absolutely right that it should do so. If we are going to better understand how the world is adapting to climate change we need to understand a lot more than we do at the moment when it comes to how different organisms are affected by changes in temperatures, changes in the salinity and acidification of the sea and other factors as well. I think, as I say, that there is substantial research funding over the next three years into projects which will look into a whole range of areas, and of course taxonomy will be important in this process. From my limited understanding—and I am very conscious of the expertise that is in this room today—there are big changes taking place in this world at the moment, and from reading some of the transcripts before appearing here today it is quite clear that this is a significantly expanding area and when you look at the advances that have taken place at a molecular level, which is transforming this world in many ways, it does provide enormous opportunities. Again, one of the strengths of the UK is that we conduct world class research in lots and lots of different areas and there are far more world class research proposals than we could ever fund as a government and decisions have to be taken, and some areas which are world class will probably not get pursued. Many will, some will not because there will be a shortage, and if there was never a shortage then I think you might wish to question the quality of the research proposals that were coming forward. So I think that all Research Councils will have to make some very tough decisions, but I would be looking to be assured that as part of the normal process that we continue to have a high quality research being conducted into all the different aspects of biodiversity within the UK and indeed our planet.

Q288 ***Lord Krebs:*** A brief follow up on that very last point. I am obviously delighted to hear your strong affirmation of the Haldane Principle but I want to ask, following up your last paragraph, what is the mechanism that DIUS has for assuring itself that under the Haldane Principle the Research Councils are making effective and appropriate resource allocation decisions, because presumably ultimately you account for the science budget and you have to ask of the Chief Executives of the Research Councils, "Assure me you are doing the job that you are supposed to do." What is the mechanism within DIUS for achieving that?

Ian Pearson: The process is that the government will set overall strategic priorities and will approve delivery plans for each of the Research Councils. It will then monitor those delivery plans at an official level on a quarterly basis. So it will monitor against performance. As I say, the individual decisions on which research proposals will be very much matters that the Research Councils themselves would decide individually and collectively across the cross council themes. It is the responsibility of DIUS as a department to ensure that research Councils have robust decision-making processes; but, again, it is not our job to second guess those decision-making processes. I will meet with the Chief Executives of the Research Councils on a regular basis to discuss their work programme and I think it is right that I should do that as an interested minister. But it is not my role to interfere in the minutiae of the delivery plan of a particular Research Council. It just would not be appropriate for any Minister to do so.

Q289 ***Lord Soulsby of Swaffham Prior:*** Can we come to the Research Assessment Exercise, the bête noir of departmental chairmen. It is widely viewed as a major driver of the decline in minority disciplines

such as taxonomy. How is the government proposing to avoid this adverse effect in the replacement mechanism, namely the Research Excellence Framework?

Ian Pearson: I have read that in some quarters the Research Assessment Exercise has been viewed as being a driver of the decline of what you might call minority disciplines, but HEFCE itself would not, from my understanding, accept that, and I see no conclusive evidence to that effect. Often where research capacity in a particular discipline is in decline there can be a number of reasons for that and I often think that the Research Assessment Exercise can be blamed for lots of things but I am not sure that this particular case is one in point. I would just note in passing as well that in response to the report that Baroness Walmsley chaired there has been a response in the current round of the Research Assessment Exercise, and I think it was Professor Mace, when she gave evidence to you, who said that she was on one of the research panels and she had very much taken to heart the recommendations in your previous report in this area, and was giving due credit to working subjects like taxonomy as part of the assessment exercise. So the current round of the RAE has taken on board the Committee's views and recommendations. As far as the Research Excellence Framework is concerned, again you will have picked up some comments within the research community about the reliance on bibliometrics and how that might affect research funding in the future, in particular in disciplines like taxonomy. Indeed, there have been concerns more widely within the research community about the use of bibliometrics. You will be aware that the Secretary of State, John Denham, announced on 24 April in a written statement to both Houses that the next steps were implementation and development of the Research Excellence Framework, and in essence what he said in that statement is that we have moved towards a single unified funding and assessment framework for all subjects, but within this the balance of metric indicators, including bibliometrics, and light-touch expert review will vary according to the subject. He also announced that in order to allow sufficient time to develop this more flexible approach HEFCE will now build an additional 12 months into the time table for designing a new framework. So it is currently envisaged that the overall objective would be to have this fully operational in time for the beginning of academic year 2014–15, so it is a significant period of time away from this. But certainly the concerns that you have expressed as a Committee are already being taken on board as part of our thinking on the Research Excellence Framework and there will be certainly a lot more work that will be done between now and 2014–15 because we all have a shared interest in getting this right and these can be very difficult and complex decisions about how funding the frameworks work. I think it is right that we take the time that would be needed to make sure that we design the best possible framework.

Q290 ***Lord Soulsby of Swaffham Prior:*** So we can take it that metric based assessments will be part of the Research Excellence Framework in the future?

Ian Pearson: I think there is quite a strong consensus that metric should play a part in any assessment exercise framework, including the newer Excellence Framework. What weighting you give to metrics compared with light-touch peer review is something that I still think is very much for discussion and development, and obviously HEFCE have been leading on the consultation on the Research Excellence Framework and will continue to want to listen to views.

Q291 ***Lord Soulsby of Swaffham Prior:*** But if this is going to rescue the taxonomy situation it seems to me that you must have a positive aim in this area.

Ian Pearson: I am not sure I would want to use the word "rescue" because I do not accept that taxonomy is necessarily in need of rescuing. What as a government we will want to be convinced about is that we have a robust Research Excellence Framework that is fit for purpose and takes into account the whole range of disciplines and operates in a transparent and fair way and has the full confidence of the whole research community. That, I think, has to be the objective for us.

Q292 ***Lord Soulsby of Swaffham Prior:*** One of the problems with the Research Assessment Exercise is a head of a department or a Dean in a school can miss out minor areas in the consideration and they never get the chance to be reassessed. What I am concerned with is that they are included and they are assessed even though they might be a minor part of a departmental effort.

Ian Pearson: I think those are certainly points that we can take away and consider as part of our deliberations on what a Research Excellence Framework needs to look like for the future. I am aware that there have been a huge amount of submissions from university departments, from researchers and a range of other organisations as part of the consultation process that has been conducted so far, and there is certainly plenty of time for further discussions and representations as we look to develop that Research Excellence Framework for the future.

Q293 ***Earl of Selborne:*** Minister, this country has benefited enormously over the years from national, regional, and local biological recording schemes and the data that has accumulated, particularly the long term databanks are extremely useful in delivering

environmental policy, action plans, whatever. But of course leaving aside the possible lack of professional taxonomists it relies very much on volunteers and we certainly had evidence that while birds and butterflies may well be well recorded in future the less attractive or less well known species are in decline and the amount of volunteers is, quite frankly, declining. So there is a need to try and recruit and enthuse a new generation of people in biological recording. Does the government have a role in helping to build capacity on this and, if so, how would it set about doing that?

Ian Pearson: I personally participated in some of these surveys by reporting the wildlife in my back garden, as I think probably a number of us have. The use of volunteers to provide information for research is very much something that a government welcomes and I know is valued by the research community. In response, Lord Selborne, can I say about one of the initiatives that is taking place at a general level within government, which is that the Economic and Social Research Council in partnership with the Office of the Third Sector in the Cabinet Office and the Barrow Cadbury Trust is commissioning an independent multidisciplinary research centre for the third sector, and this is aimed at in general building capacity in the voluntary sector and its intention is to develop knowledge and expertise with and for the third sector, including the voluntary and community sector and social enterprise as well. That is something that is taking place at a general level; I think a total of ten and a quarter million pounds is currently available for the initiative as a whole and a call for proposals was announced in January of this year. Obviously that is not something that is specifically aimed at biodiversity but the intention is at a national level where there will be a single research centre and there would also be three capacity building in clusters as well, which would aim to create a new generation of high quality researchers committed to what we call the coproduction of knowledge and its application to the third sector. So that is one way in which to build some capacity. I do not think it is the only thing that we need to do, but one of the things that has been a theme for this government has been the involvement of the third sector in the delivery of public sector policy and public services, and I have no doubt that that will remain in the future.

Q294 ***Earl of Selborne:*** One of the issues which has been presented to us—and I think I understand this—is that if you are trying to enthuse locally a new generation or existing people in some of these rather more obscure areas of biological recording you need access to collections and that means you have to have the specialist information available and, quite frankly, access is very difficult. A lot of these collections are held and inadequately curated and it is not just the money to allow these collections to be properly maintained. Again, is this something of which the government has been made aware?

Ian Pearson: I am certainly aware that this has been raised as an issue by some of the people that have been providing evidence to this Committee, and again I will be interested in your considerations as to how significant a problem you believe this to be. I would like to add a point to this, which is about what we are doing as a government to encourage people to do science, technology, engineering and mathematics. Both the work of the STEM Programme within our school system and encouraging more people to do STEM subjects at university and going on to do careers and stuff because I think the more that we can actually persuade people of the fundamental importance of science to solving the world's greatest problems, the more we can enthuse them and get them excited about science the more we potentially have people who may be working in science but have maybe gone into other jobs in the future but might want to contribute as volunteers. So I think that the work we are doing on STEM schools, the work of our 18,000 science and engineering ambassadors in schools is important not just for our STEM Programme and ensuring that we have a pull-through of bright, qualified science graduates that are going to get jobs in the workforce, but I think it is important again to the potentially the volunteering agenda and the contributing to the very areas that we have been talking about.

Q295 ***Chairman:*** Thank you very much. I think this simply underlines some of the main issues that we have focused on and will focus on. Clearly the way in which science, which is very much your patch, so to speak, increasingly has to inform government policy and it means that the underpinning of all of this becomes more and more important. But equally, as you pointed out, it involves several other departments, and the minute you talk about museums DCMS, how do they link up with the schools and so on and so forth, which is why we will continue to press this across the government coordination. The notion of joined-up government is not dead yet! Thank you very much for your time. These are the questions that we wanted to discuss with you and we look forward to sending you a copy of our conclusions and hearing your reactions.

Ian Pearson: Thank you very much for the opportunity.

WEDNESDAY 21 MAY 2008

Present	Colwyn, L	Sutherland of Houndwood, L (Chairman)
	May of Oxford, L	Walmsley, B
	Northesk, E	Warner, L
	Selborne, E	

Examination of Witnesses

Witnesses: Rt Hon Lord Rooker, a Member of the House, Minister for Sustainable Food and Farming and Animal Health, Defra, and Rt Hon Margaret Hodge, a Member of the House of Commons, Minister for Culture, Creative Industries and Tourism, DCMS, examined.

Q296 ***Chairman:*** May I welcome the Ministers very warmly indeed. We appreciate you are very busy people and have given us time. We are starting a couple of minutes early on our schedule which I hope is helpful and I am assuming we will be about an hour if that is possible. We have a number of questions we would like to cover. Lord Rooker and Margaret Hodge welcome. I mention your names not because we do not know them but for the record it is important to have them on file. We have our names around the table. There is a sheet declaring what our interests are so we need not go through all of that. Would either of you like to make an opening statement?

Lord Rooker: I have one comment I would like to make. I realise you were due a Defra minister a few weeks ago but I just want to put on record that at moment my department is involved in 28 Select Committee inquiries, leading on 24. We are stretched to breaking point in terms of resources. I want to make that absolutely clear. It is not a criticism of this Committee, it cannot be, but we have never ever been involved in so many inquiries at the same time.

Q297 ***Chairman:*** It is important to have that point on the record. We appreciate the pressure you are under which is why we welcome you here today. Our own Committee has had some of the consequences of that. Even identifying which would be the most appropriate minister to come from the department is sometimes an issue which doubtless is a reflection of the spread of responsibilities of, in this case, the two departments. My first question is reasonably apposite in that context and is to do with the fact that government funding for taxonomy and systematics is very, very widely dispersed. Our earlier report, which Baroness Walmsley chaired, recommended quite strongly that we would like to see a single focus. Clearly that relates to the amount of work any department takes on but equally it relates to where the community, and groups like ourselves trying to inquire into the situation, go when they want a statement of what government policy is. I wonder if you would like to react to that question.

Lord Rooker: I have read some of the background. I freely admit, by the way, that I have been at Defra for two years and a week at the moment and the only time I have actually addressed this issue is in the last week since I came here. I realise I have probably come across the issue more than I appreciated when I first heard what the subject was having visited a range of laboratories. We have three laboratory agencies, Central Science Laboratory, CEFAS and the VLA, but we directly fund Kew which although it is independent is actually funded by Defra. Then there is the John Innes Centre, ICAR and Rothamsted all of whom we buy research from. We are, as a department, probably second only to the Ministry of Defence in having our policies based on science in Defra. I think I can say that without qualification. I have never been challenged when I have said that and that was the line some years ago. We are very heavily dependent on science for our policy right across all of Defra's responsibilities and, that being so, we have three agencies of our own but we are a customer of all the others. We have occasionally had problems over funding of some of the research councils, because we were such a heavy customer of their own agencies they seem to think we should do the core funding. The point I want to make is we are a user of this particular branch of science to a greater or lesser extent and, of course, we help fund projects through the Darwin Initiative around the world in taxonomy. I have no evidence that we are hamstrung in achieving our objectives in terms of our contract. We do very little blue skies in that. There is horizon scanning but 95 per cent of our £300-odd million worth of science expenditure is very much applied to cover our policy areas. We collaborate with other departments and discuss with other departments. We probably have not made it so clear in our memo the kind of contacts we have around departments but we do not see ourselves as a provider of the science or the individuals. We have assisted funding training abroad through Darwin but essentially we are a customer of the particular science maybe on a grand scale to a greater or lesser extent. Kew is, as you appreciate, very much a large user.

Margaret Hodge: From my perspective, I am speaking to a group of very eminent scientists. Until I realised I was coming to give evidence to this Select Committee I knew not a lot about taxonomy, to be honest, so I am grateful for the opportunity of being able to mug it up and learn a little about it. Is there a problem? Our role is we fund the museums, and in particular we fund the Natural History Museum, but there are a number of other museums which have collections that have to be assessed through the science of taxonomy and systematics. I think both of us would say we deal with a whole range of issues where there are a number of government departments with an interest and involvement. We have learnt to work across government rather effectively where there is a mutual interest. To give you one example on this area with Defra, I managed to convene recently a meeting around Darwin 200, which is going to be an important commemoration year, where I brought together a colleague of Jeff Rooker's from Defra, someone from DCSF and somebody from DIUS and sitting around that table there were probably five or six other departments represented, all of whom had an interest. People often get worried that things fall through the cracks in the way that Ian Pearson mentioned to you when he was giving evidence. I think when you try to paper over one by re-organising departmental responsibilities all you do is you find new cracks emerge. It is quite appropriate we have the responsibility for the museums, particularly the national museums. They have a number of purposes and an important one for you is the scientific purpose, but they do have others around visitor attractions, education resource and all that sort of stuff which we are well suited to pursue. Where there is an issue where we need to talk to other departments, we do very quickly either on the phone or in meetings.

Q298 ***Chairman:*** There are two aspects which have concerned us and one is that whatever structure you have within government of departments it will not match completely what human life is like. There are bound to be variations and that is just part of the reality of life but that makes it very important to pay attention, as you say, to making sure that the cracks do not develop into great fissures of one kind or another. What kind of cross-departmental discussion takes place, how it is facilitated, is it ad hoc and is there a regular set of meetings is one of the questions. I know that scientists and academics often feel neglected and that is just part of the reality of life. I have been one so I know. On the other hand, something that was put to us very strongly by the community is the health of the discipline and the community where decisions in one department might affect the consequences of being able to deliver the services for another department. We are concerned whether there are enough trained people in the system and whether the flow of funds from one direction, be it DIUS or the research councils, is inhibiting or enhancing that training for skills that other departments, Defra not least, will require. There are really two aspects to this.

Margaret Hodge: First of all, in relation to taxonomy I have never been asked to attend a meeting with other ministers around this issue because nobody in that world has raised it as an issue about which they have a problem. Were that to arise, we would meet. It would be ad hoc meetings but we have never been asked for one. If the community is saying to you they feel that there is not coordination, I think they have not articulated that in any way effectively into government and if they were to do so we would respond pretty promptly. The second is I think diversity of funding for this and other areas is always a strength rather than a weakness. It is a strength because it means you are not entirely reliant on one department or one institution. There are a number of bodies with funding potential from the research councils through to HEFCE, to Defra, to ourselves. You can go on and on who could support this particular discipline. I think that is a strength and also makes the discipline itself think and justify its relevance in a whole range of policy areas and I do not think that is a bad thing either. It may feel neater to have one minister, one department and one budget but I actually think there is a lot of benefit to be said from the relationship that exists now particularly for taxonomy. From what I picked up in preparing for the Committee today, actually taxonomists need to work rather closely with other disciplines if they are to fulfil their objectives. Probably the status quo is right and if they are worried they should tell us.

Lord Rooker: I agree entirely with that. The seven organisations I mentioned in my first comment, the three Defra laboratories and the four others, I have visited them all, gone behind the reception areas as it were, and to the best of my knowledge nobody has ever raised an issue relating to training or not enough people coming through at all. The contrast I would give, so as far as Defra is concerned, is another branch of our service, the veterinary service. Quite clearly there is not much argument that we are the key user as a ministry and in many ways a provider. If there was a problem with the number of vets in the country, particularly with farm animals and disease control, and we use an enormous amount of private sector vets, we would be the department and we would know about it. Indeed people go off into the cushy part of the veterinary service rather than the farm animals but we would know about that. With this issue, this crosses species. We are dealing with plants, animals, all kinds of little bugs. My private office checked on one of the web sites to find out what

it was all about and I got this incredible note which says basically there is estimated to be 30 million species of animals, plants and bacteria in the world and we have identified 1.7 million so there is quite a bit of work to do.

Q299 ***Lord May of Oxford:*** 30 million is a bit over the top.
Lord Rooker: There is clearly a job to be done but that goes right across and it is a planet issue in that sense. With our Darwin Initiative we have funded 700 projects in 146 countries over a period of time and, as Margaret says, this crosses the boundaries. There are other parts of government where it is very convenient for the centre to lump everything in one place because it is easier to cut and control the budget when you have done that but you reduce flexibility if you do that. I am not saying there is no scope for change. Maybe, but I do not know, it goes on a par with machinery of government issues but there are always changes going on in the science and the way we organise ourselves. Central Science Laboratory is being converted and will be called the Regulatory Science Agency and plant health is going into that. There are these issues going on all the while with changes. In the memo that Defra provided the Committee early on in March, we gave the set up in our own three laboratories, SEFAS, CSL and the VLA, of the number of people qualified in various branches of taxonomy. As I say, I have seen no evidence, and have had it confirmed from officials more recently, that we have any problem getting the work done that needs doing either for ourselves or with our collaboration because these things are a collaboration with other departments.

Q300 ***Lord May of Oxford:*** I agree with you that a certain amount of diversity can be constructive. I can give you an example when the Natural History Museum became able to go to the research councils, which happened when I was a trustee and before. Just to declare the interest, I was chairman of the trustees. That is good but, at the same time, there are lots of counter-examples where it is a problem. To give what I think is an example, we have a hugely important fungal collection which is a really important resource of growing importance under climate change. It used to be owned by a thing called CABI that is now at Kew. My understanding, which is imperfect, is that it is not at all clear who is going to fund this. In a time when money is short, it is natural that people of goodwill will all suggest that it is somebody else's responsibility. We have heard a lot of evidence to the general tenor that it would be helpful perhaps if there were an identified point of definitive reference which would stop the ping pong that can go on.
Margaret Hodge: There are so many issues across government that I have to deal with day to day. No doubt when you were advising government you found that there were a number of people involved in the funding and of course you try and bat it off to somebody else in the first instance. When money is tight that might be your initial reaction, but actually I found that over those issues over time you just do sit down with other people involved and sort it. You have to sort it. We do have a machinery of government mechanism if things go very badly wrong and that is Cabinet Office will then, from the centre, instruct us what to do if we are not able to come to a decision among ourselves. A very different example is Ironbridge Museum which is outside Telford. Defra is involved and we are involved because we have the World Heritage Site and there is a flood challenge there. There is lot of money involved to put that right. We have had quite a number of meetings over time between local government, Department for Communities and Local Government, yourselves, ourselves, and others involved. In the end, because that was a lot of money, Cabinet Office took the decision as to who should be the lead department with accountability. There is a mechanism in government should things go wrong. I have to say we are the main funders of the Natural History Museum. They are the key specialists, as I understand it, in this particular discipline and I think they have done pretty well in terms of funding through us. This time around, interestingly enough, we managed to get an extremely good Comprehensive Spending Review settlement relative to other departments and we have passed that on to the Natural History Museum and others so they have done well. Nobody has come to us, either from the producer or the consumer side, and said there is a problem here of under-funding. I can see people feel a bit nervous about having to relate to four or five different departments and all that goes with that, but nobody has flagged this up to us. Maybe the Committee will, as an issue which requires us to get around the table and sort it through. That has not been flagged up with me at all. When I was looking at the evidence, going back to your very original question about lack of people with appropriate training, the Natural History Museum themselves said they can recruit people quite easily. Of course, they will want more money, everybody does. They, amongst all our museums, were pretty relieved and gratified by the spending review settlement they received this time around.
Chairman: We will probably come back to that but I should stress it is not simply the money but is an issue of the health of the discipline. Is someone looking across the board at this where pulls in one direction lead to gaps in another direction?

Q301 ***Baroness Walmsley:*** That takes us to the next question. The Committee may have some sympathy with Mrs Hodge in terms of knowing what taxonomy

and systematics are before she came to read up for this. Both ministers will be aware that I chaired the last of these reports, the second one and this is the third one. My theory was I was one of the few members of the Committee who knew what it was and that is why I was chosen. Going to the last report, one of its recommendations was that Defra take the lead in setting up a co-ordinating body to bring together the researcher and the user community. At that time Defra actually initially accept that recommendation but has not actually taken it forward. In oral evidence we have heard that Defra sees itself both as a user, and we have heard that again from the minister today, but also as the co-ordinator but we do not actually see that co-ordination role happening. Although I think the Committee accepts that it is healthy to have disparate sources of funding, there is a feeling, and there certainly has been in the evidence we have received, that somebody needs to be the leader to make sure that people do work together and co-ordinate. Somebody should take the lead, as Mrs Hodge has just said, in sorting it and this is a real problem. In the evidence we have had from the Fresh Water Biological Association and from the Centre for Ecology and Hydrology, they have told us that they have difficulty in fulfilling their responsibilities under the Water Framework Directive because they cannot get enough of the right trained people. Although, as Mrs Hodge rightly says, the Natural History Museum, and they have told us themselves, do not have difficulty in recruiting it is a world-famous organisation and of course they do not have difficulty. They have been getting their people from abroad and there is a feeling there is not enough home-grown taxonomic expertise available. It is emerging to us that it is a symptom of the fact that nobody is taking the final responsibility about the health of this whole discipline. Why has Defra not done that, will it do that or should it be the Cabinet Office? It seems a last resort suggestion from Mrs Hodge that that should be the case. Perhaps the Committee is feeling that one should not have to go to that last resort. The other thing we wonder is why if we are hearing that there is a problem that the ministries are not hearing there is a problem. Clearly you are not and you have just told us that. The question is who is listening to the systematics community and where are the roots by which they can make their concerns known? There is a growing demand for these sorts of specialities because of climate change.

Lord Rooker: On your point about you hearing the noises and we are not, I am obviously concerned about that. If there is substance in that then quite clearly the communications are not working. If you are searching for a Manpower Services Commission on taxonomy so you can look at what is going to be done, where the flow of people are and fit them into the right slots, then that certainly is a task that is not a function of the user government departments. You are asking whether we train but presumably it starts maybe in the research councils and universities. It is a fair point. If I go over the past, obviously clearly having chaired the previous Committee you no doubt feel personally aggrieved and offended that Defra did not do everything that you thought it should do which is why I have this little note to read out. Defra told the inquiry that officials in Defra pursued the spirit of that recommendation through the two key committees concerned with priorities for biodiversity research, that is the Biodiversity Research Advisory Group which does the national issues, and the Global Diversity Sub-committee of the Global Environmental Change Committee, which handles global issues and on which both users and providers are represented. Kew and the Natural History Museum attend both and that meets the need for facilitating co-ordination. Defra saw its responsibility was not to co-ordinate the user community but to co-ordinate its activities with those of the other users and providers. Defra saw its role somewhat narrower. It also says here this is not a hair splitting distinction. We do not own this sector and that is the point. This may be, by the way, a factor in other branches of science. It is self-evident that if it is happening here then it is happening elsewhere. Is it good that it has split and diversified or have we problems where someone can see the way the science changes and if you do nothing in 10 years time you have a real problem on delivering on what you need for the users like Defra? I fully accept that. We were looking at getting value for money but making sure we co-ordinated our activities with others but not to seek to co-ordinate, if you like, the sector and become the champion. I do not want to have a problem between ministries but Lord May mentioned about CABI and I am not sure if that is the shortened version. Was that the fungal group that moved?

Q302 ***Lord May of Oxford:*** Yes.

Lord Rooker: This is where a problem arises if it moved from the Natural History Museum. It has moved into Kew now and someone has asked Defra for more money to fund it but we have no money. We are strapped for cash. I just heard Mrs Hodge say that they had a very good settlement.

Margaret Hodge: We have given it all away.

Q303 ***Chairman:*** I am beginning to feel like a ministerial dating agency!

Lord Rooker: This is under discussion with Defra. Our director of science, Miles Parker is discussing this but there is very little likelihood of funding. The request is for some £750,000 over the CSR period with a following open-ended commitment. We are due to have a meeting with the Defra Kew Quarterly

Liaison Committee on the 18 June. I am not sure where the funding was originally and how it has arrived at a Defra-funded body because although Kew is independent, and rightly so chaired by the noble Earl, and I declare an interest as a friend of Kew, the fact of the matter is we do not run Kew. We fund the grant-in-aid and we have protected it as much as we could. I was up before the Committee in the other place on this defending to the last no more cuts at Kew. We have increased the capital but we have truly a straight line on the revenue. Everybody else has had some cuts at Defra so there is an issue there. If something is transferred into the body and they pop along to Defra and say we have this new responsibility now and we would like the funding then I have to have a serious look at this. I will have to see where the funding was beforehand. I am not criticising this because it is a good thing to have done, and I presume that is the reason it has been done, but we will have to look at that. To answer Baroness Walmsley's question, Defra made the best of trying to operate in the spirit of that recommendation but we do not own the sector so we cannot order or boss other bits about who would not necessarily listen to us in that way.

Q304 ***Chairman:*** A bit of co-ordination there might have been helpful insofar as if somebody is coming from there to there and it is cross-departmental do they carry the money with them?
Lord Rooker: As I already said, the director of science is onto this and it is being looked at by officials and will be on the agenda of the meeting on the 18 June.

Q305 ***Baroness Walmsley:*** I understand the distinction that the minister makes between what the recommendation thought it was and what Defra thought it was doing in terms of co-ordination but, in the end, somebody has to take responsibility for making sure there are enough people with the appropriate skills. I just wonder whether we ought to go back to where the taxonomist is born. A taxonomist is trained initially at a university but then gets the meat of his or her experience and usefulness actually working somewhere like the Natural History Museum or Kew or one of your laboratories. Perhaps it should be DIUS who should have the responsibility because no one university can do it. If we have a lack of appropriate skills, given the rising demand which we do believe there is, somebody really needs to take hold of it. I wonder if the ministers feel that perhaps DIUS might be the appropriate ministry given that we accept that diversity of funding is fine.
Margaret Hodge: DIUS has clearly the responsibility for ensuring that the higher education places are available. I am coming at this with some experience of other areas where we have skill shortages all over the place in all sorts of areas. What you try and corral is the employer, the student and the institution. You have to get those three elements coming together. If there is a real shortage, and Jeff has said he does not experience this, among the users one would expect them to be in very close discussion with the higher education institutions to make sure they provide the training places. I know that the Natural History Museum has 90 PhD students in there at any one time, and they have a lot of international students at any one time. If there is a need for more, again that has to be expressed and negotiated through those three elements: the universities working together with the users and then of course attracting students. The other thing I know, as with so many science areas, in the last 10 years with the endless jobs I have had, is we are trying desperately hard to encourage young people to see science as a future. I am sure that this Committee has probably done endless inquiries. Again, we all work very hard together. I am quite proud of the work we have done with DCSF and the Natural History Museum to encourage and bring alive to young people the exciting and challenging prospect of a career in science be it taxonomy or elsewhere. I am not sure it is all your responsibility. We will lead you to the outcome that you want but I think it is a shared responsibility. DIUS clearly fund the higher education sector and are responsible for the research councils. They have to bring that to bear and come together with the users and all of us doing what we can to attract young people to see this as a good career prospect.
Lord Rooker: I am not in favour of leaving it to the market and I make that absolutely clear. I am not in favour of a laissez-faire approach to this. We are world leaders in many fields and one of the reasons we are world leaders is people have thought about what needs doing and have tried to adjust ourselves accordingly to that. On the other hand, you need ideas to gel, people to change careers, have the flexibility. I presume with over 100 universities and the courses we have that the courses are run for a purpose and a reason and by and large you get an output. We do want a flow of international people to come to our laboratories and our facilities as that is not only good for our economy but good for the collaboration we have around the world. I am not in favour of central planning. I am not saying there should not be a responsibility to seize the problem, to measure the problem and see the necessary levers are pulled to create those. I have said in a narrow area, another part of Defra, we would take responsibility and work if we were seriously short of experts. In this field it is more diffused across government but quite clearly it needs to be looked at. If you are getting evidence there are difficulties, I have not picked it up, and I have not picked it up from officials since being alerted to this inquiry.

Q306 ***Lord Warner:*** I want to approach this more from a very simple supply-side proposition. All the evidence we have had suggests that there is a shortage of what you might call the foot soldiers called taxonomists in this area. Users are moving into a position where the age structure of the existing taxonomists is such that a lot of them are going to retire in the next few years. The demands for their services are increasing, the supply is reducing and people are looking abroad increasingly for some of the key posts that have to be filled. That has come up in relation to the Natural History Museum. In other areas, nursing is a good example, government has accepted that it cannot supply enough and has gone abroad and has a highly skilled migrant programme. We would like to know if the government is, in a sense, relaxed that you deal with the supply side problem by recruiting abroad or is it their policy to actually grow enough of their own to meet the needs in the sector? Whatever is the government's responsibility, and this goes beyond individual departmental responsibility, in view of that you have to have a mechanism for responding to it. The Department of Health responds to the shortage of nurses by recruiting abroad and has a policy and a strategy for doing that. It may be that we should have a strategy and policy for doing that in relation to taxonomy. We are struggling with knowing where the government is on that supply side issue.
Margaret Hodge: The Department of Health is the employer. The Department of Health, in effect, represented the employers. It found a shortage in a particular area of nursing, if you take that as an instance, and it then intervened to do that. In this particular area they would go to DIUS as the obvious place to go. If those who employ and use taxonomists feel that there is a shortage of training places in our universities for taxonomists, they would have to engage in a conversation with DIUS and HEFCE to encourage that. If they feel strongly that they want to introduce some financial incentives to recruit young people into that particular discipline for study, they would have to look at that. I am with Jeff on this. We cannot centrally plan this in any other way. You can touch any sector of the economy where there is a skills shortage and, in the end, the employers have to put the demands. The young people go where the jobs are or where the incentives are. The incentives maybe financial, we can make it more attractive to them and work on all that, but that is where the relationship has to be; I do not think it is for us to do it.

Q307 ***Lord Colwyn:*** You have dealt with the funding issue of Kew asking Defra for more money for their merger. My question is about government response to emerging priorities. UK conservation priorities in the past have been supported by a vast wealth of taxonomic knowledge. However, improving our scientific understanding of the emerging field of ecosystem services provision requires vastly improved knowledge of microbes, fungi, soil, fauna and marine invertebrates to mention a few. How is the government responding to these new scientific priorities specifically the demand for new taxonomic knowledge?
Lord Rooker: We work with other departments. Defra's science expenditure is about a third of a billion pounds in various forms. I suspect there is not a research council that we do not actually work with in terms of funding arrangements. We are developing an initiative side on the Living with the Environment Change which we are developing with the research councils. This has been mentioned by previous witnesses to the Committee. One of the objectives is to address the need for evidence on the ecosystems services. The research programme for this is currently under development and I think it will probably be a bit later before we can come back to give more details on this. We are looking at the views of the users of the science in the community and if there is perceived requirements for systematics and taxonomy we will seek to address that. There is work going on. It is not as if we are out of the loop, as it were. I do not have a ready-made answer but there are discussions going on at the present time and we will develop that with the research councils. That is the same in other areas of science. Essentially Defra are a customer. I hate the term in a way but it explains where we are. Virtually all of your science is bought in. We have three of our own agencies. For various reasons they are in-house but they work for the private sector and other government departments and deal with the European Union. We are essentially a customer and, therefore, we will look at individual projects and fund research projects. It is not a question of us handing over what is core funding to other bodies and institutions. This issue that you raise is covered by our present discussions with research councils, and proposals are being worked on at the present time.

Q308 ***Earl of Selborne:*** That brings me on to relationships with the research councils and the extent to which the research councils are fulfilling the sort of basic research that might be helpful to the executive agencies and to Defra. I should say in parenthesis that we are talking about this in the UK context but one has to recognise that at the moment so many countries have signed up to the Convention on Biological Diversity that we suddenly realise there is around the world what is known as the taxonomic impediment which, in the supplementary evidence, Defra has addressed very helpfully. They recognise that around the world there has to be a lot more expertise. It is no good importing nurses from Zimbabwe as the National Health Service might, we have to provide the expertise for these countries to

identify their own biodiversity and to manage it. There is, as I say, this taxonomic impediment which we, as a host of collections at the Natural History Museum and Kew and the like, have a responsibility as part of our Imperial baggage. We do have a responsibility to help people manage this. In fact, it seems to me systematics seems not to be the dreary discipline that people imagine. Taxonomy has a bad reputation but it is actually moving rather fast and DNA is moving it on rapidly. I am not sure, after the initial prod we gave the research councils after our first and then our second report, whether we have not lost the momentum again. I wonder whether you, as a customer, in Defra think that the research councils, BBSRC and NERC, are losing interest and whether they need a little bit of encouragement to go back to funding this sort of area of work.

Lord Rooker: Probably they do need a kick and do need to put more funding into this, but we would say that would we not. We would encourage that. I do not think there is any doubt about that. We always want more to be done. You are absolutely right referring to our baggage from the past. Given the fact that most of the countries on the planet are far richer in biodiversity than we are but a lot poorer in resources, there is a massive contribution. It works both ways as well. I am sure there are economic advantages for us. We would always want more but we are not satisfied that the research councils have put enough into support our policy objectives. As I say, there has been an ongoing area, particularly the BBSRC, believing that we should fund the core funding simply because our customer spend is more than 15% of their total. They seem to think there is an issue in the past. I know this has been addressed by the Select Committee in the other place and I had a long session in front of them with our late Chief Scientific Adviser on this. There is an issue there but we welcome the extra work they are doing. We continue to work with both NERC and BBSRC to identify the areas that we want to work in. We would like them to be strong in the areas where we are a customer, which means we need to discuss in advance the kind of projects we want to be working with. It is people's careers, people's lives, and there is a value for money issue as well, there is no doubt about that. I suspect they could always do more.

Q309 ***Earl of Selborne:*** Given your interest as a department in trying to sort out this taxonomic impediment will you be talking to the research councils to see if they could help you more?

Lord Rooker: I have to, having just given that answer. Defra is involved here in a big way. As I said in my opening remarks, we are a huge user of science second only to the MoD. As we are a user and a provider we need to know the providers have the capacity and wherewithal, but we do not necessarily fund the capacity. We deal with lots of other research organisations so it is certainly an issue I would be happy to follow up, on the basis that we are not the bottomless pit some would wish. There are financial limits that we are up against, I do not deny that, but we want the system to work well so when we come along as a customer for a project we can get it at home, in-house as convenient as possible for our own users as that makes common sense.

Q310 ***Lord May of Oxford:*** As you probably know, my fifth question was DCMS devolves decisions on spending for taxonomy but I am going to skip that in the interests of time and go to two somewhat sharper follow-ups I would like to ask. I should say Lord Krebs is the person who knows more about this than I but he could not be here so this is partly his question. Declaring the interest, I know it is true in Oxford at the museum there where the Huxley-Wilberforce debate was first, the Committee has received evidence that many local and regional museums do not actually receive grant-in-aid as such but receive money under an initiative called regional hubs or renaissance hubs. It is used, in a sense, for two purposes. It is used for outreach partly in support of the curation of the collections which themselves are a vital resource in delivering the biodiversity action plan, but there is another interface between DCMS and the renaissance thing and Defra delivering biodiversity. I think it is super the way all sorts of amateurs and NGOs are involved in doing that. It is something we can all take pleasure and pride in and is an important thing for these local and regional museums. Secondly, it is really important in sowing the seed corn in engaging young people. It is not just the big things like the Natural History Museum but it is all the local things. I would like to be reassured that DCMS feels that its policies are indeed ensuring that these two purposes are being served well and will continue to be served well.

Margaret Hodge: I am really excited by the Renaissance programme. I think it is one of the really good things we have done over the last five or 10 years. Most of those regional museums were in appalling decline and neglect before we started focusing some additional resources on them. We are convinced of the importance of the programme. We again funded it with inflation proof funding which was the best we could do in this funding settlement. It is good and secure for this period. All I can tell you is I am a huge and enthusiastic supporter of it. In fact, you will be pleased to know we are working hard with all the national museums to get them to give even further added value into curatorial support into the regional museums and also sharing their collections much more widely. The big emphasis at the moment is how we can do more in the regions than we are

currently doing. The funding is secure for this spending review.

Q311 ***Lord May of Oxford:*** That is encouraging. Defra have a Chief Scientific Adviser. They had someone who was pretty good and they have just had somebody come on board who is really quite outstanding. He was co-editor of the Millennium Ecosystem Assessment, before that chair of part of the IPCC, Bob Watson. The new chief scientist is somebody with a background in this general area so I think you are going to be more driven from within. DCMS, on the other hand, with my experience in the Natural History Museum, was up and down. The Natural History Museum is a pretty odd entity in some ways. It is not like the other museums. It is one of leading institutes in taxonomics and systematics not just in support of museums. Do you think it would be helpful if you had, perhaps like transport on one or two days a week, a Chief Scientific Adviser who would have more expertise in this area and understanding of the interfaces and connections?
Margaret Hodge: I did pick up in the papers that it was a recommendation from the previous Chief Scientific Adviser and we had not taken it forward. We are now taking it forward apparently, in stretching the definition, by bringing in an economist which is a probably a good thing for DCMS.

Q312 ***Lord May of Oxford:*** I would argue strongly it would depend on the economist. Some of these people believe in all this fundamentalist stuff. It has to be the right one.
Margaret Hodge: We are a small department but where we are cutting back is on our central bureaucracy and that is how we are affording the better settlements out in the field. What I see as a positive way forward is what I do in other areas for which I have responsibility, you bring in experts as and when.

Q313 ***Lord May of Oxford:*** If you just had a person one day a week, and if you get the right person, you would have an anti-bureaucrat.
Margaret Hodge: The budget is jolly tight on the internal bureaucracy. However, I do think you have a point in saying should we need advice on particular issues, arising perhaps out of the conclusions of this inquiry, we would need to secure expert support to ensure that we respond properly to it. I do not think that will be somebody on the books even one day a week. We could bring in people, and we do that, for example advisers on fine art to determine whether or not we accept works in lieu of death duties and that sort of thing. It would be on that basis. The point is well made but all I say to you is these are really tough times and we are losing 20 per cent of our in-house staff at the moment and that is where the cuts are coming.
Lord Rooker: I reiterate what Lord May said about Defra, obviously being a re-tread minister at MAFF in 1997 to 1999 before the present system arose and then coming back in 2006 to virtually the same department plus a bit of environment and to see the difference in having a Chief Scientific Adviser who is actually part of the management but actually an outsider. Howard was one day a week, nominally at Warwick University where he had been a professor for many years. Bob Watson is at East Anglia University, part of the Nobel Prize winning team but a part of the management at Defra but not of it in that way. Also, because he is there all the while rather than particular projects, he actually sees the bigger picture in Defra and is able, therefore, to call in the extra advice that we need in support of our own scientific team. I pay tribute to the suggestion. Originally it came out of Bob and Dave King that it had to be done differently. My experience of this department, because I have now been in it in two phases, is it is an incredibly superior system to what used to be the case. To have someone who is with us but not of us and actually linked outside as well works extremely well at Defra.
Chairman: That is probably why one of our other sub-committees on heritage and the arts and science made the same recommendation with regard to DCMS. It is not just this particular group that is raising the question of science advice. We put that to you but we hear what you say.
Baroness Walmsley: Could I go back to regional museums and ask what their role is in attracting young people to taxonomy perhaps through the means of their education programme or their outreach programme? Is the funding for this also secure and stable? Given the shortage that we have identified, does government have a role in encouraging young people to take up careers in taxonomy? I tend to see taxonomy as the football premier league of science. By that I mean that the premium league is the most successful football league in the world and that is because it is full of footballers from other countries who are the best of their kind, but they are not qualified to play for England that is why the England national team does not do as well as the premier league. I draw a parallel here.
Lord May of Oxford: I think is a muddled parallel.

Q314 ***Baroness Walmsley:*** I personally feel we should not be relying on foreign taxonomists exclusively. It is very important to encourage our own young people to take up those careers.
Margaret Hodge: I agree with that. Whether it is taxonomy or other sciences, I agree whole-heartedly. It is an incredibly difficult nut to crack and one that we have been attempting to address, and I say this as

an ex-Education Minister. We took endless initiatives trying to make the whole of science and engineering a much more attractive career option for young people. Of course we have a role and we try hard but we could always do more and we are always up for new ideas. From my previous experience I think employers do not do enough. It is getting young people into the situation where they can see if they trained they could then embark on the exciting career. I have to say it is also the academic institutions. I will never forget having tea in the House with four young people who had all won engineering awards of excellence from the Russell Group of universities. They all said they nearly gave up engineering and would have done because it was so boringly taught, but the only thing that kept them in it was the work experience. We have all got something to learn about trying to make science an attractive discipline which young people choose to follow. The things we are doing from DCMS in our little way with our tiny budget with DCSF, what we call our real world science programme which looks particularly at children in the secondary school phase from Key Stages 3 to 5. I think it is successful. The work that the Natural History Museum has done around taxonomy courses they tell me they are going to have 1,000 A-level students attending those courses this year. That is not bad going but again we can do more. You asked me about the regional museums. I have not brought the stats with me but I can let you have them. If you look at the statistics about attendance at museums, which is one way in which you can open people's eyes to the potential, we have done far better at extending access to groups who would not in the past have attended in the regions than we have done in the national museums. I put that down a lot to the Renaissance programme that we have, the Renaissance hubs, which pays massive dividends. We know that once a child goes into a museum once they are likely to return again either with their family or on their own so that is very important. The only thing I would say is we have this new programme, Finding Your Talent. We have the money to pilot it during this Spending Review. The idea there is to build on the success of the five hours a week access that young children have to sports. 85% now do at least two hours, building up to five hours, and the ambition is to do the same around the rest of the DCMS family, the culture part. Part of that programme will be visiting museums and getting engaged in activities within the museums. Interestingly enough we have enough money for 10 pilots and we had 150 applications which shows the enthusiasm out there for trying to find new ways of engaging children in culture in the broadest sense of which the museum sector is a part.

Q315 ***Earl of Northesk:*** Biological recording schemes which help deliver data supporting conservation and environmental policy have traditionally relied on wide engagement and skilled volunteer recorders but the declining number of volunteers makes the future of this system precarious. What is the government doing to help build capacity in this voluntary sector?
Lord Rooker: That is a good question but I do not have an answer.
Margaret Hodge: Is this around volunteers working in local and regional museums?
Earl of Northesk: Yes, gifted amateurs.
Chairman: Even recording sightings and selection of insects, birds or whatever.
Lord May of Oxford: What is the evidence for this? For example, I think bird recordings are about half the data and that is on the up and up. At one point somebody did an estimate that there were 64 million bits of data about plants and animals in Britain of which 37 million were on birds, which is OK and understandable but a bit weird.
Earl of Northesk: It was reported over the past few days that the British Waterways Board was inviting members of the public to do a recording exercise for them. The volunteer system is out there so where does the government engagement lie?

Q316 ***Chairman:*** We did have evidence but not in relation to birds, it was fresh water particularly. People like looking for birds and get up at four o'clock in the morning to look for them.
Margaret Hodge: Every government department is trying to grow the volunteering capacity for all sorts of reasons, civic engagement and building the strength in communities as well as contributing to the particular discipline. We have a fantastic number of volunteers who support our heritage infrastructure. Half a million is the figure that comes to mind—400,000 or 500,000. Around the Olympics one of the key principles there is to try and ensure that we grow the volunteering capacity in every potential. Yesterday visiting the Chelsea Flower Show they were really keen that we should ensure a proper green element to what we do there. We are all trying to do what we can on volunteering. We are passing the buck a little bit. The lead department is the Office of the Third Sector which sits in the Cabinet Office and co-ordinates all that activity around volunteering. The RSPB has the biggest voluntary membership.

Q317 ***Lord May of Oxford:*** 1 million.
Margaret Hodge: All political parties look on it with huge envy.

Q318 ***Lord May of Oxford:*** People like this deliver the Biodiversity Action Plan.
Lord Rooker: Because I have good support behind me I have an answer to the question which I had not previously seen. There is a contribution, and for us it is about 300,000 through the National Biodiversity

Network for local record centres. Our contribution in 2007–08 was, through the National Biodiversity Networks, about 104,000 which is going up to 160,000 in 2008–09, and the fund for innovation in local record centres over £180,000. The ad hoc funding includes the development of the butterfly monitoring scheme and the production of trends from the various national bird surveys co-ordinated by the Trust for Ornithology. We do have a programme and there is an area for volunteers. What happens, and what I find with many of these projects, is when those volunteers are out there it is not Defra badged. They do not know they are working for the government, if you know what I mean. This is one of the great problems in some ways. Sometimes it is a good thing because you get more people to help if they do not know it is the government. Funding through the voluntary sector where you can cut corners, cut red tape, get cracking and get a commitment, that can be really enthusiastic is something we wholly support. Those are a couple of examples. It is not a small amount of money, and the money goes father in the voluntary sector as well.

Q319 ***Chairman:*** The evidence we have is mixed. People love birds so you get a lot of that, but they are not so keen on snails but that is quite important. Certainly fresh water, we have been told, is a problem. If we do feature this in our report perhaps you might take it on yourself to ensure that the Cabinet group realise that volunteering goes a long way beyond helping old ladies and gentlemen across the street or bob-a-job or whatever and this is very important. This is how we capture many of the young scientists who become the future leaders in the field. This has been a very helpful session and we thank you very much indeed. You will see our report in due course. It is a follow-up report and we will see it in sequence and, if necessary, come back to it.
Lord Rooker: Thank you for giving us a chance to learn a bit more.

Written Evidence

Memorandum submitted by Mr Henry S. Barlow

Thank you for your invitation to submit my comments on developments in taxonomy in the UK in recent years. I first submitted comments to the House of Lords Select Committee on the subject chaired by the late Lord Dainton in 1990.

Although neither a professional nor indeed a practicing taxonomist, I have worked closely with distinguished insect taxonomists, publishing their work, for over 30 years.

I have no hesitation in stating that taxonomy in the UK, insofar as the Natural History Museum is concerned, has suffered dramatically in recent years. The problems are writ large in the saga to date of Darwin Centre Phase 2, referred to in an article in Nature 447: 908 June 2007.

The primary failing, by Trustees and NHM management, arose when documents submitted to the Trustees in 2001 estimated that 4.6 km of standard storage space were required to house the entomological and botanical collections in the new DC2 building. The current design was accepted following a competition for architects, based on the 2001 specifications. Inexplicably in 2004, the detailed specification for the new building provided for only 3.4 km of the same storage space. This discrepancy was neither explained by management to the Trustees, nor picked up by the Trustees themselves. As a result, the management has since the date when the final design was approved, been vainly attempting to fit one quart's worth into a pint pot. The "solution" appears to lie in creating what was supposed to be a temporary arrangement, under which part of the collections would be housed in the former Darwin public gallery on the first floor as a permanent arrangement. Nor is it clear where the library facilities, essential for taxonomic research, are to be housed in the 10 years or so it will take to put all the relevant literature online.

Lying behind this is the inexplicable decision by the Trustees to demolish the old, and structurally sound Entomological wing, allegedly on the grounds that it was a health and safety hazard, without a proper Health & Safety report.

The demolition took place despite individual personal appeals to the Trustees. The result is that a building not fit for purpose for health & safety reasons but capable of being remedied is being replaced by a very expensive new building not fit for purpose due to lack of capacity.

Staff members with many years of experience working with the collections who attempted to put forward constructive suggestions were ridiculed, and they feared that their careers in the NHM would be at risk if they attempted to raise such matters publicly.

There can be little long-term hope for taxonomy and systematics in the UK, so long as the country's premier taxonomic institution is run in such a manner. The latest insult comes at the end of an announcement of a Palaeonotology Seminar: "Thoughts on the Past Present and Future of Natural History Museums" on 24/1/08, which reads: "Perhaps the most difficult change for natural history museums to cope with in the coming years, however, will be the progressive loss of physical collections as the institution's primary rationale." This suggests that the collections are suddenly perceived as being almost irrelevant for museum-based research and there is no strategy or even a desire for building collections in the future. Have the lunatics now taken over the asylum?

The ultimate responsibility for the NHM lies with DCMS, singled out in an article in the Sunday Times of 13 January 2008 which quoted the former Chief Scientific Advisor to the Government, Professor Sir David King. In this article he was quoted as saying that he was dismayed at the lack of scientific understanding of government departments, particularly citing DCMS in this regard.

What constructive steps can now be taken, given that the new structure of DC2 is complete? It is suggested that as a first step, a formal decision should be taken to ensure that at all times at least two places on the board of Trustees be reserved for:

(a) An individual respected by the scientific community who has had at least 15–20 years' experience working on the NHM, or comparable collections.

(b) An individual who has had hands on experience running a comparable world class museum.

Such individuals should be proactive in constructively questioning and probing management proposals, and ensuring that research posts were only given in the NHM to individuals whose work depended on the use of the NHM collections (as opposed to work which could equally well be undertaken in any university zoology department). If this were to be done effectively, there is at least a chance that the decline in taxonomy, which is one of the essential tasks of NHM, could be reversed, and with it the so far inexorable slide towards extinction of qualified taxonomists themselves.

If DCMS is unable to accept and act on this suggestion, consideration must be given as to whether DCMS is the appropriate government department to have responsibility for the NHM's incomparable collection of 70 million specimens: a collection which cries out for world heritage recognition.

In conclusion it is necessary to stress yet again that the collections represent a unique cultural record of the natural world. If taxonomy and systematics are to survive, it is imperative that priority is given to their care and conservation.

22 January 2008

Memorandum submitted by the Biological Recording in Scotland (BRISC)

Background

BRISC came into being in 1975 to provide a central focal point for biological recorders in Scotland. It has since evolved into an organisation that represents both recorders and Local Record Centres in Scotland. In recent years it has undertaken an advocacy role on Strategic issues affecting biological data to serve best those it represents.

Biological Recording is defined as: the collection, collation, management, dissemination and interpretation of spatially and temporally referenced information on the occurrence of biological taxa, assemblages and habitats.

Response

BRISC is only responding to parts of Questions 2, 7 and 8, where it feels it can provide a relevant input. Whilst other questions are of interest to BRISC any comments on them would be based on anecdotal evidence.

Question 2

What is the role of systematics and taxonomy and, in particular, in what way do they contribute to research areas such as biodiversity conservation, ecosystem services and climate change?

Taxonomic knowledge is obtained by sound and up-to-date systematic research. The ability to accurately identify and name taxonomic units (eg genera, species and sub-specific taxa) is fundamental to understanding the taxonomic units being studied. The understanding of systematic inter-relationships, even of well-known taxa, increases awareness of intrinsic factors that may impact on the responses of individual taxa to anthropogenic and natural processes. UK research in biodiversity conservation and climate change has tended to be directed towards individual species and often almost in isolation from related species, or the species assemblage and habitat within which they occur.

How important is this contribution and how is it recognised in the funding process?

Baseline information is still required for many taxa throughout the UK, in spite of assertions to the contrary.

Most taxonomic expertise relating to UK species is now vested in voluntary organisations and non-professional individuals, rather than with the professional scientific community of universities, museums and research institutions, resulting in much of the UK taxonomic expertise being unfunded. This does not provide for a sustainable future for taxonomy in the UK. Prior to the 1980s taxonomy and systematics had formed part of undergraduate biological sciences courses at many UK universities and basic taxonomic principles were part of O/GCSE and A level syllabuses with an awareness of species often starting at primary school level.

The UK's role and particular expertise in taxonomy and systematics research should be recognised and supported at universities and at national and other major museums, particularly when so many of the issues in biodiversity conservation, ecosystem services and climate change are national and global.

Question 7

Does the way in which taxonomic data is collected, managed and maintained best meet the needs of the user community?

There is a profound failure by potential "users" of taxonomic data to realize that they even require such information and, therefore, they do not identify what data is required. As a result the "providers" of taxonomic data, who are undertaking their recording on a voluntary basis, need to second guess the data requirement of an ill-defined "user Community" and do not necessarily undertake the most required recording.

Many of those involved with biological recording have been aware, since the 1980s, of changes in the range and abundance of species and assemblages and changes to habitats which appeared to relate, at least in part, to climatic variables. This awareness prompted voluntary groups to advocate the need to establish national surveillance and monitoring schemes and to maintain the few schemes that had been established earlier. However, funding was refused or reduced to level that delivered only part of the necessary data. It was not until after 2000, when voluntarily managed schemes began to deliver incontrovertible data, that governmental agencies began to recognise that such organisations and schemes had a role to play in supplying data.

It is particularly important at a local level for the "user community" to be able to ask for information that is sensible and deliverable. However, in Scotland, Government guidance to local authorities and other users to seek data from "your local biological records centre" is nonsensical, as very few exist.

At regional and local levels, taxonomic expertise is now almost exclusively vested in the voluntary community, such as through local natural history societies and wildlife trusts. Local museums, which used to provide access to collections, literature and advice, are very rarely given resources to maintain that role.

What is the state of local and national recording schemes?

Anecdotal evidence to BRISCs indicates a woeful lack of support to both local and national schemes. BRISCs belief is that most taxonomic knowledge is almost wholly dependent on the voluntary sector and gained without significant public funding.

Question 8

What is the role of major regional museums and collections?

It is important to distinguish between major regional/national museums, such as those in Edinburgh and Glasgow, which are custodians of some national and international taxonomic expertise and the truly local museums. The national collections are extensive and generally accessible for use, with at least some curatorial staff. Glasgow (Kelvingrove) has an extensive collection but little scope for taxonomic research. Some local museums have extensive and often important collections, few curatorial staff and usually no role in taxonomic studies or taxonomic training, other than through specially funded outreach projects aimed at schools. Many smaller local museums, although they may have good, even important collections, often have no specialist trained curatorial staff.

How are taxonomic collections curated and funded?

BRISC does not believe that there is any systematic curating and funding of taxonomic collections, but considers this to be of great importance, both for validation of biological records and for the training of new generations of naturalist specialists and taxonomists.

Collections are probably of greatest value when held at local museums, although local museums would probably have difficulty in accepting collections due to space and financial constraints, which in turn would present problems over the provision of access.

4 February 2008

Memorandum submitted by BioNET-INTERNATIONAL

BioNET-INTERNATIONAL (BioNET[1]) is a UK-based, international not-for-profit organisation recognised under the United Nations[2] as "the most comprehensive network" for taxonomy and by a Darwin Initiative review[3] as probably the most important network in the field world-wide. Coordinated by a secretariat hosted in the UK by CABI since 1993, BioNET is mandated to provide advice on taxonomy to the Secretariat of the Convention on Biological Diversity (CBD) as a member of the Coordination Mechanism of the Global Taxonomy Initiative. This evidence draws on BioNET's experience of working with CABI and other UK taxonomic institutions internationally and with taxonomists, end-users and relevant policy and regulatory forums world-wide, particularly in the developing world.

General observations:

UK taxonomic facilities and expertise are enormously valuable and very often unique resources at the global, not only UK level. Indeed, UK biological collections and associated information and human resources are overwhelmingly concerned with forms of life that occur outside the UK. We recognise that the rich legacy of investment in taxonomic resources has allowed UK institutions and experts to take leading roles in founding pioneering international initiatives in taxonomy, for example the Global Taxonomy Initiative, Global Biodiversity Information Facility, the Catalogue of Life and BioNET. Considering the global reach and relevance of UK taxonomic facilities and organisations, we urge this inquiry to give appropriate consideration to the status of the international dimensions of UK taxonomic work and capacity building.

The UK, as party to multilateral agreements concerned with the environment, trade and development, has accepted significant obligations to contribute to taxonomic capacity building in the developing world, either specifically (as under the CBD or World Summit on Sustainable Development) or as an integral part of its wider commitments to scientific and technical capacity building. A number of excellent taxonomic capacity development projects drawing on UK expertise have been supported by the Darwin Initiative, many of which demonstrate the real benefits taxonomy brings to CBD implementation and sustainable development. However, these generally remain isolated examples of good practice and, being focused on CBD implementation, do not address the building of capacity and sharing of best practice needed to generate taxonomic products and expertise that support agriculture, trade standards, biosecurity, health, etc. The larger investment needed to transform developing country access to and participation in taxonomy requires development assistance funding which in turn requires an appropriate distribution of funding responsibilities between Defra (which leads on most multilateral environmental agreements) and DFID (which leads on capacity development according to developing country and multilateral priorities). Currently it appears there is little connection between the multilateral commitments to capacity development entered into by the former, and the capacity development programmes of the latter. As a consequence, capacity building in taxonomy, which is highly dependent on international collaboration for training, access to collections, technology dissemination, mentoring and developing information products is one area where the potential for UK impact on development goals is far from being realised.

The state of systematics and taxonomy research

1. *What is the state of systematics research and taxonomy in the UK? What are the current research priorities? What are the barriers, if any, to delivering these priorities?*

Investment in taxonomy increasingly needs, as in all sciences, to be prioritised to respond to the demands of society and new scientific questions. It is important, therefore, to ask what the research priorities should be so that resources can be directed at these. However, priorities for study will depend on the stakeholder being consulted. Taxonomists can inform on and might prioritise major gaps in knowledge of taxa occurring in the UK or elsewhere. Equally, stakeholders from, eg, other fields of biology and ecology, or who are non-scientific end-users of species names and identification aids, can best inform about priorities from their perspectives. Regulatory authorities using names in areas open to legal dispute may, for instance, be most in need of internationally accepted lists of controlled species with names—including common names and synonyms—that have been agreed by a consensus of taxonomists and are regularly updated by an online system. In asking what the research priorities are or should be, all types of stakeholders need to be consulted.

[1] BioNET's Mission is to *Enhance human well-being and biodiversity conservation by building capacity to discover, name, and classify the world's living organisms.*

[2] CBD decision VI/8.

[3] Wortley, A H and Wilkie, P (2005), Annex 4, *Thematic Review of Darwin Initiative's contribution to the GTI*, DEFRA and ECTF. Accessible from http://linkger.com/2ede3a (accessed 30 January 2008) and forthcoming on http://darwin.defra.gov.uk/reports/thematic_review.GTI.pdf.

2. *What is the role of systematics and taxonomy and, in particular, in what way do they contribute to research areas such as biodiversity conservation, ecosystem services and climate change? How important is this contribution and how is it recognised in the funding process? How is systematics integrated in other areas of research?*

In biodiversity conservation, taxonomy is one key source, for instance, of baseline data on species occurrences needed by environmental managers to reduce the rate of biodiversity loss and meet the 2010 Biodiversity Target (adopted by the CBD and incorporated in the Millennium Development Goals of the UN). Invasive species are one of the two most persistent threats to ecosystem services; management of invasive calls on taxonomic support for detection, monitoring, control and eradication. Data held in biological collections allows prediction of climate change impacts, risk assessments and rational planning of protected areas. More broadly, the benefits of taxonomy to society are diverse and increasingly well documented[4]. Indeed, taxonomic research (and the products and data this generates) is highly relevant to human well-being (eg agriculture, health, biosecurity, biotechnology), not only management of the natural environment. That taxonomy is integral to development has been recognised at the highest international level in the Plan of Implementation of the World Summit on Sustainable Development[5]. A number of countries—Brazil, China, Mexico for example—that are rich in biodiversity are investing significantly in taxonomy, demonstrating that, like Europe and other parts of the "developed world", they see a taxonomic infrastructure as integral to their well-being. But in much of the world taxonomy is poorly supported and very often poorly integrated with other sciences and applications and development processes. Communicating the relevance of taxonomy to the challenges of today continues to be vital for building the political and popular support needed to build capacity where there is none and revive and sustain the science where it is out of fashion.

3. *Does the way in which systematics research is organised and co-ordinated best meet the needs of the user community? What progress has been made in setting up a body to lead on this? What contribution do the leading systematics research institutions make both nationally and internationally?*

Taxonomists are not the only users of taxonomy, yet typically assessments of "taxonomic needs" seek to understand priorities only from the research or practitioner perspectives. In contrast, the innovative user-driven UK GTI Needs Assessment[6]—delivered with Defra, NHM and UK-GTI steering group support—is a strong basis for understanding what taxonomic products and research are needed by users in one sector—biodiversity conservation—in the UK. The challenge now is twofold: (a) to use the insights and lessons from the Assessment to promote the development of necessary information, research and capacity to meet the identified end-user needs; and (b) undertake assessments following similar methodology in other fields which benefit greatly from taxonomic support such as agriculture (including trade related issues) and health. Evidence to date suggests that use of the UK Needs Assessment to prioritise research and other taxonomic effort has been slow. There appears to be a lack of even the minimal resources needed for ongoing coordination and facilitation of taxonomist / end-user relationships.

Internationally, Defra has supported NHM and BioNET in applying similar user-oriented methodology to needs assessments for invasive species management globally, and for biodiversity conservation and use in Ghana[7]. At the European level, the European Distributed Institute of Taxonomy (6th framework European network of excellence) has a strong focus on engaging users and understanding their needs for taxonomy. The challenge for such assessments is to incorporate their findings into the appropriate policy forums and inform taxonomists, non-taxonomist users and funding bodies in such a way that they can take action to meet needs identified.

4. *What level of funding would be needed to meet the need for taxonomic information now and in the future? Who should be providing this funding?*

In addition to national funding sources, an international mechanism is needed to finance taxonomy where it can bring most benefits—the developing world—and to enable realisation of the innovative, web-based approaches that are transforming the pace at which the science can be practiced and delivered to benefit users in science and society. With heightened concern about the biodiversity crisis, popular excitement at species discovery (new marine life forms, new primates in Southeast Asia, etc.) and growing Corporate Social

[4] www.bionet-intl.org/why
[5] WSSD Plan of Implementation, paragraph 44s
[6] http://www.nhm.ac.uk/research-curation/biodiversity-museum/global-taxonomic-initiative/uk-taxonomic-needs-assessment/index.html
[7] http://www.bionet-intl.org/opencms/opencms/tnaPages/default.html

Responsibility programmes, there is scope to explore the establishment of public-private partnerships for taxonomy. The goal should be new, sustained multi-million sources of funding that complement existing national funding programmes.

5. *How does funding in other countries compare? Could there be more international collaboration? If so, what form should this collaboration take and how might it be achieved?*

International taxonomic partnerships such as EDIT and BioNET, together with informatics initiatives (GBIF, Catalogue of Life etc) provide unprecedented opportunities to accelerate the delivery of high value taxonomic information, products, research and services in support of sustainable development, climate change adaptation and biodiversity conservation and benefit sharing. The UK, through our major national institutions and international organisations such as CABI and Species 2000, is playing a leading role. Yet international collaborative programmes each struggle for funding from year to year. BioNET has attracted modest, restricted funding for projects from DFID and DEFRA, but to date the UK has not joined a consortium of other countries, led by Switzerland, in supporting core activities, making its continued location in the UK uncertain.

In an era of ever more fragmented taxonomic capacity world-wide, unprecedented information and communication technologies and growing international commitments to environmental stewardship and development, current taxonomic facilities can best serve all their users through international integration and partnerships. Those countries strong in capacity—the former Soviet Union countries and Cuba, for instance—can benefit from marketing their services and expertise through research cooperation, information sharing and training partnerships, thereby providing a solution to some of the more urgent taxonomic needs around the world. The UK is a leader in making taxonomic partnerships work—including examples supported by the Darwin Initiative. Could this UK expertise not be used to mobilise existing capacity in this way?

6. *What impact have developments in DNA sequencing, genomics and other new technologies had on systematics research? In what way has systematics embraced new technologies and how can these research areas interact successfully and efficiently?*

Use of DNA sequencing, notably in "DNA barcoding", is attracting growing and already highly significant research interest. Contrary to the view of some non-taxonomists, the use of DNA sequences as characters does not threaten to make taxonomists redundant. Rather, it is empowering them to focus more time on the interesting research questions, while delivering identification support and biodiversity assessments to more users more quickly in many more places. The benefits of However, if significant amounts of information be accessible only with DNA data, or tools be made available to speed up identification using sequence data, there will be a need for UK to work with developing countries to enable their participation and assistance in generating data. There will also be a need to ensure that national legislation under the CBD Access and Benefit-sharing regime does not impede taxonomic research across national boundaries.

Data collection, management, maintenance and dissemination

7. *Does the way in which taxonomic data is collected, managed and maintained best meet the needs of the user community? What is the state of local and national recording schemes?*

Digitisation of UK-held specimen data, specimen images and information as well as literature is providing ready access to these resources to taxonomists anywhere in the world. This is needed to enable rapid response, with appropriately presented information, to applied and research questions alike. There is then a need to ensure:

- the technology is deployed to facilitate easy access to digitised information and data in a coherent fashion,
- that "users" in developing countries as well as "providers" in the UK and other industrialised nation can provide information,
- that appropriate quality control and fitness-for-use measures are introduced,
- that funds and priorities are developed to significantly accelerate population of the systems with data and information,
- that appropriate changes in the sociology of research institutes are developed, to enable use of time in this area.

8. *What is the role of the major regional museums and collections? How are taxonomic collections curated and funded?*

9. *What progress has been made in developing a web-based taxonomy? How do such initiatives fit in with meeting demand for systematics and taxonomy information? How do UK-led initiatives fit in with international initiatives and is there sufficient collaboration?*

This overlaps a little with the response to question 7. Progress in this area must not be limited to pilot projects only, but enabled to extend to be the default mechanism for publishing taxonomic information. This will require action within the taxonomic community at the level of the Codes of Nomenclature, as well, as work with publishers to allow open access to published studies, and the development of a means of sustainable long-term access to such digitised resources. The technical issues transcend taxonomy, but cannot be resolved without the involvement of taxonomists. It will also require funding to increase content.

10. *What needs to be done to ensure that web-based taxonomy information is of high quality, reliable and user-friendly?*

11. *How does the taxonomic community engage with the non-taxonomic community? What role do field studies play?*

Engagement of the taxonomic community with the non-taxonomic community continues to be highly inadequate. Too often, taxonomists work in a high degree of isolation from other biological disciplines and the wider biodiversity and policy communities. Taxonomic institutions and initiatives such as NHM, RGB Kew, BioNET, EDIT and GBIF recognise and can point to examples of pioneering work that address aspects of this disconnect, for instance case studies, user-taxonomist forums, strategies and policy development. These need supporting and expanding and coordination at the UK level.

Skills base

12. *What are the numbers and ages of trained taxonomists working in UK universities and other organisations?*

13. *What is the state of training and education in systematics and taxonomy? Are there any gaps in capacity? Is the number of taxonomists in post, and those that are being trained, sufficient to meet current and future needs across all taxonomic subject areas?*

Training and education, especially in lesser studied groups such as fungi and nematodes, is in critical decline, a state mirrored by the elimination of employment opportunities in the UK.

Memorandum submitted by the Biosciences Federation

Summary

1. Systematics and taxonomy are enabling sciences that are fundamental in answering policy and research questions for the major scientific and social challenges of this century; preserving biodiversity, maintaining ecosystem services and adapting to climate change.

2. They underpin many other areas of bioscience, support economically important activities, and enable the UK to comply with its legal and moral obligations to protect the environment and its natural resources.

3. The UK has international centres of excellence for systematics and taxonomy, and collections of international and national importance. It also benefits from active groups of amateurs, some of whom carry out and publish research of the highest quality.

4. Systematics and taxonomy research in universities is disadvantaged by the Research Assessment Exercise (RAE), to the detriment of research and training.

5. Too little of the skills base is now held by professionals. Amateurs continue to play an essential and valued role, and require a properly funded infrastructure.

6. Current funding and policy mechanisms are not well co-ordinated and fail to take account of the particular needs of this area of enquiry.

Recommendations

1. A periodic (five-yearly) survey of the state of systematics and taxonomy research, education and skills base in the UK.

2. The Research Excellence Framework must include measures of excellence relevant to nationally important areas of research, including systematics and taxonomy.

3. Strategic longer-term funding mechanisms to support research and the necessary infrastructure including taxonomic collections, libraries and long term monitoring.

4. Funding mechanisms for outputs that are fundamental to taxonomy, such as writing monographs and identification keys.

5. The Environment Research Funders Forum should be specifically funded to monitor and co-ordinate taxonomy and systematics research and training, working with users, employers, the systematics community and other interest groups.

6. The Government Office for Science should use its co-ordinating role to ensure that government departments work together, identify their policy and research needs and fund the necessary research and infrastructure.

7. The Department for Environment, Food and Rural Affairs (Defra) must recognise the strategic role of taxonomy and systematics in delivering key policy objectives.

8. The Department for Culture Media and Sport (DCMS) should appoint a chief scientist to ensure that it has the best advice on the museums and collections of scientific value which it supports.

9. A major funding initiative to improve the quality, compatibility and usability of molecular taxonomic databases.

10. It should be a condition of publication of taxonomic research for the data to be deposited in a web-based database.

11. Funding for specialist courses and training fellowships in strategic subjects where there is an identified skills gap.

About the Biosciences Federation, British Ecological Society and Institute of Biology

The *Biosciences Federation* (BSF) is a single authority representing the UK's biological expertise, providing independent opinion to inform public policy and promoting the advancement of the biosciences. The Federation brings together the strengths of 44 member organisations (plus seven associate members), including the Institute of Biology and British Ecological Society.

The *British Ecological Society* is the learned society for ecology in the UK. Founded in 1913 and with over 4,000 members, the British Ecological Society supports ecologists and promotes ecology, the study of living things and their relationship with the environment in which they live. The Society's mission is to advance ecology and make it count.

The *Institute of Biology* (IOB) is an independent and charitable body charged by Royal Charter to further the study and application of the UK's biology and allied biosciences. IOB has 14,000 individual members and many specialists learned Affiliated Societies.

Together, BSF and IOB represent a cumulative membership of over 65,000 individuals, covering the full spectrum of biosciences from physiology and neuroscience, biochemistry and microbiology, to ecology, taxonomy and environmental science.

Definitions

In this submission, we define the terms as follows:

Systematics is an activity in the biological sphere which takes a comparative approach.

Taxonomy is a subset of systematics, involving the description, identification and naming of organisms.

The state of systematics and taxonomy research

Q1. *(a) What is the state of systematics research and taxonomy in the UK?*

A1a. Tackling climate change, conserving biodiversity, and maintaining the ecosystem services (on which we all depend for our health, wealth and wellbeing) are the major scientific and social challenges of this century. It is increasingly apparent that they are interconnected, and that solutions for one area can bring substantial benefits to another. *Systematics and taxonomy research are fundamental in answering policy and research questions that are relevant to these issues.*

We are not aware of a comprehensive survey of the state of systematics research since the UK Systematics Forum survey 11 years ago. The Forum published a strategy and identified research priorities[8]. The Natural History Museum's taxonomic needs assessment[9] in 2006 identified and prioritised areas, where taxonomic information is needed for biodiversity conservation in the UK and its overseas territories, but did not identify which of these needs resulted from a lack of taxonomic expertise rather than failure to disseminate information. The UK Biodiversity Research Advisory Group has identified an extensive list of biodiversity research needs[10], but with surprisingly little reference to taxonomy and systematics research. These strategies and surveys seem disappointingly uncoordinated.

The UK has international centres of excellence for systematics and taxonomy, and collections of international and national importance. It also benefits from active groups of amateurs, some of whom carry out and publish research of the highest quality.

Experts in systematics and taxonomy tend now to be employed in museums and botanic gardens rather than universities, and we understand that there is a big decline in specialist taxonomists in these institutions too.

Much of the skills base in taxonomy is now held by amateurs, who do much valuable work. Many of them are over retirement age. Local recorders are often in their sixties, and few new ones are coming thorough to replace them. For example, the recorders group of Hertfordshire Natural History Society has 25 recorders (a large group for a county). Two of these individuals are under 35, four in their 40s, ten in their late 50s, six over 60 and three in their 70s.

In bacterial systematics, the output of the UK—measured by the number of papers per year describing new bacterial species or other taxa—has fallen from over 25 in 2000, to less than ten in 2007. This is largely due to the winding up of two very active and internationally recognised research groups in UK universities. Only one of these was due to retirement of the principal investigator.

Does it matter that taxonomy and systematics research is leaving universities? We believe it does. Any systematist at a university nearly always has a main research interest in another area. The leading systematic institutions make an excellent contribution and universities can and do look to them for expertise, co-supervision of research students, teaching on MSc courses and sometimes teaching undergraduates. But these are always as adjuncts and it makes a difference, for example in reduced interaction with students that they are not in the universities themselves.

Data from the *International Journal of Systematic and Evolutionary Microbiology* (published by the Society for General Microbiology) illustrates the decline in UK-based research to describe new species of bacteria. UK papers comprised 8-10 per cent of papers in this journal in 2000-01. Now, only 2 per cent of the papers are from the UK, and almost none of the overseas papers have a UK co-author. In comparison, following a large injection of funding from the South Korean Government, the number of papers from Korea has increased 12-fold in the past five years. A similar decline in UK-authored papers is seen for articles in the *Lichenologst*[11].

We recommend a periodic (five-yearly) survey of the state of systematics and taxonomy research, education and skills in the UK. This might usefully be carried out by the Environment Research Funders Forum, as part of its planned review of skills needs and training priorities in the environmental science sector for the next ten years (see Q12). Such a review must be co-ordinated with related reviews, for example of biodiversity, climate change impacts and ecosystem services research. We call on the systematics community to actively support a review and provide data and evidence to it.

[8] The web of life: a strategy for systematic biology in the United Kingdom http://www.nhm.ac.uk/hosted_sites/uksf/web_of_life/index.htm
[9] United Kingdom taxonomic needs assessment (2006) Natural History Museum/Defra
[10] Research needs for UK biodiversity (2007) UK BRAG/Defra http://www.jncc.gov.uk/pdf/BRAG_REPORT_2003-2006.pdf
[11] Submission to this inquiry by the British Lichen Society.

Q1b. *What are the current research priorities?*

A1b. It is not realistic to attempt to describe as many species as possible across all phyla before they become extinct—resources would be stretched too thinly and the project would take hundreds of years. Given the huge gaps in our knowledge of species from most phyla, *priorities need to be driven by research and policy questions*.

For example, when searching for new antibiotics, we know from earlier taxonomic research that most current antibiotics come from small subgroups of species of actinomycete bacteria—so these subgroups would be a priority for future investigations for new drugs. If asking questions about the impacts of climate change, it might also be important to fill gaps in our knowledge of known groups. Diatoms are very useful in studying ocean currents and the effects of ocean acidification, so further research on this group is likely to be fruitful for improving our understanding of ocean change in a changing climate.

Q1c. *What are the barriers, if any, to delivering these priorities?*

A1c. The main barriers are a lack of a new generation of taxonomists to replace those that will soon retire, funding, and the tyranny of the Research Assessment Exercise (RAE). Universities are reluctant to appoint taxonomists to permanent posts, since the value of this work is not recognised by RAE criteria: they don't bring in large grants or publish in high impact journals. Young researchers turn to areas which give them better long-term prospects. Those staff that do remain in universities are mainly over 50.

Training and education in systematics and taxonomy is a major problem because of the paucity of university systematists. Most of the country's conservation biology courses at undergraduate or MSc level, for example would benefit from more teaching in these areas. For a more detailed discussion of training and education issues and barriers, see Q13.

Funding is also a barrier. Taxonomy falls into a gap between research councils' funding. A project proposal needs to be predominantly non-taxonomic, with a small taxonomy element, to succeed. It is rarely possible to get funding to write a monograph on a new species or to produce a species key—both these outputs are fundamental to progress in taxonomy, and are necessary preludes to answering the policy-relevant questions that taxonomy can address. But because they are relatively cheap but lengthy projects (mainly requiring staff time), they are hard to get funded via existing mechanisms.

Many freshwater invertebrate identification keys, for example, are over 50 years old and badly in need of updating. Compliance with the Water Framework Directive requires assessing the ecological status of surface waters. One might reasonably expect that such assessments would benefit from up-to-date keys.

Specific funding for taxonomy initiatives in the past have been welcome, but short lived. Most current research that gets funding is at the molecular level, which is important for the theoretical/evolutionary approach but not sufficient if looking to identify an organism in the field.

In a SWOT analysis,[12] the Environment Research Funders' Forum identified concerns over the funding, maintenance and accessibility of long-term data sets, the ageing academic research population in general and in environmental science in particular, the lack of integration across the research councils and the continuing difficulty of securing funding for cross-disciplinary research. While this analysis does not focus on taxonomy and systematics specifically, these concerns chime with our experience in these areas.

The funding infrastructure has not yet fully recognised the need to support strategic culture and other taxonomic collections and datasets, long-term monitoring programmes and libraries. Climate change has demonstrated the enormous value of these resources in answering questions that are now vital to understanding, monitoring and tackling the effects of global change. For example, the (poorly named) Continuous Plankton Recorder Survey in the North Atlantic and North Sea, was discontinued for a period during which important changes happened in the plankton[13]. It was not recognised by funders at the time that continuous records of plankton would be so important today in answering important policy questions about changing climate, ocean currents and fisheries.

Culture collections are a vital component of the endeavours of taxonomy and systematics, and are constantly threatened by erratic funding. Consistent and long term core funding is needed for these national treasures, agreed via a peer review process. Too much emphasis is given in expecting culture collections to survive as commercial services, when they also have a national and international value for policy and research.

[12] http://www.erff.org.uk/documents/Finalversion.pdf

[13] Dickson, R., Colbrook, J.M. and Svendsen, E. (1992). "Recent changes in the summer plankton of the North Sea." ICBS Marine Science Symposia 195: 232–242.

For museum collections, an active taxonomist curator attracts visitors to use the collections as they can give advice and information on the spot. Fewer taxonomist staff means the collections are not maintained, not updated, become less attractive to enquirers and less relevant to modern needs, eg comparing identifications and training.

Academic libraries, even in world class institutions such as the Natural History Museum, cannot afford to take all the relevant journals and are therefore no longer comprehensive reference libraries. Much published material of relevance to this community is not yet available electronically, and even where it is available may not be affordable to the community of amateur taxonomists upon whom the system relies.

Open Access publishing will help amateurs to read the academic literature, but may be a barrier to publishing if they are expected to pay to publish in open access journals and their work is not funded by a grant. 40 per cent of papers in the International Journal of Systematic and Evolutionary Microbiology do not acknowledge grant funding, so we assume that this research is not funded by grants. The Society for General Microbiology is currently funding the digitisation of the entire archive of the International Journal of Systematic and Evolutionary Microbiology, and will make this freely available online as part of its charitable mission to disseminate knowledge.

The Living With Environmental Change (LWEC) initiative provides an opportunity for properly co-ordinated funding, focussed around an important research question. The major funders are making available £1 billion of funding from 2008-2011. *We urge the taxonomy and systematics community to be proactive in helping LWEC develop into a sustainable funding model that can persist beyond the end of the initiative.*

We recommend:

— That the Research Excellence Framework must include measures of excellence relevant to nationally important areas of research, including systematics and taxonomy.

— Strategic longer-term funding mechanisms, to support research and the necessary infrastructure including taxonomic collections, libraries and long term monitoring. A proportion of government and research council funding for climate change and biodiversity initiatives could be earmarked for taxonomy and systematics research and training that underpin such projects.

— Funding mechanisms for outputs that are fundamental to taxonomy, such as writing monographs and identification keys.

Q2. *What is the role of systematics and taxonomy and, in particular, in what way do they contribute to research areas such as biodiversity conservation, ecosystem services and climate change? How important is this contribution and how is it recognised in the funding process? How is systematics integrated in other areas of research?*

A2. Systematics and taxonomy are enabling sciences that are fundamental in answering the policy and research questions in conservation, ecosystem services and climate change. They also underpin many other areas of bioscience and support economically important activities including agriculture, fisheries, horticulture, bioprospecting, medicine and veterinary science.

They enable the UK to fulfil its legal and moral obligations, for example in the UN Convention on Biological Diversity, EU Habitats Directive, EU Water Framework Directive, CITES and the Ramsar Convention.

They allow government bodies including Defra, the Department of Health, Ministry of Defence, Home Office and their agencies to monitor progress in meeting our national biodiversity targets, identify invasive alien species, identify and monitor new and emerging diseases of people, crops and livestock, and prepare for and respond to bioterrorist attacks.

This strategic contribution of systematics and taxonomy to our economy, health, well-being, security and ability to diagnose environmental problems is not currently recognised by the funding system. Fundamental university-based research in this area is disadvantaged by the Research Assessment Exercise, as described in the answers to Q1. Grant applications fall between the gaps of research council remits. Several government departments are responsible for overseeing and funding the main institutions and centres where taxonomy and systematics are carried out, and are responsible for policy areas for which taxonomy and systematics provide the evidence base.

Taxonomic skills and data are essential for any conservation or biodiversity project. Biodiversity Action Plans (BAPs) are incomplete because only well studied species are included. For example, the national BAP mentions only three freshwater invertebrates; the southern damselfly, freshwater pearl mussel and the native crayfish. Yet, in the specialism of a member of our working group, we know that the Trichoptera (caddis fly

family) have at least seven listed as Red Data Book 1 (ie critically endangered) species, one of which is almost certainly extinct. This group is not mentioned in any BAP. The threats to many species may be underestimated if few people can identify and record them.

Q3. *Does the way in which systematics research is organised and co-ordinated best meet the needs of the user community? What progress has been made in setting up a body to lead on this? What contribution do the leading systematics research institutions make both nationally and internationally?*

A3. We believe that more progress should have been made in bringing together the main partners with an interest in this area: government departments, research councils, museums, learned societies and others. The Systematics Initiative was too narrowly focused—a wider focus around climate change issues might be more fruitful. There has been little leadership from government departments and the professional and learned societies (including ourselves) in addressing this problem. We think that there is a role for the Environment Research Funders Forum here, since it already comprises all the main funders of taxonomy and systematics research and institutions.

When IOB asked Defra in 2006 for an update on progress in taking forward actions stemming from the 2002 House of Lords *What on Earth?* report, Defra told us: "I am afraid that as a result of the tight financial situation in Defra, prioritisation of our objectives and strategic outcomes has resulted in progress in systematics falling below the threshold to command the necessary resources".
We are concerned that the Department for Culture, Media and Sport (DCMS) has failed to appoint a chief scientist, despite having accepted in 2005 the clear advice of the Government's own review[14]. DCMS funds the Natural History Museum and has policy responsibility for the museum sector that is so important for taxonomy and systematics in the UK.

We recommend:

- The Environment Research Funders Forum should be funded to monitor and co-ordinate taxonomy and systematics research and training, working with users, employers and other interest groups.
- The Government Office for Science should use its co-coordinating role to ensure that the government departments (including Defra, DCMS, DIUS, DH and the devolved administrations) work together to identify their policy and research needs, and fund the necessary research and infrastructure.
- Defra must recognise the strategic role of taxonomy and systematics in delivering key policy objectives.
- DCMS should appoint a chief scientist to ensure it has the best advice on supporting museums and collections of scientific value

Q4. *What level of funding would be needed to meet the need for taxonomic information now and in the future? Who should be providing this funding?*

A4. The survey of the state of systematics and taxonomy research, education and skills base in the UK (which we recommend under Q1a) should address the first of these questions.

Given the numerous government departments, agencies and non-departmental public bodies who fund taxonomy and systematics research, it has not proved possible to discover how much funding is currently provided, nor how much might be needed.

We welcome the efforts of the Environment Research Funders' Forum (ERFF) to bring some clarity and co-ordination to environmental science funding, and encourage them to build on their portfolio of reports[15].

Defra publishes public sector and NGO expenditure on biodiversity as one of its biodiversity indicators[16], but strangely this does not appear to include research council expenditure. These figures suggest that expenditure is increasing, but over 90 per cent of Defra's spend is on countryside stewardship schemes, and research spend is flat [17].

NERC provides information on its grants and studentships in systematics and taxonomy[18]. PhD studentship figures seem to show a dramatic decline over the past three years; 17 started in 2005, ten in 2006 and three in 2007. There is no clear trend in grant funding over the past ten years, and large variations from year to year in the number and total value of grants awarded for this area. Peak years were 1999 and 2004 (32 grants worth

[14] http://www.culture.gov.uk/Reference_library/Publications/archive_2005/response_to_ost.htm
[15] http://www.erff.org.uk/reports
[16] http://www.defra.gov.uk/news/latest/2007/biodiversity-0612.htm
[17] http://www.jncc.gov.uk/pdf/Report_on_indicators_of_spending_on_biodiversity.pdf
[18] http://www.nerc.ac.uk/research/gotw.asp

1,290,000 in total and 30 grants worth a total of £1,170,000 respectively), with 1998 and 2005 having the lowest awards (15 grants, £337,000 and 14 grants, £311,000 respectively).

The ERFF *Strategic analysis of UK environmental monitoring*[19] shows that over a fifth of monitoring is carried out by volunteers and is unfunded, including "nearly all of the invertebrate voluntary recording schemes as well as other plant, invertebrate, mammal, amphibian and reptile recording schemes". This useful report identifies many other issues pertinent to this inquiry: that there is insufficient baseline data and data on long term trends in soil biodiversity, that many monitoring activities have incompatible databases so that information cannot be brought together to inform policy, and that the highest risks to good environmental monitoring are (inadequate) funding and staff continuity.

Funding for nationally important science of this sort must come from Government, its agencies and research councils. As we have asserted in our answers to other questions, this must recognise the need for long term funding, support for collections and monitoring, support for outputs that are not rewarded via the RAE, and support for training in field work, laboratory and identification skills.

Q5. *How does funding in other countries compare? Could there be more international collaboration? If so, what form should this collaboration take and how might it be achieved?*

A5. In Poland more respect is given to evolutionary biology, taxonomic work and systematics—even small universities have departments of evolutionary biology. We could certainly learn from our eastern European colleagues. Many UK graduates in biology finish university without being able to use an identification key.

A member of our working group, worked with colleagues at the University of Lodz in Poland on a Leonardo da Vinci project, to bring 21 Masters graduates to the UK for six months for work experience[20]. Many of them were employed here because they could identify to species level a range of organisms (especially plants, freshwater and terrestrial invertebrates). In Poland they maintain a classical education and science graduates studying botany or zoology possess good identification skills. Several of them have gained permanent employment here in the UK because of their taxonomic skills—which are far ahead of our own graduates.

Although this is good news, it would be unwise to assume that we can always purchase—and retain—skills in the market place when we need them. We cannot expect to bring in experts from overseas with expertise in specific diseases (such as Bluetongue) fast enough to identify suspected cases, for instance.

Q6. *What impact have developments in DNA sequencing, genomics and other new technologies had on systematics research? In what way has systematics embraced new technologies and how can these research areas interact successfully and efficiently?*

A6. Molecular science and technologies continue to benefit systematics research and taxonomy, and supplement but cannot replace traditional methods in most cases. For example, molecular biology has made identification of new microbes relatively cheap and rapid, but under current rules one has to be able to grow a new microbial species in order to name it—sequencing its DNA only allows a provisional name to be allocated to a presumptive new species. At the same time, bulk gene-sequencing approaches have revealed that the number of bacterial species still to be described is much greater than previously thought: probably at least 100 times as many as the 8000 or so species currently named.

We expect that pocket sequencing technologies being developed for military applications will soon become more widely available, and cheap enough for use by both professionals and amateur systematic biologists. In theory, this could allow identification of a known species from its DNA, without the need for morphological identification by an expert. But the quality and quantity of taxonomic data in DNA databases is a major limitation to the usefulness and accuracy of such approaches for the foreseeable future. Skills in traditional taxonomy will always be required to assign a DNA sequence to a particular species in the first place. And discovering new species is where the fieldwork gets exciting and becomes taxonomy.

Once data in DNA databases are of the necessary quality for a significant number of species of interest, this technology could free up the time of expert taxonomists for identifying new species, rather than for helping others to confirm the identity of known species.

We recommend a major funding initiative to improve the quality, compatibility and usability of molecular taxonomic databases, since these have the potential to revolutionise systematics and taxonomy.

[19] http://www.erff.org.uk/reports/reports/reportdocs/enviro_monitoring.pdf
[20] http://www.leonardo.org.uk

Data collection, management, maintenance and dissemination

Q7. *Does the way in which taxonomic data is collected, managed and maintained best meet the needs of the user community? What is the state of local and national recording schemes?*

A7. A standardised format for taxonomic databases is crucial to allow data to be compared across databases. Small databases could usefully be combined to make them more useful and accessible. Climate change research requires long term datasets, and these need a critical mass of data before they become useful.

Recorder groups provide a considerable amount of data at county level. Recorders are people with taxonomic expertise, often retired academics or talented amateurs, who take responsibility—as volunteers—for recording the species of their "group" of organisms. For example, there will be recorders for mosses and liverworts; ants, wasps and bees; flora; birds etc. The recorders feed this information into County Biological Record Centres and to the National Recorder for their group. They also give information to wildlife trusts. They produce atlases such as the Flora of Counties or County Bird Atlases. These books include detailed information on the ecology, morphology and distribution of a wide range of species.

Local and national recording schemes are patchy. Some taxonomic groups are well recorded (such as birds, butterflies and dragonflies), whilst some groups are omitted from records as there may not be someone within a particular county able to identify them. One county has appointed a fish recorder after a 20-year gap. Most recorders send their records to a national recorder for their group and some submit their data to the National Biodiversity Network (NBN) gateway.

Recording work is entirely voluntary. County Biological Records Centres are being downgraded in many areas. The Hertfordshire recording group is currently trying to encourage its recorders to put their records into electronic formats and to lodge copies with the local Biological Records Centre. *The NBN is a very positive development for taxonomy, but is still evolving and deserves more support*.

Q8. *What is the role of the major regional museums and collections? How are taxonomic collections curated and funded?*

A8. Museums and collections are vital. They may be the only places to look at specimens to confirm identification. Regional and national museums and collections are also now the main location for research that was once done in universities.

The collections of Biological Resource Centres (BRCs), such as botanic and zoological gardens, culture collections and natural history museums, have traditionally been strongholds of taxonomy- and biodiversity-related science in the UK. We feel that these world-class assets need to be maintained. Their funding should be secure and long-term. These organisations house considerable taxonomic expertise (traditional and molecular), have access to the expertise of retired and honorary researchers and in most cases the relevant, worldwide scientific community. Ideally, we would like to see more funds available for post-doc positions and studentships and to give visiting experts a base. These measures would allow the survival of current knowledge and knowledge enhancement, through research and knowledge transfer from visiting experts and the opportunity to foster excellence in the systematists and taxonomists of the future.

Q9. *What progress has been made in developing a web-based taxonomy? How do such initiatives fit in with meeting demand for systematics and taxonomy information? How do UK-led initiatives fit in with international initiatives and is there sufficient collaboration?*

A9. Web-based taxonomy is a useful development, with real potential to provide cheap access to data. Users need to be able to follow a dichotomous taxonomic key. We believe that the keys are too hard to use at present and should be simplified.

Web-based information is getting better all the time but quality control is an issue, especially when inviting amateurs to provide data. An open peer review model might be a way forward.

We recommend that it should be a condition of publication of taxonomic research, for the data to be deposited in a web-based database, in the same way that DNA sequence data must be deposited. This would require an infrastructure to be developed.

Q10. *What needs to be done to ensure that web-based taxonomy information is of high quality, reliable and user-friendly?*

A10. Web-based taxonomy information should be similar to that produced by facilities that collate DNA sequence information, ie a core facility with long term funding that can give continuity and adapt to feedback. This would allow the consistent presentation of data from multiple inputs across the biological sciences community.

The production of a good dichotomous key is vital, using high resolution photographs showing the confirming or key features. Those of us who use a microscope see little likelihood of a replacement for a text version.

Training modules on web-based and molecular taxonomy should be incorporated into relevant postgraduate courses, and made available to practicing taxonomists who wish to update their knowledge and skills.

Q11. *How does the taxonomic community engage with the non-taxonomic community? What role do field studies play?*

A11. There is strong empirical evidence for the benefits of outdoor education for all age groups,[21] but biology fieldwork continues to decline in schools[22].

Field studies and ecology field trips are especially valuable. They provide memorable, inspiring and enriching experiences for the participants. They train people in the correct sampling and collection methods and in core identification skills. These skills need constant reinforcing; "learning by doing". The engagement of taxonomists with students is the main way in which many interact with the "non-taxonomic community".

Some counties run a program of field days for the general public, focusing on a particular group of organisms. Natural History Societies are keen to encourage new members (especially younger members) to participate. Recorders are often happy to act as mentors, but the uptake can be disappointing.

Skills base

Q12. *What are the numbers and ages of trained taxonomists working in UK universities and other organisations?*

A12. We are not aware of a source of data on the numbers of taxonomists, the age structure of the profession and future needs.

The University of Hertfordshire has three trained taxonomists, all over 50 years old. Data on the number and age structure of the Herts recorders group is provided under Q1a.

We understand that the ERFF will shortly be conducting a survey to identify the skills needs and training priorities in the environmental science sector for the next ten years. We urge the select committee to encourage ERFF to include taxonomy and systematics in this survey, with additional government funding if necessary.

We recommend the learned societies and professional bodies that represent taxonomists and systematists to collaborate in conducting and publishing periodic surveys of their members in order to collect a time series of data, which can be used to substantiate (or refute) concerns that the skills base is at a critically low level, and to share these data with ERFF and others. (This is a part of recommendation 1.)

Q13. *What is the state of training and education in systematics and taxonomy? Are there any gaps in capacity? Is the number of taxonomists in post, and those that are being trained, sufficient to meet current and future needs across all taxonomic subject areas?*

A13. We are worried by the decrease in teaching of field skills, identification skills, whole-organism work and lab skills in schools and at undergraduate level in the UK. This is caused by several factors, including reduced funding and (sometimes unfounded) health and safety concerns. HEFCE reduced funding for subjects with lab and field-based elements (the ratio of financial support for laboratory based subjects compared to humanities was reduced from 2.0 to 1.7, resulting in a loss of more than £1,000 per student per annum). And university biosciences departments—like physics departments—are running at a deficit of 25–30 per cent, according to a preliminary study commissioned by the Heads of University Biological Sciences (HUBS)[23]. These factors mean that universities may be compelled to axe the most expensive elements of courses, including lab and field work, so that undergraduates are unlikely to get the hands-on biology experience needed for a career in taxonomy and systematics.

[21] http://www.field-studies-council.org/documents/general/NFER/NFERper cent20Execper cent20Summary.pdf
[22] http://www.field-studies-council.org/reports/biologyfieldwork/report1/index.aspx
[23] http://www.brad.ac.uk/acad/lifesci/HUBS/Meetings/2007November/Report/ReportHUBS20071114.pdf

Anecdotal evidence suggests that students coming from school to study biological topics as undergraduates, no longer know or can name the body parts of a plant or insect, nor can they identify common species such as garden birds or buttercups. Degree courses and modules covering systematics and taxonomy have been removed from many universities, fewer degree courses in ecology, botany and zoology are on offer, few students graduate with taxonomic skills, and few taxonomists are now employed by universities. While we would expect that some traditional courses will disappear and new ones will replace them—as a welcome mark of a university system that responds to changing needs and priorities—*the UK continues to need scientists who can read a taxonomic key, have experience in whole-organism biology, and possess fieldwork skills.*

A 1997 survey of university teaching by the UK Systematics Forum, found that around 60 per cent of the universities that responded taught systematics as an optional or compulsory unit at elementary level; and only a third of the respondents offered more advanced level teaching in the subject[24].

The UCAS web site shows 33 institutions offering UK zoology degrees (not combined with other subjects), seven offering botany degrees, seven for ecology, and 26 for environmental science. In contrast, 138 institutions offer degrees in business studies. There are no undergraduate degrees in systematics or taxonomy, but a few at Masters level.

Education at all levels is needed. A number of specialist bodies such as the Marine Biological Association[25] provide education and outreach activities, and could do more if funded.

An interesting initiative which we believe should offer a model for the future is the Masters bursary scheme funded by the Defra Marine Aggregate Levy Sustainability Fund[26]. Defra has responsibilities for licensing, including extraction of sand and gravel from the seabed, and Ministers agreed that a levy should be placed on this industry, known as the Marine Aggregate Levy Sustainability Fund (MALSF).

The MALSF Steering Committee recognised that—while there have been significant advances in understanding the nature and scale of impacts of marine aggregate dredging on physical, historic and biological resources—knowledge remains incomplete for much of the coastal waters in England. There is virtually no information on whether localised impacts on seabed communities that are potential food for fish, have a detectable effect on ecosystem function and fisheries of economic significance. To improve training in systematics, MALSF has supported a bursary scheme for Masters students. Four students are now participating, and at the time of writing (January 2008) their project work has yet to be finalised.

We recommend funding for specialist courses and training fellowships in strategic subjects where there is an identified skills gap. Universities that run specialist courses can then build up the team, expertise and critical mass to resurrect the skills base and attract overseas students to gain further funding.

Authors of this response

This response was written by a working group comprising member organisations of BSF and affiliated societies of IOB, supplemented by information from our policy committees.

4 February 2008

Appendix

Member Societies of the Biosciences Federation

Association for the Study of Animal Behaviour
Association of the British Pharmaceutical Industry
AstraZeneca
Biochemical Society
Bioscience Network
British Andrology Society
British Association for Psychopharmacology
British Biophysical Society
British Ecological Society
British Lichen Society
British Mycological Society
British Neuroscience Association
British Pharmacological Society
Experimental Psychology Society
Genetics Society
Heads of University Biological Sciences
Heads of University Centres for Biomedical Science
Institute of Animal Technology
Institute of Biology
Institute of Horticulture
Laboratory Animal Science Association
Linnean Society
Nutrition Society
Physiological Society
Royal Microscopical Society
Royal Society of Chemistry

[24] http://www.nhm.ac.uk/hosted_sites/uksf/web_of_life/education/index.htm
[25] http://www.mba.ac.uk/education/education_outreach.php?education
[26] www.alsf-mepf.org.uk

British Phycological Society
British Society of Animal Science
British Society for Developmental Biology
British Society for Immunology
British Society for Matrix Biology
British Society for Medical Mycology
British Society for Neuroendocrinology
British Society for Plant Pathology
British Society for Proteome Research
British Toxicology Society
Society for Applied Microbiology
Society for Endocrinology
Society for Experimental Biology
Society for General Microbiology
Society for Reproduction and Fertility
Universities Bioscience Managers Association
UK Environmental Mutagen Society
Zoological Society of London

Associate Member Societies

BioIndustry Association
Royal Society
Wellcome Trust
Medical Research Council
Biotechnology & Biological Sciences Research Council

Additional Societies represented by the Institute of Biology

Anatomical Society of Great Britain & Ireland
Association for Radiation Research
Association of Applied Biologists
Association of Clinical Embryologists
Association of Clinical Microbiologists
Association of Veterinary Teaching and Research Workers
British Association for Cancer Research
British Association for Lung Research
British Association for Tissue Banking
British Crop Production Council
British Inflammation Research Association
British Marine Life Study Society
British Microcirculation Society
British Society for Ecological Medicine
British Society for Parasitology
British Society for Research on Ageing
British Society of Soil Science
Fisheries Society of the British Isles
Freshwater Biological Association
Galton Institute
Institute of Trichologists
International Association for Plant Tissue Culture & Biotechnology
International Biodeterioration and Biodegradation Society
International Biometric Society
International Society for Applied Ethology
Marine Biological Association of the UK
Primate Society of Great Britain
PSI—Statisticians in the Pharmaceutical Industry
Royal Entomological Society
Royal Zoological Society of Scotland
Scottish Association for Marine Science
Society for Anaerobic Microbiology
Society for Low Temperature Biology
Society for the Study of Human Biology
Society of Academic & Research Surgery
Society of Cosmetic Scientists
Society of Pharmaceutical Medicine
UK Registry of Canine Behaviourists
Universities Federation for Animal Welfare

Additional Societies represented by the Linnean Society

Botanical Society of the British Isles
Systematics Association

Memorandum submitted by Booth Museum of Natural History (Brighton Royal Pavilion and Museums)

8. *What is the role of the major regional museums and collections? How are taxonomic collections curated and funded?*

Role

Taxonomy is fundamental to all aspects of the natural sciences. It underpins all work on animals and plants and cannot be dismissed as "old fashioned" or inappropriate, yet it has become increasingly unfashionable with the advent of new scientific technology. Since the Victorian period museums have been key to housing, developing, conserving and interpreting taxonomic collections. As a result most museums in the past had natural science collections made by keen amateurs as well as prominent experts in specific fields. They generously donated their material to their local museum. Changes in taste and emphasis have more recently resulted in many smaller museums disposing of their natural science collections and concentrating on "local history". Disposal has largely involved the transfer of material to larger museums with appropriate staffing and facilities. Consequently the larger regional museums have extensive and very important collections that are at the heart of taxonomy now as well as in the past. They enable scientists to try and gain order from the apparent chaotic natural world.

Many "types", those unique specimens upon which original species descriptions are based and form the ultimate reference specimen(s) for a species, are housed in these museums' collections. Not only are "old" past collections held. Provided appropriate trained and enthusiastic staff are in place, collections continue to be built up and added to. New species are described and deposited. "Voucher" (reference) material is deposited from environmental impact survey work. Keen amateurs still exist and deposit their collections as well as often helping to curate them. Collecting and unravelling the complexities of the natural world continue, albeit within the limitations of ethical and legal frameworks.

The collections provide an immeasurable source for the continued re-evaluation of species, their relationships with other species and their evolution. Without collections like these our appreciation and understanding of the natural world would be greatly hindered. The collections can be of direct benefit eg in providing reference for the identification of pests and beneficial species, and as aids in teaching students.

Further, collections are also linked with the "web" either through the museum's electronic database, via the local wildlife trust, recording schemes, through the environmental recording software such as "Recorder", the NBN Gateway etc. It is critical that collections are made public and accessible and the www is key to this. Specimens and collections come in to the museum, and once recorded these data can be uploaded and made available for others to use, or just know that such and such a species can be found in such and such museum.

Curated

Collections are curated by:

Tenured staff; dedicated professional natural historians, who have to deal with a huge amount of other museum/local authority work. They now often have little time for any taxonomic work. They are now more likely to be replaced through natural wastage by contract staff who can be employed more cheaply.

Contract staff (18-24 months); who do not have the long term commitment/time to get to grips with the collections in their care.

Volunteers; experts that give their time freely to work on museum collections. These include retired persons who in a previous life have been either professionally or, more often than not as amateurs, been extremely interested and fascinated by one or more aspects of the natural world and become "expert" in a particular group of organisms. The extent to which the amateur has advanced our understanding of the natural world should not be underestimated. What began in the Victorian era—that great time of science and exploration—continues today. Amateurs still collect and catalogue but they also record, publish (including on the web) and photograph. Many of the recording groups are amateur run or run by enthusiastic curators in their own time.

Funded

The very nature of natural science collections means that they are at high risk and require expert care (being extremely attractive to pests which like to eat them, susceptible to damp etc.). All the care, conservation and interpretation of collections requires funding. The museums that house collections are largely owned/run by local authorities and as such are under considerable pressure. Sadly, within their organisation they are often perceived to be of little importance by their authority and so are under funded—museums are at the bottom of any local authority pile and at the highest risk when it comes to annual savings, not helped by pressure from central government. During the late 1970s and early 1980s efforts were made to improve this situation through the efforts of the Area Museum Councils and the Museums & Libraries Authority. A great deal of funds were made available to cover the cost of surveying the extent of the collections in the UK and then, from these data, to provide funds for their conservation and care. Some local authorities also expanded their museum, employing qualified natural science curators. Now things have changed considerably with many authorities under financial pressure and councillors asking: "Why should the local tax payers be paying for this?"

Funds have been directed away from care of collections, something that is key to their survival and taxonomic significance and usefulness, and been focused upon "users", "accessibility" and "out reach". In recent years and now, cuts in museum staff are being made which has and is having a direct effect upon the viability of museum collections. To a small extent the development of local area networks and regional hubs has helped, but not to any great extent.

Local authorities can not be expected to fund, albeit indirectly, taxonomic work without any financial assistance. The collections need care, interpretation and to be readily available for study not just by the local government curator in charge but by students and experts alike. These museums hold the Nation's natural

history wealth, the key to taxonomic work, and are pledged to care for it and do so valiantly despite the ever-increasing pressures—but they need help and cannot be expected to continue under the present situation.

3 January 2008

Memorandum submitted by Dr Janet Bradford-Grieve

My name is Dr Janet Bradford-Grieve. I am a retired scientist who is working in an emeritus position at the National Institute of Water and Atmospheric Research (NIWA), Wellington, New Zealand. My research career has had two threads: biological oceanography (ecosystem functioning) and systematics and taxonomy of calanoid copepod Crustacea. It is on the latter subject I am now concentrating.

My observation is that in the UK, New Zealand and many other countries the situation is somewhat similar, moderated by population levels.

I recently completed a voyage aboard the German research vessel "Polarstern" in the Atlantic under the banner of the "Census of Marine Zooplankton". There was an international group of 30 researchers aboard. The young ones were mainly contributing to the genetic part of the work although there were three students and their supervisors there. But it was also noticeable that three of the experts were retired or about to retire. None of the genetic work would make any sense at the species level without the input of accurate identifications. Thus, relatively well funded genetics projects are already limited by the available systematics and taxonomic expertise.

The number of full time equivalents (FTE) in marine invertebrate systematics and taxonomy at NIWA has declined from 6 to 2.3 between 1995–96 and 2007–08 and the program was recently funded for the next 12 years without any undertaking to compensate for inflation! These 2.3 FTEs are spread over many more people so that, in order to keep professional staff employed, technical contracts have to be obtained. Needless to say NIWA is finding it increasingly difficult to retain young talented systematists as they cannot see their careers advancing in the New Zealand setting, while having to provide increasingly more technical identification services.

In New Zealand, Dr Dennis Gordon (also of NIWA) estimates there is a total of 29 marine taxonomists in Universities, Museums and research institutes who share 6.5 FTEs. This is the lowest capacity since World War II.

This decline in FTEs has occurred in a setting where:

1. The current New Zealand Government's science agenda is almost completely driven by RS&T in the service of the economy. Evidence of this can be found in the "New Zealand Research Agenda discussion document" for which input is due to the Ministry of Research Science and Technology by the end of January 2008. http://www.morst.govt.nz/Documents/consultations/NZRA-discussion-document.pdf

   The only word that you will find in this document that relates to the subject of systematics and taxonomy is "biodiversity". The context of these references is in such vague terms as to provide no guidance to funding organisations.

2. The public service has so changed the definition of different types of research since the Government reforms of the late 1980/1990s that it is really difficult to track what has happened with time. Also the New Zealand public service since the reforms has largely lost its public service ethic so we can not rely on the Government of the day being fully informed about the state of affairs ("Voltaire's Bastards" come to mind!).

3. Politicians (and their advisers in the public service) are more concerned to put "spin" around everything they do such that I am convinced they do not realise, themselves, what is happening.

4. There is increasing attention to resources going to databases and collections, communication with "endusers" and the public such that that actual systematics and taxonomic research is fast disappearing.

The UK has been a great leader in the past and still plays a very important international role. I also think systematics in every country should play an international role. There is an unconscious tendency for new workers to enter the field internationally, by filling gaps that have been generated by retirements or historical neglect. My impression is that talk of identifying priority areas is a red herring to cover up that fact that Governments generally have no intention of improving the resources and is a sign that the public service wants to micromanage.

Ideally, countries would be contributing each according to their ability (approximately population related), thus pulling their weight internationally and being a resource for other countries where a particular specialty is absent. This sharing of the load is particularly important where we are faced with biosecurity, disease, resource and conservation problems. Unfortunately, for this to happen, someone would have to take the lead internationally.

The final problem that professional systematists and taxonomists face is the belittling of their expertise. There is a widespread belief that "identification" equals "systematics and taxonomy" without recognising the source of the identification expertise they value and what has to be done to support this expertise.

30 January 2007

Memorandum submitted by the British Embassy, Rome

1. Italy is one of the richest countries in Europe and in the Mediterranean basin in terms of species biodiversity, including over 57,000 species in its fauna and over 6700 species in its higher plant flora (196 familiae and 1267 genera). Within European countries, it has the highest number of plants, as well as terrestrial and freshwater animals (46,200 species). As a whole, Italian terrestrial and inland water animals represent more than one third of the European fauna (35 per cent). Italy encompasses three bio-geographical regions: Alpine, Continental and Mediterranean; their co-presence and articulation are among the principal reasons for the elevated biodiversity in this country.

2. The Italian Ministry of Environment, Directorate for Nature Protection, published in 2005 a report written by more than 100 researchers and experts (botanist, zoologist, forestry, etc.) concerning the status and trends of Biodiversity in Italy, which presents an up-to-date scenario of national knowledge on biodiversity. The report shows the contribution and value of Italian biodiversity (genetic, species and ecosystem) in Europe and the world, and describes national scenarios based on the ecosystem approach of CBD. In the same year was also produced a CD called "GIS Natura" containing a national map and thematic databases. Both these instruments are, at the moment, the most exhaustive synthesis on biodiversity at national level and represent an important baseline for action (local or national) in relation to the 2010 target aiming to halt the biodiversity loss.

3. The physical and biological heterogeneity of Italy determines the great variability of Italian landscapes. One of the most important instruments for biodiversity protection is the Nature 2000 Network; a co-ordinated and coherent system of areas aimed at protecting different habitats and species of Community interests. It follows the Habitat Directive of the EC and a new report on the status of species in Italy is due to be issued soon.

4. Although there are not yet national official red lists, within a selection of 10,000 species of terrestrial and inland water fauna, 4.4 per cent was estimated to be endangered, 8.5 per cent vulnerable, and approximately 20 per cent very rare and considered nearly threatened. Finally, 46 species within this small selection are to be considered regionally extinct. Regarding plant flora, different studies have been undertaken to prepare national lists of endangered species of vascular plant, lichens, bryophytes, fungi and freshwater algae.

Major features of National Biodiversity Strategy and Action Plan

5. Italy's commitment in relation to the CBD was put into effect through Law No. 124 of 14 February 1994, which ratified the Convention on Biological Diversity. Upon ratification of the Convention, the document entitled "Strategies and Preliminary Programme to Implement the Convention on Biodiversity in Italy" was drawn up, and then approved by the CIPE (Interministerial Committee for Economic Planning) on 16 March 1994. This document started several national activities on biodiversity through different environmental policy instruments and financial resources available at that time. The objectives of the strategy are grouped into 9 work areas and specific actions are associated with each objective. The work areas are: (i) knowledge of Italian biodiversity heritage, (ii) monitoring of the state of biodiversity, (iii) education and training, (iv) in-situ conservation, (v) promotion of sustainable activities, (vi) containment of risk factors, (vii) ex-situ conservation, (viii) biotechnology transfer and safety, and (ix) international cooperation and eco-diplomacy. There have been different attempts to define a national Plan for Biodiversity, but it has not been possible to find an agreement. In the last years, there have been different actions to improve and spread the knowledge on biodiversity as well as to sensitize different stakeholders regarding the objectives of the Convention. These actions allowed a "new deal" including a new national coordination of initiatives on biodiversity.

Global Taxonomy Initiative—Italian Activities

6. The Nature Protection Directorate of the Italian Ministry for the Environment and Territory, being the National Focal Point for the Global Taxonomy Initiative (GTI) has elaborated the thematic report on the implementation of the work programme at national level.

The effort of managing and updating the databases is carried out with the collaboration of the "Comitato Scientifico per la Fauna d'Italia" (CSFI) for the zoological part, and of the Societ~ Botanica Italiana (SBI) for the botanical part. The CSFI, in particular, has been coordinating, organizing and supervising the publication of the "Fauna d'Italia" volumes and the main taxonomic activities in the country since 1989.

The creation and implementation of such resources will allow identifying the current gaps of the Italian taxonomic production in terms of:

1. taxonomic groups;
2. geographic areas and/or environments, with reference to the CBD cross-cutting issues
3. knowledge instruments, also computerized ones, such as check-lists, identification keys, data on fauna and flora.

Resources:

Thematic report on taxonomy in Italy (2005)
http://www.cbd.int/doc/world/it/it-nr-gti-en.pdf

On-line databases:
Checklist of Italian Fauna
http://www.faunaitalia.it/checklist/

Checklist mapping
http://www2.minambiente.it/Sito/settori_azione/scn/CHM/data/Ckmap_53.zip

Measures Taken to Achieve the 2010 Target

7. Italy, as a EU member state, is contributing to implement at regional and national level the "EU Action Plan to 2010 and beyond" annex I to EU Council conclusions "Halting the loss of Biodiversity by 2010", adopted in December 2006.

Furthermore, Italy has been the first Party to commit as a Government at the IUCN/CE initiative called "COUNTDOWN 2010" (www.countdown2010.net). The initiative was launched during the Malahide conference on Biodiversity in Europe, under the Irish EU presidency in April 2004. The official Italian engagement was signed on the occasion of the first meeting of the AHOEWG-PA1 in Montecatini.

8. In the last year, Italy is especially focusing on the elaboration, by 2010, of a national strategy for biodiversity through a participative process with national and local institutions, as well as other stakeholders coming from the private sector and civil society.

To achieve the 2010 target, it is necessary to make a big effort in terms of organization and public awareness on the status of Italian biodiversity, conservation and sustainable use of its resources, according to the CBD objectives.

9. In 2004, Italy instituted the Inter-ministerial Committee for Biodiversity whose mandate is going to be adapted according to political environmental priorities on saving energy, climate change and biodiversity itself.

Useful Links

Biodiversity in Italy—Ministry of Environment Website:
http://87.241.41.49/index.php?id_sezione=1662
http://87.241.41.49/index.php?id_sezione=1707
Italian Clearing House Mechanism
http://87.241.41.49/index.php?id_sezione=1661

4 February 2008

Memorandum submitted by the British Lichen Society

SUMMARY:

1. Lichen taxonomy has proved essential in identifying lichens as part of the wider National Biodiversity effort. Lichen identifications are crucial in assessing air pollution, environmental site condition, habitat quality, monitoring changes, and so on. Lichens have also been important in fundamental science such as symbiosis and the origin of life.

2. There has been a dramatic decline in numbers of lichen taxonomists in Great Britain since the 1970's. Currently there are only 5 professional, salaried practitioners who study lichen taxonomy and only as a part of their job. They are all employed by museums or botanic gardens.

3. Most lichen taxonomy is now done by amateurs and retired professionals. To maintain their expertise these amateurs need access to institutions with trained professionals and collections.

4. The lichen taxonomic community is ageing. Most are close-to or beyond retirement age.

5. There are very few young people entering the subject.

6. Natural history museums in general find it hard to find suitably trained applicants.

7. Employment opportunities in taxonomy are decreasing and career prospects are poor.

8. Lichen study is increasingly becoming excluded from its traditional stronghold in museums.

9. There are no lichen taxonomists left in British Universities.

10. Field studies are an essential part of taxonomy and its training but these courses are now rare in schools and Universities.

11. British lichenology has lost international competitiveness as evidenced by the over 90 per cent decline in numbers of published papers by UK-based authors over the past 50 years.

12. Current research priorities should include (1) monographic treatments of outstanding genera and species complexes, (2) a review of molecular work on lichens and its efficacy in solving taxonomic problems, (3) an identification aid to fungal parasymbionts and parasites, (4) a co-ordinated national distributional database of lichens and sites of lichen importance, (5) a web-based identification guide with descriptions and illustrations of every species.

RECOMMENDATIONS:

1. The image of taxonomy needs improving, and not just for lichens. Government needs to show a lead in encouraging taxonomy and acknowledging its role in fundamental bio-systematics. A strong taxonomic basis is needed for all studies on biodiversity, ecology, environment, etc., where lichens are involved.

2. University funding needs to be revised away from crude measures of research output involving published papers which penalises research entailing long-term studies, such as taxonomic monographs and identification aids.

3. National Museums and their funding bodies need to focus more on nationally relevant biodiversity studies and less on being internationally competitive in fashionable, big grant-attracting areas.

4. Regional museums, managed by local government, need to pay more attention to their local collections and employment of taxonomically-trained staff. Their government funding, based on indicators like visitor figures, means that collections care and enhancement and employment of skilled taxonomists are considered of minimal importance.

5. More emphasis needs to be placed on the value *per se* of taxonomy to fundamental science and biodiversity. This value needs to be assessed by measures other than the present crude ones of numbers of publications or visitors. School national curricula and University courses should include taxonomy as a subject and give relevant training.

6. Taxonomy jobs need to be created in all areas, such as Government, Museums and Universities. Career structures need to be established so that taxonomists do not have to leave their professional discipline in order to progress.

The British Lichen Society:

The British Lichen Society has about 700 members of whom over half are from countries outside the UK. It publishes *The Lichenologist,* the premier international scientific journal devoted to all aspects of lichen studies. Largely through the activities of the BLS and its members, lichens have become prominent in environmental studies, particularly air pollution and habitat quality assessments. Lichen studies have also played a large role in the wider issues of symbiosis and the origin of life.

It should be noted that the British membership of the BLS is overwhelmingly amateur. Most pursue another profession, or are retired, and count lichens as an interest. Nevertheless, many substantial contributions have been made by its members, including the ground-breaking work on air pollution and lichens and lichens as indicators of habitat continuity.

Taxonomy and systematics form the greater part of current published research on lichens. Large numbers of new species are described every year but their systematics remains somewhat problematical. Recent developments in molecular studies have given much new data but there remains a lack of general agreement on lichen classification. The dual nature of lichens (fungus plus alga or cyanobacterium) makes their taxonomy and systematics a challenging issue.

However, environmentalists from many disciplines require accurate methods for identifying lichens, particularly in the field. The new edition of the British lichen flora to be published in 2008 shows that many accounts are still provisional. This is especially critical for fungal co-symbionts which make a large contribution to the national biodiversity but their identification remains very difficult for most practitioners.

The state of systematics and taxonomy research:

1. *What is the state of systematics research and taxonomy in the UK? What are the current research priorities? What are the barriers, if any, to delivering these priorities?*

The *Lichens of the British Isles,* to be published in 2008 describes all the species known in the British Isles, about 1700 in total. But it excludes some 600 fungal para- and co-symbionts. The publication is supported financially by the BLS and a small grant was made available from Natural England to help with secretarial duties. However the body of the work was prepared almost entirely by unfunded amateurs with some crucial mentoring from professionals who have retired or are close to retirement. It highlights many instances of unresolved taxonomic problems and lack of knowledge of lichen distribution and ecology.

Only incomplete databases of lichen distribution exist; the most complete being for Scotland. Similarly, information on sites of lichen importance is fragmentary and out-of-date. The lists of species of conservation importance currently available are provisional because of the fragmentary nature of the distributional data.

Current research priorities should include (1) monographic treatments of outstanding genera and species complexes, (2) a review of molecular work on lichens and its efficacy in solving taxonomic problems, (3) an identification aid to fungal parasymbionts and parasites, (4) a co-ordinated national distributional database of lichens and sites of lichen importance, (5) a web-based identification guide with descriptions and illustrations of every species.

The barriers to delivering these priorities are (1) declining numbers of skilled, professional and amateur taxonomists, (2) lack of Universities, Museums and other institutions supporting lichen taxonomic work or studies with strong "biodiversity" component, (3) lack of long-term funding to support research requiring long periods of data-gathering and evaluation, particularly fieldwork. A fourth barrier soon to be realised will be the retirement and demise of those lichen-experts who can train the next generation of researchers.

2. *What is the role of systematics and taxonomy and, in particular, in what way do they contribute to research areas such as biodiversity conservation, ecosystem services and climate change? How important is this contribution and how is it recognised in the funding process? How is systematics integrated in other areas of research?*

Lichen taxonomy is essential for identifying species. Lichens are notoriously difficult to identify by non-specialists. It requires skilled workers to communicate species concepts so that non-specialists can identify lichens. Only a limited number of species can be identified in the field so the fieldworker needs laboratory backup to complete identification. Identifiers also need access to literature. Studies needing an up-to-date lichen taxonomy include assessments of environmental site and habitat quality to allow decisions on the designation of nature reserves and other protected sites. Ongoing identifications are needed to assess changes in site quality owing to climate change, air pollution, etc.

The importance given to lichens in site assessment is variable. Some government and local authorities recruit lichen specialists while others do not. This seems to depend on funding, when birds and flowering plants tend to be prioritised at the expense of lower plants and invertebrates. It also depends on the availability of lichen experts who are few in number.

3. *Does the way in which systematics research is organised and co-ordinated best meet the needs of the user community? What progress has been made in setting up a body to lead on this? What contribution do the leading systematics research institutions make both nationally and internationally?*

We cannot identify any co-ordination of lichen systematics research. Over-arching terms like "biodiversity" or "environment" might include a lichen research element. There is no evidence that lichen systematic research has benefited from the setting-up of bodies like the UK Systematics Forum. All systematic research currently undertaken by professionals in the UK is by individuals following their own interests.

4. *What level of funding would be needed to meet the need for taxonomic information now and in the future? Who should be providing this funding?*

A change in priorities is needed in Universities, Museums and other institutions. In recent years it is well-known that systematics and taxonomy have become devalued in academic institutions in favour of research that is more attractive to funding bodies. What needs addressing is the image of taxonomy and to raise the profile of its importance in science and to the nation. Systematics in general is a casualty of the strong incentives for universities and other institutions to recruit staff who will maximise grant income and publish in journals of the highest impact. The government should provide funding for strategic appointments in systematics research in a range of key disciplines in order to create and manage a minimum taxonomic knowledge base in the United Kingdom.

5. *How does funding in other countries compare? Could there be more international collaboration? If so, what form should this collaboration take and how might it be achieved?*

It seems that taxonomy is more valued in European Universities than in Britain. This is based on the increasing numbers of academic researchers in Europe. The analysis of articles published in *The Lichenologist* (see end) suggests that now, only 5-10 per cent of them are from British studies compared with over 90 per cent from foreign sources. This strongly suggests a much greater lichenological activity abroad than in Britain. This is the reverse of the situation 40 years ago when British articles predominated.

6. *What impact have developments in DNA sequencing, genomics and other new technologies had on systematics research? In what way has systematics embraced new technologies and how can these research areas interact successfully and efficiently?*

There has been a shift of attention away from purely morphological taxonomic studies to those supported or even dominated by DNA sequence analysis. In some instances this has affected the validity of conclusions when DNA and morphological data seem to conflict. There is an urgent need for an in-depth review of DNA sequencing methodology and its relevance to lichen systematics. A guide needs establishing for new researchers in this area.

One consequence of the new technology is that it is a barrier for the morphologist-taxonomist who needs access and funds to use it. Traditionally, considerable lichen taxonomy has been done by amateurs in their own homes, using morphological criteria which require little more than a good microscope. In the 1970s, lichen chemistry became popular for distinguishing lichen taxa, necessitating additional techniques not available to the amateur. However, this has not proved a serious barrier as some institutions have assisted amateurs with chemistry facilities. But with the drastic reduction of university and museum lichen-taxonomist staff these resources have become scarce to amateurs. This and the additional demands of DNA technology may help to account for the great reduction in taxonomy publications from British amateur authors.

DATA COLLECTION, MANAGEMENT, MAINTENANCE AND DISSEMINATION:

7. *Does the way in which taxonomic data is collected, managed and maintained best meet the needs of the user community? What is the state of local and national recording schemes?*

Taxonomic data is collated by the BLS in the form of a British Is. lichen checklist and synonym list. The BLS also maintains lists of protected and endangered species. These are available to all on their website. The BLS is also preparing the National Lichen Flora publication (see 1. above). Several individuals have published books and booklets to guide beginners, based on the BLS sources. Maintenance of these data is by amateurs and the small number of available professionals. As most list-maintenance is done by non-professionals, and the few professionals involved are not specifically funded for these activities, many are out-of-date. There is a shortage of accessible beginner's guides, and easily used guides to the lichens of specific habitats, especially those specified as a priority in Biodiversity Action Plans.

There are two national lichen recording schemes, both under the *aegis* of the BLS. One was started in the 1960s, and although computerised, gives limited data and in only a 10-km map square format. The other scheme, started in the 1990s, aims to be more comprehensive but lacks funding and progress is slow. A number of habitat-related schemes, such as for woodlands, heath lands and maritime sites have become out-of-date.

It is intended that the BLS database will be available to the NBN (National Biodiversity Network) when mature. Few lichen records exist on the NBN site other than those in the Scottish Site Lichen Database (see below).

Local (countywide) lichen recording schemes are operated by some amateurs but are not widely available. In our experience local record centres tend to concentrate on birds and wild flowers. Lower plants are sometimes included if there happens to be a locally-based amateur source of data. A problem with giving records to local data centres is that they lack lichen expertise and lichen information in databases contents can be unreliable.

A Scottish Site Lichen Database is operated by RBGE and the BLS. Currently with 260K records, it is now available on the NBN. It was originally compiled through a grant from SNH, and applications are being made for further funding to keep it up-dated

8. *What is the role of the major regional museums and collections? How are taxonomic collections curated and funded?*

Lichen specialist staff were once frequent, in regional museums such as Leicester, Dundee, Halifax, Norwich, Hampshire and others where substantial lichen collections exist. These personnel and institutions provided teaching and research facilities for local and even national interests. Their collections were both historic and were kept up-to-date. They were invaluable as sources of information for local researchers and could be used by beginners learning identification. In addition, these museums served as a repository for collections made by local collectors and have provided considerable information on environmental change. Many of these museum personnel were influential in lichen taxonomic and distribution research. But, since the late 1980s nearly all staff have been lost from these museums and not replaced, or at best, have been replaced by generalist "collections managers" with no taxonomic expertise. The result is that the collections are dying through not being maintained. Worse, the collections are not updated with new material, making them increasingly historic and irrelevant to modern needs. At the moment, only Dundee, Southend and Leicestershire Museums Service have curators with active lichen interests but these are fitted in with a wider remit towards general Natural History and administration. Two of these curators (Dundee, Leicestershire) will have retired by 2009, the third (Southend) by 2015.

The taxonomic collections and established staff in local museums are funded by grants from the Government (Museums, Libraries & Archives Council), the Comprehensive Spending Assessment and Council Tax. Progressive reductions in levels of public spending have significantly reduced budgets and shrunk museum staff numbers. Increased reliance on Best Value Indicators and MLAC targets intending to increase visitor figures have meant that background research, collections development and maintenance have been downgraded in favour of "outreach" and programmes designed specifically to increase visitor numbers.

Of the National Museums, NHM holds the premier British and International lichen collection, while RBGE, and NMW have collections primarily relevant to those countries but with some international interest. These are curated by, at best 1–2 staff, often as part of wider duties. NHM has no active full-time lichenologist as the post is used primarily for mineralogy studies. The Herbarium Assistant post is vacant and has proved difficult to fill for the past 15 years. The pattern has been for foreign nationals to take the post temporarily. Both RBGE and NMW curators have duties wider than just lichens. RBG Kew does not have an official lichen role as this was transferred to NHM many years ago. All national museums are funded by government.

9. *What progress has been made in developing a web-based taxonomy? How do such initiatives fit in with meeting demand for systematics and taxonomy information? How do UK-led initiatives fit in with international initiatives and is there sufficient collaboration?*

None exist in Britain apart from species lists maintained by the BLS web site. Several web-based taxonomic sites exist in other countries, most notably Italy, which has an identification guide, but relatively few British species are included.

10. *What needs to be done to ensure that web-based taxonomy information is of high quality, reliable and user-friendly?*

Any web-based system needs provision for ongoing maintenance and updating. At least one dedicated staff member needs to be lichen-literate in order to communicate with specialists who submit the data and to evaluate it for accuracy.

11. *How does the taxonomic community engage with the non-taxonomic community? What role do field studies play?*

Field studies are promoted by the BLS by field meetings and workshops that are also available to non-members. The workshops have almost always been taxonomic in nature, aimed to educate and are guided by an expert.

The Field Studies Council was once a great influence in educating non-specialists and school children. Usually the intimate relationship between taxonomy and ecology was well-promoted. But the FSC has come under pressure from declining student take-up and the need to increase prices. Often planned courses do not take off through lack of applicants. The decline in field and systematic biology teaching in schools and universities is thought to be behind this. Up to the 1970s, annual attendance at a field course was often mandatory for students and children.

RBGE has introduced a "lichen-apprentice" scheme that trains newcomers to Lichenology. It has a local remit and, although originally financed by a grant from SNH, it is no longer funded except in staff time and laboratory/library facilities.

Those amateur lichenologists that are available locally are known to give field meetings and day-courses, often to wildlife trusts, natural history societies, etc. These courses aim at a very basic or broad introduction; just a taster in the hope that someone will become interested.

A new approach has been the Community Heritage Initiative (CHI) run by Leicestershire County Council, and funded by the Heritage Lottery. This 5-year project sought to foster an introductory natural history interest in the general public, advising and supporting Heritage groups, often on taxonomic/identification/biodiversity issues, with several sessions on lichens. Experts were recruited to teach on its events and courses. Funding ceases for this programme in November 2008.

The "Living Churchyard" project (National Agricultural Centre, Stoneleigh) also had a strong lichen component.

Skills base

12. *What are the numbers and ages of trained taxonomists working in UK universities and other organisations?*

See also Question 8. The table shows there are only 5 British professional salaried staff with at least a minimal lichen-taxonomic interest. All pursue lichen taxonomy part-time, along with a wider remit towards natural history, fungi, lower plants, etc. The senior NHM post is not active in lichen taxonomy, while the herbarium assistant post is vacant from February 2008, and has proved difficult to fill in the past. NHM also has three part-time unsalaried Research Associates in lichen taxonomy, all retired professionals. RBGE has one trainee in Conservation biology who is being trained in lichen identification.

Of professional non-taxonomic lichenologists, two regional museums have curators (Southend, Dundee) while only three Universities have such staff; the Nottingham lecturer is close to retirement while those at Bristol and Bradford have retired.

Organisation	*Staff*	*Remit*	*Trained taxonomist?*	*Age*
NHM	1 Snr Curator	Mineralogy/lichens	No	40+
	1 herbarium assistant	Lichens	?	post vacant
RBGE	1 curator	Ascomycetes/lichens	Yes	58
	1 trainee	Conservation Biology	No	30+
NMW	1 curator	Lower plants	Yes	40+
RBG Kew	1 curator	Fungi-Ascomycetes	Yes	40+
Leicestershire Museums	1 curator	Natural History	Yes	63

An emerging issue is the difficulty of finding suitably trained or experienced staff to fill Museum posts in Natural History. The issue has been highlighted several times by NatSCA (Natural Sciences Curators Association) and several posts are unfilled. There is a great problem with career prospects and progression. The profession is deemed unattractive by young graduates because few posts are available and the only career progression lies in moving out of systematics into administration or wider "Natural History" duties. There is a small number of lichen consultants (about 5), who do fieldwork and environmental assessments on a casual basis. These rely on Museum staff, collections and libraries for support, and were originally mentored by professional lichen taxonomists.

13. *What is the state of training and education in systematics and taxonomy? Are there any gaps in capacity? Is the number of taxonomists in post, and those that are being trained, sufficient to meet current and future needs across all taxonomic subject areas?*

Much of this was answered above. No training in lichen systematics or taxonomy apparently exists in British Universities or other colleges as part of a formal degree course. It is possible that a lecture on lichens may be given to students at some time in their career. Lichen taxonomy appears to be seen as irrelevant to the needs of modern biology compared with say, molecular studies. This contrasts markedly with the position 30–40 years ago when most Universities had Lichenologists, including schools of Lichenology at Oxford, Bristol, Aberdeen and four of the London colleges and others. Over the past 25 years only five PhDs have been awarded with a high lichen taxonomic component in the UK. Only two of these focussed on British lichen taxonomy and biodiversity, the rest concerned lichens world-wide. These were

1999 Univ. Liverpool, candidate a Thai resident, now deceased

1997 Univ. Sheffield, candidate moved to the USA to seek work

1986 Univ. London, Canadian candidate moved back to Canada

1991 Kew, candidate now works on fungi

1982 RBGE, candidate is curator of fungi and lichens

The only lichen systematic training given is by the BLS or the occasional course run by members locally to wildlife trusts, natural history groups, or some extra-mural courses run by University departments, principally Bristol and Leicester, using local experts as the trainers. Field courses have almost disappeared from University curricula.

ADDITIONAL POINTS NOT COVERED ELSEWHERE.

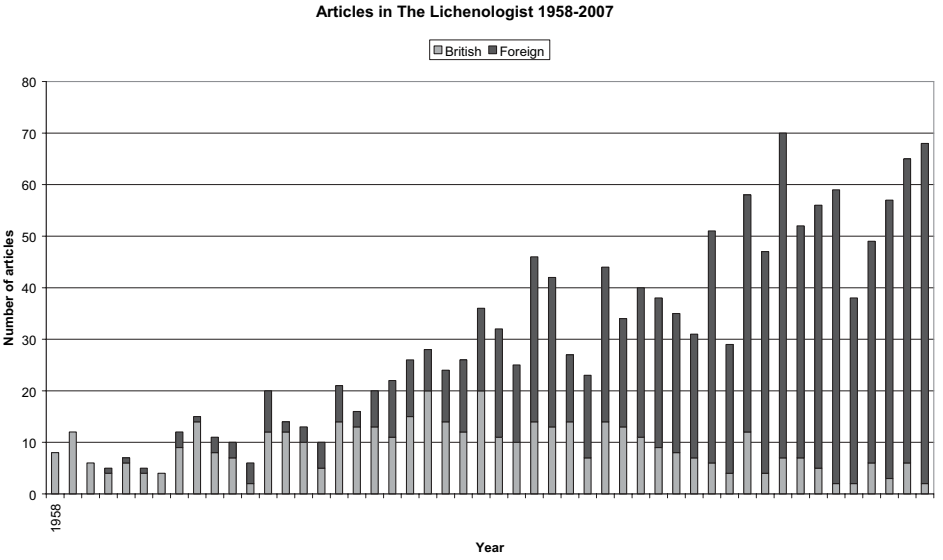
The chief problem lies in the very small and declining number of professionals and amateurs in lichens. They have almost disappeared from Universities and Museums.

If this situation persists, within five years the body of national lichen expertise will lie entirely within the amateur community, unsupported by any national organisations.

The priorities of relevant research need to be reconsidered. At the moment it appears that lichen research is missed out in favour of projects that are more attractive to grant-awarding bodies, more topical or fashionable, internationally competitive, etc. We are losing out on the fundamental basis of British biology that is—a knowledge of its species, where they live and how well they are doing.

An indication of how far British Lichen studies have deteriorated can be seen from an analysis of the titles occurring in *The Lichenologist* for the 50-year period 1958 to 2007. The table shows that while total submissions have increased 6-fold; those from British-based authors have declined dramatically. The British-based articles, occupying over 90 per cent of the early volumes now occupy less than 10 per cent of the total.

This low figure actually looks better than it is. Of the few British-based articles submitted in the past 10-15 years, most have been reports of field meetings, literature listings, editorials, etc., and not leading-edge research. British lichen research has been overtaken internationally.



4 February 2008

Memorandum submitted by the British Mycological Society

Background

The British Mycological Society is a learned society established in 1896, and a registered charity; it is the second largest society concerned with mycology in the world. The aim of the Society is to promote all aspects of the study of fungi, and it currently has a membership of 1246, including a wide range of professional and amateur mycologists. It publishes three scientific journals, the main one being *Mycological Research* (monthly; Impact Factor 1.86; and is the world's second most-highly cited journal in the field) and also has a symposium series.

Summary

Fungal systematics in the UK is in a worse state than at any time since the 1930s, and urgent action is needed if the needs of industry, medicine, agriculture, conservation, mycophagists, and amateur naturalists are to be met. The existing institutional structure needs to be re-examined, and, in view of a situation becoming increasingly critical through retirements, it is suggested that an interdepartmental committee be established to consider the issue as a matter of urgency. In particular it should consider the proposals made here for: (1) a decentralized National Mycological Institute be formed based on the existing national institutions; and (2) a specialist postgraduate training programme be established.

The state of systematics and taxonomy research

1[27]. Systematic and taxonomic work on fungi carried out in the UK is at its lowest point since at least the 1930s. There has been a marked decline in systematic posts and research in the UK over the last decade as a result of restructuring of institutions, vacated positions not being filled, and retirements. The number of full-time fungal (including lichen) research systematists in the UK (excluding curator positions and persons doing small numbers of identifications for amateurs or as part of site surveys) is currently only 10 (including 3 lichenologists) across all institutions and universities. There is only one fungal systematist in the entire UK university system now (and he is due to retire in the next year). These figures compare with at least 23 systematic research posts in mycology in 1997. The result is that little systematic work on fungi now takes place in the UK, and that the UK has ceased to be a major contributor to systematics research on fungi. A major

[27] Numbers of paragraphs reflect those used in the "Call for Evidence".

factor in this is the lack of recognition of mycology as a discipline independent from botany and microbiology, and a failure to recognize the huge amount of work required to place fungal systematics on a secure modern foundation.

2. Fungi are major component of biodiversity, with some 12,000 species (including lichen-forming species) recognized in the UK and additional discoveries being made continuously; species new to science are repeatedly being found, including conspicuous mushrooms as well as microscopic species. They also are: (1) valuable as indicators of climate change, as reflected in extended periods of mushroom-fruiting; (2) crucial but rarely appreciated components of global carbon cycles and budgets (as sources and sinks), where they are involved in the release of about ten times more carbon than all human activities; (3) essential to the well-being to existence of plants and numerous animals (invertebrates and vertebrates) with which they form mutualistic symbioses; and (4) practical bioindicators of air quality, habitat richness, and ecological continuity. Lichens in particular are used in SSSI site assessment and selection by the national conservation agencies. Important ecological work involving fungi in the UK is currently funded on an *ad hoc* basis, especially in relation to soil processes, mycorrhizas and air pollution, but is limited by inadequate systematic support.

3. There is currently no organized structure for systematic research on fungi in the UK. Institutions change policies and staffing without consultation and without the framework of a national programme. With respect to the major governmental institutions: (1) the former International Mycological Institute (now part of CABI Bioscience) now has only three systematists (two due to retire shortly), a figure reduced from 13 in the mid-1990s; (2) the Natural History Museum in London has none (from 4-5 in the 1980s-1990s); (3) the Royal Botanic Gardens 2 (from 3 in the late 1980s); (4) the Royal Botanic Garden Edinburgh still has two 2 (unchanged from the late 1980s but both are now lichenologists and there is no mushroom specialist); and (5) the National Museum of Wales, Cardiff has 1 (unchanged, and also a lichenologist). With respect to world standing, the UK has gone from being one of the foremost countries in the world on fungal systematics in the 1980s-1990s, where it had leaders dealing with fungi from mushrooms and microfungi to water moulds and lichens, to a minor player today. User needs are not being met in the UK at this time. There is little support from mycologists in post available for many aspects of applied science that involve fungi. Amongst the vital areas in need of an adequate level of fungal systematic support are: plant diseases, forest diseases, forest health (mycorrhizas), medical health, food safety, drug discovery, forensic science, prohibited substances (hallucinogenic mushrooms), biological weapons, ecosystem processes, conservation, and mushroom collectors and eaters (and their local organizations). The UK now lacks leading in-post specialists in the systematics of many groups of fungi of major economic importance, including *Aspergillus, Fusarium, Penicillium, Pythium,* and *Trichoderma,* as well as ones of medical importance as human pathogens.

4. A central service for fungal identification, backed by specialist systematists, is required. The UK has been a key world player in supply of existing taxonomic information on fungi through the databases and publications established by the former International Mycological Institute, and while some of these continue they are under-resourced and depend on 1-2 dedicated staff soon to retire. However, databases and web-based systems will not meet the needs of users alone. Specialist support is required to deal with the numerous novel taxa to science still being discovered and critical identifications. Specialist systematists are also needed to provide specialist training for those involved in government plant health, public health, and conservation services. Funding of mycology nationally could best be achieved by the establishment of a centrally managed and resourced, but decentralized, National Mycological Institute. This could be based on the existing institutions and collections, but with independent government funds and management. The Society estimates that such a national institute would require an annual staff and consumables budget of about £ 2.5 million to provide a centre with an adequate range of specialists.

5. Most countries in Europe still have strong fungal systematics research and teaching groups in the universities, many continuing traditional morphotaxonomy alongside or integrated with molecular phylogenetic approaches. Major museums generally have 2–3 fungal (including lichen) systematist and are centrally funded. The major world centre is now the Centraalbureau voor Schimmelcultures in Utrecht which is funded almost entirely by the Royal Academy of Sciences of The Netherlands and about 90 staff. In North America, the USDA support both the National Fungus Collection at its Beltsville site and the main US collection of living cultures at its Peoria laboratories (we understand that the American Type Culture Collection which depends on sales now has no fungal systematists). There used to be complementary appointments made between the Dutch collection and the International Mycological Institute, and that type of collaboration could perhaps be initiated again if a new centre were established in the UK.

6. Molecular systematics has revolutionized the understanding of the evolution of, and relationships between, different fungal groups, and classification systems have been radically revised as a result. Generic and species concepts have also been extensively revised, as molecular data has shown many not to comprise single biological entities, as previously assumed. Whole-genome comparisons can be expected to yield exciting new

data pin-pointing genes involved in key functional processes; about 40 fungi are now completely sequenced or scheduled to be in the next year. The major breakthroughs in fungal molecular phylogenetics have been achieved by international collaboration, especially through the NSF-supported Assembling the Fungal Tree of Life (AFTOL) initiative; the major output papers have 40-65 co-authors, including several based in the UK. However, molecular approaches cannot proceed without a high level of whole-organism systematic support. Without that collaboration and input, errors in interpretation and misidentifications abound and call the integrity of the work into question. It has been estimated that around 20-25 per cent of the fungal sequences in GenBank are based on wrongly identified material, and GenBank itself has representatives of not more than 15 per cent of all described fungus species; the comparison of sequences with those in GenBank alone is thus not an alternative to having material studied by a specialist. While welcoming the Consortium on the Barcoding of Life (COBOL) movement in endeavouring to obtain some sequence data from many more species, because of the huge knowledge gap with so many undescribed fungal species we do not see it as a panacea. Further, because of problems in identification, it is essential that there are public repositories for voucher specimens and cultures for material sequenced so that identifications can be checked and experiments repeated or built-on. At present, the living and dried reference collections in the UK are not sufficiently well-supported to perform this task. As a result UK researchers now often deposit vouchers in, or obtain strains to use from, overseas collections. Alternatively, they continue to hold strains in unsatisfactory conditions for long-term storage in their own laboratories.

Data collection, management, maintenance and dissemination

7. The former International Mycological Institute became the world reference point for systematic mycological information in the 1940s, and this has been continued by CABI Bioscience using electronic databases. The centre produces the *Index of Fungi* cataloguing all newly described fungi worldwide, and the *Index Fungorum* database which now covers around 425,000 scientific names of fungi. This database is available free on the worldwide web, and also now has links to original pages of some cited older publications. This is a world service, but has become inadequately resourced. It could be edited to a much higher standard with respect to information on currently accepted names and synonyms, which would make it even more valuable to users. The British Mycological Society is responsible for a national Fungal Records Database, which has inputs mainly from amateur mycologists, and which co-operates with the UK National Biodiversity Network (NBN). At present the data is predominantly of macrofungi and mainly input and maintained by volunteers. Because of potential problems with identifications, the records database has to be used with caution by conservation agencies and others. The British Lichen Society has an independent mapping scheme, not yet fully integrated with the NBN. Local recording and survey work on fungi in the UK is very patchy, mainly concerned with larger fungi and lichens, and almost entirely carried out by amateurs.

8. The combined collections of CABI Bioscience, the Natural History Museum London, and the Royal Botanic Gardens Kew constitute the largest specimen reference resource of fungi (including lichens) in the world, and also have the largest number of type collections. Together these collections have about 1.6 million specimens; data on those of CABI Bioscience are all digitized (ca 400,000 specimens) and current accessions and loans are now being databased at the other two centres. The collections at the Royal Botanic Garden Edinburgh are also of international importance, and there are extensive collections of national importance at the National Museum of Wales Cardiff and the Manchester Museum in particular. Small collections, mainly of lichens, are held in numerous provincial museums, many in need of curation, verification, and databasing. The London area collections are a part of the world's heritage and merit central funding accordingly, as do those in Edinburgh. Those in other museums are generally vouchers for regional and local records and publications. These regional and local collections need to be maintained and safeguarded so that they can be checked as taxonomic concepts change; this is very important when considering changes in distribution and fruiting patterns through time due to climate change, pollution, and other factors.

9. Little progress has been made in developing web-based taxonomies for fungi, except for major nomenclatural reference databases which are much in need of honing (see para 7 above). Some CDs have been prepared, mainly outside the UK, but are limited in taxonomic scope or geographical coverage. Numerous photographs of macrofungi and lichens are available on the web, but many are on the sites of amateurs and not always correctly named. Web-based systems based on monographic treatments are desirable and would empower and non-specialists to deal with many identifications themselves, but are not an alternative to having specialists as many groups of fungi are too poorly collected to enable comprehensive web-based systems to be constructed.

10. Quality of web-based systems requires a high levels of systematic knowledge from specialists with extensive field experience who collaborate with innovative computer specialists. Such systems also require extensive testing with non-specialists, something that has been a hallmark of the Field Studies Council's

AIDGAP scheme which we applaud. However, authoritative web-based systems and computerized keys are not currently been developed for any major groups of fungi in the UK.

11. Historically there has been a strong link between the professional fungal (and lichen) taxonomists at national institutions and amateurs, and many amateurs are extremely skilled and produce important taxonomic papers. However, the amateurs need the support of professional systematists, major reference collections, and specialist libraries in order to make scientific contributions. Increasingly, UK "amateurs" are collaborating with molecular systematists outside the UK and preparing joint publications with them as they are unable to obtain appropriate support from UK institutions and universities. The national institutions have also produced the monographs (eg the multivolume British Fungus Flora from the Royal Botanic Garden Edinburgh, British Truffles and Basidiomycete Checklist from the Royal Botanic Gardens Kew) which are the syntheses of taxonomic work. Their staff have also been involved in preparing field guides on which amateur naturalists and mushroom-eaters depend. In addition, the national institutions formerly provided tutors for courses run by the Field Studies Council and similar bodies, as well as specialist workshops for more experienced amateurs and also field excursions. With so much interest in collecting fungi for food authoritative identification guides and hands-on training in identification are essential to minimize poisonings, but the specialists formerly able to undertake such outreach studies have not been replaced as they have retired and so fewer such courses are now run.

Skills base

12. The number of systematic mycologists in the UK, 10, is at its lowest level since the 1930s and only one of those is employed in a university (see para 1).

13. There is now almost no teaching of systematic mycology at any university in the UK, and we are not aware of any substantial courses devoted to the subject in biology or microbiology departments. This means that graduates are being produced in these subject areas which lack even basic knowledge on fungi and how to identify them that are needed to support careers in many applied aspects of science, including plant pathology, food safety, pharmaceuticals, and human health. In addition, there are no longer any formal postgraduate courses devoted entirely to fungal systematics run in the UK. Further, the last two PhDs in fungal systematics by UK nationals were completed in 1995 and 1998, and both of those mycologists subsequently took up permanent posts in the USA. The former International Mycological Institute used to make a major contribution to the MSc in Pure and Applied Plant (and Fungal) Taxonomy run at the University of Reading and the MSc in Fungal Biotechnology at the University of Kent; these mainly attracted overseas students, some of whom went on to obtain PhDs co-supervised by Institute staff, but these students returned home and the former arrangements ended in the late 1990s. In the absence of postgraduate training programmes, where vacancies have arisen for fungal systematists in the UK the positions have invariably either been filled temporarily by mycologists from other countries who have subsequently returned to their own countries, or the posts have remained unfilled (eg the Royal Botanic Gardens Kew has twice failed to fill an advertised position for a much-needed specialist on larger fungi). The lack of trained fungal systematists also means that there is no national pool from which pharmaceutical industry, plant health, food safety, and medical centres can recruit mycologists with high skill levels. In addition there are no UK PhD-level mycologists available to compete for more general systematic positions that arise in universities. In order to rectify the present situation, consideration might be given to: (1) financing a new MSc in Pure and Applied Fungal Systematics to be taught by current institution-based and retired specialists; and (2) funding promising graduate students to work with experienced mycologists so that the expertise could be passed on (this was highly successful in the NSF-supported PEER programme in the USA).

[14]. In view of the critical nature of the current situation as a result of recent and impending retirements and restructurings, the Society considers that it would not be inappropriate for an inter-departmental committee to be established to consider the special situation in mycology and the particular proposals made herein.

Memorandum submitted by The British Phycological Society

0.1 The British Phycological Society is the professional body in the UK which promotes the study of algae. It has a worldwide membership of professional phycologists and people who use algae in their work, including researchers, governmental and non-governmental environmental consultants and industrialists.

0.2 Algae are phylogenetically heterogeneous, comprising all those photosynthetic organisms that lack vascular tissue and cuticles. The evolutionary mechanisms and pathways by which they have evolved are still controversial, and hence the subject of intense research (especially in the USA, Japan and Germany), after an earlier phase of research using ultrastructural evidence in which the UK played a leading role. Algae contribute almost half of the annual global net fixation of CO_2 and play a predominant role in the

biogeochemical cycling of silicon. They are also ecologically important as the basis of most aquatic food webs, in controlling nutrient fluxes in freshwater and marine ecosystems, and in stabilizing near-shore sediments. Some seaweeds are important foodstuffs and sources of pharmaceuticals and food additives, and have potential use as treatments for human ailments such as cancer and high cholesterol. Microalgae are increasingly being assessed for their potential to produce biodiesel and other biotech products. Some microalgae have resistant exoskeletons with species-specific morphology, which has led to their adoption as indicator organisms for stratigraphy, ecological monitoring (eg for the Water Framework Directive), and studies of long-term environmental change, including climate change. The species-level diversity of algae is still poorly known and documented, except in the larger seaweeds, and detection of biogeographical patterns is compromised by an inadequate species concept and lack of validated records. Few authoritative identification texts exist, and web-based taxonomies are at very early stages of development, though they have immense potential because morphology is difficult to describe verbally and identification is greatly facilitated by good photographs and drawings.

1. *What is the state of systematic research in the UK?*

1.1 Algal taxonomists in the UK are highly active and in demand but increasingly ageing. Numbers in full-time employment have declined markedly over the last 20 years. Evidence of the decline of algal taxonomists in post is shown in Table 1. Taxonomic research in macroalgae for the UK is concentrated at The Natural History Museum (NHM) and Queen's University, Belfast. Other expertise is primarily made up of retired individuals or a few who are consultants. Microalgal taxonomic research is concentrated at the NHM and Royal Botanic Garden Edinburgh (RBGE) and is mostly focused on diatoms, reflecting their high species diversity. When algal taxonomists have retired in the last 10–20 years, they have not been replaced except for one marine algal specialist at the NHM. One systematist has been recruited by the Dunstaffnage Marine Laboratory, but as a culture technician, not as a taxonomist. Apart from the diatomists, there will be no-one in a research post left working on any freshwater algae after spring 2008.

1.2 The current research barriers in taxonomic phycology largely relate to the lack of specialist individuals who can be called upon and the difficulty of obtaining funding for pure taxonomy from the main research bodies such as NERC. The onus of consultation (eg the latest call for input into the Changes in the Wildlife and Countryside Act 1981, Schedule 9 relating to the sale of non-native species) falls upon the same few individuals and this can be costly in terms of time.

2. *What is the role of systematics?*

2.1 A major role of algal systematics is species discovery, identification and understanding relationships, which has changed radically for many groups since the application of molecular tools c. 10–20 years ago. Even in the UK where algae have been studied for over 250 years, we are still discovering and describing new species; with the number still undocumented probably in the thousands, judging by recent molecular studies of model species complexes.

2.2 The UK has a strong user group for algal taxonomic information/data. Users include Natural England, Scottish Natural Heritage, Countryside Council for Wales, Environment Agency, Scottish Environment Protection Agency, Environment and Heritage Service, Marine Biological Association, Freshwater Biological Association, Centre for Ecology and Hydrology, Field Studies Council, consultancies and researchers in universities who use algae for their work. There are a number of individuals within these organizations who have very good identification skills and there is a synergy between these users and the algal researchers, which the British Phycological Society actively seeks to promote through its own meetings and other activities.

2.3 Algal taxonomy makes a major contribution to biodiversity, conservation and to personnel working in water industries such as the Environment Industry. For example:

2.4 (i) Algal taxonomists have actively responded to the UK Plant Diversity Challenge (the UK's response to the CBD's Global Strategy for Plant Conservation) in the production of "Important Plant Areas for algae" in 2007. The internationally agreed criteria on which the work is based, assume a comprehensive knowledge of species and diversity within a given geographical area. Of the five authors of this report (3 marine and 2 freshwater), only one is in a taxonomic post, three are retired and one, who trained as a phycologist, is a consultant specializing in newts, dormice and barn owls.

2.5 (ii) Algal taxonomists have initiated the development of identification tools required for the European Water Framework Directive (WFD). Here, a new flora, "Green seaweed of Britain and Ireland" was published in 2007. Given that the UK did not have algal taxonomists with all the specialist expertise necessary, the

project was achieved by bringing together an international team. Of the fifteen authors, only three had full-time employment in Britain (including one of the authors of the "Important Plant Areas for algae" doc), and one retired. The other authors were based in Denmark, USA, Belgium, Ireland, The Netherlands and Finland. Apart from Denmark, the overseas authors were between 10 and 20 years younger than those in post in the UK. There was no direct funding for staff time for this project but the production of the book was sponsored by the Scottish Natural Heritage, Environment Agency, Scottish Environment Protection Agency, Environment and Heritage Service, Marine Biological Association and the British Phycological Society.

2.6 (iii) By actively writing the "Freshwater Algal Flora of the British Isles", another identification tool required for the WFD was produced. This identification guide to freshwater and terrestrial algae, published in 2002, was compiled by twenty-six authors. As with the new green seaweed flora (2.5 ii), it was necessary to assemble a team of international scientists since so few algal specialists are in post in the UK. Sixteen were from the UK, but of this number eight are retired and two work for consultancies. The rest were from Denmark, Switzerland, Canada, USA, Ukraine and Poland and most are over 50 + or retired. Any direct funding only covered expenses, although NERC provided funds to cover the preparation of illustrations. The book was sponsored by English Nature, Scottish Natural Heritage, Countryside Council for Wales, Northumbrian Water, Freshwater Biological Association, The Systematics Association, The Linnean Society, Environment Agency, NERC and the British Phycological Society.

2.7 (iv) The WFD also uses benthic diatoms as one estimator of environmental health. Collaboration between an independent environmental consultant, university ecologists and institutional taxonomists provides regular checks on the quality of identifications by the environment agencies, and a first version of an expert key on CD-ROM was completed in 2006.

2.8 (v) The WFD also requires identification of other algae (including freshwater macrophytes) to assess "good" ecological status. Collaboration between Durham University and the NHM resulted in two multi-access expert keys on CD-Rom with the project completed in 2002. The project was funded by the Environment Agency and the key is also on-line and available to all staff of the Agency.

2.9 (vi) Input into the UKBAP process. Algal taxonomists have played an active role in identifying UKBAP algal species and in the consultation process.

6. *What impact have development in DNA sequencing, genomics and other technologies had on systematic research?*

6.1 DNA sequencing has had a profound impact on systematic and taxonomic research for the algae. It is normal now for molecular data to be a part of algal taxonomy and systematics. DNA bar-coding initiatives are underway in the UK for some algal groups but progress is slow given the lack of manpower and difficulty in obtaining funding. The UK currently leads the world with respect to diatom bar-coding, but this pre-eminence is unlikely to be maintained without targeted new funding opportunities. Although DNA sequencing studies have lead to a fundamental re-organization at some of the higher taxonomic levels, at the species level the taxonomy they have had little impact at lower levels for most groups of microalgae. The taxonomy of most microalgae is still based on descriptive taxonomy with molecular studies largely confined to those few to be found in culture collections.

7. *What is the state of local and national recording schemes?*

7.1 It is possible to submit algal records at both the national and local level through several different routes, including NBN, MarLIN, CEH, Mermaid and other provincial biological records centres. However, none of these is dedicated strictly to algae, nor are they using a standardized species list, except in the case of JNCC's Recorder 2000 which uses "A Coded List of Freshwater Algae of the British Isles" compiled in 1998 by staff at the NHM, Durham University and the Freshwater Biological association (all now retired). The list was up-dated in 2005 by a retired member of staff at the NHM. Any standard list requires up-dating from time to time by experienced taxonomists.

7.2 Quality assurance of identifications is extremely limited or non-existent. The Council of the British Phycological Society via its Biodiversity and Conservation Committee, is in the process of developing a recoding scheme for the algae which will have a panel of specialists for identification verification. The anticipated panel will include: UK: 2 in post (NHM and Queen's), 5 retired, Overseas: 3 in post. These records apply mostly to macroalgae.

7.3 For microalgae, there are long time-series records for marine phytoplankton, eg from the Continuous Plankton Recorder, and detailed records of freshwater phytoplankton are available for some lakes in the English Lake District. However, interpretation of these and other old records is becoming increasingly difficult because of changes in taxonomy made necessary by molecular evidence; voucher material is rarely available, except for diatoms.

11. *How does the taxonomic community engage with the non-taxonomic community?*

11.1 Unlike societies such as the BSBI, the British Phycological Society does not have an amateur following. Engagement with the non-taxonomic community is down to individuals. This is strong in the south-east of England, but only because of one retired individual. Any engagement usually comes about through field excursions or short courses designed to suit the needs the professional scientists as well as the amateur. These courses are run on a regular basis by retired and in-post algal taxonomists (see also 13.2).

Skills base

12. *What are the number and ages of trained taxonomists working in UK universities and other organizations?*

12.1 The number and ages of trained taxonomists working in UK universities and other organizations are given in Table 1.

13. *What is the state of training and education in systematics and taxonomy?*

13.1 The small number of algal taxonomists in posts, most of who are not in the university sector and therefore not regularly teaching, by default limits the amount of training and education that can be provided by specialists. This is compounded by the lack of jobs in algal taxonomy in the UK. It is a high risk strategy to train research students in algal taxonomy and has to be done on the basis that they will have transferable skills in order for them to find employment once they have qualified. This is further compounded by the lack of funding.

13.2 The only training in algal taxonomy is through courses organized and run by retired and in-post algal taxonomists. These courses have come about in response to a recognized need. There are three, well-established freshwater algal identification courses of 5–7 days duration each year, one of which has been running for 16 years and another for 13 years. They are run by three retired and one in-post taxonomist. There are two seaweed identification courses, 3–5 days duration per year, one in England and the other in Scotland geared to research students, research workers and staff in conservation agencies and environmental consultancies.

13.3 The gap in capacity is noted in 1.1 for freshwater algae. Given than the majority of algal taxonomists in posts are now over 50, there will be a gap in capacity in the UK sector in the next 5–10 years in almost all algal groups unless there is considerable investment in training and algal taxonomic posts or reliance of recruiting from overseas.

Table 1

THE NUMBER OF ALGAL RESEARCH TAXONOMISTS IN THE UK: CURRENT AND 10–20 YEARS AGO

University/other institution	*Number of current research taxonomists*	*Age*	*Number of taxonomists: 10-20 years ago*
Dunstaffnage Marine Laboratory	1	40+	0
Freshwater Biological Association	2 retired	60+, 90+	2
Heriot Watt University	1	60+	1
King's College London	0	n/a	1
London University (North London Poly)	0	n/a	1
NHM	4.8 in post, 4 retired	40-80+	11 in post, 2 retired
RBGE	2	55+	3
Royal Holloway, University of London	0	n/a	1

University/other institution	*Number of current research taxonomists*	*Age*	*Number of taxonomists: 10-20 years ago*
Queen's University Belfast	1	50+	1
Plymouth Marine Lab	1 retired	75+	2
Portsmouth University	0 in post, 3 retired	60-75	4
Scottish Marine Biological Association	0	n/a	1
University College London	2	40+-55+	2
University of Birmingham	1 retired	65+	1
University of Bristol	1 retired	80+	3
University of Buckingham	0	n/a	1
University of Dundee	1	60+	1
University of Durham	1 retired	70+	1
University of Glasgow	0	n/a	1
University of Leeds	0	n/a	1
University of Liverpool	0	n/a	3
University of Plymouth	1	45+	0
University of Wales, Bangor	0	n/a	2
University of Westminster	1	50+	1
Independent professional	2 retired	70+	2
Non-professional	1 retired	70+	5

4 February 2008

Memorandum submitted by BugLife

1. *What is the state of systematics research and taxonomy in the UK? What are the current research priorities? What are the barriers, if any, to delivering these priorities?*

There has been little progress in addressing the issues raised in the previous inquiry. There is a strong perception of continued erosion in the number and expertise levels of professional taxonomists employed by museums and universities and a continued reduction in the availability of professional taxonomic expertise in the UK. Museum based experts are expected to work on projects undertaken as contracts by their institutes. As a result they are less able to support largely unfunded taxonomic work in the UK. In effect this results in government resources directed into UK taxonomy and systematics being diverted to subsidies a semi-commercial operation. At the same time more museums are charging the public and volunteer experts for providing opinions on the identification of specimens. This is reducing the access that the public has to the UK's taxonomy resource. Much of the work in this field is undertaken in the voluntary sector: the main pool of expertise remains among professionals whose taxonomic studies are a hobby and amateurs who record and identify species in their spare time. More needs to be done to harness this energy and expertise more efficiently.

2. *What is the role of systematics and taxonomy and, in particular, in what way do they contribute to research areas such as biodiversity conservation, ecosystem services and climate change? How important is this contribution and how is it recognised in the funding process? How is systematics integrated in other areas of research?*

Systematics and taxonomy are the foundation of our knowledge of the diversity of invertebrates around us. Current biodiversity action relies on sound species identifications. Where the identification, status and requirements of a species have not been defined it is impossible to set conservation priorities.

Understanding how life on earth will respond to climate change and how we will need to interact with these changes so as to minimise the damage to biodiversity is dependent on taxonomic expertise and is critical to our future health and wellbeing.

The understanding of agricultural ecosystems is essential to developing cost effective and environmentally benign farming practices. Parasitic wasps are very important tools for controlling populations of pests. There are so few taxonomists left in Europe that it is not proving possible for researchers to accurately name the species they are studying. Hence, one group studying the use of parasitic hymenoptera for pest control is unable to compare results with other studies as they are unable to determine if they are investigating the same species.

3. *Does the way in which systematics research is organised and co-coordinated best meet the needs of the user community? What progress has been made in setting up a body to lead on this? What contribution do the leading systematics research institutions make both nationally and internationally?*

No comment.

4. *What level of funding would be needed to meet the need for taxonomic information now and in the future? Who should be providing this funding?*

Targeted funding is required to build up taxonomic expertise in museums and universities and to ensure that more people are trained in the identification of invertebrate species.

The benefits of taxonomic expertise are accrued broadly across the populace in terms of a healthier environment, ecosystem services, improved agricultural practices and medicinal benefits. At the same time there is little commercial imperative to undertake this service, hence it is appropriate that this is funded from the public purse.

5. *How does funding in other countries compare? Could there be more international collaboration? If so, what form should this collaboration take and how might it be achieved?*

No comment.

6. *What impact have developments in DNA sequencing, genomics and other new technologies had on systematics research? In what way has systematics embraced new technologies and how can these research areas interact successfully and efficiently?*

Developments in DNA sequencing, genomics and other new technologies play an important role in unraveling complex groups of species. It is however difficult for amateurs and those undertaking research on a voluntary basis to engage with these new technologies.

Data collection, management, maintenance and dissemination

7. *Does the way in which taxonomic data is collected, managed and maintained best meet the needs of the user community? What is the state of local and national recording schemes?*

Local and national recording schemes for invertebrates play a vital role in collecting, interpreting and mobilising biological data. With the exception of the more popular groups such as butterflies and dragonflies, these schemes exist solely through the voluntary effort of enthusiastic individuals. There is an urgent need for adequate funding and resources to be targeted at the support of local biological record centres and national recording schemes and societies.

8. *What is the role of the major regional museums and collections? How are taxonomic collections curated and funded?*

Museums act as important archives of taxonomic information. Voucher specimens are particularly important for invertebrates and it is essential that museums are able to accept newly collected material and to curate this effectively so that it is maintained as an increasingly valuable resource.

9. *What progress has been made in developing a web-based taxonomy? How do such initiatives fit in with meeting demand for systematics and taxonomy information? How do UK-led initiatives fit in with international initiatives and is there sufficient collaboration?*

Limited progress has been made towards a web-based taxonomy. Many groups of invertebrates are inadequately covered by traditional keys, or the available keys are out-dated or difficult to use. User-friendly keys are appearing, but progress is slow and heavily reliant on volunteer specialists. Before significant progress can be made with web-based taxonomy it will be necessary to develop traditional keys for many of the less well known groups.

10. *What needs to be done to ensure that web-based taxonomy information is of high quality, reliable and user-friendly?*

To ensure that web-based taxonomy is user-friendly it is essential that users of all abilities and experience are involved in its development and testing and that there are sufficient taxonomic experts involved to provide an authoritative tool. There is also a need to ensure that such initiatives are funded in the long term, otherwise there is a risk that they will become outdated.

11. *How does the taxonomic community engage with the non-taxonomic community? What role do field studies play?*

Engagement with the non-taxonomic community is critically important and field studies play a major role in this. The ESRC funded "Amateurs as Experts" project looked at collaborations such as the anglers' monitoring initiative and found that there is no single way of working with the variety of Britain's amateur expert naturalists. In particular there is a lack of professional mentoring for amateur naturalists. Without such mentoring it may be difficult, if not impossible for an amateur to progress their taxonomic knowledge.

Experienced naturalists are a unique and valuable resource with a long history in British society. There needs to be more explicit recognition that these naturalists are often the drivers of biodiversity conservation work.

Skills base

12. *What are the numbers and ages of trained taxonomists working in UK universities and other organisations?*

Professional expertise in universities and other organisations appears to have continued to decline severely over recent decades. Systematic biology is virtually dead because funding is very poor or non-existent and career opportunities are few. Figures, particularly for universities, are difficult to define as research staff have not historically been categorised according to their taxonomic skills.

We would draw attention specifically to the taxonomy of parasitic hymenoptera, mites and nematodes. The animals may be small, but in each group there are thousands of species and they occur throughout the UK in every ecosystem. Yet our taxonomic knowledge is so low that we do not even have an estimate of how many species of mite or nematode occur in the UK. There have been more general taxonomists on these groups employed in the past, but now all the work seems to be focused on pest groups and there is very little work on cataloguing the extensive wild faunas.

13. *What is the state of training and education in systematics and taxonomy? Are there any gaps in capacity? Is the number of taxonomists in post, and those that are being trained, sufficient to meet current and future needs across all taxonomic subject areas?*

Though biodiversity is recognised in a growing number of university environmental courses, the need for sound taxonomic experience is hardly acknowledged and amateurs continue to represent the main core of taxonomic expertise. The education system fails to provide the skills in taxonomy that conservation bodies and voluntary organisations require. This deficiency means that for us as a conservation charity, and others in the sector, it is very difficult to recruit staff and volunteers with the necessary skills in identification and species level ecology. It is increasing difficult to find the opportunity for in-house training for the development of taxonomic skills and voluntary organisations are faced with having to pick up the costs for taxonomic training.

Memorandum submitted by CABI (CAB International)[28]

1. *What is the state of systematics research and taxonomy in the UK? What are the current research priorities? What are the barriers, if any, to delivering these priorities?*

Systematic mycological activity has continued to decline in the UK since the previous House of Lords report. The number of fungal (and lichenological) systematists in UK universities is now almost zero, staff have not been replaced in Government institutions, and CABI's capacity has suffered a further substantial reduction. Printed systematic research output has declined significantly, and most papers from UK sources now come from retired staff and knowledgeable amateurs. Without active intervention, it is likely that fungal systematics will be effectively extinct in the UK within ten years.

2. *What is the role of systematics and taxonomy and, in particular, in what way do they contribute to research areas such as biodiversity conservation, ecosystem services and climate change? How important is this contribution and how is it recognised in the funding process? How is systematics integrated in other areas of research?*

Fungi play critical roles in ecosystem services (especially carbon cycling) and plant health (mycorrhizas, endophytes, pathogens), and are likely to play a major role in buffering ecosystems against climate change. There does seem to be an "out of sight, out of mind" approach to funding; fungi are considered to be "difficult" to work with as they are mostly hidden in soil etc.; this would argue for higher levels of funding to compensate for the technical challenges. Fungi are also key organisms in applied areas such as plant and animal health, trade, pharmaceuticals, industrial enzymes etc.—this questionnaire seems to ignore the fact that systematics plays a very significant role in human development as well as natural ecosystems.

3. *Does the way in which systematics research is organised and co-ordinated best meet the needs of the user community? What progress has been made in setting up a body to lead on this? What contribution do the leading systematics research institutions make both nationally and internationally?*

In mycological terms, coordination is hardly relevant as there are few specialist staff to coordinate. On a wider scale, initiatives in the past (eg the UK Systematics Forum) had rather limited value, and organizations such as the Linnean Society and Institute for Biology perform some of these roles. Assuming funding is not unlimited, funds should be concentrated on institutions actually performing the work rather than setting up coordination bodies.

4. *What level of funding would be needed to meet the need for taxonomic information now and in the future? Who should be providing this funding?*

Information is currently provided largely by the private sector through subscriptions to journals, sale of books etc, but the internet is very rapidly gaining ground especially in databases of names, distributions etc. There is a widespread, somewhat naive feeling amongst the taxonomic community (and some consumers) that all taxonomic information should be free to the end user. However, public sector organizations do not have the resources to achieve this and the private sector needs to recover their costs.

5. *How does funding in other countries compare? Could there be more international collaboration? If so, what form should this collaboration take and how might it be achieved?*

Systematic mycology is well funded in some European countries, but in general the level of support is poor and declining. The USA has benefited from substantial investment in taxonomy recently through the National Science Foundation; our own collaboration with these initiatives has been very restricted as funding has not been open to us. CABI has a worldwide remit to provide support (mostly financed by third parties such as the Darwin Initiative) to systematics research with a focus on developing countries, and has worked productively with organizations such as BioNET-International to build capacity in countries poor in financial resources. The support that UK taxonomic institutions provide to less-developed nations is substantial, and deserves emphasis in this review.

[28] CABI (CAB International) was formerly the Commonwealth Agricultural Bureaux. It is an intergovernmental not-for-profit organisation with centres in ten locations worldwide and with headquarters in the UK, with a major research portfolio in applied biological sciences for sustainable agriculture and environmental safety. Its origins nearly 100 years ago were as a agricultural pest identification and information service, funded by a consortium of countries of the then British Empire. CABI's remaining taxonomic capacity is focused on mycology, so this response comes from that perspective.

6. *What impact have developments in DNA sequencing, genomics and other new technologies had on systematics research? In what way has systematics embraced new technologies and how can these research areas interact successfully and efficiently?*

Sequencing has revolutionized systematic mycology and our understanding of it in the last 5–10 years; the contribution of the UK has been minimal and has led to a substantial reduction in international influence by our nation. However, there is insufficient effort in the integration of morphological and molecular classifications, leading to duplication of effort and the risk of 250 years of research being abandoned. This is a particularly important issue in the naming of species and organism groups; taxa are interpreted in different ways leading to widespread confusion. In the long term, molecular systematics will completely supplant morphological systems; at present the UK is doing little or nothing to prepare for this event.

Data collection, management, maintenance and dissemination

7. *Does the way in which taxonomic data is collected, managed and maintained best meet the needs of the user community? What is the state of local and national recording schemes?*

Generally yes, with the support of the National Biodiversity Network and international initiatives such as the Global Biodiversity Information Facility. However, most recording schemes operate through volunteer activity, often associated with Learned Societies for some of which the majority of their income is derived from publications via traditional publishers. The push for open/free access to all new scientific knowledge (eg the recent change in US law to mandate this for all publically funded research) threatens this model and thus will precipitate a decline in the income for these organizations and their ability to fund data collection and management. More coordination (as well as financial support) would be beneficial. Government institutions should have the resources to play a more active role in support of these activities.

8. *What is the role of the major regional museums and collections? How are taxonomic collections curated and funded?*

CABI has one of the five most important dried fungus collections (fungal "herbaria") on a global scale, and also houses the UK national fungus culture collection. Both collections are functionally digitized with key information available on-line at no cost. CABI receives no external funding for this, and cannot continue to support UK (and global) mycology in this way indefinitely. CABI is currently in negotiations with RBG Kew to transfer the dried collections to Kew and is seeking funds from Defra to support this action, and to find financial support for the living (culture) collection through joint screening initiatives.

9. *What progress has been made in developing a web-based taxonomy? How do such initiatives fit in with meeting demand for systematics and taxonomy information? How do UK-led initiatives fit in with international initiatives and is there sufficient collaboration?*

Web-based taxonomy is not fundamentally different from traditional taxonomy, it simply provides a more efficient system of data management, analysis and delivery. CABI provides substantial amounts of taxonomic opinion free on the internet, but cannot do this indefinitely without some form of income stream to pay for its generation and, perhaps more importantly, maintenance. CABI is a founding member of the UK based, but of global extent (approx. 50 collaborators), Species 2000 which, in collaboration with the North American (Canada, Mexico, USA) based ITIS, produces the Catalogue of Life (currently at version 8). The CoL is used by many global initiatives and organization not least of which are GBIF, Encyclopaedia of Life, IUCN, FAO. However, funding for this activity is not secure for the medium and long term future.

10. *What needs to be done to ensure that web-based taxonomy information is of high quality, reliable and user-friendly?*

Using a combination of "community" software and tools, Web 2 technology, automated data rankings and top level custodianship/validation will ensure high quality, reliable and user-friendly (at many levels) taxonomic information (see also 9 above). Following on from this, a national web-based identification system is technically feasible, but cannot be delivered without national coordination and financial support. This is particularly important as existing systems are often developed by amateurs without sufficient taxonomic knowledge to ensure that their images etc. are correctly identified, or perhaps worse still, by high profile data-harvesting portals which rapidly become out-of-date.

11. *How does the taxonomic community engage with the non-taxonomic community? What role do field studies play?*

SKILLS BASE

12. What are the numbers and ages of trained taxonomists working in UK universities and other organisations?

We are not aware of any specialist systematic mycologists in the UK University system. Government institutions employ a small number, but almost all are nearing retirement age, and recent practice seems to have been not to replace systematics specialists in mycology. CABI currently employs four systematics staff but all are nearing retirement and will not be replaced (see below).

13. *What is the state of training and education in systematics and taxonomy? Are there any gaps in capacity? Is the number of taxonomists in post, and those that are being trained, sufficient to meet current and future needs across all taxonomic subject areas?*

CABI receives three per cent of its income (roughly £600,000 per annum) from member government contributions, with the United Kingdom contributing around one third of this sum. These funds are to support the running costs of the organization as a whole, which has a much wider remit than systematic research (see www.cabi.org). Until recently the UK funds were provided by Defra (and perhaps could therefore be implicitly construed to support systematics) but are now the responsibility of DfID, so priorities for spending are likely to move even further away from taxonomic support towards development projects. Member country income has declined substantially since 1992, when 11 per cent (£1.7 million per annum) was provided by government contributions (the United Kingdom provided £584,000). In the last 15 years CABI has drastically reduced the number of PhD grade taxonomists in its employ (see table below), and decided to prioritise research in fungi (mycology), in part because of the paucity of fungi specialists elsewhere and the shortage of taxonomic data on fungi. However, even in this priority area the number of taxonomists has been reduced by 80 per cent since 1992. Furthermore, the taxonomic activity of the mycologists is increasingly general with more time devoted to income-generating rather than basic taxonomic activities. CABI is now planning to divest itself of specialist in-house systematics expertise completely through transfer of its remaining taxonomists to RBG Kew, and to buy in specialist services when required.

Taxonomists employed by CAB International 1992–2008

	1992	*2002*	*2008*	*2011 (projected)*
Bacteriology	1	0	0	0
Entomology/arachnology	12	0	0	0
Mycology	15	7	3	0
Nematology/parasitology	6	1	1	0

4 February 2008

Memorandum submitted by the Centre for Plant Diversity and Systematics at the University of Reading

Questions 13 and 14: *The Skills Base*

We answer Questions 13 and 14 first, as these apply directly to the training role of the Centre for Plant Diversity & Systematics at the University of Reading. We follow this with our evidence under questions 1—12.

Question 13: *The State of Training*

The Centre for Plant Diversity and Systematics in the School of Biological Sciences at the University of Reading provides a "full service" university training and research centre, focused on plant taxonomy and systematics. We pride ourselves on training students who "know their plants" and become proficient in nomenclature, taxonomic description and field and herbarium collections practice, alongside the modern developments in molecular systematics and biodiversity informatics. The Centre includes the Reading Herbarium and the Species 2000 Catalogue of Life programme secretariat, as well as use of the adjacent Botanic Garden (Harris Garden) and the School of Biological Sciences glasshouses and experimental grounds.

Training is carried out through i) a successful and well-established Plant Diversity MSc course with its Taxonomy Stream, ii) an extensive PhD Programme and iii) a Molecular Systematics Short Course. At Reading there continues to be a strong taxonomic and systematics thread within the BSc courses in Botany, Zoology and Biological Sciences. There is a close institutional link with RBG Kew and NHM, as well as an informal relationships with the Royal Horticultural Society (RHS), Carter Ecological Consultancy, the Eden Project, and Cardiff University (Computer Science). Some staff from these organisations contribute to the MSc and Short Courses and to PhD supervision. The RHS and Carter Ecological provide sponsorship for one bursary and one part-lectureship. Our alumni make a significant contribution to the workforce now employed at the national institutions and in UK ecological consultancies (as well as in recent times training the directors of RBG Kew, RBG Edinburgh and of Botany at the RHS). Alumni also occupy prominent positions in herbaria and botanic gardens around the world. Flagship research programmes have included *Flora Europaea* (1959—1993), *Flowering Plants of the World* (1975—1978, 2005—2007), the *UNEP Global Biodiversity Assessment* (1993—1995) and *Species 2000 Catalogue of Life* (1997—current). NHM, RBG Kew, CABI and Cardiff University (Computer Science) are major partners in the Species 2000 Catalogue of Life programme. However, over the last 10 years there has been a reduction in taxonomic scope—we no longer employ a full-time taxonomic mycologist or bryologist, both areas in which we were highly reputed.

Only a few years ago there would have been nothing exceptional about the existence and scale of this university centre. In the current climate, however, we should be clear that this Reading University Centre is itself highly unusual in the UK and a rarity to be cherished. However it also appears that if it were not for the major international success of the Species 2000 Catalogue of Life programme it could be difficult for it to continue to flourish and meet its goals. It is fortunate that there has been research income of several million pounds in biodiversity informatics, Species 2000 Catalogue of Life and other high-profile areas alongside taxonomy. It is against this background that the evidence given below focuses on two issues:

(i) public interest in a range of biodiversity issues is such that it now expects and needs quality taxonomic coverage (albeit at various levels), not only for all known UK biota, but also for all known global biota. How will this be delivered by the UK and the international workforce?

(ii) for such a target to be met, even accepting a two-speed taxonomy with not all taxa fully described, there is a need to expand the workforce and to discipline production-scale taxonomic coverage, with monographic and floristic treatments and the related enhancement of taxon databases. How can national planning and resourcing ensure that university centres, such as that at Reading, both continue and expand so as to be able to train this enlarged workforce?

Question 14: *The Numbers and Ages of Trained Taxonomists.*

The number and ages of taxonomists currently working at the Reading University Centre is as follows:

Age class	* *Taxonomists*	+ *Emeritus Taxonomists*	~ *Associated Systematists*	*Total*
25—35	2	-	0	2
35—45	3	-	4	7
45—55	1	-	5	6
55—65	2	-	2	4
65	-	5	-	5
Total	8 (5 permanent posts)	5	11 (8 permanent posts)	24

* Taxonomists: Taxonomists, qualified, employed full time at the Centre for Plant Diversity & Systematics (CPDS) within the School of Biological Sciences at University of Reading (includes Herbarium, and Species 2000 Secretariat).

+ Emeritus Taxonomists: Taxonomists, qualified, presently active in research and teaching, employed part-time at CPDS Reading.

~ Associated Systematists: qualified, employed full time in the wider School of Biological Sciences (in germplasm diversity, phylogenies, plant identification, biodiversity informatics).

* + ~ : these figures exclude all students (MSc & PhD), technicians, clerical, and other support staff.

COMBINED RESPONSE TO QUESTIONS 1 AND 2: THE STATE AND ROLE OF SYSTEMATICS AND TAXONOMY.

Systematics and taxonomic research is certainly alive and active in the UK—but in the extremely limited sense that a number of innovative research programmes, largely justified as novel techniques, are successfully funded, and in many cases are at the forefront of international research. The BBSRC BiodiversityWorld e-Science national pilot project, was one of the largest grants to a university taxonomic/biodiversity informatics group in recent times. What is not happening is the application of these taxonomic research techniques on a sufficiently wide scale to achieve the taxonomic research coverage needed in the modern world.

Appreciation of the direct practical role of taxonomy has seen a sea-change since the last review. The globalisation of biodiversity and climate change studies, the clear needs for monitoring, regulation, and modelling at multiple scales for all biota, and the practical indexing of biodiversity knowledge of all kinds on the internet have combined to put core taxonomy—names, classifications, checklists, monographs, and collections with the associated informatics products—at centre stage. They are now seen as the core underpinning scientific infrastructure on which much of biodiversity science and applied biodiversity management is based—indeed now ripe for expansion not reduction. In addition to the evident needs to complete coverage of the UK biota, a significant number of the major pillars of the world taxonomic infrastructure are developed or hosted in the UK—the Species 2000 Catalogue of Life, nearly all the major Nomenclators (Zoological Record, International Plant Names Index, Index of Fungi, ZooBank) as well as three of the globally significant collections and taxonomic production centres, NHM, RBG Kew and RBG Edinburgh.

What is missing is a funded agency responsible for co-ordinating and funding the UK contribution to taxonomic coverage—research in the sense of exploring, completing and updating the taxonomic territory, but separate from research into novel techniques. Because of the needs for monitoring, regulation and modelling, we do now need "functionally complete" coverage of the UK biota, and, in partnership with other top taxonomic countries, we do need functionally complete coverage of the world biota. The fact that the UK contributes a major component to the world taxonomic infrastructure, may once have been thought of merely as a legacy and responsibility arising from the collections and our colonial past. But in the modern world it becomes an opportunity for the UK to develop its place in international biodiversity science, associated with our UN Convention on Biological Diversity (CBD) responsibilities, and international-scale concern for the environment and consequences of climate change.

Question 3a: *Organisation and Co-ordination*

No—systematics research in the UK is neither organised nor co-ordinated, and as a result the products do not in many cases meet the needs of the user community. There are large gaps in taxonomic coverage and occasionally even duplications in the taxonomic sectors covered. The body set up after the 1991–92 review was ineffective and has ceased to operate.

For instance the taxon focus of taxonomic PhD's at University of Reading is largely haphazard in that it follows the individual interests of the staff members and candidates, albeit after some consultation about gaps with colleagues at other institutions. There is no national or international plan or gap analysis into which such studies could be inserted.

There is of course some informal cooperation that helps achieve a spread of projects, but this should not be mistaken for effective co-ordination.

Question 4: *The Level of Funding Needed.*

Our view is that in addition to current funding through the research councils (NERC & BBSRC), and core funding to NHM, RBG Kew and RBG Edinburgh, there should be a new separate stream for research leading to taxonomic coverage and taxonomic currency—to provide fresh taxonomic monographs to fill gaps, and to enhance currency of maintained taxon databases. Planning, co-ordination and funding should be organised by a new body, such as a National Taxonomic Board with terms of reference explicitly related to UK and global taxonomic need, and funded staff assessed on this basis alone. It is natural for the national institutions to play a major role, but it is also essential that access to the fund is open to other key organisations in systematics, such as the university taxonomic centres, CABI, the Species 2000 Catalogue of Life organisation etc.

As examples:

(i) Each of the University centres should have support for one full time monographer, and the associated collection support. This is needed so that all student trainees (MSc and PhD) may have first hand experience of monographic work as well as phylogenetic, molecular and informatics skills.

Such monographers should be assessed by appropriate criteria that recognise the special nature of this kind of work and not those of the Research Assessment Exercise (RAE).

(ii) Each of the University centres should have baseline support for its working collections. Survival of these collections is tenuous; they are essential for taxonomic training and for research, but their funding is difficult to justify by current student cost/RAE-bound criteria. The Reading Herbarium is both a teaching collection and an international research resource for Mediterranean plant taxonomy, but the EC supported Euro + Med PlantBase, for example, that used the herbarium extensively, and occasional Darwin grants make little impact on the true cost of staff and operation. One curator and collections support should be provided by the National Fund. Such curators should be assessed by appropriate criteria and not those of the RAE.

(iii) After careful evaluation each of the Global Species Databases based in the UK and contributing to the Species 2000 Catalogue of Life used by the Global Biodiversity Information Facility (GBIF) and the Encyclopedia of Life (EoL), should receive small but continuous support for maintaining and enhancing taxonomic currency. As examples, the Monocots part of the Kew Global Checklists needs to be properly maintained at Kew, the Tineidae and other Lepidoptera databases (and CATE and EDIT) databases at NHM, and the International Legume Database & Information Service (ILDIS) (Leguminosae) database maintained at Reading—all need to be continuously enhanced for the Catalogue of Life to meet the public demands now being put on it. Staff involved with the databases should be assessed by appropriate criteria.

(iv) It is strategically important for the UK role in global biodiversity actions that the Species 2000 Catalogue of Life receives sufficient support to develop its full role. Achieving one million species was celebrated in 2007—but "going the extra mile" to complete the 1.75—2 million known species by 2012 requires both direct research and running cost funding, but also adequate support for the supplier databases mentioned in iii). Staff should be assessed by appropriate criteria.

Question 6: *Impact of New Technologies.*

One of the advantages of embedding taxonomic training centres in the universities, rather than the national taxonomic institutes, is the breadth of cross-fertilisation possible with a wide array of related disciplines. So on the issue of DNA and other technologies—yes, not only does DNA sequencing enable work on phylogenies, gene pools and barcoding but, at Reading we are using these technologies to link with a wide array of exciting topics. We work with Mexican biodiversity and regulation authorities to establish means of identifying legally and illegally exported populations of rate cacti. The systematics group work with the crop germplasm projects of the horticulture group, both to provide molecular and genetic characteristics of cultures (The Reading International Cocoa Quarantine Centre, and shortly the National Fruit Collection at Brogdale), in a major Plant Genetic Resources Forum and Global Environment Facility initiative in Crop Wild Relatives, and in the first steps at integrating crop databases into the Catalogue of Life. There is work with the Council of Europe on invasive species, and work on utilising online taxonomic catalogues in the modelling of species distributions (BBSRC BiodiversityWorld Project, projects in the University of Reading Walker Institute etc), and joint projects with Systems Engineering and the Informatics Research Centres within the University.

Question 8: *The Role of Regional Collections*

The University of Reading Herbarium is an actively expanding teaching and research herbarium—"regional" only in the sense that it is not national, and actually widely consulted internationally for its Mediterranean "regional" coverage. It supports training in herbarium practice for the MSc and PhD students, provides a base for the loans from elsewhere by PhD projects, and provides an active research base for some contributors to Flora-writing projects—particularly *Flora Iberia, Flora Pratique du Maroc,* and others in Italy and Lebanon. Links with Moroccan and Spanish institutions has been strong, and supported by Darwin Initiative and EC Regional Projects.

It is curated by a senior curator, and a qualified junior curator, financed by the School of Biological Sciences as part of the MSc teaching programme, and as a component of The University of Reading Collections Network. The curators take an active part in field expeditions and tutor students in collecting practice. The two of them are acknowledged as international class plantsmen who provide the core of the Reading "know your plants" training. However, accreditation and support by the Museums and Galleries Commission, so helpful to small zoological museums, appears not to be available to teaching / research herbaria. Despite the success and vigour of this programme at Reading, it is nonetheless vulnerable to the financial targets of a normal university school.

Like many of the small-to-medium sized herbaria, the Reading Herbarium has some difficulty in maintaining its dissemination programme that makes information freely available on the internet, and actively promotes data-sharing, particularly with partner institutions in Morocco. However the public provision of such information has now become a national commitment, made both to the CBD (Decision VIII/11, para 3), but also to GBIF. This service needs in future to be tied to the support for collections at the university centres, both to provide a national infrastructure for this activity, and to enable the appropriate training of students.

Question 10: *Quality and Reliability of Web-based Taxonomy*

There are three key components to the quality and reliability of web-based taxonomy. i) All assertions should be backed by a documented source—a specimen, document or publication. ii) Peer review is used to maintain quality and to oversee choices. iii) Exposure to open public usage, commentary and feedback ensures that there is constant pressure to enhance what is there. At Reading we see this user pressure assisting the herbarium catalogue, the ILDIS LegumeWeb database and the Species 2000 Catalogue of Life. Data from the Reading herbarium is visible on the GBIF public portal, from ILDIS LegumeWeb is on the Catalogue of Life public services, and the Species 2000 Catalogue of Life appears as the principal taxonomic backbone on the GBIF, EoL and many national and regional biodiversity portals around the world.

Recommendations

Recommendation 1): *Establish a UK National Taxonomy Board.*

A UK National Taxonomy Board should be a body established to secure the following tasks:

(a) to monitor taxonomic coverage of the UK biota, to work with other nations to monitor the state of taxonomic coverage of the global biota, and to report to the public what progress has been made in each five year period.

(b) to prioritise new monographic, floristic and faunistic research in the UK, and to administer funds for the support of new treatments according to the priorities that it has set.

(c) to prioritise the taxonomic enhancement of taxon databases and public taxon data systems in the UK, and to administer funds for the support of these databases and public data systems according to the priorities that it has set.

(d) to work with the national taxonomic institutions and the universities to prioritise and establish a network of recognised UK university taxonomic centres, and to review the training and progress that has been made in each five year period.

(e) to work with the universities and national institutions to prioritise the needs for monographic research and collections practice at each of the recognised university taxonomy centres as part of the training process, and to administer funds for the support of monographic, floristic and faunistic specialists and research collections in each of the recognised university centres according to the priorities that it has set.

It is important that this body should be independent of the national taxonomic institutions and university centres, but should work closely and positively with them to stimulate and enlarge their activity in this area activity.

Recommendation 2): *Provide Part Support for the University Taxonomic Training Centres.*

(a) Fund wholly one monographic research taxonomist within each of the recognised university taxonomy centres.

(b) Fund in part one research collections curator within each of the recognised university taxonomy centres.

(c) Fund in part the operating costs of a small research collection sufficient for teaching and research as part of a negotiated agreement with each university to make long-term infrastructure provision for the collection to continue.

Recommendation 3): *Public Recognition of a small set of National University Taxonomy Centres.*

There is a need to explicitly recognise the national taxonomy centres at a small set of universities, for two reasons. The first is to identify them as national training centres to potential students and sponsors. The second is to assist internally with negotiating the special provisions needed for such a centre to be supported within a university. The process of making this assignation and periodically reviewing performance could be placed in the hands of a new UK Taxonomy Board, one of the national learned societies (The Systematics Association or the Linnean Society of London) or Defra or HEFCE.

NB. The NERC Taxonomy Initiative designated and established three such centres (at Imperial College, Glasgow and Reading). However supporting and co-ordinating mechanisms were not developed at the time, and the funding emphasis on molecular research was seen by some commentators to detract from the true purpose of the initiative. That initiative came to an abrupt end, and the fact that it was not further supported by NERC made it difficult to encourage continued "matching" support from within the universities.

Recommendation 4): *Establishing a new National Fund.*

New funds in the order of £3–6 million p.a. are needed for UK taxonomists to make real headway with taxonomic provision. Funds should be made available by HM Government through Defra or DIUS. A variety of mechanisms could be examined for establishing the monitoring and prioritisation of taxonomic coverage, for funding extensive monographic taxonomic work and enhancing relevant databases, and for providing the necessary support for training in the universities. Our recommendation 1) above is just one of several ways in which this could be enacted.

4 February 2008

Memorandum submitted by the Department of Plant Sciences, University of Oxford

This submission touches on issues relevant to the review from a university perspective. Currently, the Department has an active research group in systematic botany that comprises a university reader, Royal Society Research Fellow, Curator of Herbaria, three externally funded research staff, 2–3 post-graduate students, a herbarium technician, and a part-time partly externally funded botanical artist. The group's work centres in and around two recently refurbished herbaria that house 800,000 specimens (http://herbaria.plants.ox.ac.uk/). The Oxford Plant Systematics Group carries out undergraduate teaching, post graduate training in systematic botany and research across a broad systematics agenda. This level of activity is partly reliant upon financial support from the Royal Society (two URF'S over the last ten years to fund taxonomic monographs), and significant endowed funds that support herbarium staff and maintenance of the collections. In addition, these activities are supported by the department in the form of a salary for a lecturer, and by external grants (currently 3 substantial Darwin Initiative grants and a number of very small grants from other bodies).

An important aspect of the modern systematics approach is to combine elements of specimen-based revisionary taxonomy with hypothesis driven research, in the belief that both strands are synergistic for high quality research. This approach builds on a rich history of traditional herbarium and field-based taxonomy combined with new methods and sources of data to elucidate evolutionary history. For example, writing monographs of key taxa that combine descriptive taxonomy with analytical methods can be pivotal in underpinning many of the big questions in evolutionary biology while at the same time playing a central role in contributing to the overall research goals of systematics. This approach underpins the ability of university based systematists to participate with colleagues in the RAE whilst maintaining some level of activity in revisionary taxonomy. Given the current research environment within Universities (funding, RAE) it is unrealistic for any active researcher not to pursue high impact hypothesis driven science. At the same time, combining revisionary taxonomy in the context of a hypothesis driven grant application can be unrealistic given that taxonomic elements tend to be long-term. For example, our current monographic projects in Oxford on *Strobilanthes* (c. 400 species) and *Lupinus* (c. 275) span 14 and 8 years respectively. Without Royal Society funding these two monographs would never have been started and the opportunities for graduate training in taxonomy (7 PhD students since 1999) would not have been realised.

Systematics is an integral element of the medium and long term projected research priorities involving plant biology for the 21st century (biodiversity, climate change, food, fuel, fibre and feedstock security). Maintaining taxonomy within the university sector even at existing levels is important for the intellectual long term well being of the subject. It is also crucial for training the next generation of systematists as well as educating students in organismal biology. If this vision is realistic and we strongly believe that it is, then the

tension between high impact science and descriptive taxonomy, which lies at the heart of the perceived demise of taxonomy in the University sector, has to be resolved.

An initiative for funding revisionary taxonomy within the university sector would enable existing and future systematists to apply for grants to maintain this aspect of their activities. We believe that such an initiative would automatically encourage taxonomic revisions of groups that are key to addressing a range of pure and applied research priorities.

4 February 2008

Memorandum submitted by the Dr Henry Disney Ph.D

In response to the Draft call for evidence: Systematics research and Taxonomy for the House of Lords Science and Technology Committee, I give below some personal observations, rather than a more systematic review, as I have been campaigning for many years on this subject but to no avail.

I made two submissions to the early 1990's House of Lords Select Committee on Science and Technology Systematic Biology Research—

Disney, R. H. L., 1991. Evidence from Dr R. H. L. Disney, Department of Zoology, University of Cambridge. *House of Lords session 1990-91 Select Committee on Science and Technology Systematic Biology Research. Written evidence received up to 21st May 1991.* HL paper 41. London: HMSO. Pp. 71-73.Disney, R. H. L., 1992. Evidence from the University of Cambridge, Department of Zoology. *House of Lords session 1991-92 Select Committee on Science and Technology Systematic Biology Research. Volume II Oral evidence and written evidence received after 21st May 1991.* HL Paper 22-II. London: HMSO. P. 305.

The result has been an insufficient balance between the support for the three main branches of taxonomy.

1. Alpha Taxonomy deals with the recognition of species, the description of new species and the production of identification key.
2. Beta taxonomy is concerned with the production of classifications of the species into genera, families, orders etc. based on the discovery of their evolutionary (phylogenetic) affinities.
3. Gamma taxonomy is concerned with sub specific taxa (subspecies, polymorphisms, ecotypes, etc).

While the extra funds for Beta Taxonomy, mainly for molecular phylogenetics, was a most welcome outcome resulting from the 1990's report, along with the use of molecular data in Gamma Taxonomy, the support for Alpha Taxonomy has got worse. The study of Alpha Taxonomy is essential for Biodiversity assessments and conservation evaluation as well as in relation to pathogenic organisms, pests, vectors of parasitic infections, insects, etc., in forensic cases and the use of biological control agents.

I have continued to highlight the plight of Alpha Taxonomy:- Disney, R. H. L. 1993. Systematic biology research. *Linnean* 9: 14-17. Disney, R. H. L., 1996e. The extinction of the lesser funded taxonomist. *Science & Public Affairs* 1996(3): 4-5.Disney, R. H. L., 1998a. Growing dearth of taxonomists. *Biologist* 45:6.Disney, R. H. L., 1998b. The naming game. *New Scientist* 2130: 53.Disney, R. H. L., 1998e. Rescue plan needed for taxonomy. *Nature, London* 394: 120.Disney, R. H. L., 1999a. The plight of taxonomy. *Biologist* 46: 6-7.Disney, R. H. L., 1999b. Insect biodiversity and the demise of alpha taxonomy. *Antenna* 23: 84-88. Disney, R. H. L., 2000b. The relentless decline of taxonomy. *Science & Public Affairs* October 2000: 6.Disney, R. H. L., 2002j. Alpha taxonomy. *Sherkin Comment* 32: 14.
Disney, R. H. L. & Durska, E. In press. Conservation evaluation and the choice of faunal taxa to sample. *Biodiversity and Conservation*

While the response has been sympathy and agreement, the funding of Alpha Taxonomy has continued its decline. Thus in my own field of entomology, the majority of specialists on large families of small insects are now retired professionals (like myself) and amateurs. Most of the latter tend to be parochial (eg only studying the British species of a family). With regard to funding support for professionals, before retirement from 1984 until 1998 I was entirely funded by private trusts. Every application to NERC was turned down, despite precisely the same applications being funded by a private trust (eg Leverhulme, Isaac Newton Trust, etc.). NERC would have funded the use of molecular data to solve problems (such as sibling species versus polymorphism) but NOT the basic research that would reveal such problems in the first place!

Since retirement I have existed on small grants and occasional fees for undertaking forensic work. The result is that I cannot afford the use of molecular methods unless a collaborator has funding. Likewise I now rarely use the Scanning Electron Microscope because of the cost. I have virtually ceased to attend scientific meetings because of the costs involved.

With regard to my standing as an entomologist, I am recognised as a world specialist on the scuttle flies (Diptera: Phoridae), which are the ultimate in biodiversity in that the larvae exhibit a greater range of larval habits than any other family of insects that have ever existed. My driving force has been a desire to advance knowledge of these habits, but in order to do so, I have had to undertake an immense amount of Alpha Taxonomy as the family has long been notorious for the complexities of species recognition. The result is that I have published more than most: and collaborated with more co-authors (mainly field workers) than most. I summarise my publications record thus:

Sole authorship papers	297	Phoridae publications	374
Joint authorship papers	146	Other	69
Total	443	All scientific publications	443

I currently have two dozen papers in press.

In addition I have tried to encourage ecology based on sound taxonomy by being co-founder and co-editor of the acclaimed *Naturalists' Handbooks* series (see below). I have also been a founder member of the Field Studies Council AIDGAP scheme that produces user-friendly identification keys.

I trust these highly personal comments will serve to illustrate that, despite not receiving a penny from NERC, I have tried to make a contribution to Alpha Taxonomy—which is the branch of taxonomy that is increasingly starved of funds. Other advances, such as web-based keys and catalogues are most welcome, but increasingly they tend to ignore the fact that the majority of species remain unknown to science.

Naturalists' Handbooks

Founded and edited by Dr S. A. Corbet and Dr R. H. L. DisneyInitially published by Cambridge University Press but subsequently published by the Richmond Publishing Co. Ltd for the Company of Biologists1. Insects on nettles. By B. N. K. Davis. 1983. Second edition 1991.2. Grasshoppers. By Valerie K. Brown. 1983.3. Solitary wasps. By Peter F. Yeo & Sarah A. Corbet. 1983. Second edition 1995.4. Insects on thistles. By Margaret Redfern. 1983. Second edition 1995.5. Hoverflies. By Francis S. Gilbert. 1986. Second edition 1993.6. Bumblebees. By Oliver E. Prs-Jones & Sarah A. Corbet. 1987. Second edition 1991.7. Dragonflies. By Peter L. Miller. 1987. Second edition 1995.8. Common ground beetles. By Trevor G. Forsythe. 1987. Second edition 2000.9. Animals on seaweed. By Peter J. Hayward. 1988.10. Ladybirds. By Michael Majerus & Peter Kearns. 1989.11. Aphid predators. By Graham E. Rotheray. 1989.12. Animals of the surface film. By Marjorie Guthrie. 1989.13. Mayflies. By Janet Harker. 1989.14. Mosquitoes. By Keith R. Snow. 1990.15. Insects, plants and microclimate. By D. M. Unwin & Sarah A. Corbet. 1991.16. Weevils. By M. G. Morris. 1991.17. Plant galls. By Margaret Redfern & R. R. Askew. 1992. Second edition 1998. 18. Insects on cabbages and oilseed rape. By William D. J. Kirk. 1992.19. Pollution monitoring with lichens. By D. H. S. Richardson. 1992.20. Microscopic life in *Sphagnum.* By Marjorie Hingley. 1993.21. Animals of sandy shores. By Peter J. Hayward. 1994.22. Animals under logs and stones. By C. Philip Wheatear & Helen J. Read. 1996.23. Blowflies. By Zakaria Erzinclioglu. 1996.24. Ants. By Gary J. Skinner & Geoffrey W. Allen. 1996.25. Thrips. By William D. J. Kirk. 1996.26. Insects on dock plants. By David T. Salt & John B. Whittaker. 1998.27. Insects on cherry trees. By Simon R. Leather & Keith P. Bland. 1999.28. Studying invertebrates. By C. Philip Wheater & Penny A. Cook. 2003.

29. Aphids on deciduous trees. By Tony Dixon & Thomas Thieme. 2007

20 December 2007

Memorandum submitted by the East Midlands Local Records Centre and Evidence Group (EMLRC) of the East Midlands Biodiversity Forum.

Background

The East Midlands Local Records Centres (EMLRC) was set up in 2002 as a forum to exchange information, techniques and examples of good practice between the Local Records Centres of the East Midlands, namely those working in Leicestershire, Rutland, Derbyshire, Nottinghamshire, Lincolnshire and Northamptonshire.

In 2007 The EMLRC joined the East Midlands Biodiversity Forum (EMBF) as a specialist sub-group and renamed the East Midlands LRC and Evidence Group. The EMBF is the main biodiversity (and now geodiversity) advisory group to the East Midlands Assembly and has made major contributions to the East Midlands Regional Spatial Strategy which highlights the importance of habitat protection and recreation, and the need for accurate biodiversity information and monitoring statistics to measure change due to management and climate effects.

The National Biodiversity Network defines an LRC as

> *"a not-for-profit service run in partnership for the public benefit, which collects, collates, manages and disseminates information of known quality relating to marine and terrestrial wildlife, wildlife and geological sites and habitats for a defined geographical area"*

Local Records Centres (LRCs) are now recognized as an important part of any local biodiversity group and network which is responsible for protecting and developing the biodiversity of an area. They are key information centres between individual recorders and the users of information in the planning, land management and nature conservation worlds. The EMLRCs hold over 7 million ecological records between them.

Response

The EMLRC group wishes to comment on Questions …..

1. *What are the barriers..*

A key barrier remains the lack of recognition in the wider biological and nature conservation industries of the importance of systematics.

2. *The role of systematics… How important…. Integration with other areas of research…*

The correct identification of species in the environment is the most important starting point of any environmental research. This is aided by pertinent research on the naming and relationships of species, the creation of usable identification aids, the creation and maintenance of stable checklists and their availability electronically in recording software, and the requirement from funding bodies that adequate voucher specimen collections are created and maintained as a fundamental part in any research based on species or habitat.

3. What progress has been made in setting up a body to lead on this?

LRCs look towards the National Biodiversity Network (NBN) to represent the views of the wider recording community, as the NBN Trust has direct contact with the Natural History Museum, the JNCC and others who have a systematic responsibility or requirement. To take on this role however it would need to be more formally connected to LRCs though a national or regional network and other groups of users, including the academic world and funding research councils.

The Natural History Museum would also be well-placed but would need to have a means of consulting with local users of taxonomy and systematics which it currently does not have, and has no track record of consulting the wider recording world. It of course has a commendable record in systematic research and in recent years more focus in supporting taxonomic work most useful to the UK.

The funding research councils have funds but no track record of promoting taxonomic good practice by, for example, the creation of voucher specimens in support of research, the preservation of key samples and the payment of their long-term curation.

A new body would need to be empowered to set the priorities for research, consult widely, be accountable for that, and be a statutory consultee to the planned priorities of the key players—the research councils, Natural History Museum, Natural England, NBN, JNCC etc. It could report on how bodies it advised were responding to its priorities.

7. *Does the way in which taxonomic data is collected….*

Most LRCs have connections with their recording communities and other data suppliers, as well as a wide range of data users.
Weak areas are:

- Most LRCs are under-resourced to carry out all the functions and process all the information available or required.
- There is no development of RECORDER, the main record management package, to enable it to work well with Geographical Information Systems.

— There is no development of RECORDER to allow cost-effective data entry and editing by individuals through a website.

— There is no development of RECORDER to allow better access to map-based information via local websites—as opposed to the NBN.

— There is no development of the NBN Gateway to allow direct accessing of local LRC databases.

What is the state of local and national recording schemes…

— National Societies provide very variable access to their information. The NBN should negotiate detailed access to all National Society records.

— Some national societies do not break down their data to the county level.

— Some NGOs refuse to break down their information to a regional or county level, making this important information resource unavailable.

8. *What is the role of major regional museums?*

Some major regional museums have lost curatorial posts in the past 10 years. Museums have a major role in the holding of collections to aid accurate identifications, to support expert curators and to house new voucher material. The importance of museum collections needs to be more widely known in the conservation and land management world and this link should be promoted by the NBN. Links from the NBN website should be made to collection level inventory websites such as FENSCORE and BioCase (http://fenscore.man.ac.uk/ and www.biocase.org/ respectiveley)

11. *How does the taxonomic community engage with the non-taxonomic community*

The importance of taxonomics and systematics needs to be raised within the whole of biology—schools, universities, research funders, NGOs as well as natural history societies and LRCs.

Taxonomy and identification skills should have an enhanced role in the teaching of biology, along with the importance of collections. Biology GCSE and A-level should include a module on the identification of common plant and animal species as a means of encouraging local knowledge of the local environment.

Field studies opportunities have a potentially very important place in the teaching of identification skills. Attending substantial field course should be part of a specialist qualification for Biology teachers.

Memorandum submitted by the EDIT Consortium

Executive Summary

1. Given the Government's reaction to the last report '*What on earth? The threat to the science underpinning conservation*', it is unlikely that significant new funding can be expected as a result of the current enquiry. It is the view of the EDIT consortium that a sensible strategy would be to seek to establish clear responsibility for a number of infrastructural issues, viz:

1. identify which science funding body should include data generation as part of their mandate;
2. put the funding for taxonomic collections, including living materials, into a long-term strategic plan with clear lines of responsibility;
3. identify which science funding body should be responsible for the development an effective means to map between alternative systems (specifically DNA and morphological) so that we keep the best elements of the existing knowledge base while embracing new approaches;
4. identify which science funding body should lead the development of infrastructure to move taxonomy from an artisanal to an industrial structure;
5. identify which science funding body should be responsible for developing a metric to assess contributions published directly to the web, which will measure significance of taxonomic work independently of the print publications in which the material appears and influence science managers to use the metric in assessing staff output;

6. Support for open access publications, by whatever means are necessary;
7. identify a mechanism to create an independent archive for electronic publications;
8. Stop the loss of taxonomic expertise, and ideally, reverse this negative trend reversed over 5–10 years. This must involve examining the policies that have driven taxonomy out of UK Universities.

Background

2. The European Distributed Institute of Taxonomy (EDIT) consortium consists of 27 partner institutes supported by the European Union. The consortium has six operational and structural objectives : to reduce fragmentation and to transform taxonomy into an integrated science; to strengthen the scientific, technological and information capacities needed for Europe to understand how biodiversity is modified through Global change; to progress toward a transnational entity by encouraging durable integration of the most important European taxonomic institutions, forming the nucleus of excellence around and from which institutions and taxonomists can integrate their activities; to promote the undertaking of collaborative research developing, improving and utilising the bio-informatics technologies needed; to create a forum for stakeholders and end-users for taxonomy in biodiversity and ecosystem research; and to promote the spreading of excellence to fulfil the needs of biodiversity and ecosystem research for taxonomy based information. Further information can be found at http://www.e-taxonomy.eu

The state of systematics and taxonomy research

3. The number of described species globally has increased linearly over the past 50 years, whereas the estimated number of living species has increased tenfold. With the advent of climate change, the destructive potential of Invasive Species, the increasing anthropogenic mobility of some species and the global interests of many European countries, any country has potential interests in the global biota. The motivation to create the EDIT consortium was to integrate the pool of taxonomic expertise such that expertise would be available within an European context, if unavailable within any particular state. Furthermore, integration of European taxonomic institutions is expected to allow recruitment to fill gaps in coverage.

4. Estimates for the total number species varies between 4 and 10 times the number already described (1.8 M) and at current rates, preliminary descriptions and names could be completed by 2050 for the lower bound and effectively never for the upper bound.

5. The majority of taxa to be discovered are very small (<1 mm), including microbial. The current balance of expertise is estimated to be 4,000-6,000 professional taxonomists and 30,000-40,000 amateur taxonomists across the world (http://tinyurl.com/yw82xx). For a discussion of the term 'taxonomist' see Enghoff & Seberg (2006)[1]. There are few data available on the spread of taxonomic expertise of the amateur community, but amateur microscopical societies, eg the Quekett Society http://www.quekett.org, lists only 17 others worldwide of which 5 are British. This implies that much of the recent productivity will not translate into very small organisms. It is difficult to see how one could manage and direct such an amateur workforce and particularly how to maintain taxonomic standards.

6. Taxonomic science of the highest international quality, specifically descriptive and nomenclatural studies, can be conducted by individuals with quite basic equipment: indeed there are numerous self-funded amateurs in this category. Lacking an intrinsic dependence on large or expensive equipment, there is no natural driver to establish fora in which the taxonomic community can debate priority and no obvious purpose for such a priority list. Priority is therefore normally established locally. One objective of the EDIT project is to establish a level of managerial collaboration between major taxonomic institutions which may develop a mechanism to determine Institutional priorities for research.

7. The advent of DNA-based methods requires a source of reliably identified specimens from which DNA can be extracted. Consequently the morphologically best-represented and most-studied groups will inevitably be best represented in sequence databases. Groups with poorly developed basic taxonomy or poorly represented in Museum collections will not necessarily benefit from this new technology, although DNA-based methods can increase descriptive productivity by assisting in the characterisation of species and the establishment of relationships. There is also a danger that DNA-based taxonomies will de-couple from morphologically-derived taxa, of which there are vastly more presently defined. There is a particular risk that mapping of species concepts between the two definition types will increase levels of confusion and noise in the databases.

8. EDIT was conceived on the premise that taxonomy cannot address the shortcoming described in paragraph 3 if we continue with current practices, essentially independent of the amount of funding applied to the problem. It is essential that we develop better ways of working and the strategy being followed by EDIT is to

use Web technology to facilitate collaborative working and by more efficient exposition of the results of taxonomic effort. There is not yet evidence that teams of taxonomists work faster than the same number of individual taxonomists, but multidisciplinary teams including taxonomists can more effectively focus taxonomic effort. Nevertheless, EDIT views it as essential to move taxonomy from an artisanal to an industrial basis which will mean that the process needs to be broken down into steps to increase throughput efficiency (see the report "Taxonomy in Europe in the 21st century" attached as an appendix). Critical to the development of this vision will be mechanisms to deliver credit, ie the means for career advancement, to those undertaking the work (see paragraph 25).

9. EDIT is predicated on facilitating taxonomy (nomenclature, identification and systematics1) as it is currently practised. Although we recognise the need for a fundamental change in taxonomic practice, it is not clear that new approaches will deliver the required properties of stability and accessibility. Should we choose to abandon description and Linnean nomenclature in favour of identifiers, while it may increase throughput, it is not certain to meet the needs of the bioscience community, policy makers, environmental management, education and the public in general. What is needed is an effective means to map between alternative systems so that we keep the best elements of the existing knowledge base while embracing new approaches.

10. In order to change taxonomic practice, an EDIT goal, we consider it essential to accommodate the methods used by taxonomists now, including publication vehicles. This is in large part to avoid jeopardising perceived career progression based on established mechanisms.

Data collection, management, maintenance and dissemination

11. In 2006 the United Kingdom Taxonomic Needs Assessment, conducted by the Global Taxonomic initiative, determined that "In the UK the following types of information, listed in order of importance, were identified as important for biodiversity conservation but not sufficiently accessible;

1. Habitat requirements of animals/plants
2. Information on local species distributions
3. Information on regional species distributions
4. Geographic Information System (GIS) data
5. Information on name changes
6. Lists of invasive alien species
7. Specialised identification services (taxonomic)

In the Overseas Territories the following types of information, listed in order of importance, were identified as important for biodiversity conservation but not sufficiently accessible;

1. Habitat requirements of animals/plants
2. Distribution maps
3. GIS data
4. Identification keys"

12. Data access is undoubtedly a major bottleneck both to taxonomists and to users of taxonomy. It is here that we expect Web technologies to have the most significant impact. It is essential that we unlock the store of information currently held on paper in libraries, even the best of which cannot be comprehensive. These data need to be re-structured to give access to names, descriptive information, linked to specimen and collection information and mapped onto other digital resources, such as molecular databases. The key barrier to this is cost, especially the tyranny of publisher charging access fees to old, obscure material that they no longer sell on paper, but also the cost of extracting and structuring text-based material to make it amenable to data mining.

13. Taxonomic publications characteristically have low initial impact but are accessed and cited over many decades. Consequently primary taxonomic output, especially the larger monographs, is marginalised from the high-impact journals. The NHM (London) published 2222 papers in the financial years 2003-2007 in 649 journals: 39 per cent of journals (23 per cent of papers) were not included in the Science Citation Index and consequently did not have impact factors. The pressure on editors to drive their Impact Factor ever upward is driving descriptive taxonomy into more obscure journals that are less effectively accessible to internet search (eg Web of Science) and thus more difficult to find. Furthermore, the pool of referees available to such journals is often more restricted, so it is hard to manage issues of data quality.

14. EDIT considers that data access is central to improving efficiency, so is developing a "cyber-platform" (http://www.editwebrevisions.info/content/work-plan) that will capture data in a structured manner and make it available to users. We have adopted the design developed by the CATE project (http://www.cate-project.org) and have offered community web sites (scratchpads; http://www.editwebrevisions.info/scratchpads) that have gathered 237 users from 28 countries, creating 53 sites with 102,000 pages since their launch in March 2007. The principle is to allow users to deposit data in any form, but to encourage building structure into the data which can be garnered into a common data resource (Common Data Model) and made available through a program interface to other applications.

15. It is usually the case that funding for infrastructure can be secured to built data structures (eg EDIT) but it is rarely the case that funding can be found to populate those structures. Since it does not lead to funding, the population of databases does not earn any credit for the data generator in terms of career progression. Populating databases is consequently often opportunistic: the data are often not optimally structured and even more rarely compliant with current standards and ontologies. Perhaps even worse, there is rarely funding for long-term maintenance of these data sets which too often become 'orphaned' when their creators retire or move on. It would benefit the enterprise to establish a data centre to have responsibility for curating data in a manner similar to the care of specimens.

16. A common request to taxonomists from other communities is for identification guides, ideally keys, but at least monographic treatments to facilitate accurate identification. A related EU project, Key2Nature (http://www.key2nature.eu/en/index.html) plans to build identification keys to specific geographical regions. To do this they need standardised descriptive data presented in a matrix fashion. These data will not be generated within Key2Nature itself; the project is predicated on the assumption that they will be generated by the taxonomic community. The project's goals are to give access to eLearning tools for identifying biodiversity.

17. DNA-based methods, while falling in price rapidly, are still comparatively expensive for the most commonly studied groups in environmental impact assessments. Whereas there is no doubt that these techniques will be invaluable in the future, current efforts to build the barcode databases necessary to support them are limited by the availability of authoritatively identified organisms from which to extract DNA.

18. Ultimately taxonomic authority rests on the ability to compare an unknown with a standard held in a recognised collection. It is imperative that these collections, which taken collectively constitute a very large-scale distributed research infrastructure, be maintained. The most expensive (in terms of cost per collection item) are under most threat and are the collections of living cultures that underpin microbial systematics. We note with concern the current situation at RGB Kew resulting from the funding difficulties in which Defra finds itself.

19. The current Rules of Nomenclature require new taxa be described and named, or any other taxonomic act, in paper publication. This is currently being addressed by parallel paper and web publication. It is likely that the Zoological community will move to accepting web-based publication in the moderately near future. To allay the major concern it is urgent that a central archive strategy be put in place, independent of the publishers themselves, to fulfil the role that repository libraries have traditionally played. It is obviously desirable that we move to an open-access model for taxonomic literature and away from the current models which often requires data generators to pay substantial fees to publishers.

Skills base

20. The only survey of UK taxonomists of which we are aware (http://tinyurl.com/2z3nl8) can be summarised as follows.

Age	*Total*	*per cent*	*Male*	*Female*
<20	2	0	1	0
21–30	14	2	8	2
31–40	155	19	120	32
41–50	230	29	184	47
51–60	235	29	206	26
>60	169	21	152	20
Not given	56		31	16
Total	861		702	143

21. These taxonomists were reported from 176 institutions and had expertise in 192 taxonomic groups, detailed at <http://tinyurl.com/ywhsuv>. It is of course not possible to infer trends from a single sample

point, but it is of concern that close to 60 per cent are between 40 and 60, with a further 20 per cent past normal retirement age.

22. European science is facing a tremendous loss of taxonomic expertise. Despite the availability of a well developed taxonomic infrastructure, European taxonomic research, including its collection management aspects, increasingly relies on an aging taxonomic community, with permanent staff often over 50 years old and with a significant input by retired researchers and skilled amateurs who frequently have to self-fund their research. <http://tinyurl.com/2yb82j>

23. Efforts to find enthusiastic young people with an interest in becoming qualified taxonomists are thwarted by insufficient training opportunities and a lack of long-term professional prospects. To address this problem, education is an essential component of EDIT. The main challenge is to stop the loss of taxonomic expertise, and have this negative trend reversed in 5-10 years from now. EDIT will strive to achieve this by increasing the transfer of knowledge and by establishing an integrated European training programme for taxonomy. In parallel, public education will increase the awareness of the vital contribution that taxonomy can make to biodiversity and ecosystem research, and consistent lobbying will contribute to enhance interest of decision-makers and funding agencies.

24. UK University education in whole organism biology, and consequentially systematics, seems to be in sharp decline judging by the educational records of those appointed to the Natural History Museum and Royal Botanical Gardens, Kew & Edinburgh. Increasingly appointees are recruited from other countries. It is noteworthy that many of the UK-trained taxonomists employed by these Institutions come from the pool of graduates trained on courses in which the Institution staff are heavily involved in teaching (Reading and Edinburgh Universities; Imperial College, London). This increased involvement helps to disguise the decline in University staff equipped to teach taxonomy.

25. A key barrier to change is the mechanism by which scientific productivity is now measured. Such is the weight placed on impact factors and citation rates that it is difficult to produce the large coherent works required for taxon identification while getting employer's recognition, or worse, getting tenure. EDIT seeks to develop a metric to assess web-based usage and assign credit to data creators as an alternative to the Citation Index.

26. It is relevant to note the State of Emergency declared by the EPPO Council (http://tinyurl.com/2hwj3a):

> "The work of National Plant Protection Organizations (NPPOs) relies on scientific expertise, but the services providing this expertise increasingly lack staff, funds and training.
>
> On the one hand, the whole scientific basis of the phytosanitary field is quickly eroding. Taxonomy, classical plant pathology and other scientific fields which are vital for sustaining sound public policy are threatened with extinction, because they are no longer in the forefront of science priorities.
>
> On the other hand, the need for phytosanitary expertise, training and research is substantially and continuously increasing. The number and complexity of plant pest problems increases every year. New developments and new technology have to be mastered, going far beyond existing expertise.
>
> Unless urgent action is taken, indispensable expertise and scientific disciplines will irreversibly disappear, and NPPOs will be unable to do their duty."

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Memorandum submitted by Mr Bill Ely

I operate the Rotherham Biological Records Centre, I am an entomologist and I am the Yorkshire Naturalists Union's recorder for Parasitic Hymenoptera. My concerns stem from these roles and my position as a consumer of taxonomic research on the insects of the UK.

Point 1: from my point of view, systematic research (as evidenced by the existence of guides/keys to British insects) is generally good.

While collecting, recording and identifying our local entomofauna I find that the key works on the British fauna are good for bugs, beetles and the smaller groups such as mayflies, dragonflies and lacewings. I have enough literature to cope with the flies but some of this is culled from European works and is often quite old. There is a need to complete the coverage of the British flies and bring it up to date. Among the Hymenoptera the sawflies and Aculeates (bees, wasps and ants) are generally well-provided for, though a guide to solitary

bees is badly needed. Information on this group has been published in a variety of journals going back to the 1920's but an up-to-date work is necessary. The main gap from my point of view is in the Parasitic Hymenoptera, a large group of families containing c5,000 UK species. A few guides to the British fauna exist (in English) but there are large gaps where nothing has been published over the last 50 years. While these insects may be considered a low priority (because of the small number of individuals who take an interest in them) they form a significant part of our biodiversity, they impact on many other invertebrate groups, their value in biological control is very clear and, as "top predators", and they have potential value as indicators of site quality.

I suggest that it would be useful to draw up a list of families (and, where appropriate, subfamilies) of the UK fauna and flora with a note of the date when guides/keys in English were last published. Perhaps it would be useful to note where guides have been published to particular genera where these post-date the family keys. This would show up the gaps and inform decisions regarding funding priorities.

There is widely-recognised need to encourage more naturalists to take up the study and recording of our wildlife, and the existence of readily-available keys in English, is central to that encouragement.

In a world where the insects are changing in response to changing climate the keys should be to western Europe rather than just the UK biota, so that additions such as the Lesser Emperor Dragonfly (which arrived in England about ten years ago and has now reached South Yorkshire) can be recognised.

The main barrier to filling the gaps is a lack of workers in the neglected groups.

Point 5: Some of the gaps in UK literature are filled by workers in other countries. Klaus Horstmann in Germany, for example, is a prolific worker in the Ichneumonidae. Some of his work has been translated into English (and I am fortunate that I had access to a translation service at Doncaster Museum which achieved much of that work) but it would be useful to provide funding for his (and other workers') output to be translated into English and then made available to the rest of us. As the fauna and flora of the UK are subsets of the European fauna and flora some link (other than personal contacts) would be useful.

Point 7: As a biological recorder I have a particular interest in taxonomic data. The coverage of local records centres (LRCs) across the UK is patchy, as is the distribution of records. Both tend to be concentrated in urban centres while the most biodivers areas are less well served. This, of course, reflects local funding and staff resources for the LRCs and numbers of recorders for the records. There are also discrepancies within the records—about half of the 1.2 million records in Rotherham BRC's databank are bird records and this reflects the overwhelming concentration of bird records nationally. It does not provide an objective basis for biodiversity studies.

Local recording schemes are patchy and rely upon the skill and enthusiasm of individuals. The fact that there is almost no reliable basis for such schemes is not really an issue until the situation where no-one steps forward to take up the burden. When that occurs there is a danger of the accumulated data being lost. Local recorders are being encouraged to deposit a copy of their records with a LRC, but this has its own problems. Not all LRCs have secure funding and some are operated by charities. They may be at risk in the future. Some recorders may welcome the security of a back-up to their records
but may not wish the LRC to be able to use them (bizarre but true). If the LRC takes on this role it is at cost to its core business, which cannot be right.

Point 8: It is not only the "major" museums which have a role here. For our LRC it is the local museum which houses our voucher/reference collection. In order to encourage young people to take up the study of the less popular groups of fauna and flora, it is necessary for adequate reference collections to be available locally. They should not have to travel tens or hundreds of miles to do this. A joint voucher/reference collection meets both needs.

Point 9: As far as the Parasitic Hymenoptera is concerned, I have tried to find taxonomic information on the Internet with minimal success. Perhaps understandably, editors only put the titles of papers on the web rather than the full text. Therefore, trying to find the characters for a particular species is usually a waste of time. I have found copious information on museum specimens around the world and lists from different areas but very little of taxonomic use.

Point 12: The number of taxonomists actively working on the Parasitic Hymenoptera in the UK can probably be counted on the fingers of one hand and they are either retired or have curatorial duties as well.
Their numbers are quite inadequate to deal with the task facing them. Some method of encouraging team-work involving a number of taxonomists (perhaps investigating the parasite loads of particular host groups, as happens at Leiden University) would be a way forward.

Memorandum submitted by Dr. Genoveva Esteban

1. *What is the state of systematics research and taxonomy in the UK? What are the current research priorities? What are the barriers, if any, to delivering these priorities?*

State of systematic research and taxonomy in the UK: still declining. Molecular approaches to systematics do get funding, but whole-organism-biology studies get nothing or almost nothing in comparison.

Current research priorities: molecular tools do not answer ecological and/or conservation questions. Research on species and their ecological function in nature gets little attention, unless molecular tools are incorporated in the research. This is a mistake.

Barriers: lack of funding for non-molecular taxonomic/systematic research, especially studies related to the ecological role of whole organisms. There is a lack of investment on whole-organism initiatives.

2. *What is the role of systematics and taxonomy and, in particular, in what way do they contribute to research areas such as biodiversity conservation, ecosystem services and climate change? How important is this contribution and how is it recognised in the funding process? How is systematics integrated in other areas of research?*

The only way to detect the effect of climate or environmental change is by the direct observation of, eg a community of organisms (be it plants, animals or microbes), and how that community has changed either in composition or in relative species abundances. This is still cheap and fast to do, but it is little recognised in the funding process (see response to point 1 above). Systematics and taxonomy can be incorporated in other areas of research by changing their name so that potential reviewers do not look at it with "bad" eyes. For example, "traditional taxonomy" becomes "biodiversity".

3. *Does the way in which systematics research is organised and co-ordinated best meet the needs of the user community? What progress has been made in setting up a body to lead on this? What contribution do the leading systematics research institutions make both nationally and internationally?*

4. *What level of funding would be needed to meet the need for taxonomic information now and in the future? Who should be providing this funding?*

Research Councils like NERC could provide funding for taxonomic information, both for new and for keeping and updating national archives. The UK used to be a leading nation in taxonomic research ever since the 19th Century. Some senior managers of certain public organisations refer to taxonomy as "stamp collection", which highlights the level of unawareness that exists at such levels. Funding provided could be the equivalent to, eg one of NERC's Thematic Programmes (some of which, incidentally, have proved to be very productive, taxonomically speaking in the past).

5. *How does funding in other countries compare? Could there be more international collaboration? If so, what form should this collaboration take and how might it be achieved?*

Yes, there could be more international collaboration, especially for knowledge-transfer initiatives, eg training, workshops and seminars.

6. *What impact have developments in DNA sequencing, genomics and other new technologies had on systematics research? In what way has systematics embraced new technologies and how can these research areas interact successfully and efficiently?*

DNA sequencing has taken over completely. A taxonomic study without a molecular section is a lost study unless it has a large conservation-only component. Some work on taxonomy and systematic has incorporated new technologies only to demonstrate the usefulness of the phenotype alone for explaining how nature works, how ecosystems function, and the patterns of biodiversity at local and global levels.

Data collection, management, maintenance and dissemination

7. *Does the way in which taxonomic data is collected, managed and maintained best meet the needs of the user community? What is the state of local and national recording schemes?*

Some schemes have been withdrawn funding completely—so, they depend on charitable donations. To meet the needs of the user community taxonomic data should improve web-based information and the way they transfer the knowledge accumulated in their databases. Such databases are now important historical records for studies on global change biology and local/national climate changes.

8. *What is the role of the major regional museums and collections? How are taxonomic collections curated and funded?*

I can talk by my own experience. I consider myself lucky as I was offered (and I accepted) a job at one of London's leading universities to bring taxonomy back to the curriculum. I am currently using national culture collections and similar facilities to improve teaching of taxonomy at the University, and to get students to realise the wealth of knowledge that exists in UK museums and collections. NERC subsidises some culture collections, which also get a limited extra funding from the business of selling cultures.

9. *What progress has been made in developing a web-based taxonomy? How do such initiatives fit in with meeting demand for systematics and taxonomy information? How do UK-led initiatives fit in with international initiatives and is there sufficient collaboration?*

Some progress has been made with web-based taxonomy. The valuable datasets that exist at local and national level should be available on-line—this would be a great step forward. However, the main component of taxonomy, ie taxonomists themselves, is in very short supply and still declining—this should not be underestimated.

10. *What needs to be done to ensure that web-based taxonomy information is of high quality, reliable and user-friendly?*

Promoting taxonomy in schools and universities, and to get students to be involved in preparing user-friendly web-based taxonomic information.

11. *How does the taxonomic community engage with the non-taxonomic community? What role do field studies play?*

Field studies seem to be declining too (I was told this when I joined the University). Promoting this kind of work in primary and secondary schools would indeed help to form the researchers of future generations that will safeguard natural Britain. There are many enthusiastic teachers and students out there that do not have the chance to collaborate with scientists or do not even know there are scientists in the area where they live. The Royal Society and other organisations are helping to overcome this problem, eg Partnership grants.

Skills base

12. *What are the numbers and ages of trained taxonomists working in UK universities and other organisations?*

I would not know the answer, other than that the age has significantly increased in the last 15 years and that the number of taxonomists has decreased as older taxonomists have gone into retirement.

13. *What is the state of training and education in systematics and taxonomy? Are there any gaps in capacity? Is the number of taxonomists in post, and those that are being trained, sufficient to meet current and future needs across all taxonomic subject areas?*

Current numbers are not enough to meet current or, especially, future needs unless, of course, taxonomists are not needed anymore (as some people seem to claim).

Memorandum by the European Mycological Association

This evidence has been prepared specifically for this enquiry and is submitted on a corporate basis by the *European Mycological Association* (EMA) which is the learned scientific society representing mycology in Europe within the IUBS (International Union of Biological Science) framework. The Association has members in 37 European countries including the UK and seeks to cover all aspects of mycology in Europe.

Summary. Systematic mycology underwrites many fields of science and technology, including biodiversity conservation, climate change, ecology and the pharmaceutical industry. Despite impressive contributions, particularly in web-based taxonomy, the UK is losing its historical world-leader position in this field: systematic mycology is much better funded in many other countries. Without immediate action, fungal systematics and taxonomy in the UK will be extinct within ten years. Systematic mycology is currently totally absent from the UK education system. Skills are not adequate for current needs and numbers of experts have declined catastrophically. Funding is very urgently needed to train a new generation of systematists. It is in the interest of the state to provide that funding.

The state of systematics and taxonomy research

Question 1. *What is the state of systematics research and taxonomy in the UK? What are the current research priorities? What are the barriers, if any, to delivering these priorities?*

1.1. *The state of systematics and taxonomy research in mycology in the UK.* To be blunt, the state is dire. Without vigorous and immediate intervention, fungal systematics as a professional scientific activity will be extinct in the UK within ten years. The level of systematics and taxonomy research on fungi in the UK was more or less stable up to 1992 (ironically the year of the Rio Convention). Since then, it has declined catastrophically. The decline has continued and perhaps even accelerated since the previous House of Lords report. There are now, effectively, no fungal systematists (and this includes lichenology) employed in UK universities. Staff have not been replaced in Government institutions. Both remaining mycologists in the Royal Botanic Gardens, Kew are near retirement. In the Royal Botanic Garden, Edinburgh, the situation is perhaps slightly better, but numbers are still very small. The world-leading International Mycological Institute (CABI) ceased to exist in 1998. The number of mycologists within CABI has declined and their average age has increased dramatically: in 1977, there were 15 mycologists, average age 42 (some younger, some older); these figures were the same in 1992; there are now 3 mycologists employed by CABI with an average age of 55. These remaining mycologists spend most of their time in project management, in compiling or editing publications which review the work of others, and in preparing project proposals: time allocated for research is negligible. Printed research output has declined significantly (the CABI series *Mycological Papers* is a good example: 16 numbers published during the 1980s, 12 in the 1990s, 1 since 2000 and the series has now been discontinued). Most papers on fungal taxonomy from UK sources now come from retired staff and knowledgeable amateurs.

1.2. *Current research priorities.* This is largely a "wants" list: without trained systematic mycologists to do the work, research priorities are meaningless.

1.2.1. Provide meaningful and usable information on-line about fungal diversity. For taxonomic mycology, this is perhaps the highest priority, making sure that people working with biodiversity conservation, climate change and similar topics have easy access to understandable information about when and where fungi occur.

1.2.2. Continued descriptive "alpha taxonomy". In mycology, there is general agreement that less than 10 per cent of the world's estimated 1.5 million fungal species have so far been described (the figure most widely cited being about 5 per cent): new species can still be found within a 100 km radius of the centre of London.

1.2.3. Re-evaluate taxonomies below ordinal level in the light of molecular work. 2007 saw the publication of major US-funded work providing for the first time a classification of the fungi down to ordinal level based on molecular information. The availability of this classification provides an important new opportunity.

1.2.4. Production of monographs with identification keys. Most taxonomic orders of fungi lack recent monographic treatment. This is the equivalent, for animals, of saying that there are no recent monographs of carnivores, cetaceans, insectivores, marsupials, pinnipeds, rodents etc.

1.2.5. Carry out missing research taken for granted in other biological groups. Taxonomic topics adequately studied in botany and zoology (chromosome numbers, developmental biology, electron microscope studies, molecular work etc. etc.) have invariably been much more poorly covered in mycology because this branch of biology has suffered long-term under-funding: there is a huge amount of catching up to do.

1.2.6. Provide taxonomic support for studies of the "nano-world". There are different levels of biosphere studies: from the space and macro-levels which are easily visible, down through the micro-level. Molecular biologists, biochemists and ecologists are now taking their research down to the smallest levels in the expectation of new practical discoveries and insights into biosphere function. They need taxonomic expertise, particularly of the fungi, which are an important part of that "nano-world".

1.3. *Barriers.* There are a lot of barriers. The following list is not exhaustive.

1.3.1. Very poor public awareness of the unique status and importance of fungi. Fungi belong in their own separate biological kingdom. They are not animals or plants, and they do not fit into the vague and generalized category of micro-organism. But without them, life as we know it on this planet would not be possible. Despite a campaign by the British Mycological Society, there is, more or less, no teaching about fungi in the national school curriculum. The result is that future voters, politicians, senior civil servants and other decision-makers come out of school with no knowledge that fungi even exist, let alone that they might be important.

1.3.2. No human resources to do the work. There are no undergraduate or postgraduate degree courses in mycology: no specialist mycologists are being trained (and there will very soon be nobody to train them). In any case, there are currently no jobs to be had in systematic mycology in the UK. There are not enough existing systematic mycologists to maintain even a basic infrastructure of the science—leading scientific societies, editing publications, refereeing manuscripts, maintaining websites, curating collections etc.

1.3.3. Vicious synergy. The poor awareness of fungi and the absence of human resources combine to produce a cycle of decline. Mycologists are not consulted when decisions are being made about allocating resources (because there are no mycologists to consult). As a result, fungi are not prioritized. There are then fewer funds for mycological research (but unless urgent action is taken, there will soon be no mycologists to apply for them anyway).

1.3.4. Projects with misleading titles. Projects and initiatives with titles which imply broad taxonomic coverage give the impression that all groups—including fungi—are being covered. That includes any project with a title containing the word "biodiversity" or "ecology" and no further qualification—for example the "Heritage Biodiversity Library". But fungi are not covered by such projects unless at least one mycologist is explicitly included as part of the project team, and that is almost never the case. The result is that funding agencies suppose the work on fungi has been done, and will not later fund mycologists who apply to complete the forgotten fungal component. Such projects unintentionally seriously undermine mycology. Funding agencies need to be alerted, so that any project with such a title is not approved unless a mycologist is involved.

Question 2. *What is the role of systematics and taxonomy and, in particular, in what way do they contribute to research areas such as biodiversity conservation, ecosystem services and climate change? How important is this contribution and how is it recognised in the funding process? How is systematics integrated in other areas of research?*

2.1. *The role of fungal systematics and taxonomy.* These aim to describe and classify the fungi in ways which reflect the natural relations they have with each other, particularly in terms of their evolution. They also seek to provide means of identifying fungal species. Unlike plants, for example, most fungal species are still undiscovered and undescribed, and identification of species remains difficult. Although molecular techniques are increasingly used, they are in any case strongly dependent on correct identification of the sequences with which they are being compared.

2.2. *Contribution to biodiversity conservation.* UK fungal taxonomists played a key role in establishing the movement for fungal conservation in Europe and beyond, and continue to play key roles in that movement. In the last six years, they have also been involved in producing checklists for the UK basidiomycetes and for all fungi in the Caribbean, and in developing for Cuba a national strategy for conservation of fungi. They are

providing the ascomycete component of the IUCN Sampled Red List Index project establishing baseline data for different groups of organisms for the Rio 2010 objectives (IUCN-compatible conservation status evaluations for 1500 randomly sampled species), and have set up major websites providing access to substantial databases about fungi worldwide (further information below). Biodiversity hotspots have generally been identified on the basis of bird, mammal, insect or plant diversity. Fungal diversity has not been taken into account. There is increasing evidence, however, that hotspots for fungal diversity are often very different places. Temperate conifer forests, for example, are not typically considered biodiversity hotspots, but there are well over 1000 species of fungi associated with Scots pine alone—maybe half of them known only from pines, and over 200 known only from Scots pine—and the list is far from complete. Very different areas are likely to be identified as biodiversity hotspots when fungi are taken into account. Molecular identifications are accessible only to commercial organizations with the resources to pay the high costs involved. Biodiversity research, particularly in poorer countries, does not have such resources, but can generally cover the costs of traditional taxonomists, who are therefore critical in this field. One further point: there is still a tendency for people working with biodiversity conservation to regard fungi as part of the problem rather than as part of the solution (for example, the view that it is necessary to protect a rare plant species from fungal disease when the disease itself may occur only on that plant and may be even more rare). Fungi are rarely taken into account when devising nature reserve management plans. Fungal conservationists are trying to address these problems through education.

2.3. *Contribution to research on ecosystem services.* Fungi occur in all ecosystems, including the oceans and extreme environments such as Antarctica. Assessing ecosystems without taking into account the fungi is like taking care of computer boxes but not the chips inside. Yet major pieces of work continue to be published considering ecology and climate change without any mention of the fungi (see "Projects with misleading titles" above). Fungi play a phenomenally important role in ecosystem services, for example in recycling of carbon and mineral nutrients. They are also major factors as symbionts ensuring plant and animal health or agents causing plant and animal diseases. They furthermore are valuable indicators of ecosystem stability and of environmental pollution. The continuing very limited understanding of their exact roles in these areas combined with difficulty in identifying them (many are undescribed species) means taxonomic support is critical if this work is to be done in a meaningful manner.

2.4. *Contribution to research on climate change.* Fungi will surely be critically important in climate change: today's plant diseases of France, for example, may be England's plant diseases of tomorrow. The ability of many fungi to disperse long distances by airborne spores makes these organisms particularly able to exploit such changes, and changes in distribution of invasive fungi may be expected to occur naturally as a result of climate change: some will be invasive, others "refugees". Climate change may also cause some indigenous species currently rare (and quite possibly also unknown to science) to become extinct, and others to become more abundant and cause problems for humankind: the sudden spread of *Phytophthora ramorum*, the chromistan "fungus" causing sudden oak death, may be a good example. Those researching climate change, like those involved with biodiversity research, are unlikely to have the resources to pay for molecular identification. Websites showing known distributions of fungi (see below) will be very important in monitoring changes of distribution.

2.5. *Importance of these contributions.* If the fungi are not factored into research on biodiversity conservation, ecological services, climate change and similar themes, the scientific results are likely to be defective. The contribution by systematic mycologists in achieving this could be potentially enormous, but it is necessary to have these scientists in the first place.

2.6. *Recognition by the funding process.* The EMA endorses CABI's view that, for fungi, the approach by funding agencies seems to be "out of sight, out of mind", and that, as fungi are considered difficult to work with, they should get higher levels of funding to compensate for the technical challenges. For systematic mycology to survive, positive discrimination in funding is necessary.

2.7. *Integration in other areas of research.* Fungi are also key players in applied areas, including biodegradation, biodeterioration, biological control, forensic science, human health and pharmaceuticals. Because these areas tend to be better resourced, molecular identifications are starting to be used. Commercial companies working in these areas cannot be relied on to maintain systematic mycology: within the last five years, a case occurred where one company, having found a promising fungal product, promptly fired its mycologists to divert that money to product development.

Question 3. *Does the way in which systematics research is organised and co-ordinated best meet the needs of the user community? What progress has been made in setting up a body to lead on this? What contribution do the leading systematics research institutions make both nationally and internationally?*

3.1. *Does organization of systematics research meet the needs of the user community?* The stark decline in the UK's capacity for systematic mycology strongly suggests that current organization and co-ordination of systematics research in this field absolutely does not meet needs: Britain's historical world-leader position in this area is now almost gone. The present set up gives every appearance of failing in all respects.

3.2. *A body to lead on co-ordination of systematic research on the fungi.* With the demise of the International Mycological Institute in 1998, there is now no obvious body to lead on such co-ordination: the botanic gardens of Kew and Edinburgh hold national collections of fungi, but in the last five years, both have removed all mention of fungi from their mission statements; the Natural History Museum treats fungi as part of botany; a recent Natural Environment Research Council pamphlet on biodiversity failed to mention them at all; the British Mycological Society has declined dramatically in membership numbers over the past few years; from what used to be the Nature Conservancy, Natural England (formerly English Nature) treats fungi as part of botany; only Scottish National Heritage recognizes the fungi as different, and so may be appropriate to lead in Scotland. Most of these organizations are vulnerable to the criticism of failing to discharge their duties in respect of at least one of the biological kingdoms for which they are responsible.

3.3. *National and international contributions by leading systematics research institutions.* CABI mycologists still provide the three cornerstone publications which maintain world fungal taxonomy: the *Dictionary of the Fungi*, *Index of Fungi* and *Bibliography of Systematic Mycology* (further discussed below), but without urgent and long-term support, it is hard to see how they will continue for much longer. Other than these, there is now only a trickle of published work new research coming from the CABI mycologists. Mycologists in Edinburgh and Kew continue to publish, but there is little or no work on fungi (including lichens) coming out of the Natural History Museum. The main opportunities for British systematic mycologists to contribute nationally and internationally are currently through funding for individual projects (for example the UK Darwin Initiative) and through private dedication. Through these contributions, British mycologists maintain two of the world's five most important websites providing free access to taxonomic information about the fungi (*Cybertruffle*—www.cybertruffle.org.uk and *IndexFungorum*—www.indexfungorum.org/Names/Names.asp). The same British mycologists also hold influential positions in or have influence with the European Council for Conservation of Fungi, the European Mycological Association, the Encyclopaedia of Life, the Global Biodiversity Information Facility and the Taxonomic Databases Working Group.

Question 4. *What level of funding would be needed to meet the need for taxonomic information now and in the future? Who should be providing this funding?*

4.1. *Levels of funding needed.* If systematic mycology in the UK is to be saved, immediate funding is needed to train a new generation of mycologists before the current professional mycologists vanish completely. This means at least six fully-funded PhD studentships, plus the promise of secure employment on completion of their degrees. It also means funding Britain's remaining systematic mycologists—assuming they are willing—for the time needed to supervise these people. The number of remaining mycologists is now so low, that probably overseas study would be necessary for some of the students. The absence of systematic mycology at undergraduate and masters level should be urgently addressed. Information about fungi should be added to the school national curriculum. Urgent steps need to be taken to ensure that the CABI fungal reference collections and mycological library are secure (without such a library, production of the *Dictionary of the Fungi*, *Index of Fungi* and *Bibliography of Systematic Mycology* will be impossible). Taxonomic information should, ideally, be free to the end user, and the internet is a good medium for achieving this. In mycology, British mycologists are world leaders in provision of high quality information freely on the internet, but the two main websites are very vulnerable: in each case only one person understands how they function and there is no understudy. Secure long-term financial support for these websites would be a key contribution.

4.2. *Who should provide this funding.* The government. First and foremost, funding fungal taxonomy is in the interest of the state. Systematic mycology does not bring quick and easy money, but it is fundamental for a lot of other fields. Skilled and experienced taxonomists working on difficult groups of organisms are hard to find and easily lost, and with them goes Britain's world-leader position. Fungal dried reference collections, no less than art galleries and museums, are national treasures and part of the nation's heritage. Living collections are a national resource for discoveries, development of new technologies and for protection of human, animal and plant health etc. British Members of the EMA have commented that, compared with the costs of a

millennium dome, wars in Afghanistan and Iraq and the hosting of Olympic games, the amounts needed to keep systematic mycology alive in Britain are minimal. These modest amounts needed would be government money well-spent.

Question 5. *How does funding in other countries compare? Could there be more international collaboration? If so, what form should this collaboration take and how might it be achieved?*

5.1. *Funding levels compared.* Britain has moved from being adequately funded for systematic mycology (in the 1970s) to very poorly funded (the present situation). In some other parts of Europe the level of support is also not so good and in some places it is declining. Systematic mycology is, however, well funded in some European countries. In Russia systematic mycology thrives, with a new Academy of Mycology (its first congress, in 2002, resulted in an abstracts volume of about 450 pages) and many young mycologists (there are around 200 mycologists currently involved in biodiversity, conservation and taxonomy of fungi). Funding for systematic mycology in Sweden is good, with admirable results. Under dynamic leadership, the Centraalbureau voor Schimmelcultures (Netherlands) has stepped in to fill much of the role which belonged to the former International Mycological Institute up to 1998—a serious loss in scientific credibility for UK mycology. Systematic mycology is continuing in Austria, Germany, Spain and Poland. The USA has benefited from substantial investment in taxonomy recently through its National Science Foundation. British collaboration with their initiatives has been very restricted as British mycologists do not qualify for US funding. There is good support for mycology in Australia and New Zealand. Mycology is vibrant in Brazil, China and Japan, with many young mycologists.

5.2. *International collaboration.* As British systematic mycology fades, the remaining few taxonomists are pressed to try to cover all aspects of the science, and this is physically impossible. Research and development needs different people of different skills and different attitudes and temperaments: only diversity leads to prosperity. The very few British systematic mycologists do, however, have an influence much larger than their number might suggest. They are currently actively collaborating with mycologists in at least the following countries: Argentina, Armenia, Belarus, Brazil, Bulgaria, China, Cuba, Dominican Republic, Georgia, India, Kenya, Morocco, Netherlands, Poland, Russia, Saudi Arabia, South Africa, Spain, Ukraine, USA, Venezuela.

5.3. *Suitable forms of collaboration.* More international collaboration is possible. Limits are the low number of British mycologists and to a lesser extent funding. Important areas where international collaboration should proceed are:

5.3.1. teaching (the passing on of existing skills in fungal taxonomy before they are lost);

5.3.2. further development of international freely-available internet resources in fungal taxonomy;

5.3.3. exchanges to bring overseas experts in fungal taxonomy to Britain to help train the postgraduates which are urgently needed (see above);

5.3.4. international involvement in collection of new material, including field studies, with support for identification and isolation of resulting specimens to enhance fungal reference collections (in many African countries formerly administered by Britain, new information about fungi suddenly ceased to be generated when they became independent in the 1960s);

5.3.5. establishment of groups able to help poorer countries develop national strategies for fungal diversity conservation in line with the Rio Convention objectives;

5.3.6. development of groups with expertise in mycological aspects of climate change;

5.3.7. development of additional specialist international committees to promote conservation of fungi.

Question 6. *What impact have developments in DNA sequencing, genomics and other new technologies had on systematics research? In what way has systematics embraced new technologies and how can these research areas interact successfully and efficiently?*

6.1. *The EMA supports the CABI statement on this subject.* Sequencing has revolutionized systematic mycology in the last 5–10 years. The contribution of the UK has, however, been minimal and has led to a substantial reduction in its international influence. There is insufficient effort to integrate morphological and molecular classifications, leading to duplication of effort and the risk of 250 years of research being abandoned. This is particularly important in respect of naming species and organism groups; taxa are interpreted in different ways leading to widespread confusion. The UK is ill-prepared for changes which are

coming in this field. Funding is needed to ensure postgraduate students are taught sequencing techniques and have careers to go to afterwards gathering molecular data from British fungal reference collections: the current absence of funding means these hugely important resources are not being properly exploited.

Data collection, management, maintenance and dissemination

Question 7. *Does the way in which taxonomic data is collected, managed and maintained best meet the needs of the user community? What is the state of local and national recording schemes?*

7.1. *Management of taxonomic data.* The contribution by British mycologists to this aspect of taxonomy is outstanding and globally recognized. The most important taxonomic data for any group of organisms is the list of scientific names—if that list is not kept up to date, nobody knows what has already been described. In mycology, the CABI publications *Dictionary of the Fungi* and *Index of Fungi* fulfil this role. The *Dictionary of the Fungi*, now running to its tenth edition, provides the world standard fungal taxonomy at generic level and above. *Index of Fungi* is a high-quality paper publication of global importance, but there are serious concerns among systematic mycologists about its future, given that it is produced with no external financial support. The internet-based nomenclator, *IndexFungorum*, provides a huge resource of the older names, and if registration of fungal names is ever adopted will probably supplant *Index of Fungi*, but it is also vulnerable, being in the care of a single mycologist nearing retirement. The second most important source of taxonomic data is literature. The CABI publication *Bibliography of Systematic Mycology* fulfils this role for new mycological literature. The *Cyberliber* website (part of *Cybertruffle*) is the mycological on-line equivalent of botany & zoology's "Heritage Biodiversity Library". Over 125,000 scanned images of pages of mycological literature are already freely accessible from this site, which is growing rapidly and is fully integrated with *IndexFungorum*. Information about the occurrence of fungi worldwide is supplied on-line from two major websites based in Britain: one is *Robigalia* (part of *Cybertruffle*), and the other is the database of the IMI fungal dried reference collection. *Robigalia*, in particular, provides information in 9 different languages including Chinese, English, French, German, Portuguese, Russian and Spanish. Collectively, all of the resources discussed above give outstanding service to the user community. In general, database systems designed for botany and zoology are not suitable for mycological information, because they are unable to record associated organisms (fungi, being heterotrophs, usually grow on parts of other organisms). In botany and zoology, associated organisms, such as fungi, are not generally noted, even though they are essential ecosystem components. As a result, the databases resulting from initiatives driven by botany and zoology, such as GBIF, are very limited in what information they can supply about ecological interactions, and they do not handle mycological information so well as databases custom-designed for fungal information.

7.2. *Local and national recording schemes.* Computerization of the British Mycological Society's foray records database began in the early 1980s, and there are now well over one million records digitized. The database is, however, also vulnerable, being run by the same mycologist near retirement who looks after *IndexFungorum*, again with no understudy. There are many local recording schemes. In general, these use rather simple database structures, but collect valuable data in significant amounts. At least some of these are linked to the British Mycological Society's database and from there to the National Biodiversity Network gateway.

Question 8. *What is the role of the major regional museums and collections? How are taxonomic collections curated and funded?*

8.1. *Role of museums and collections.* There is no museum or garden specifically devoted to the fungi. At best there may be token displays in more general natural history museums, though even this is not usual. The four internationally important fungal dried reference collections in the UK are located in CABI, Edinburgh, Kew and the Natural History Museum (lichen-forming fungi only). They are major repositories of type specimens, and are an invaluable record of the historical geographical and temporal occurrence of fungi. This type of information is particularly useful for biodiversity and climate change research. The collections tend to complement each other rather than overlap. Chronic and severe underfunding has meant that active curation of the CABI fungal dried reference collection stopped several years ago, although a small GBIF grant enabled key elements of its records to be computerized and put on-line. Kew, by comparison, is actively curated. Only small parts of the Kew and Edinburgh fungal collections have been digitized. The CABI collection is arranged in alphabetical order. The Kew fungal collection, by comparison, is arranged using the Saccardo taxonomic system which was developed in the 19th century. This is now significantly different from modern taxonomic opinion. If, as has been mooted, the CABI and Kew collections are amalgamated, these differences will cause many practical difficulties. In comparison with the CABI, Edinburgh, Kew and Natural History Museum collections, which are internationally important, other UK fungal dried reference collections are small and

play a more limited role. The collections in Edinburgh, Kew and the Natural History Museum receive state funding. The CABI dried reference collection and the CABI living fungal collection (one of the largest in the world) receive no external funding and cannot continue to support UK (and global) mycology indefinitely under such conditions.

Question 9. *What progress has been made in developing a web-based taxonomy? How do such initiatives fit in with meeting demand for systematics and taxonomy information? How do UK-led initiatives fit in with international initiatives and is there sufficient collaboration?*

9.1. The British-based *IndexFungorum* and *Cybertruffle* websites (together with the USDA fungal databases website, the New Zealand Landcare fungal website and Mycobank—run from the Centraalbureau voor Schimmelcultures in the Netherlands) are the world's main mycological websites. Collectively they are making significant steps towards a web-based taxonomy, and they serve a huge volume of freely available systematics and taxonomy information about the fungi, mostly but not entirely in English (some of the *Cybertruffle* databases are multilingual). The *Cybertruffle* databases are specifically designed to make it easy for other websites to establish hyperlinks, a feature used very effectively by *IndexFungorum*. In general, collaboration is good. *IndexFungorum*, in particular, fits very closely with English-language international initiatives.

Question 10. *What needs to be done to ensure that web-based taxonomy information is of high quality, reliable and user-friendly?*

10.1. In general, the web-based taxonomy information delivered for mycology by *Cybertruffle* and *IndexFungorum* is of a highly professional quality, given the very limited resources available. Those resources are not enough to develop a web-based taxonomy which is interactive, permitting different experts to correct and update databases remotely—one possible way of making the quality even higher. If this is wanted, it will be necessary either to wait for international initiatives outside the UK to develop suitable systems and eventually apply them to mycology, or to provide financial support so that the main UK-based websites can move in that direction. Further funding is also necessary to improve reliability, which is currently dependent on the dedication of individuals. Feedback from mycological users suggests that both of these websites are already user-friendly. Provision of information in the languages of different users makes the *Cybertruffle* websites globally user-friendly in a unique manner not duplicated by other taxonomic websites.

Question 11. *How does the taxonomic community engage with the non-taxonomic community? What role do field studies play?*

11.1. Not all taxonomists are naturally good at communicating their interest and skills to the general public. In systematic mycology, one outstanding communicator, Prof. Roy Watling, has been retired for several years, and among the few professional fungal taxonomists in the UK, none stands out as a similar communicator. Prof. Stefan Buczacki, well known from the BBC programme "Gardeners' question time" is now probably the best known mycologist in the UK, but he is not a systematist. UK taxonomic mycology needs someone with that sort of ability in public relations to act as a publicist, drawing attention to significant and interesting discoveries, and making sure these reach television screens, radio and the pages of newspapers. The general public is not, however, society's only non-taxonomic community. In recent years, through a UK Darwin Initiative grant, UK systematic mycologists have been working with the military in the UK and Ukraine on management of training areas, and with nature conservation organizations on preparation of reserve management plans. Field studies have a strong potential role, but the tendency in recent years has been for the British Mycological Society to move in the direction of being a professional body rather than a learned society—a controversial move which has tended to discourage amateur membership, with a depressing effect on attendance at field meetings.

Skills base

Question 12. *What are the numbers and ages of trained taxonomists working in UK universities and other organisations?*

12.1. For mycology, probably zero in UK universities and fewer than ten in other organizations.

Question 13. *What is the state of training and education in systematics and taxonomy? Are there any gaps in capacity? Is the number of taxonomists in post, and those that are being trained, sufficient to meet current and future needs across all taxonomic subject areas?*

13.1. *State of training.* At present, there is probably no formal training or education in fungal systematics and taxonomy in the UK at any level.

13.2. *Gaps in capacity.* There are huge gaps in capacity. For the fungi, the UK now meets the Darwin Initiative's criteria for countries in need of help: it is rich in biodiversity but poor in resources. There are no professional mycologists employed in the UK to work on the Agaricales or other major groups of basidiomycetes (the mushrooms and toadstools), one part time mycologist covers the rusts, there is no coverage for smuts, the five professional mycologists (including one lichenologist) working on the huge assemblage of ascomycetes simply cannot cover many orders. Coverage of the coelomycetes, for example, an important group of asexual stage ascomycetes, is non-existent. There are no professional taxonomists who are experts on chytrids, chromistans or myxomycetes.

13.3. Sufficiency of skills for current and future needs. The number of taxonomists in post is not sufficient to meet current needs. There are no taxonomists being trained. Within ten years there will be no professional fungal taxonomists to meet any future needs.

4 February 2008

Memorandum submitted by the Global Biodiversity Information Facility (GBIF)

The Global Biodiversity Information Facility (GBIF) is an international body with the overall aim of furthering technical and scientific efforts to develop and maintain a global information facility for sharing digital biodiversity data. The United Kingdom is one of the founding members, and a key Voting Participants in GBIF.

GBIF appreciates the opportunity to respond to this Call by the United Kingdom's House of Lords Science and Technology Committee for evidence on systematics and taxonomy. In this document, GBIF responds to questions in category (b) of the Call, on data collection, management, maintenance and dissemination.

I. Specimen Data

GBIF wishes to recall that the United Kingdom, as a Party of the Convention on Biological Diversity (CBD), has agreed to implementing the Global Taxonomy Initiative Work Programme (http://www.cbd.int/gti/pow.shtml) and the Global Strategy for Plant Conservation (http://www.cbd.int/gspc/strategy.shtml). In addition the UK agreed at the last CBD COP8 to … *provide free and open access to all past, present and future public-good research results, assessments, maps and databases on biodiversity, in accordance with national and international legislation;* (Decision VIII/11, paragraph 3). Data on biodiversity certainly includes data coming from natural history collections.

GBIF applauds the role that the United Kingdom's natural history museums and herbaria have played in curating specimens (natural history and organism-culture), especially type specimens, from all over the world. In addition, the UK has historically been a centre of concentration of taxonomic (including nomenclatural) and systematic expertise. Some UK taxonomists and systematists disseminate the products of their professional efforts via the GBIF network.

— GBIF, through its Work Programme, has been supportive of these efforts. Since its inception in 2001, GBIF has provided €378,435 in "seed funding" towards digitisation of data from natural history specimens, as well as to populate databases of names of species. GBIF has also supported the Catalogue of Life partnership (UK's Species 2000 + USA's ITIS) to a total of €351,404.

The Natural History Museum in London alone holds some 70,000,000 specimens. The United Kingdom currently serves nearly 15,000,000 data records through the GBIF network. Of these, 174,000 are natural history museum specimen-based; 14,761,000 are records from observational Initiatives rather than being based on the specimens that are collected and studied by taxonomists and systematists.

— GBIF wishes to emphasise the urgency and responsibility of the United Kingdom to liberate the data associated with specimens and culture collections held by museums, herbaria and other collections in the UK. These data are of potentially vital importance to enable, among many purposes and benefits[29],

— modeling of biotic responses to climatic or anthropogenic environmental change,

[29] Chapman, A., 2005. *Uses of Primary Species-occurrence data* http://www.gbif.org/prog/digit/data_quality/UsesPrimaryData

— designation of appropriate protected areas,
— prediction of the impact of invasive species or released genetically-modified organisms,
— establishing scalable measures of the rate of biodiversity loss,
— documenting species present in any given country or region,
— supporting the development of a global taxonomic information system that will help to remove the "taxonomic impediment".
— The United Kingdom has the unique opportunity of becoming a world leader in the area of digitisation and dissemination of data from natural history collections. Because it historically has had a leadership role in taxonomic/systematic collecting, the UK houses unique specimens and cultures (including types) from almost every part of the world.
— At present there is a sense of disappointment among the international systematic and taxonomic community that the UK has not yet assumed this leadership role. This community would enthusiastically welcome a significant increase in the rate at which UK museums and other collections are liberating their data.
— In the United Kingdom's House of Lords Science and Technology Committee's report of 2 May 2002, the importance of digitising the systematic biological collections was highlighted. The Committee noted that this would be a move that would both increase accessibility of these data and help to update the archaic image of systematic biology. However, the progress of the United Kingdom in achieving this goal to date has not been encouraging. The current rate of data digitisation and dissemination hampers the progress of systematics and taxonomy not only in United Kingdom, but worldwide.
— There is a need to increase core funding to United Kingdom collections/museums specifically for databasing and digitisation activities.
— It is desirable that United Kingdom museums/collections collaborate with the mega-biodiverse and other countries of origin of the specimens in their collections to evolve project design. This would reaffirm the UK position on free and open access to primary biodiversity data, as well as encourage and attract new opportunities for funding and collaboration.
— Toward this end the UK museum/collection community, in consultation with Defra and other relevant Government Departments, should rapidly develop a strategy for digitisation and dissemination of its natural history data, especially those collected as a part of publicly funded projects.
— GBIF could assist the UK in holding
— coordinated discussions with countries of origin whose collections are held in UK museums/ collections
— meetings of United Kingdom museums, herbaria and other collections with representatives of mega-diverse countries and countries-of-origin, together with international funding agencies, to develop programmes of work and long-term funding and collaboration strategies.
— In order to industrialise the process of digitisation, UK museums/collections should explore the possibility of outsourcing relevant components of the process to ICT firms and R&D institutions from developing nations such as India, Brazil, South Africa, etc., as a cost-effective option.

II. Names Data

There is a pressing, global need to complete an electronic list of all species of animals, plants, fungi and micro-organisms so far named by taxonomy. This list requires inclusion of all synonyms and alternate names applied to all species known to science. Such a list is not yet complete and GBIF is playing a key role in this endeavor through its ECAT work programme.

A complete list of names of all known organisms is necessary as an indexing device in order to associate specimen-level biodiversity data with other scientific data associated with the species they represent. As a communication device, the list also underpins international legislation, and enables practitioners in conservation, ecology, pest control, quarantine etc to communicate effectively.

Such a list needs to be freely available on the internet in a form interoperable with the data on specimens, and other biodiversity data.

The United Kingdom holds both significant literature and staff trained in nomenclature and taxonomy. It also has a history of developing datasets that are subsets of the envisioned complete list.

— GBIF urges that the relevant institutions in the United Kingdom, such as the Natural History Museum, Royal Botanic Gardens Kew, Royal Botanic Garden Edinburgh, Plymouth Marine Laboratory, CABI, Species 2000 and others, as well as national funding agencies such as BBSRC and NERC, actively collaborate to

— ensure that the full catalogue of known life on Earth be completed by 2010, and

— that new names generated by future taxonomic activity are automatically added to the globally shared electronic list.

6 June 2008

Memorandum submitted by E.F. Greenwood MSc, FLS, FMA

Introduction

My interest in the work of this committee is twofold.

1. My work on the Lancashire flora (flowering plants and ferns) depends on the continuing research into the systematics and taxonomy of the British flora and;
2. My professional museum experience provides expertise in the problems facing regional and local museums and especially in making collections available to the public.

Lancashire Flora

Systematics and taxonomy

To write a local flora requires a detailed knowledge of the taxonomy of the plants, including critical groups and horticultural taxa, found in the area to be studied. It is impossible for one person to have this knowledge and reliance has to be made on the support and expertise of others. In a little studied area, such as northern Lancashire, fewer than ten people have been able to contribute significantly to the gathering of data over the last 40 years. Significant help requires the systematic survey at different times of the year of each of the 462 tetrads (2 x 2 Km squares of the National Grid). Each of the volunteers who undertook detailed surveys at different periods over the years achieved high levels of competence in identifying British plants. Nevertheless I have had to visit every tetrad, often on many occasions over the years, to achieve even reasonable cover. Without this data and review of historical information, it is impossible to monitor change at the local level. Data from these local surveys is submitted regularly for national schemes.

However as recorder for VC 60, it is essential that I have access to the latest research on the systematics of the British flora. Today the Botanical Society of the British Isles (BSBI) provides this information. This is a voluntary organisation, although in recent years it has received project funding. Nevertheless, the Society prides itself on the collaboration it obtains between professional taxonomists and the amateur sector. This collaboration enables the Society to undertake national surveys, publish a scientific journal, *Watsonia*, and hold scientific conferences and to publish monographs on identifying the British vascular flora.

During the 1950s and 60s, Britain enjoyed a remarkable period of training and research in taxonomy. This led to such "landmark" publications as the *Flora of the British Isles* (1957), *Flora Europaea* (1964—1980) and *Atlas of the British Flora* (1962) and their subsequent revisions and new editions etc. Over the last 40 years or so many monographs and identification aids, mostly published by the BSBI, have been published but all have relied on the professional expertise of systematists most of whom were trained in the 1950s and 60s. Today the last products of this period are being published, eg *Sedges of the British Isles* (2007), *Flora of Great Britain and Ireland* (1996 → (two out of five volumes published to date)) and "Hybrids in the British Flora" (to be published 2008/9). All these books, fundamental to the study of the flora of the British Isles rely on professional but now retired taxonomists. Amateur botanists have also contributed to or written a number of manuals or handbooks, eg works on *Rosa* and *Rubus.* Unfortunately, most amateur botanists do not have access to modern scientific techniques and facilities to enable them to fully utilize the available resources needed for modern taxonomy. Once gone (and death is inevitable) it will be difficult to replace the lost expertise of the present but elderly generation of taxonomists for many years, even if training courses (at degree and post graduate level) started today.

Nevertheless a few and even quite young systematists are employed today but they are rarely allowed to do taxonomic research. It is therefore clear that the three main national institutions will have to recruit new staff from overseas and it is questionable if their duties will embrace the taxonomy of British biota in the face of world priorities.

Yet it is my view that if there is to be any credence in continued monitoring and conservation of the British flora, the need for professional taxonomic and systematic expertise in the face of relentless environmental pressures (eg climate change, atmospheric pollution etc), is never more urgently needed.

Data collection, management and dissemination.

As a vice-county recorder for the BSBI my data is shared with the hub or centre of the national botanical recording network for forwarding to relevant bodies and at the 10km square level to the public via the internet. However the primary data for VC 60 remains with me.

I have long been an advocate of local biological recording centres, and many years ago established the N.W. Biological Field Data Bank for site based data covering the old counties of Lancashire and Cheshire at what is now World Museum Liverpool (Greenwood, 1971). It was also my intention, but never achieved, to link the data bank records to voucher specimens in the herbarium, hence my belief that suitable places for such centres were in museums. Unfortunately in the non-digital age this was difficult but today it should be no problem to make such links. The data bank at Liverpool has been inactive for well over ten years and although the data has been transferred to more recently established biological record centres, where appropriate, remaining data has been boxed and put in "deep" storage. I fear that in time it will be forgotten and perhaps lost. This will then follow the pattern of previous schemes in the region, which my original ideas were designed to halt.

Whilst the detailed records of the BSBI may well be passed to local biological record centres, where they exist, in Lancashire this is not possible as there is no centre. However collaboration takes place with Lancashire County Council, which maintains a database for their own largely planning purposes and the Wildlife Trust for Lancashire, Manchester and N. Merseyside. Nevertheless the detailed information in my possession, accessed via the BSBI, is rarely requested and it must be remembered I am a volunteer and I could not cope with many enquiries.

The Role of Local and Regional Museums

Shortly before I retired in 1998, I presented a report to a specialist group at the Annual Meeting of the Museums Association, detailing the loss of natural history curators (unpublished). I believe that since then the decline has continued. Despite recent reports on collections in museums (see Wilkinson, 2005 and the *Museums Journal* for July 2007 for recent projects and reports in this field) it is my perception that natural history, if mentioned, is a very low priority in the work of arts based local and regional museums and that the decline of natural history curators continues. Furthermore those that remain, or are put in charge of the collections, hold junior posts or have little knowledge of the collections. As a consequence they are hardly in a position to comment within the wider context of collection curation and accessibility. Indeed it seems to me that there are few in more senior positions or on governing bodies, who have the least idea of the significance of natural history collections and despite the emphasis on the so called public access to collection's they remain largely inaccessible.

When I was professionally engaged in museums, I was passionate about public access and use of collections not meant for traditional public display. This was as relevant to the humanities as to natural history. Over many years we developed at Liverpool a methodology for public access to the collections through the Natural History Centre (Greenwood *et al*., 1989). However the constraints of little space for storage and consultation of collections and the lack of documentation of the collections, all ultimately dependant on the lack of finance, prevented any meaningful breakthrough in getting the collections accessible to the public. Yet over the years curators were ever optimistic that conditions would improve and in the post war period many important collections were acquired for the nation. Many have said the curators were foolhardy.

Then the opportunity arose in the 1990s when for World Museum Liverpool new space and lottery funding coincided to re-develop the museum. The new Museum opened in 2005 and has greatly improved storage conditions and access to the natural history collections since the committee last considered these issues. It has also provided new and improved conditions for the Natural History Centre (with a similar hands-on centre for the humanities) and new public displays, yet the crucial funding for collection documentation has never been forthcoming. Without this meaningful accessibility to the collections is strictly limited.

In my work on the Lancashire flora I have felt it essential to consult a wide variety of sources in county record offices and museums around the country. In general terms access to collections of archives is much easier than to natural history collections. Almost all record offices have some form of digital access available either on line or locally. This is rarely available for natural history and where natural history curators have been lost it sometimes takes great persistence to get access of any kind.

There are exceptions. A group of natural history curators, without significant funding, have made considerable progress in documenting their collections and making them available on the internet. This has mostly involved some of the smaller collections but the Manchester Museum amongst the larger museums has made progress. Like Liverpool the Museum benefited from lottery funding for improving storage (for most of my professional career conditions were appalling) and other funding has enabled progress to be made in documenting their collections. For me personally there are considerable holdings of northern Lancashire voucher specimens at Manchester and this has enabled me to thoroughly review the significance of a number of species accidentally introduced with imported grain 100 years ago. I am therefore able to do much of my work remotely from home and then only consult the specimens themselves at a later date if needed. Nevertheless funding for collection documentation remains largely unavailable but through the group of natural history curators, a system has evolved utilizing the internet and the public to get the latter to document the collections remotely (Wolstenholme & Humphrey, 2006).

The end product of this initiative enables the user anywhere in the world to interrogate the collections remotely, to not only see the data attached to the label, but to see the specimen and original labels in full colour. This is making collections truly available. Yet it is unrealistic to expect the general public to complete the work at even one large institution for free. A job that is fundamental to the work of the institution and that should be considered as a priority for basic funding, not only by the governing body, but also by the Government

Unfortunately and put simply, natural science in museums is not a priority. I believe provincial collections are at risk from neglect or possibly disposal.

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E.F.Greenwood

I have spent a lifetime studying the flora of northern Lancashire and for part of the area (VC 60) I am the BSBI's vice-county recorder. I was also for a period an editor of their journal *Watsonia.* Currently I am writing a local flora of northern Lancashire.

In my professional life I curated the botany collections at what is now known as the World Museum Liverpool. However for many years before retiring in 1998 I was head of the Museum reporting to the Director of the then National Museums and Galleries on Merseyside with direct access to the Board of Trustees. During this period I was responsible for the Museum and all its collections. I feel my main achievement was to develop the master plan for acquiring new space (acquisition of the old technical college situated below the Museum) and developing an essentially new and enlarged museum for public display, improved public access and new storage for the collections.

In my own time I maintained a continuous commitment to the Wildlife Trust for Lancashire, Manchester and N. Merseyside and of which I am currently a trustee.

Since my retirement I have devoted my time to the study and conservation of the Lancashire vascular flora.

Memorandum submitted by the Hertfordshire Natural History Society

Summary

1. Systematics and taxonomy are under funded and the requirement for these skills when dealing with the big questions of today, is under estimated. In particular, the role of taxonomy relating to biodiversity issues and climate change (neither of which can be dealt with without large input from these disciplines) is unappreciated.

2. Much of the expertise in species recording comes from amateurs, many of whom are in the older age spectrum. County Recorders take on much of this work on a voluntary basis, feeding the information to local (usually County) Biological Records Centers and to National Recorders. Centers of excellence for systematics and taxonomy such as the Natural History Museum and Kew Gardens also utilize the skills of amateurs.

3. Schools and universities no longer cover taxonomic skills in any detail, and little is covered at undergraduate level. There are few young people being trained in these skills, which will leave us with an impoverished national skills base.

4. There is a requirement for greater government commitment to this area of research and skills development. In particular this commitment must be a long term commitment if government seriously wishes to turn things round. Government should not make a commitment in this area based on new technology alone. Much of the applications at the molecular level being suggested have been over-estimated and will not prove useful for many decades.

2. *What is the role of systematics and taxonomy and, in particular, in what way do they contribute to research areas such as biodiversity conservation, ecosystem services and climate change?*

How important is this contribution and how is it recognised in the funding process?

How is systematics integrated in other areas of research?

The role is vital. If you can't identify and distinguish what you have, how can you begin to talk about biodiversity? It's not a "sexy" area of research for funding- unless one is looking at the molecular level. The contribution of taxonomy is vital and strangely undervalued. We have very few taxonomists in the UK and even fewer coming through. A couple of years ago I worked with colleagues at the University of Lodz in Poland on Leonardo da Vinci project (over an 18 month period) to bring 21 Masters graduates to the UK for a period of 6 months for work experience. Many of them were employed because they could identify to species level, a range of organisms (especially plants, freshwater and terrestrial invertebrates). In Poland they maintain a classical education and science graduates doing botany or zoology have good identification skills. Several of them have gained permanent employment here because of their taxonomic skills—far ahead of our own graduates. In Poland they still have departments of Evolutionary Science, and commonly employ 30 botanists within a department.

As to integration with other research—well taxonomic skills are essential for any conservation and any biodiversity project. Many of us view BAPs as being incomplete because we know that only those species well studied are included. For example, the National BAP mentions only 3 freshwater invertebrates, the southern damselfly, freshwater pearl mussel and the native crayfish. Yet in my own specialism I know that the trichoptera (caddis) have at least 7 listed as RDB1 species (Red Data Book species, RDB1 are those species listed by the IUCN as being critically endangered), one of which is almost certainly extinct! This group is not mentioned in any BAP in the UK. We therefore underestimate threats to many species, often because locally and nationally, there are few people able to identify and record certain groups. With regards to climate change, there will be species that could prove to be excellent indicators of change, but do we have the people who can actually recognize them?

4. *What level of funding would be needed to meet the need for taxonomic information now and in the future? Who should be providing this funding?*

If government is serious about biodiversity, global change, system services etc. then government should fund it. Unfortunately any funding is likely to get lost in molecular research rather than taxonomic support.

6. *What impact have developments in DNA sequencing, genomics and other new technologies had on systematics research?*

In what way has systematics embraced new technologies and how can these research areas interact successfully and efficiently?

Great advances are being made in the molecular field, but we still have to ask what's happened to the field taxonomic skills that are essential tools in conservation, biodiversity etc. These have been neglected. At the molecular level there are some well funded projects but this area is over emphasised. Recent progress suggests that in the future there is scope for molecular identification in the field. However, one has to know what one actually has first! If it doesn't have a name how do you know what you have (apart from a DNA code)? These developments are very many years away from realisation, and we will still need systematics & taxonomic skills to make sense of the information.

Data collection, management, maintenance and dissemination

7. *Does the way in which taxonomic data is collected, managed and maintained best meet the needs of the user community?*

What is the state of local and national recording schemes?

Collected primarily by local County recorders. Fed to the local Biological records center and / or to National Recorders. Some specialist recording carried out, eg national survey for bumble bees or dragonflies. Some Counties publish information/records for particular groups and there are national publications (Birds in particular with the National Atlas). Not all recorders are keeping their records in electronic format. We are currently trying to get all our recorders to put their records into electronic formats and to lodge copies with the local BRC. National Biodiversity Network (NBN) is great, but still evolving and deserves more support. As chair of a county recorders group, I have to say that the state of local & national recording schemes is patchy. Some groups are well recorded such as birds, butterflies and dragonflies—others may not even have someone within the county able to identify certain groups—so these are omitted. Don't forget this work is all voluntary. County Biological Records Centers are being downgraded in many areas and many of their records come from their County Recorders. County Natural History Society recorder lists (the level where most recording is done) are variable. A quick look at a few web sites illustrates the problem. London Natural History Society has 15 recorders with 2 vacancies and 2 recorders also record for Hertfordshire. Hertfordshire has 28 recorders. Essex lists no County recorders, nor does Oxford or Cambridge, although for instance Oxford has rare plant recording within its society. Bedfordshire record 20 groups. Yorkshire Naturalists Union, list 17 groups that they record.

8. *What is the role of the major regional museums and collections?*

How are taxonomic collections curated and funded?

The role of museums and collections is vital. May be the only places we can look at specimens to confirm identification. No idea as to funding—but had visitors over from Kenya last summer, one of whom helped put the Natural History Museum's collection of Lake Victoria's cichlid fish in taxonomic order. They had been neglected and were out of date because they were no longer a key interest of the current curator. Would indicate that not all groups, even important ones, have the right level of resources.

9. *What progress has been made in developing a web-based taxonomy?*

How do such initiatives fit in with meeting demand for systematics and taxonomy information?

How do UK-led initiatives fit in with international initiatives and is there sufficient collaboration?

A few basic keys available. For my own work we are fortunate to have the FBA (Freshwater Biological Association) text keys for freshwater organisms in the UK. Some electronic keys are now being developed, but those I have tested are not what I would use day to day as they have not been shown to be particularly user friendly. Potential for electronic keys in this area from some groups but may not be suitable for all. Feel that there is a push to make short cuts which does away with the underpinning knowledge in this suggestion. Photographs are great in matching what you have with what's on a screen, but some still require microscope skills and knowledge of a taxonomic group's morphology.

10. *What needs to be done to ensure that web-based taxonomy information is of high quality, reliable and user-friendly?*

A good dichotomous key using high resolution photographs showing / confirming the key features. For those who of us who use a microscope, see little likelihood of replacing text version.

11. *How does the taxonomic community engage with the non-taxonomic community? What role do field studies play?*

Field studies, ecology field trips are especially valuable. They train people in the correct sampling and collection methods and in identification skills. Only learn by doing and this type of skill needs constant reinforcing. As to engaging with the non taxonomic community, I do this mainly with students. Some Counties run a program of field days for particular groups of organism for the general public and our county (Hertfordshire Natural History Society) we are also keen to encourage new members (especially younger members) to participate. Recorders are often happy to act as mentors- however, the uptake is disappointing.

Skills base

12. *What are the numbers and ages of trained taxonomists working in UK universities and other organisations?*

Within in my institution, University of Hertfordshire, there are now only 3, two over 50 years in age and one over 60. For the Hertfordshire Natural History Society recorders group, 2 are in their 30's the majority are over 50, a few in their late 60's and a couple over 70. No sign of younger members coming through.

13. *What is the state of training and education in systematics and taxonomy? Are there any gaps in capacity? Is the number of taxonomists in post, and those that are being trained, sufficient to meet current and future needs across all taxonomic subject areas?*

At undergraduate level there is little taxonomy taught. Some at Masters level. The majority of students studying biological / ecological subjects as undergraduates no longer know, or can name the body parts of a plant or insect. They may have briefly touched on it at GCSE, if we are lucky, but the majority cannot remember it.

At our institution we have no "taxonomist" in post. I am employed as an ecologist—but not all ecologists have taxonomic skills. So the state of training is dire. Even if we did train them up, there is no career structure in place!

4 February 2008

Memorandum by the International Trust for Zoological Nomenclature

Summary

The International Trust for Zoological Nomenclature (ITZN) is the UK-based charity dedicated to the support of the International Commission on Zoological Nomenclature (ICZN). ICZN was founded in 1895, at a period of confusing instability in the scientific naming of animals, and continues to be the internationally recognised regulator of zoological nomenclature. ICZN is now poised to provide its essential services in a manner that is dependable, durable, and freely accessible to the world-wide community of scientists and other users of its products through a web-based development known as ZooBank.

It is essential for the scientific community that ICZN is positioned to provide this complete service before the end of the first decade of this new century. In the context of the service provided by ICZN to the UK and international community of systematic biologists, taxonomists and the many other users of animal names, it is anomalous, if not incredible, that the implementation of ZooBank should not be supported by UK national or international grant-giving bodies. A serious re-appraisal of the funding arrangements for ICZN is overdue. A regulatory body of this importance to science should not be funded solely through the voluntary efforts of members of a small UK-registered charity.

Background

The International Trust for Zoological Nomenclature (ITZN or "the Trust") is the UK-based charity dedicated solely to the funding of the International Commission on Zoological Nomenclature (ICZN or "the Commission"). The Commission was founded in 1895 by the International Congress of Zoology, out of earlier organisations that included such notable biologists as Charles Darwin and Richard Owen. The aim of the Commission was then, and is still, to bring stability to zoological nomenclature.

Stable nomenclature is at the heart of rigorous communication about biodiversity. Species names provide the "anchor" to which all taxonomic, ecological, molecular and conservation data are attached. Legal protection and policy are also linked with names, not actual (mortal) animals, on the assumption that the groups

indicated by the names are consistent through time and among places. Scientific discussion relies on names having unequivocal, context-independent meanings. Medical and veterinary implementation requires indisputable identifications. Although discovery and delineation of species may receive the emphasis of high-profile press coverage, all taxonomic practice is crucially dependent on a stable nomenclature to provide a steady platform on which to build. ICZN is the single professional organization devoted to ensuring that this work happens in a globally consistent way providing continuity both for new species discoveries and for the correction of errors in past works.

ICZN provides and regulates a uniform system of zoological nomenclature ensuring that every animal has a unique and universally accepted scientific name. Currently the Commission is composed of 27 elected Commissioners from 19 countries around the world. These are leading zoologists who collectively represent all the major fields of zoology. In 2004 ICZN began a restructuring and modernisation programme to match the expanding capacity of information and communication technology (ICT) to underpin its service to the international scientific community.

ZooBank

No analyses of patterns of biodiversity are immune to problems of unreliable nomenclature. Unfortunately, rates of error in linking names with their intended objects are very high due to the non-persistent nature of web pages (URLs regularly change, resulting in "link-rot"). Access to definitive nomenclatural sources remains difficult and is a part of biodiversity work that is often skimmed over by researchers. Error rates can then perpetuate throughout the analyses, sometimes multiplicatively, providing further examples of the adage "garbage in, garbage out". In order to tackle this problem ICZN is developing a web-based nomenclatural tool, known as ZooBank, that will persistently maintain and disseminate nomenclaturally verified data for animal names using globally unique identifiers (GUIDs) for each animal name. This will then act as the source for "clean" data for the many other downstream biodiversity tools such as the large-scale taxonomic initiatives of EDIT, Tree of Life, etc.

This initiative, to provide a universal, open-access, register of all species names, freely accessible via the World-Wide Web, was first announced in the journal *Nature* in September 2005. Favourable comments followed in both the popular and more specialised science press, and the concept has since received the universal support of scientists and policy makers. ICZN now has 117 Scientific Affiliates who have signed a Memorandum of Cooperation supporting the aims and objectives of ICZN, including ZooBank (Annex). A preliminary version of ZooBank, containing 1.6 million scientific names, was launched in August 2006 (www.zoobank.org) with the registration interface still under development. The ultimate achievement of ZooBank will mark the attainment of ICZN's major objective, to provide enduring stability in nomenclature. It will be of huge significance to taxonomists, present and future, and the sciences dependent on their work, but will not eliminate the permanent need for a regulatory commission (ICZN) to oversee the process, with powers to resolve the more complex problems.

The Trust's prospects 2008-2010

Financial stability of the ICZN secretariat, for the time being, is guaranteed by modest reserves held by the Trust, annual income from sales of the *Bulletin of Zoological Nomenclature* and of any future editions of the *Code*. Accommodation for the ICZN Secretariat, generously provided by the Natural History Museum, London, is not under threat. Under existing rules, however, ICZN is ineligible for UK Research Council funding, and the Trust receives no institutional support, UK government or international funding (eg, UNESCO). The development of ZooBank, arguably ICZN's most important current activity, therefore presents a severe challenge to the Trust as the funding organisation. Given the importance of ZooBank to the huge national and international community of taxonomists, systematic biologists and the many other users of animal names, now and into the future, it is anomalous, if not incredible, that the funding for this revolution in the working methods of ICZN should be wholly dependent on the voluntary efforts of the members of a small UK-registered charity.

Initial costs will be incurred for retrospective registration of animal names, ie, checking data against original publications going back to 1758, a task that can best be undertaken by experts in each specialised area of taxonomy. When the system is established ICZN will retain its essential regulatory role, ensuring a stable and "clean" nomenclature that is an absolute necessity for all biodiversity work. Given that there are at least 1.6 million described animal species, and perhaps five to six times as many yet to be named, the ZooBank initiative ranks as a large-scale priority for biodiversity classification and management, ranking with other "big" science such as medicine or astronomy.

At this stage, ITZN predicts that the cost of implementing ZooBank will be £1M. We have conditionally been pledged a quarter of this by the Gatsby Charitable Trust. ITZN hopes that, if the UK scientific funding bodies take a lead, the international community will respond in order to achieve the implementation of ZooBank within the shortest possible time.

The Committee's Questions

What is the state of systematics research and taxonomy in the UK? What are the current research priorities? What are the barriers, if any, to delivering these priorities?

Stable scientific names underpin systematics research and taxonomic classifications. Since 1895, this stability has been provided in zoology and all related fields of endeavour (including agricultural, veterinary and medical research, parasitology, the study of vectors of human, animal and plant diseases, etc.) by the *International Commission on Zoological Nomenclature* (ICZN, or the "Commission"). The Commission consists of 27 eminent zoologists from 19 countries, governed by a president and council, with a secretariat staff operating from an office in the Natural History Museum, London (NHM). The ICZN secretariat oversees the periodic publication of the updated *Code of Zoological Nomenclature* (the "Code"), which acts as the global foundation for the regulation of animal names.

Nomenclatural problems arising from systematic or taxonomic research, that require active intervention to arrive at a stable solution (via the Commission's plenary power) are put to the ICZN by the scientists involved. These applications are published as technical papers and disseminated as widely as possible for professional comment, before the Commissioners are individually polled for their collective decision. The Cases, Comments and definitive, binding Opinions reached by this process are published in the *Bulletin of Zoological Nomenclature*, with abstracts of Cases, Opinions and Comments (published in full) freely available online via the ICZN website (www.iczn.org). The current priority of ICZN is to bring animal nomenclature into the 21st century by adopting IT/bioinformatics to the fullest extent, ultimately providing the Commission's regulatory services through a web-based system, freely accessible to those who use scientific animal names. This hugely important project has been titled *ZooBank*. ZooBank is recognized as the ultimate source for robust and "clean" nomenclatural data both for established animal names and for the registration of newly discovered species, and is rapidly gaining the support of the broad scientific community with over 100 scientific institutions and societies having signed up to this initiative. Large scale biodiversity informatics projects such as the Encyclopedia of Life (EOL) lack the capacity and authority to ensure stable nomenclature, with ZooBank being "a vital partner" to their success (Jesse Ausubel, Chair of EOL Steering Committee). The support for ZooBank extends across the spectrum of taxonomy end-users, with comments such as the following not uncommon:

> "*This accomplishment is a first major step towards completing the Linnaean enterprise, which is essential for mapping Earth's still poorly known fauna. With the firm foundation ZooBank aims to provide, the rest of biology will be immensely strengthened, and humanity correspondingly benefited*" (Professor Edward O. Wilson, Harvard University, leading authority on biodiversity);
>
> "*This is a hugely significant step for animal conservation. With ZooBank in place we will all have access to a single reference list of animal names, and so discussions about priority species and habitats can proceed with greater clarity and speed.*" (Professor Georgina Mace OBE FRS, Imperial College, London, leading authority on biodiversity).

What role do systematics and taxonomy play in research into biodiversity conservation, ecosystem services and climate change? Is that role recognised in the funding process?

Biotic response to climate change will determine whether there is disruption of ecosystems and loss of their services from invasive and introduced organisms. Accurate taxonomy is key in all aspects of modelling, monitoring, and assessment of biotic response to past climate change, however this is underpinned by sound, universal and well-regulated nomenclature. Similarly, conservation efforts are meaningless without a stable nomenclature that serves the needs of legal protection and policy formulation, both of which legislate on *names*, not individual entities. Nomenclature is integral to all biodiversity and systematic research. However, the ICZN is not a basic research organization, thus its work is not eligible for research council funding. The ICZN is financially supported by a UK-registered charity, the International Trust for Zoological Nomenclature (ITZN or the "Trust"). The Trust receives no institutional, governmental or international funding and is run by a volunteer board. It is absurd that such an important service to science should be dependent on charitable donations from private sources.

Does the way in which systematics research is organised, co-ordinated and funded best meet the needs of the user community?

ICZN provides a vital service to the community of users of animal names, as is evidenced by global attention to our mission. The development of ZooBank will be the definitive source for nomenclatural information for animals, and thus will increase good taxonomic practice throughout the research community. It will also be poised to ensure validity of the 16,000 to 18,000 new names for animals described each year (many more than among plants or bacteria). Thus ZooBank, and the work of the ICZN, provide both an axis and a hub for maintaining and disseminating high quality data. As a critical link in high standard taxonomic practice that both organizes and coordinates information, it is short-sighted that the ICZN and ZooBank are under-funded and dependent on private charitable and trust contributions.

What is the role of the major museums and collections in taxonomy research? How are taxonomic collections curated and funded?

Zoological nomenclature is founded on the identification and safe custody of *type specimens* which (under the *Code*) should be deposited at a museum or institute of recognised standing. There is thus a fundamental relationship between a stable zoological nomenclature and the responsible curation of specimens at these institutions. The work of the ICZN adds value to collections; the significance of type collections is dependent on the legitimacy conferred by nomenclatural acts. The ICZN secretariat also relies heavily on access to the library at the Natural History Museum, South Kensington, which is the best collection of natural history publications in the world. This regular, practical use of the library increases its effectiveness on a global scale. Thus our location within the museum is key to our effective functioning and adds value to the core functions of the museum as an archive of type specimens and literature. This key role deserves governmental recognition and funding.

What progress has been made in developing web based taxonomy? What can be done to ensure web based taxonomy is reliable and of high quality?

ICZN and ZooBank are at the forefront of making web-taxonomy accessible. The deployment of ZooBank will provide a web-based regulatory system for a stable, high quality zoological nomenclature, underpinning all animal sciences. The essential software is already developed, a demonstration data set of 1.6 million names has been accessed from Zoological Record, and the first newly described species have been registered. We are now in need of specific funds for retrospective registration of unverified names on a large scale to ensure completeness. This project will require an expansion phase to be effective, but in the long term will be self-supporting as the scientific community self-registers names (in the manner of GenBank). In concert with development of ZooBank, the ICZN will make facilitation of reliable web-based taxonomy and the archiving of new species descriptions central in developing the next edition of the *Cod*e (projected publication time in 2010). Funds are now required for the implementation of this essential project.

Does the UK have adequate numbers of trained taxonomists? What is the state of training and education in systematics and taxonomy?

ICZN is an international body, serving the international community of scientists using animal names, but is based in the UK due to the quality of the collections, library and history of work on taxonomy. The Commission's services are constantly in demand by this international community and, through its regulatory role, ICZN adds value to the UK's taxonomic resources. As there are severe shortages of taxonomic specialists, a fully-functioning nomenclatural regulatory body must work through an active networking process on a global scale. Current training in biology often lacks the basics of nomenclatural practice. Given appropriate resources, the ICZN is prepared to contribute to systematics and *Code* related nomenclatural training programmes at a number of levels, from introductory university courses to postgrad speciality courses. We also see that eventually part of our mission is to provide guidance for the active taxonomic community, to improve its understanding of nomenclatural practice through ZooBank. In an idealized sense, once ZooBank is fully established it will guarantee improved nomenclatural practice through the *Code*

compliant registration of all new species and overall, decrease the traditional work of the regulatory body. We recognize that the role of the ICZN will need to evolve as genetic species descriptions and taxonomic practices adapt to meet the biodiversity crisis. We are uniquely poised to meet these demands and expect that the role and function of ICZN will increase exponentially in coming years.

Annex 1

TRUSTEES OF ITZN & COMMISSIONERS OF ICZN

Members of the Trust	*Members of the Commission*
The Earl of Cranbrook (Chairman) (U.K.)	Dr M. Alonso-Zarazaga (Spain)
Dr P.L. Forey (Secretary and Managing Director) (U.K.)	Dr N. G. Bogutskaya (Russia)
Dr H.M.F.P. André (Belgium)	Dr N. G. Bogutskaya (Russia)
Dr M.N. Arai (Canada)	Prof D. J. Brothers (South Africa)
Mr H.S. Barlow (Malaysia)	Prof D. G. Fautin (U.S.A.)
Prof D.J. Brothers (South Africa)	Dr M. J. Grygier (Japan)
Prof W.T. Chang (China)	Dr R. B. Halliday (Australia)
Dr J.A. Compton (U.K.)	Prof I. M. Kerzhner (Russia)
Mr P. Cooke (U.K.)	Dr M. Kottelat (Switzerland)
Dr M. Dixon (U.K.)	Dr F.-T. Krell (U.S.A.)
Prof J. Forest (France)	Dr S. O. Kullander (Sweden)
Prof R.A. Fortey (U.K.)	Prof Dr G. Lamas (Peru)
Prof J.I. dos R. Furtado (Singapore)	Prof S. Lim (Malaysia)
Dr M.K. Howarth (U.K.)	Prof S. F. Mawatari (Japan)
Dr T. Jones (U.K.)	Prof A. Minelli (Italy)
Dr S. Knapp (U.K.)	Dr P. K. L. Ng (Singapore)
Prof Dr O. Kraus (Germany)	Dr T. Pape (Denmark)
Dr Ch. Kropf (Switzerland)	Dr L. Papp (Hungary)
Dr M. Luc (France)	Prof D. J. Patterson (U.S.A.)
Mr A. McCullough (U.K.)	Dr R. Pyle (U.S.A.)
Dr E. Macpherson (Spain)	Dr G. Rosenberg (U.S.A.)
Prof A. Minelli (Italy)	Prof D. X. Song (China)
Dr T. Nishikawa (Japan)	Prof P. S{tys (Czech Republic)
Dr J.L. Norenburg (U.S.A.)	Mr J. van Tol (The Netherlands)
Dr A. Polaszek (U.K.)	Dr Z.-Q. Zhang (New Zealand)
Dr M.J. Oates (U.K.)	
Mr N.J. Robinson (U.K.)	
Mr R. Steele (U.K.)	
Dr A. Wakeham-Dawson (U.K.)	
Dr G. Walker (U.K.)	

Annex 2

ICZN Affiliates

Academia Sinica, Taiwan

Acarological Society of America

American Arachnological Society

American Association of Veterinary Parasitologists

American Fisheries Society

American Malacological Society

American Museum of Natural History

American Society of Animal Science

American Society of Ichthyologists and Herpetologists

American Society of Limnology and Oceanography

American Society of Mammalogists

Aquarium—Musée de Zoologie de l'Université de Liège
Arachnologische Gesellschaft e. V.
Arbeitsgemeinschaft der Institute für Bienenforschung e.V.
Arbeitskreis Diptera
Asian Society for Environmental Protection
Asociación Entomolóxica Galega "Luis Iglesias"
Association of Applied IPM Ecologists
Association of Field Ornithologists
Association of Reptilian and Amphibian Veterinarians
Australian Society for the study of Animal Behaviour
Australian Academy of Science
Australian Entomological Society
Australian Museum
Australian National Insect Collection
Australian Society for Limnology Inc.
Australian Society for Parasitology
Australian Society of Herpetologists
BirdLife International
Bombay Natural History Society
British Arachnological Society
British Dragonfly Society
Canadian Society of Zoologists
Chicago Herpetological Society
China Zoological Society
Coleopterists Society
Conchological Society of Great Britain and Ireland
Conservation International
Commonwealth Scientific and Industrial Research Organisation, Entomology
Department of Biological Sciences, University of Alberta
Department of Biology, University College London
Department of Zoology, University of New Hampshire
Deutsche Gesellschaft für Herpetologie und Terrarienkunde e. V.
Deutsche Zoologische Gesellschaft e. V.
Entomological Society of America
Entomological Society of New Zealand
Entomological Society of Southern Africa
Estonian University of Life Sciences
Federation of Animal Science Societies
Florida Museum of Natural History
Freshwater Biological Association, U.K.
Gesellschaft deutschspr. Odonatologen e.V.
Gesellschaft für Schmetterlingsschutz e.V.
Global Biodiversity Information Facility
Harrison Institute
Ichthyological Society of Japan

Institute of Evolutionary Biology, The University of Edinburgh
Institute of Systematics and Evolution of animals, Polish Academy of Sciences
Institute of Zoology, London
Institute of Zoology, National Academy of Sciences of Belarus
International Bryozoology Association
International Palaeontological Association
International Society of Hymenopterists
International Society of Zoological Sciences
Internationaler Entomologischer Verein e. V.
International Federation of Tropical Medicine
Japanese Society of Systematic Zoology
Koninklijke Antwerpse Vereniging voor Entomologie v.z.w.
Koninklijke Belgische Vereniging voor Entomologie
Landcare Research, New Zealand
Latvijas Entomoloģijas biedrı∼ba
Linnean Society of London
Lithuanian Entomological Society
Marine Biological Association
Marine Conservation Society
Micropalaeontological Society
Münchner Entomologische Gesellschaft e.V.
Museo de Zoologia, Universidad de Navarra
Museo di Zoologia, Universitá di Roma "La Sapienza"
Muséum d'histoire naturelle de la Ville de Genève
Museu de Zoologia Universidade de São Paulo
Museum für Naturkunde Humboldt-Universität zu Berlin
Museum of the North, University of Alaska
Museum voor Dierkunde van de Universiteit Gent
Natal Museum, Pietermaritzburg, South Africa
National Biodiversity Network Trust
Natural History Museum, London
New Zealand Marine Sciences Society
North American Benthological Society
North of England Zoological Society
Organization of Nematologists of Tropical America
Royal Society of New Zealand
Royal Society of Victoria
School of Biological Sciences, University of Bristol
School of Biological Sciences, University of Wales, Swansea
Senckenbergische Naturforschende Gesellschaft
Slovenská entomologická spoločnost'
Sociedad Hispano-Luso-Americana de Lepidopterologia
Societa Entomologica Italiana
Societea Lepidopterologica Romana
Society of Population Ecology, Japan

Society of Vertebrate Paleontology

South African Institute for Aquatic Biodiversity

Southern Californian Association of Marine Invertebrate Taxonomists

Strickland Museum of Entomology, University of Alberta

Swedish Museum of Natural History

University of Alberta, Museum of Zoology

Vlaamse Vereniging voor Entomologie

Wiener Coleopterologen-Verein

Wildlife Conservation Society

Wildlife Trusts

World Association of Copepodologists

Zoological Museum, University of Copenhagen

Zoological Society of Bangladesh

Zoological Society of London

Zoological Society of Southern Africa

Memorandum submitted by Professor Marcel Jaspars

Although I am not a taxonomist, my work would be impossible without interaction with taxonomists. The work that I do is the biodiscovery of compounds from marine invertebrates and microorganisms with possible applications as pharmaceuticals and biomedical research tools. The interactions are vital to my research at several levels:

1. Field taxonomy—if possible all collections of marine invertebrates (sponges, soft corals, seasquirts) collected for my work are performed in collaboration with a taxonomist. I work together with Klaus Feussner at the Institute of Applied Sciences and the University of the South Pacific in Fiji, who is an expert at Fijian soft corals, and Chris Battershill of the Australian Institute of Marine Science, who is a sponge taxonomist and biotechnologist. Working with these scientists is vital to assess rapidly in the field whether the species collected has already been collected before, thus reducing wasted effort and the identification of a specimen to the family, or even genus level in the field, as we often have a target list of species for collection. However, the number of marine invertebrate taxonomists worldwide is very low, with few sponge specialists (*ca* 30) and only a handful of soft coral experts who are not nearing retirement age (*eg* Phil Alderslade, Darwin Museum, Australia; Leen van Ofwegen, Naturalis, Leiden, the Netherlands). With seasquirts, the situation is even more serious, and for the region I am interested in there is really only one authority (Patt Kott, Brisbane). Despite the obvious attractions, few people are taking up marine invertebrate taxonomy—the loss of Michelle Kelly from the NHM meant the UK lost its authority in sponge taxonomy. There are still pockets of excellence and the recent appointment of Jo Porter (bryozoan specialist) at Aberystwyth, means that there are some young scientists entering the field. The value of drug discovery from marine invertebrates is exemplified by the EMEA's recent approval of Yondelis (Trabectidin), derived from a seasquirt, for the treatment of soft tissue sarcoma, for which there is no other treatment. In addition, roughly 30 marine invertebrate derived natural products are in, or are nearing, clinical trials for a variety of diseases. The loss of our ability to do taxonomy on these species would bring this promising field to its knees.
2. In the work involving marine microorganisms, taxonomy is essential as the rediscovery rate of natural products from these organisms is greater than 99 per cent. This means that robust polyphasic taxonomy is essential to indicate the existence of a new species that may then be investigated for novel biologically active chemical entities. The UK used to be at the forefront of marine microbial taxonomy, but the recent retirement of Alan Bull (Kent) and the impending retirement of Mike Goodfellow (Newcastle) means that the UK will lose its unique position in this field.

Memorandum submitted by Mrs Patricia Lorber

"If you do not know the names of things, the knowledge of them is lost too" Linnaeus, *Philosophia Botanica,* (1751)

Background Information

My job is that of Biological Records Officer of the Norfolk Local Records Centre, housed in the Environment & Waste Section of the Department of Planning & Transportation of the Norfolk County Council. I am making this submission in my individual capacity.

My understanding is that for many years research in taxonomy in the United Kingdom has been poorly funded and its teaching omitted from most undergraduate biological science courses, but this analysis is best left to the academic submissions you will doubtless receive. I want to focus on the practical work of the Norfolk Local Records Centre.

The Centre takes its responsibilities in terms of biodiversity, the Natural Environmental and Rural Communities Bill and other planning legislation very seriously when, as happens almost daily, it is consulted for information on environmental surveys for planning and conservation purposes. The Centre holds nearly a million biological records, the earliest going back to 1605—a Peregrine Falcon at Hunstanton. For the accuracy of our records and the knowledge they embody we depend very heavily on a circle of dedicated naturalists—the County Recorders, each one an expert on a particular group. Only a few have had formal taxonomic training, but have learnt from others and painstakingly trained themselves.

I have asked four of our recorders to give me examples within their specialisms to indicate how, without reliable and expert knowledge, our records would be meaningless because they could refer to a completely different species.

I am sure that the examples cited below, or others very similar, are relevant to all Records Centres in all the counties in the United Kingdom. I hope that my examples will offer an indication of the taxonomic difficulties encountered in a highly specialised branch of Local Government, and thank Drs. Roy Baker, A.R. Leech P. Lambley and Mr Chris Jones for highlighting demonstrative examples of their work.

Examples

Mollusca:

Oxyloma sarsi (Esmarck). Slender amber snail. RDB2.

Found in less than ten sites in the U.K. Can only reliably be separated from *Oxyloma pfeifferi* (Rossmässler)—Pfeiffer's amber snail—by dissection of the penis.

Segmentina nitida (Müller) Shiny ram's-horn snail.

Confined to a few sites in Norfolk/Suffolk, Kent, Sussex and Somserset levels. While it is unnecessary to dissect to separate it from *Hippeutis complanatus* (L.), the Flat Rams-horn snail—it is always wise to examine the shell form microscopically, especially with young specimens. A number of Norfolk records in the 1990s are unreliable because they have been recorded by observers with insufficient experience.

Lepidoptera:

The Grey Dagger, *Acronicta psi*, is included on the new BAP List. This can easily be confused with the Dark Dagger (*A. tridens*) which does not appear on the list. The only accurate way of differentiating between the two is through microscopic examination of the genitalia.

Leeches

One of the best examples of lack of taxonomic expertise causing a potentially wide problem, is the discovery that at least some of the medicinal leeches used in research are not *Hirudo medicinalis* but *Hirudo verbana*, which has implications for patients and conservation. Decades of medical research and hundreds of academic papers have been called into question after the discovery that scientists may have been studying the wrong blood-sucking leech. At least 115 chemical compounds have been developed from what researches thought was the medicinal leech, with many being used in drugs in the pharmaceutical industry. Genetic analysis has now shown that the leech that led to the discoveries may have been the species *Hirudo verbana*. The findings could prove disastrous to scientists and pharmaceutical companies because it suggests that their researches,

new drugs and patients were based on the false premise that the medicinal leech was the species studied. It could be equally devastating for the leeches themselves, which as *H. medicinalis* has legal protection, but as *H. verbana* have no defence against being collected from the wild by the hundreds of thousands.

Fungi:

Two examples of economic importance are given:

Armillaria mellea. Common Honey fungus. There are at least four British species in this group. Extensive research is needed to establish the species criteria and their ecology.

Ganoderma applanatum/Ganoderma australe. The former has spores which are 6.508.5μm long while the latter has much longer spores—8-13μm).

For a forester, it becomes very important to distinguish between species that vary greatly in their pathogenicity. *A. mellea* is known to kill trees, especially oaks that have been weakened by drought or other pathogens. *A. osloyae* is known as a violent pathogen of conifers. On the other hand *A. gallica* is usually an innocuous saprophyte, living on organic matter in the soil. A forester finding an *Armillaria* fruiting in the woods would need to be able to tell whether or not there is a potential problem with *Armillaria* root disease so that mitigative procedures could be taken if necessary.

Cantharellus friesii. Orange Chanterelle (a Biodiversity Action Plan [B.A.P] species) has significantly longer spores (8.5-12μm) than the widespread *Cantharellus cibarius* with spores 7.5-9μm.

Lichens

Enterographa sorediata (B.A.P. sp.) is hard to distinguish from two much more common species *E. crassa* and *Schismatomma decolorans*. The Churchyard Lecanactis *L. hemisphaerica* (BAP) is now known to be a form of another rare species *L. grumulosa* and not a new species, but it required taxonomic work. *Caloplaca luteoalba* is also difficult to separate from some other species, and most of the BAP species in Norfolk were found only when there was a botanical taxonomist employed in the museum service.

Memorandum submitted by Professor (Emeritus) Amyan Macfadyen, M.A., D.Sc. Oxon

In my view, accurate Taxonomy is essential to the effective pursuit of most biological disciplines and especially that of ecological systems, because even closely similar species have frequently been selected to occupy different niches and differ in many biological characteristics.

Today the number of biologists able to identify animals accurately, especially invertebrates, is limited and diminishing. Some factors contributing to this situation include:

1. The change of emphasis in teaching at all levels away from systematics to areas such as biochemistry, genetics and areas relevant to medicine.
2. Consequentially there is a shortage of teachers with the skills and enthusiasm able to interest students in systematics.
3. The decline in fieldwork, partly due to excessive emphasis on safety. Fieldwork is a primary generator of interest in and fascination with animal life among young people and many famous ecologists have testified to this.
4. Excessive reluctance among teachers and youngsters to kill any animals despite the massive mortality, which occurs as a result of human intrusion in any habitat, especially when toxic substances are used. Correct identification is often impossible with live animals especially arthropods.
5. The widespread use of audiovisual material as a substitute for actual contact with specimens, live or dead often leading to lack of appreciation of the real context, size and provenance of organism.

Cost is, of course an important factor in evaluating all teaching methods and field natural history may well involve transport costs. These can often be minimised by the use of local habitats, gardens and vivaria and the actual equipment required for the above studies need be far less than that used for most laboratory based work.

Positive steps should be taken to remedy the above situation and to encourage field biology in schools and in courses in higher education. The situation has deteriorated to the extent that there is a serious shortage of instructors and this should be remedied by training courses. These need not be expensive if use is made of the

facilities available to museums and non-governmental organisations such as the Field Studies Council and the British Ecological Society.

This is an area where relatively modest funds could achieve excellent results, but time is of the essence because the availability of instructors is declining fast due to retirement and death. Relatively short courses of a week or less could be mounted to teach particular techniques and the identification of "difficult" groups such as Diptera, parasitic Hymenoptera, major taxa in the soil fauna and so on. The funds should be available both to the institution conducting the courses and as bursaries for the students.

February 2008

Memorandum submitted by the Mycology sub-committee of UK BRAG[30]

Fungi are critically important organisms as symbionts of most plants, as recyclers of carbohydrates and minerals, as pathogens of plant and animal disease, as food sources for humans and other animals, as sources of valuable chemicals and in food and beverage processing. Lichens are particularly important in the formation of soils and as indicators of change within the environment. The majority of the world's fungi (estimated at 1.5 million species, of which only 8-10 per cent have been described) are as yet unknown to science, and even in the UK where native biodiversity is relatively well documented dozens of species of fungi new to science are discovered each year.

1. *What is the state of systematic research in the UK?*

1.1 There has been considerable loss of mycological expertise since 2002, particularly in UK universities; research in fungal taxonomy no longer occurs at Reading or Exeter, and the effort is much reduced at London, Sheffield and Newcastle. Two taxonomic mycologists remain in Liverpool John Moores University and Birkbeck College, London, but these posts are unlikely to be replaced upon retirement of the individuals involved. Since 1996 there has been a $>$ 50 per cent decline in the number of PhD-level taxonomic mycologists in UK universities. The experts that remain are, typically, in their 50s and, despite careful succession planning in some instances, budget cuts have meant that the majority of these are unlikely to be replaced upon their retirement.

1.2 UK taxonomic expertise in mycology (including the study of lichens) is therefore currently focused on five main organisations: CABI, NHM, NMW, RBGE and RBGK. CABI and RBGK currently share the brunt of the taxonomic mycology burden within the UK: CABI concentrating on ascomycetes (often microscopic and containing especially important groups economically) and its living culture collection, RBGK on basidiomycetes (often macroscopic and containing many important plant symbionts), and NMW, NHM and RBGE on lichens and rusts. All five institutes hold extensive fungal reference (herbarium) collections.

1.3 Specialist fungal culture collections are also maintained by organisations such as the Scottish Crops Research Institute and Forest Research, but also often under severe threat through lack of funding. In the case of FR, of a worldwide collection of 1500 *Phytophthora* cultures, about half died in a warm weather episode in the 1990s as a result of inadequate support resources. In addition, FR holds a culture collection of 9,000 individual of *Ophiostoma* species (an ascomycete), mainly those species which cause Dutch elm disease and at least one of which is now close to extinction. These cultures have been gathered over 40 years, mainly 1970-1990, come from all over the world, and represent a huge and detailed resource (eg for reference and genome sequencing), but which despite their significance receives no financial support for maintenance.

1.4 It is important to acknowledge that some specialist mycological expertise (in some cases considerable taxonomic and phylogenetic expertise) is distributed among and applied in certain government funded research institutes other than those traditionally considered to be engaged in taxonomy research. This is especially the case with fungal pathogens of plants and animals. Examples include the Scottish Crops Research Institute (SCRI), Forest Research (FR) and the Royal Horticultural Society (RHS). FR currently has a PhD grade taxonomist funded under the Defra Darwin Initiative to work on *Phytophthora* taxonomy, specifically on species barriers in *Phytophthora* species.

[30] The UK Biodiversity Research Advisory Group www.ukbrag.org

Number of PhD-grade taxonomists	*Mycologists*			*Lichenologists*		
	1996	*2002*	*2008*	*1996*	*2002*	*2008*
CABI	14	5	3	2	0	0
Natural History Museum				3	2	1
National Museum of Wales				1	1	1
RBG Edinburgh	2	1	1	1	1	1
RBG, Kew	5	4	4	0	0	0

1.5 In evidence submitted to the House of Lords Inquiry on Systematic Biology and Conservation (2001/2), the NHM, RBGE and RBGK, all reported that their grant-in-aid funding had decreased in real-terms since 1992 with negative effects on research and collections management and loss of professional taxonomist posts. Since then, each of the institutions has had modest increases in grant-in-aid, but not sufficient to bring them back to the 1992 levels in real terms. Drafting Note: Suggest delete this text on CABI because: 1.The 3 per cent figure is repeated in Para 8.2, with a more positive slant, 2. The 1989 change happened prior to 1992.

1.6 Several policy areas are likely to require mycological expertise such as the UK Plant Diversity Challenge (the UK's response to the CBD's Global Strategy Plant Conservation), and meeting the UK's international obligations under the Convention on Biological Diversity as a major repository of the world's systematic mycological resources.

1.7 It is important to note that the loss of taxonomic expertise within fungal groups has been uneven. Much of the current research is limited to the ascomycetes & basidiomycetes. Other fungal organisms are no longer the focus of taxonomic study. In particular, oomycetes (including *Phytophthora* spp.), a relatively small group of major economic impact, are no longer studied widely. Many within this group are serious pathogens of horticultural crops and trees. The nature of these fungi means that institutes such as SCRI, FR and RHS have developed their own in-house expertise for taxonomic work on *Phytophthora* spp. They have become active and successful in combining molecular and traditional taxonomic approaches and made significant taxonomic contributions, nationally and internationally. One topical example, is the way work of FR with SCRI has highlighted the tendency of *Phytophthora* spp to hybridise, and potentially generate new species and species swarms which can have a major impact not only on affected hosts but on entire ecosystems. Other groups, such as the slime moulds, are significant components of many habitats and are largely ignored, despite their importance in ecosystem function/services.

What are the current research priorities?

1.8 There is no single national research strategy but efforts are being made via UK-BRAG and GBSC to guide activities; the 5 main non-university institutes have their own research priorities and aim to ensure that "overlap" is minimised. Research priorities in universities are largely driven by current funding opportunities. Outlined below are some potential areas of growth:

1.9 The UK has the potential to lead the world in the area of DNA barcoding for fungi, based on the unique collections deposited in our natural history collections. The development of barcoding technology (under-supported in the UK) presents an unprecedented opportunity to tackle the taxonomic impediment in mycology at a scale proportional to the magnitude of the task. Of critical importance to the success of these techniques is a reference dataset derived from reliably identified specimens using morphological techniques, a resource that depends on ongoing input by taxonomic mycologists.

1.10 The aquatic environment is especially rich in fungal diversity; opportunities for investigating fungal biodiversity within these habitats will be particularly driven by the need to establish the impact of climate change and develop mitigation and adaptation strategies, where practicable. In particular, the ecological role (& response) of marine fungal organisms in seas with changing acidity is a potential area of research of international significance in which the UK could become a leader in.

1.11 Fungi are of major importance, as symbionts, to the health of wild and cultivated plants. It has been recognised that continued seed banking (at the Millennium Seed Bank at the Wakehurst Place site of RBGK) without concern for banking of the fungal associates that many of these plants need to survive, is only a partial strategy. Longer-term efforts to bank the seed of 30 per cent of the world's plants have been proposed, but reintroduction of the majority of these species would be difficult, if not impossible, if their fungal associates are not studied and similarly conserved. However, before such a fungal conservation initiative can be added to the work of the seed bank, a great deal of taxonomic study will also be required.

1.12 Lichens are especially diverse in the UK and are extremely sensitive to environmental degradation, making them particularly good indicators of climate change and the effects of man-made disturbance and pollution in both the UK and overseas. The UK's internationally significant collections have potential to underpin research developing biomonitoring tools and for understanding climate change. Succession planning at RBGE has capitalised on the opportunity for collaboration between a lichen taxonomist and lichen ecologist invigorating research in conservation biology and climate impacts.

What are the barriers to developing these priorities?

1.13 All of the preceding opportunities are funding dependent. There is a need for a renewed recognition of the importance of mycological systematics to the UK science base.

2. *What is the role of systematics and taxonomy and, in particular, in what way do they contribute to research areas such as biodiversity conservation, ecosystem services and climate change.*

2.1 Currently, the role of extant mycology-based research in these areas is rather limited; principally, this is due to perceived (or real) funding barriers. However, NE has proposed the establishment of a Fungus Conservation Unit. NE identified RBGK as a base for this development. Such a Unit would be complementary to and very much dependent on a functioning team of taxonomic mycologists with the ability to identify and classify fungal material. The proposed Unit would consist of three full-time equivalent posts, providing support for the UKBAP, preparing conservation assessments for non-lichenised fungi in the UK and within a European context, and raising public awareness of the importance of fungal conservation. The NMW has one lichenologist on the staff whose contribution focuses on conservation work on UK lichens. The RBGE contributes principally to the conservation of lichens within the UK, under-pinning practical conservation initiatives (eg maintaining the UK checklist and red data book, providing training in identification skills) and undertaking novel research in lichen taxonomy, biodiversity and climate change science.

2.2 Development of systematics and taxonomy-based research that supports and underpins ecosystem services and climate change research has significant opportunities. The potential opportunities for the UK to lead in science and technology in DNA barcoding, marine biology and climate science, terrestrial plant/fungal interactions and biomonitoring are significant. The direct financial benefits to the UK economy from technological innovation could be significant and the indirect benefits from the possible development of adaptation and mitigation strategies to climate change are of international importance.

3. *Does the way the in which systematic research is organised and co-ordinated best meet the needs of the user community?*

3.1 Please see paragraph 2.1. The proposed merger of the RBGK and CABI collections presents an opportunity to build on existing strengths and implement a concerted approach to succession planning and the application of expertise to issues of economic relevance;

3.2 An explicit and co-ordinated succession-planning programme (focused on enhancing taxonomic research, maintaining active databases, training future generations of experts in taxonomic mycology and transferring the expertise of the generation about to retire) that ensures products currently accessible to the broader scientific community are not lost is urgently required.

3.3 In 2006, CABI separated its mycology activities into a dedicated Bioservices Unit, focusing on using fungi for the global good. Its taxonomy dependent activities include information provision (particularly, the free-to-access Index Fungorum: www.indexfungorum.org, in association with the Index Fungorum Partnership and publication of key taxonomic reference works) as well as applied research into fungi as biopesticides, conservation and sustainable use. The Unit also runs diagnostic and analytical services operating on a quality-managed commercial basis using morphological and molecular methods (including barcoding approaches) and maintains the internationally significant culture collection.

4. *What level of funding would be needed to meet the need for taxonomic information now and in the future?*

4.1 Mycology and other similar disciplines where there is a significant "taxonomic impediment" would benefit from a scheme similar to that funded by the USA's National Science Foundation's (NSF) Partnerships for Enhancing Expertise in Taxonomy initiative (PEET). In partnership with academic institutions, botanical gardens, freshwater and marine institutes, and natural history museums, the NSF seeks to enhance taxonomic research and help prepare future generations of experts.

4.2 The cost of establishing viable research programmes in DNA barcoding, marine biology and climate science, terrestrial plant/fungal interactions and biomonitoring (see paragraphs 1.2.1–1.2.4 and 2.1.1) is significant. Initial "set-up" costs would be approximately £200-500,000 per project.

6. *What impact have developments in DNA sequencing, genomics and other technologies had on systematics research?*

6.1 Molecular systematics (in conjunction with "traditional" techniques) has revolutionised some aspects of systematic research; this is particularly evident in the flowering plants where the Angiosperm Phylogeny Group has made significant advances. Fungal systematics has also embraced the molecular revolution; but, advances have been less dramatic due to funding limitations (and a lack of traditional taxonomic expertise in some groups). However, molecular biology has considerably advanced our understanding of some groups such as lichens and symbiotic basidiomycetes. Unfortunately, many groups, such as the oomycetes, have received virtually no attention and our knowledge is now decades old; the potential for molecular systematics to make significant discoveries in these fields is considerable.

8. *What is the role of the major regional museums and collections? How are taxonomic collections curated and funded?*

8.1 The capacity to carry out major collections based projects is diminishing in all institutions, but RBGK has made major investments in terms of housing for the collections (purpose-built herbarium for the 800,000 accessions, making RBGK one of the three largest mycological collections in the world). CABI and RBGK have agreed to merge their fungal reference collections at Kew (to take place in June 2008). CABI are also particularly interested in the banking of fungal cultures, and this would complement the work of the Millennium Seed Bank. The merging of the RBGK and CABI reference collections presents an opportunity to develop more focused efforts on the study of fungi. These efforts have significant cost implications, and larger impacts would be obtained if there were increased financial support available.

8.2 CABI has intergovernmental status and is owned by a consortium of 45 member countries (including the UK). Its headquarters are in the UK, and it has played a major role in the support of UK mycology for the whole of its existence. Unlike most intergovernmental organisations, it is largely self-supporting financially, with only 3 per cent of its annual budget contributed by member countries as core funding. The remaining 97 per cent is earned through information provision (CABI owns the largest agricultural science abstract database in the world) and service provision (identifications, consultancy, culture sales, project work etc.). CABI remains committed to taxonomic mycology with a focus on economically important species. It owns globally important collections of fungi, including a fully databased dried fungal reference collection containing around 400,000 specimens and a living collection (incorporating the UK National Collection of Fungus Cultures) of around 28,000 strains. CABI receives no financial support from the UK Government to maintain these collections, despite their significance as a UK scientific resource.

8.3 NHM's core funding is derived from the Department of Media Culture and Sport (DCMS). Curation of the Museum's collections is primarily funded from this source. Although NHM is home to the nation's largest and probably the world's most historically significant collection of lichen specimens, taxonomic expertise on British lichens at NHM has been significantly reduced in recent years. The collections are also of global significance, with particularly important collections from Southeast Asia. The expertise/ research of the last three curators has focused on foreign, rather than British, lichens. The collections are currently managed by an experienced lichen curator with considerable research experience, although his research activities are limited by other duties. In addition, the last three curators have had non-overlapping appointments, which has resulted in a lack of continuity of taxonomic and curatorial knowledge. In addition to its lichen herbaria, the NHM houses a historically important slime mould (myxomycete) herbarium. As there is a rapidly increasing interest in this group of organisms worldwide, NHM is ideally positioned to play a leading role in researching these organisms.

8.4 RBGE receives core funding from the Scottish Government. It holds historically important collections though is noted particularly for its comprehensive, up-to-date collection of British lichens which has contributed to modern developments in the taxonomy of British lichens. Similarly, the collection of basidiomycetes directly contributed to the base-line taxonomic treatise "Fungal Flora of the British Isles", though this is no longer actively researched by RBGE staff except for the rust-fungi.

9. *What progress has been made in developing a web-based taxonomy?*

9.1 A "Fungal Portal" was proposed as a joint venture between the BMS, CABI, RBGK and a private benefactor. Its overall aim was to establish an integrated and comprehensive digital fungal information and recording service. It would be a web-based information network that could be used to exchange data and disseminate information about fungi, initially within the UK and potentially world-wide, as a public service. An aim was to trigger a change in public understanding of fungi through innovative linkages between non-specialists and the scientific community. The Portal was to have linked a number of major existing databases that contain information about British fungi and lichens to provide a greatly enhanced and fully searchable facility, with an extensive image library and other information resources for identification and education.

9.2 A scoping exercise for the Portal was undertaken by RBGK (with input from CABI) in response to a funded request from Defra but the resulting proposal was not taken forward due to high costs and lack of an identified funding consortium

11. *How does the taxonomic community engage with the non-taxonomic community? What role do field studies play?*

11.1 It is important to define what the meaning of "non-taxonomic community" is. The field-based mycologist has often been defined (usually by others) as not being taxonomically skilled; in many instances this is incorrect. Laboratory based mycological research is often highly dependent upon the skills of field mycologists, numerous discoveries of taxonomic significance have originated in the field mycology community. Therefore, the role of field studies has been, and should remain, a significant aspect of UK taxonomic endeavour. New taxa are being described each year and this is largely due to the efforts of the BMS, the BLS and more than 30 Local Recording Groups.

11.2 The very substantial data resources compiled by the BMS cannot be accessed as efficiently as required by all those interested and there is little strategic direction on a nation-wide scale; the Fungal Portal proposal was developed as a strategy for addressing these concerns (see paragraph 9.2). In contrast, the BLS has had a strategy for the collation of high quality geo-located data since the 1960s, and the Scottish dataset (funded by SNH) is now available through the NBN with full access to all. This knowledge-base is developed by taxonomists over decades, project is in the planning stage for England and Wales.

11.3 CABI, NHM, RBGE and RBGK have substantial expertise in the production of information resources for fungal taxonomy. RBGE has had a long-running programme to publish an account of the UK basidiomycetes, and it and the NHM have collaborated with a number of other groups to produce an account of British lichen-forming fungi (a second edition is currently in preparation). RBGE maintains the British checklist for lichens and lichenicolous-fungi, the lichen red-data book, the lichen synonym list, a biannual account of literature pertaining to British lichens. RBGK and CABI have worked for some years on an account of the UK ascomycetes. CABI produced the first modern checklist of the British Ascomycota (including lichen-forming ascomycotes) in the 1980s and provided IT support for the production of the recent Checklist of the British and Irish Basidiomycota (2005, published by RBGK). Both products were linked into and augmented CABI's "Species Fungorum—towards a global checklist of the fungi" contribution to the Catalogue of Life (Species 2000 and ITIS) and also the Fungal Records Database of Britain and Ireland (hosted by CABI). CABI also produces database-driven publications such as the Index of Fungi (the mycology equivalent of the International Plant Names Index, incorporating Index Kewensis), the Bibliography of Systematic Mycology (the mycology equivalent of Kew Record) and the Dictionary of the Fungi, the key reference work for fungal taxonomy worldwide.

12. *What are the numbers and ages of trained taxonomists working in the UK universities and other organisations?*

12.1 See paragraphs 1.1, 1.2 and 1.5.

13. *What is the state of training and education in systematics and taxonomy?*

13.1 Currently, no UK University has a teaching programme in fungal taxonomy. Fungal and lichen taxonomy forms part of the curriculum of the joint University of Edinburgh/RBGE MSc course on biodiversity and taxonomy, and the joint Scottish Agricultural College/RBGE BSc Horticulture course. Most training delivered in the UK is by either the BMS, BLS or one of the Local Recording Groups.

13.2 In 2002, the BLS presented a paper on the key role of the RBGE lichen taxonomist in supporting conservation initiatives. In 2003 SNH provided funding to the BLS to support the training of "lichen apprentices". Over three years training was provided through a series of field-based and reference collection workshops and formal training in site monitoring for lichens. There is now an active group of lichen trainees, drawn from Scotland and the wider UK, who are contributing to conservation projects and scientific research on lichens.

13.3 RBGE developed plans to recruit a "trainee" lichenologist on external funding, to work alongside the lichen taxonomist; this post has been supported for three years by the Esmée Fairbairn Foundation and a benefactor and is now funded directly by RBGE. The post has provided training in lichen identification and taxonomy for a PhD-grade ecologist employed to work on the biodiversity and conservation of lichens.

13.4 CABI has a long track record of capacity building in mycology through training courses, PhD placements etc. and has been granted no less than ten awards from Defra's Darwin Initiative with a substantial taxonomic mycology component.

13.5 In 1996 NHM hired a lichen taxonomist, who trained a number of young, foreign lichenologists in molecular systematics before leaving in 2000. Unfortunately, his post was not replaced, and the resources for funding this position have subsequently been lost. NHM continues to train foreign lichenologists through various programmes such as a number of SYNTHESYS and Marie Curie fellowship visitors. The NHM lichen curator post also contains a strong element of taxonomic research.

Memorandum submitted by the National Federation for Biological Recording

Background

The National Federation for Biological Recording (NFBR) is a membership society, established in 1987 to promote, develop and represent biological recording in the UK. It is the only such society in the UK and hosts annual conferences on a range of topics relating to all aspects of biological recording. NFBR has contributed to the formation of the Co-ordinating Commission for Biological Recording and to the Commission's seminal report in 1995, and subsequently to the establishment and development of the National Biodiversity Network.

NFBR's membership is drawn from national biological societies, regional and county-based biological records centres, and individual active practitioners in biological recording.

Biological Recording is defined as: *the collection, collation, management, dissemination and interpretation of spatially and temporally referenced information on the occurrence of biological taxa, assemblages and habitats.*

Responses

NFBR is capable of responding, from a position of particular knowledge, to parts of Questions 2, 7 and 8, all of which are compound questions. This is not to say that other numbered questions are not of interest to NFBR, but to comment on them would draw mainly on experiential opinion rather than practical knowledge.

Question 2

What is the role of systematics and taxonomy and, in particular, in what way do they contribute to research areas such as biodiversity conservation, ecosystem services and climate change?

Basic taxonomic knowledge, underpinned by sound and up-to-date hierarchies from systematic research, is fundamental to understanding what taxonomic units being studied in such research. The ability to accurately identify and name taxonomic units (eg genera, species and sub-specific taxa) is central. But understanding of systematic inter-relationships, even of well-known taxa, increases awareness of inherent factors that may

impact on the responses of individual taxa to anthropogenic and natural processes. Hitherto, much UK research in biodiversity conservation, ecosystem services and climate change, and in particular conservation related research, has been directed towards individual species. Thus species have been considered almost in isolation from related species, or the species assemblage and habitat within which they occur.

How important is this contribution and how is it recognised in the funding process?

The need for basic taxonomic knowledge and studies in systematics applies even in the UK where, despite numerous and repeated assertions to the contrary, this baseline information is still required for many taxa. For example, even in a group as intensively studied as butterflies, a native species new to the UK (Réal's Wood White) was discovered as recently as 2000 in Northern Ireland.

However, most taxonomic expertise relating to UK species is now vested in voluntary organisations and non-professional individuals rather than with the professional scientific community of universities, museums and research institutions. Thus the majority of UK taxonomic expertise is virtually unfunded, at least as far as the purview of the House of Lords S & T Committee. This does not provide for a sustainable future for taxonomy in the UK. The present-day resource of UK expertise is merely a legacy of greater levels of funding in the 1960s and 70s. Prior to the 1980s taxonomy and systematics had formed part of undergraduate biological sciences courses at many UK universities, and at secondary schools, basic taxonomic principles were part of O/GCSE and A level syllabuses. Awareness of species used to begin at primary school.

When so many of the issues in biodiversity conservation, ecosystem services and climate change are supra-national or global, the UK's traditional role and particular expertise in taxonomy and systematics research must be recognised and supported at universities and at national and other major museums.

How is systematics integrated in other areas of research?

NFBR is unable to comment.

Question 7

Does the way in which taxonomic data is collected, managed and maintained best meet the needs of the user community?

One of the main issues is that most constituents of the "user community" are poor at recognising that they are either "users" or members of a "community"! As a consequence it has been for the potential "providers" to second guess what data may be required by an ill-defined "user Community" and have had to do so with minimal or no funding.

For example many of those concerned with biological recording have been aware, since the 1980s, of changes in the range and abundance of species and assemblages, and changes to habitats which appeared to relate, at least in part, to climatic variables. This awareness prompted voluntary groups to advocate the need to establish national surveillance and monitoring schemes, and to maintain the few schemes that had been established earlier. In most cases funding was refused or reduced to levels that delivered only part of the necessary data. It was not until after 2000, when the voluntarily managed schemes had begun to deliver incontrovertible data, that governmental agencies began to recognise that such organisations and schemes had a role to play in supplying data. The exception to this criticism is birds, for which many important monitoring projects, run by the voluntary sector, have been funded by the conservation agencies. However, good the data for birds may be, they can not, and should not, be used as proxy for most other UK biota.

Particularly at a local level, for example a county-based biological records centre, the challenge is to try to influence the "user community" to ask for information that is sensible and deliverable. Government guidance to local authorities to apply a range of biodiversity indicators and to seek data from "your local biological records centre" assumes an ideal that rarely exists. Consultation about biodiversity indicators and targets has been minimal at the local level, and "your local biological records centre" is almost certainly poorly resourced and largely dependent on the goodwill of volunteers to supply data. The whole edifice is built on sand!

At regional and local levels, taxonomic expertise is now almost exclusively vested in the voluntary community, such as through local natural history societies, local records centres and wildlife trusts. Local museums, which were a reliable ally to local "naturalists" by providing access to collections, literature and advice, are very rarely given resources to maintain that role. See also Question 8.

There is also the inevitable pitfall of sectoral separation. For example few professionals concerned with "pure" taxonomy are able to inter-relate with field or behavioural ecologists or biogeographers. Increasingly, taxonomic studies relate to molecular levels. Relevant as they may be, these studies do not yet make it possible

for those who require taxonomic definitions, for the practicalities of survey, surveillance or monitoring whole organisms, to use these ever-more refined definitions of taxa. Also, understanding of taxonomic units, such as species, cannot be achieved solely by the study of specimens in isolation from their environment.

What is the state of local and national recording schemes?

NFBR is aware of evidence supplied to the Committee on behalf of the National Biodiversity Network, the Yorkshire Naturalists Union and others in the local biological records centre community. The evidence these organisations have provided describe in more detail, and from better first-hand knowledge, responses to this question.

NFBR would like to reinforce the point that most taxonomic knowledge (and much research), relating to UK taxa, is almost wholly dependent on the voluntary sector, without significant public funding. Even the publication of taxonomic guides, other than a small number of commercial publications for popular groups, is dependent on voluntary organisations, membership societies and registered charities, such as the Royal Entomological Society and the Field Studies Council.

Question 8

What is the role of major regional museums and collections?

It is important to distinguish between major regional/national museums, such as those at Cardiff, Liverpool, Edinburgh and Belfast and possibly also Glasgow, Manchester and Oxford, and the truly local museums such as those at Newcastle upon Tyne, Sheffield, Norwich, Reading, Exeter and Bristol. The first four are still custodians of some national and international taxonomic expertise and, to a variable extent, also training. Their collections are extensive and generally accessible for use, with at least some curatorial staff. Glasgow (Kelvingrove), Manchester (University) and Oxford (Natural History) also have extensive collections, but fewer curatorial staff and little scope for taxonomic research other than by affiliated specialists working in a voluntary capacity. Truly local museums, such as those listed (which are among the largest), have extensive and often important collections, few curatorial staff and usually no role in taxonomic studies or taxonomic training other than through specially funded outreach projects aimed at schools. Many smaller local museums, although they may have good, even important collections, often have no specialist trained curatorial staff.

How are taxonomic collections curated and funded?

NFBR considers the maintenance and proper curation of reference and voucher collections to be of extreme importance, both for validation of biological records and for the training of new generations of naturalist specialists and taxonomists. Such collections would be of greatest value when held at local museums, but most museums have difficulties in accepting "working" collections. Even if they are able to accept them and house them adequately, long-term maintenance, curation and provision of access cannot be guaranteed. Large regional and national museums may, in theory, be able to provide a better service, except with regard to access at a local level.

2 February 2008

Memorandum submitted by National Museums Liverpool

Background

National Museums Liverpool (NML) is a non-departmental public body sponsored by the Department of Culture Media and Sport. It was established as a national museum in 1986 because of the outstanding quality of its multidisciplinary collections. Natural science collections are housed in World Museum Liverpool, which re-opened in 2005 after a major re-development programme. Botany and Zoology collections comprise 1.6 million specimens and are of international, national and regional significance. Important historic holdings are complemented by data-rich modern voucher material. Eight curatorial staff either undertake or provide support for systematic biology research as part of a range of duties. Research embraces taxonomic studies, biodiversity and conservation management projects and historical investigations. Staff are supported by five taxonomic associates and 12 general volunteers.

The state of systematics and taxonomic research

1. *What is the state of systematics research and taxonomy in the UK? What are the current research priorities? What are the barriers, if any, to delivering these priorities?*

Systematic biology is central to life sciences but poorly appreciated and sometimes derided. It provides baseline knowledge that helps us to understand the natural world. The analysis of systematic biology in the UK, provided in the UK Systematics Forum's *Web of Life* strategy document, is still valid. With minor revision and updating this could provide a valuable contribution to the current debate.

2. *What is the role of systematics and taxonomy and, in particular, in what way do they contribute to research areas such as biodiversity conservation, ecosystem services and climate change? How important is this contribution and how is it recognised in the funding process? How is systematics integrated in other areas of research?*

Systematics and taxonomy benefit the *whole of society* by contributing towards major issues affecting the quality of all peoples' lives eg sustainable resource management, environmental protection and landscape preservation. They are the basis of people's understanding, and appreciation of the natural world.

NML's UK Biodiversity Advisory Service provides a good example of the application of taxonomic expertise allied to extensive collection holdings which inform national and regional conservation organisations, local authority planning departments and industrial companies. Contemporary taxonomic collections validate and ensure accuracy in such research. Historical collections provide a reference point to assess change in the natural environment, coupled with crucial genetic information (eg Ancient DNA). Analysing data associated with NML's collections from pioneering naturalists in Australia, for instance, supports understanding of Australia's natural environment and cultural heritage and is providing evidence to assist with the reconstruction of damaged ecosystems.

3. *Does the way in which systematics research is organised and co-ordinated best meet the needs of the user community? What progress has been made in setting up a body to lead on this? What contribution do the leading systematics research institutions make both nationally and internationally?*

The UK systematic biology community is fragmented and requires coordination. Direction was briefly provided by the UK Systematics Forum in the late 1990s, which united both small and large institutions, and is an essential requirement to raise the profile of systematic biologists, and to exploit avenues of funding. The recommendation in *What on Earth* that Defra provide a lead in developing clear priorities should be progressed by bringing together systematic biologists, conservationists and the Government. Establishment of regional centres or hubs of systematic excellence could further this objective. Staff at organisations such as NML would benefit from the opportunity to link into such a centre, and to contribute scarce skills to larger projects.

4. *What level of funding would be needed to meet the need for taxonomic information now and in the future? Who should be providing this funding?*

Defra should initially fund a co-ordinating body of systematic biologists, as proposed in the *What on Earth* report. There is also a need for a ring-fenced national budget to support alpha-taxonomy and to support the next generation of systematic biologists.

5. *How does funding in other countries compare? Could there be more international collaboration? If so, what form should this collaboration take and how might it be achieved?*

Most other countries also suffer from lack of funding for systematics and taxonomic research, but in North America, Australia and some European countries such as the Netherlands there is greater support from Government, societies and institutions, and even private individuals. Many of the museums in those countries, even privately funded institutions, devote much greater proportions of staff time and resources to such scientific research than do equivalent museums in the UK. In these cases, their staff are discovering and describing more taxa and providing crucial ecological and faunistic information obtained through fieldwork.

6. *What impact have developments in DNA sequencing, genomics and other new technologies had on systematics research? In what way has systematics embraced new technologies and how can these research areas interact successfully and efficiently?*

NML responds positively to all external requests for its collections to be used for molecular biology research. However, without additional funding and staffing resources museums such as NML will be unable to provide infrastructure to support innovative collections development initiatives for new areas in science. NML staff are increasingly asked for samples of specimens for genetic research, mainly for DNA or stable isotope analysis. Most of these requests come from overseas laboratories, in countries such as the USA and New Zealand.

Data collection, management, maintenance and dissemination

7. *Does the way in which taxonomic data is collected, managed and maintained best meet the needs of the user community? What is the state of local and national recording schemes?*

There is not a consistent approach to the management of natural science collection data. Nor is there an integrated strategy for data output. NML uses the multidisciplinary soft-ware package Mimsy XG. Other museums use KE EMu, whilst conservation agencies and local record centres use Recorder, and amateur naturalists increasingly use MAPMate. A standardized format for the reporting of collection statistics is also required.

The National Biodiversity Network (NBN) is a very significant advance in making biological records available to a wide range of users. Through a series of overlays and linkages a good level of interpretation of those records can also take place, and the range of that value-added information is increasing. There is, however, a degree of overlap with local record centres, which rely on the value-added interpretation and collation of records to produce reports for their clients. The relationship between NBN, local biological centres and the national Biological Records Centre (BRC) requires clarification, to ensure efficient delivery of service and to avoid confusion amongst data contributors.

Museums such as NML are well positioned to support local and national recording schemes. Staff co-ordinate national schemes for particular taxa where they are specialists, and enjoy a close working relationship with local naturalists and societies to promote recording. Staff also provide support and specialist advice to conservation agencies in delivering the Government's Biodiversity Action Plan.

8. *What is the role of the major regional museums and collections? How are taxonomic collections curated and funded?*

The UK's major regional museums, whether national, local government or university, in association with smaller local museums with natural science collections, are ideally positioned to support systematic biology research and in particular alpha-taxonomy. The specialist knowledge and skills of staff, combined with extensive collections, provide a unique resource. Museums have a long history of bridging the gap between professional and amateur research. They provide laboratory facilities and loans for researchers, and promote public understanding of biodiversity and conservation biology in their galleries and through formal and informal learning programmes. The digitisation of collections will make data more widely available, and has the potential to create a national collection database. Collection management activities and funding for specialist staff do, however, compete for scarce institutional resources.

9. *What progress has been made in developing a web-based taxonomy? How do such initiatives fit in with meeting demand for systematics and taxonomy information? How do UK-led initiatives fit in with international initiatives and is there sufficient collaboration?*

& 10. What needs to be done to ensure that web-based taxonomy information is of high quality, reliable and user-friendly?

For many groups there are web-based image and identification resources. These encourage interest in groups and generate records and through feedback the taxonomy can improve. The best taxonomic information websites have discussion forums run by recognised experts who validate quality. There are also strong email community liaison forums for many groups (for instance, the bird curators' networks eBEAC and Avecol) where taxonomic issues are discussed, sometimes in great detail.

11. *How does the taxonomic community engage with the non-taxonomic community? What role do field studies play?*

Museums provide an excellent interface between the systematic biology community, conservation agencies, amateur naturalists and the general public. At NML we use our collections to promote understanding of the importance of biodiversity and conservation biology in our living and gallery displays, and through formal and informal learning programmes. Our award winning, interactive, Clore Natural History Centre received over 250,000 visitors in 2007. Public talks and collection tours provide further engagement, whilst collection-based practical sessions introduce the region's university and college students to the concept of taxonomic collections, and their role in supporting conservation agendas. Many national and regional natural science societies enjoy a close working relationship with museums, such as NML, and the collections provide an invaluable resource for taxonomic training workshops. Specialist staff within NML also provide training in the field for such groups.

12. *What are the numbers and ages of trained taxonomists working in UK universities and other organisations?*

There is a need for a regularly updated, fully comprehensive, national on-line register of UK amateur and professional expertise in systematics, such as the one maintained by the UK Systematics Forum in the late 1990s. The Register of UK Taxonomic Expertise, maintained by the Natural History Museum, could fulfil this role but requires further refinement. This should provide available on-line information to scientists and other organisations wishing to access scarce skills. It could also gather more confidential information, eg age and ethnic origin, that would not be available on-line, but which would help future analysis of the systematic community. At NML all but one of the senior curatorial staff are in their fifties and most are close to retirement age.

13. *What is the state of training and education in systematics and taxonomy? Are there any gaps in capacity? Is the number of taxonomists in post, and those that are being trained, sufficient to meet current and future needs across all taxonomic subject areas?*

An innovative, national strategy, embracing *all* age-groups, is required to ensure that the number of taxonomists being trained meets current and future needs and that systematic biology, in its broadest sense, is understood and appreciated by society as a whole. Museums have a pivotal role to play in delivering this strategy and improving the skills-base for systematic biology, through their formal and informal learning programmes based on the collections, and because they do embrace all age groups.

Pleasingly, some elements of systematic biology are present in Key Stages 1-3, and at NML our "offer" begins with an *animal, vegetable, mineral* session for early years and Key Stage 1 children. In 2006—2007, the vast majority of the 10,000 children attending formal learning sessions in our *Aquarium*, *Bug House* and *Clore Natural History Centre* (*CNHC*) were at Key Stage 2. There is a real need to increase the coverage of systematics in the National Curriculum at Key Stage 4. This age group does form an element of the 261,000 children attending drop-in sessions, and the CNHC's *Clore Club* provides Saturday activities for 6 to 16 year olds who are beginning to develop a deeper interest in natural history.

Unfortunately, systematic biology is poorly represented in UK undergraduate programmes. At the very least, there is a need to enhance whole-organism training amongst biologists and environmental scientists. At NML we host collection-based practicals for universities and colleges. These provide a first insight into taxonomic careers. Ideally, postgraduate taxonomic research should be directed towards poorly-understood or researched taxa.

In addition to university courses there should be an opportunity to develop skills through work-based learning. For example, this year NML is hosting an Apprenticeship as part of the British Trust for Conservation Volunteers (BTCV) Scotland's *HLF Natural Talent Bursary Scheme*. The scheme aims to address the deficit in skills identified as the "*taxonomic impediment to conservation action*" in the *What on Earth* report. The museum provides access to collections and other taxonomic resources, as well as expert mentors, to facilitate this training. Such resources also support specialist taxonomic training workshops for both amateur and professional societies.

Career taxonomists can benefit from secondments and exchanges between institutions such as museums, universities and conservation organisations, which enable them to develop new skills and benefit from working in different environments. Succession management issues should be addressed, in order to ensure the handing down of factual knowledge and continuity of collection development and research. At present curatorial staff are replaced only after they leave (if at all), which means their usually considerable knowledge and experience

disappears into the ether. Mechanisms should also be established to support staff after their official retirement dates, where appropriate, in order to benefit from such mental resources.

Similarly, systematic biology research has benefited considerably from amateur taxonomists taking early retirement and pursuing their interest in taxonomic work and biological recording. This is unlikely to continue unless an *old blood* initiative is funded to enable motivated individuals to produce keys and monographs in association with recognised taxonomic institutions, and to encourage and train the younger generation.

January 2008

Memorandum submitted by the National Museum Wales

The state of systematics and taxonomy research

1. What is the state of systematics research and taxonomy in the UK?

- Too much focus on molecular systematics and genomics at the expense of so-called traditional methods.
- Too little support for basic taxonomic training within University courses for undergraduates
- Too much reliance on "Amateur" and non-professionals to undertake basic inventory work.

What are the current research priorities?

- Synthesis of new and existing data through taxonomic revisions, Taxonomic tools and Inventory (describing new species)
- Upgrading and creating taxonomic tools
- Inventory (describing new species)

What are the barriers, if any, to delivering these priorities?

- Lack of recognition of value of all but molecular systematics and genomics in research assessments and corresponding lack of funding from research councils. All round low esteem of taxonomy as a discipline.

We believe that taxonomy and systematics have two functions, firstly to progress the biodiversity inventory and produce taxonomic tools for the biological community, and secondly to examine relationships between taxa (phylogeny).

Phylogenetics, especially when employing molecular methods, is producing fundamental shifts in our understanding of the evolutionary relationships, and is very interesting to those working in this field. Limited funding for these studies is available from research councils and is usually directed towards already well-known groups of organisms. Such studies may have practical and applied implications, but they do not often contribute to describing the mass of new organisms known to exist. Further, they contribute nothing to practical taxonomic tools (eg, identification guides) which are far from complete for European/N. American organisms and largely non-existent for tropical terrestrial and marine biotas.

Biodiversity inventories are essential to conservation biology and taxonomic tools vital in nearly all biological science. We believe that the need for taxonomic tools should be better recognised. The production of these now carries little or no value in university research assessments and the funding of such work is lacking from Research Councils. In our own experience, funding can be gained from charities such as the *Leverhulme Trust* and from external contracts. For example, Hawse have a research contract from the *Department of Trade and Industry* to produce a tool for the identification of Marine Bivalve Molluscs from within the UK Economic Zone, 0-5000 m depth. This indicates the continuing need for new tools even in the UK. However, such research contracts are infrequent and do not carry full economic costings. Consequently, they are ignored by universities, and increasingly elsewhere.

2. *What is the role of systematics and taxonomy and, in particular, in what way do they contribute to research areas such as biodiversity conservation, ecosystem services and climate change?*

Taxonomy lies at the base of most biological research.

In conservation, practitioners need taxonomic tools to recognise species. The accurate identification of species remains fundamental in ecosystem services. Infra-specific systematics is increasingly relevant to conservation and here the molecular approach is most valuable. Taxonomy is essential in climate change studies where species ranges are pertinent, and where invasive or alien species threaten indigenous faunas and economies. Taxonomy has a seldom-recognised role in generating ideas and novel hypotheses in biology, including those fields that later become research council priorities. Synthesis of information by competent taxonomists is critical to making accurate biological data accessible to other researchers, in an age when it is often presumed that this is obtainable from the Internet.

Without accurate knowledge of species limits and the habitats these taxon occupy and the nature of the threatening processes (or species), then management of conservation plans is extremely difficult and can be ineffective.

The lack of taxonomic tools for the majority of the species providing ecosystem services can limit the level to which basic research can be carried out by non-specialists on the value these species provide.

How important is this contribution and how is it recognised in the funding process?

Fundamental but poorly recognised.

We believe that these contributions are fundamental, but rarely recognised in the funding process. Indeed, it is often overlooked by our colleagues in related disciplines. For example, ecologists rarely cite the taxonomic authorities or tools they used for identifying the organisms under study. Consequently taxonomic works have a low citation rating and they are absent from the funding process. There is a real lack of funding opportunity for modest studies and early career investigations, which seldom meet the eligibility requirements of major grant-awarding bodies. Where possible, such investigations are often carried out ad hoc, and nearly free of charge, to the benefit of user groups throughout the world.

How is systematics integrated in other areas of research?

Rarely integrated.

Taxonomy is often regarded as a service rather than an integral part of a research programme, especially in ecology. It is often an after-thought and often it is avoided if possible. Poorly applied taxonomy produces inadequate and unreliable science. Even large-scale phylogenetic or barcoding studies, which might otherwise be of high quality, neglect to voucher their collections or data and so risk divorcing themselves from pre-existing fundamental knowledge

Does the way in which systematics research is organised and co-ordinated best meet the needs of the user community?

There is no co-ordination.

In our experience there is no co-ordination between the producers of systematics research to recognise or share available capacity or needs, and there is no UK wide effort to consult with user groups. If these existed we should now see resources being made available to tackle difficult groups determined by the users. Such an approach was mooted by the major Swedish Taxonomy Initiative, a 20-year project initiated in 2001 with a solid commitment to descriptive taxonomy and systematics. Unlike many approaches designed merely to make existing data available on the Internet (where most funds are diverted into web technology) the Swedish programme is designed to support the necessary supporting research.

What progress has been made in setting up a body to lead on this?

None that we are aware of.

What contribution do the leading systematics research institutions make both nationally and internationally?

In terms of integration these organisations are most active in an international context, and appear to be very successful in initiating and becoming involved in partnerships. Increasingly, however, such partnerships exclude the smaller players and there is little national integration. For example, the *National Museum of Wales*—despite its contribution to systematics and scope of collections—is excluded from the *Consortium of European Taxonomic Facilities* (CETAF). Yet the UK lead in London has no formal way in which to involve smaller taxonomic facilities spread throughout the UK. There is no estimate of the economic and social value for the taxonomic services freely provided by the UK's smaller, and often more accessible, institutions.

4. *What level of funding would be needed to meet the need for taxonomic information now and in the future? Who should be providing this funding?*

- Preserve current staffing levels for taxonomists
- Train staff in areas where gaps in expertise exist
- Reinforce the need for taxonomic research to policy makers in museums and universities
- Provide a dedicated funding stream for taxonomy open to museums and universities in the UK

We do not believe that the only solution is one of extra funding. However, some of the barriers can be overcome if we have internal and external recognition of the importance of taxonomic research in our institutions. Such recognition should prevent continuing erosion of staffing levels and preserve existing research funds.

The source of extra funding should probably be related to the user need. Some funds may come from devolved governments where taxonomy is needed to support regional conservation and environmental agencies. A central UK research fund is needed to allow the UK to contribute to resolving the global taxonomy impediment. *The Darwin Initiative*—seen by us as a beginning—has not lived up to expectations; while supporting capacity building, it rarely supported any comprehensive taxonomic research. Steps ought to be taken to ring-fence funds dedicated to fundamental taxonomy, which can yield far better value for money, in many circumstances, than molecular phylogenetics.

5. *How does funding in other countries compare?*

We are unsure of this, but schemes such as PEET (USA) and the ABRS (Australia) support fundamental taxonomic programmes in those countries. Our impression is that Europe faces a similar crisis to that in the UK, with an ageing population of taxonomists and decline in the formal university teaching of taxonomy and whole organism biology. The Swedish model is encouraging.

Could there be more international collaboration?
If so, what form should this collaboration take and how might it be achieved?

The EU-sponsored SYNTHESYS programme allowing access to facilities provided by CETAF institutions is very successful. Extension of funding to allow collaboration between individuals and smaller institutions within Europe would be helpful. Also in addition, grants giving access to facilities only available in large institutions could be useful. A grant scheme to allow researchers from overseas to access specimens from their own countries held in UK Institutions would be beneficial to many—but should not discriminate against retired individuals. Postgraduate students or active taxonomists who are not specifically employed to undertake taxonomy.

6. *What impact have developments in DNA sequencing, genomics and other new technologies had on systematics research?*

These have provided exciting new insights into evolution, but have pushed out alpha taxonomy and taxonomic tools. This is rather ironic when knowing the identity of the organisms worked on is so essential! Funding has been focused into larger organisations that could afford molecular facilities, and relegated smaller organisations and the individual to the sidelines. In higher education, the emphasis on new technologies can distract from existing ones and does not always discuss their relative merits.

In what way has systematics embraced new technologies and how can these research areas interact successfully and efficiently?

Researchers have embraced new technologies very quickly, particularly in phylogenetics, economic biology/ecology and studies involving cryptic species. However, some undoubtedly have done so because that it is the only way that they can have their research projects funded. In some cases the turnover of methodologies creates difficulties in the assessment of multiple sets of data.

Data collection, management, maintenance and dissemination

7. *Does the way in which taxonomic data is collected, managed and maintained best meet the needs of the user community? What is the state of local and national recording schemes?*

Data is collected in an *ad hoc* manner and the dissemination of such data are currently patchy. Local and national recording schemes are under funded and, in any case, mostly carried out either by amateurs or in people's spare time. The publication of results such as those generated by mapping schemes is poorly supported.

The development of the UK recording programme (National Biodiversity Network) has allowed recorders to add data in a more standardised way, however the level of taxonomic verification can be extremely variable, with little demand to link records with museum voucher specimens.

8. *What is the role of the major regional museums and collections? How are taxonomic collections curated and funded?*

National Museum Wales is a major repository of biodiversity collections relevant to Wales, the UK and internationally, with approximately 4 million specimens. The scope and size of the collection will largely determine the contribution any one museum can make. However, the collections of many museums are related to our colonial past and, as such, could contribute to alleviating the global taxonomy impediment. Currently 16 of our staff contribute to peer reviewed research in taxonomy and systematics.

As a "regional national" this institution supports taxonomic research and training in the university sector, and contributes to the work of agencies such as the *Countryside Council for Wales* and the *Environment Agency Wales*. It carries out research relevant to UK needs and works in partnership with overseas colleagues in Europe, Africa, SE Asia and the Americas. We therefore view these "regional nationals" as an integral part of the overall UK taxonomic community which should be able to integrate their work with the Natural History Museum, Kew and the Royal Botanic Garden Edinburgh.

They should also retain a regional function to support what are now devolved areas of the UK. These museums are primarily multi-discipline institutions with both cultural and science remits. Across the field, the current political priorities for such museums are often social and cultural, and they are increasingly losing their science role. They are funded by regional government or unitary authorities and, within these, are often governed by administrations geared towards the arts, social history or even tourism. Funding taxonomic research or bioinformatics based on the collections is rarely high on the priority list, with emphasis placed on exhibitions and schools education. In our own situation the majority of our taxonomic work is funded externally or is derived as an offshoot of contract work; direct funding does not support taxonomic research other than the salaries of the staff who also have curatorial and outreach duties to perform. No staff are totally dedicated to research. Over the years we have witnessed a decline in research output and reduction in taxonomically skilled staff in most large regional museums.

Unlike the situation in "leading" systematics institutions, engagement in the taxonomy agenda is low key in regional museums. Previous reviews carried out by the Select Committee appear not to have been considered by the Welsh Office or the Welsh Assembly Government, at least as far as this institution was considered. We would hope that this position can be rectified, particularly as it would appear that one of unfortunate

consequences of devolution has been the fragmentation of any UK policy on systematics, and the isolation of many institutions in the devolved countries. We believe that an overarching policy and strategy is urgently required.

9. *What progress has been made in developing a web-based taxonomy? How do such initiatives fit in with meeting demand for systematics and taxonomy information? How do UK-led initiatives fit in with international initiatives and is there sufficient collaboration?*

Clearly, the world-wide web will be fundamental in accessing much data and taxonomic information on species worldwide. However, at present, web-based taxonomy seems to be a concept rather than a reality. Most taxonomic end-users still appreciate and value traditional books as well as having information accessible via the web. Any web-based taxonomic developments will depend on having taxonomists available to carry out the initiatives. It might be judged that major UK-led initiatives are now driven more by financial imperatives than by a current utility. The longevity of websites and the maintenance of sites over time are real issues- as are compliance with the formal requirements of *Codes of Nomenclature*.

10. *What needs to be done to ensure that web-based taxonomy information is of high quality, reliable and user-friendly?*

Coordination must be developed between taxonomists and those who are skilled in web-based tools. It is vital that web-based products are presented well and easy to use. Although progress has been made in automatic abstracting software, it remains a poor substitute for quality-control by trained taxonomists. The collections and libraries that support such tools remain the primary resource.

Web taxonomy should be linked to high quality images that come from verified material that is accessible in major Museums.

11. *How does the taxonomic community engage with the non-taxonomic community? What role do field studies play?*

The lack of a new generation of taxonomists is a problem that has been often discussed with little outcome. The virtual demise of field studies in school at GCSE and A-level does little to assist in encouraging an interest in tangible natural history. Our own experiences with University students have shown us that there is a wider interest in taxonomy than might be expected. However, this interest is not satisfied or cultivated in current biological or environmental courses. Individual taxonomists are nearly always vigorous communicators of taxonomy, yet lack the institutional resources to market their subject to large audiences. The success of the BBC Natural History Unit demonstrates that the potential market for engagement is enormous.

Consideration should be given to re-incorporation of a formal requirement for field-based studies into the National Curriculum and all University courses, with appropriate funding sources to allow such programmes.

Consideration should be given to funding to provide taxonomists to provide professional training courses for teachers, youth leaders and student teachers.

Skills base

12. *What are the numbers and ages of trained taxonomists working in UK universities and other organisations?*

The National Museum Wales has 16 such individuals, the majority over 40. This is perhaps the highest number employed outside of the Natural History Museum in London. However, our perception, in general, is that the number of taxonomists in paid employment is continuing to decline. Financial imperatives in our own institution could well result in future job losses in curatorial/research posts.

13. *What is the state of training and education in systematics and taxonomy?*

We can speak only from experiences with university graduates in Wales. Little or no taxonomic training is given at the undergraduate level. During a course given to 45 marine biology masters students in January 2008 all requested more taxonomic training and all admitted to little or no formal tuition at the under graduate level. The state of basic training is probably very poor throughout the UK. On being asked if she had experience with keys a graduate volunteer said she had used them for one afternoon. Such anecdotes are widespread. The limited funding for taxonomic research means Universities do not recruit taxonomists as lecturers, so undergraduate exposure continues to decline. In turn this leads undergraduates to doubt that taxonomy is a viable career option, so further training is not sought.

Are there any gaps in capacity?

Is the number of taxonomists in post, and those that are being trained, sufficient to meet current and future needs across all taxonomic subject areas?

In a recent review that we carried out in Wales with stakeholders such as the *Countryside Council for Wales,* many gaps were recognised especially in basic identification capacity. Macrofungii, soil meso-invertebrates, algae, marine epifauna, freshwater zooplankton and marine crustaceans (not decapods) were all highlighted as areas where basic capacity was absent.

Training to fill such gaps will only be effective if posts are created for them. Currently some of these gaps are filled by retired experts or by amateurs, but the gaps are increasing as these people cease activity. Our department provides high-quality taxonomic training where possible but is limited by resources. The ratio of students or trainees to mentors or supervisors in taxonomy is a fraction of what it is in molecular phylogenetics, again reflecting the research funding bias. As the gaps in capacity increase, even fundamental taxonomic skills will continue to be lost.

If we expand our view to the international position then, in developing countries where biological diversity is high, taxonomic capacity is scant. Overseas capacity-building by institutions like ours can be very successful but is only feasible if our capacity is maintained.

Memorandum submitted by the Natural Sciences Collections Associations

The Natural Sciences Collections Association represents specialist staff that look after Natural Science Collections in National, regional, local and university museums and institutions throughout the United Kingdom and Eire. We have members in the National & centrally funded Museums at the NHM, RMS Edinburgh, Cardiff, Belfast, Dublin, Liverpool, Manchester, Kew gardens and at almost all the smaller local council museums in the UK, representing Scunthorpe, York, Leeds, Glasgow, Birmingham, Newcastle, Whitby, Norwich, Hereford, Portsmouth, Bristol, Plymouth, Dorchester, Chester, Carlisle, Bolton, Ipswich, Colchester, Winchester, Bedford, Horniman, Woolaton Hall Nottingham, Herbert Museum Coventry, Leicester, Peterborough, Maidstone, Brighton, Haselmere, Scarborough, Sheffield, Sunderland, Perth, Inverness & Jersey and at University collections at UCL London, Oxford, Cambridge, Reading, Glasgow, Hunterian, Dundee and at the Royal College of Surgeons, Holborn and the Central Science Labs at Sand Hutton. There are other collections where there are no expert curators present, which are even more "at risk" with no representative.

Systematic collections housed outside of national museums have valuable data associated with them which not only supplements but also complements the larger collections held by the National collections such as Kew Gardens and the Natural History Museum. Smaller museums hold collections not only of material of local importance but often of national & international importance as well. These collections are themselves finding that financial constraints are reducing their contribution to taxonomic study of the world biota and geology. Many of these smaller collections hold material that is the cultural heritage of the area and is a valuable educational resource for nature conservation. They are also useful for local recording and can provide foreign & historic material which may now be extinct, collected from rain forest habitats which are now decimated by third world development or hold material that might now be impossible to obtain for study due to new strict international rules on collecting.

There is an increasing shortage of funding from local government who have many competing priorities to decide between. The closure of some museums has placed collections at risk through inadequate, inaccessible storage, whilst others are dispersed or sold. Care of these collections is being compromised with the reduction of funding for suitable access and storage and especially for maintaining the expert curators in post who often are the taxonomists who can access the taxonomic data held within the collections for their own and others' research. If funding is short for posts, it is even shorter for projects (eg digitisation, databasing, web-accessibility) that would make collections and the information associated with them more accessible to the wider community. Maintaining and developing such collections is essential so that they are readily available to taxonomic research. The reduced use of university collections reflects the reduction in taxonomy based learning and research which is so important to the future of understanding how the World's geo & biodiversity and wildlife can be protected and conserved. Such university collections which are not now being actively used could become at risk, as the university sees no reason to fund and maintain an underused resource. It is imperative that maintaining the raw material for taxonomic research is properly funded, so as to make the resource available to current and future researchers in systematic biology & geology.

A necessary complement to the collections are the specialist curators, either taxonomist themselves or specialist collections managers, who can make specimens and data available to researchers. Concern is acute that this work force is ageing and there is insufficient recruitment to the sector to pass on skills to a new

generation. Posts are often lost or frozen upon retirements as resources are deployed elsewhere by cash-strapped institutions. New/potential entrants to the profession who may have good generic skills lack specialist knowledge and need to have opportunities for training from experts and a reasonable career structure to encourage them to stay in the profession. The old practice of taking on graduate trainees was one way of passing on skills. The "amateur naturalist" sector is looked to as a repository of field and identification skills but here also there is an ageing population of experts with too few younger people to learn from them. Attracting job applicants has been a particular problem where the funding (ie salary) is inadequate and this is a particular concern when so many jobs are offered as short-term contracts.

Memorandum submitted by Mr Adrian Norris

Recorder for Non-marine Mollusca Conchological Society of Great Britain and Ireland and the Yorkshire Conchological Society; Chair Yorkshire Naturalists' Union Natural Sciences Committee; Senior Curator Natural Sciences, Leeds City Museums (Retired).

The state of systematics and taxonomy research

Some elements of questions 1 to 6 are covered by my comments below

Data collecting, management, maintenance and dissemination

Question 7. In most cases, the information gathered is adequate for the purposes for which it is accumulated, for example, production of distribution maps, on a 10 km basis, however, modern demands on this data for example, for local planning purposes, far exceed the normal requirements of the data-gatherers. Problems over the legal ownership of the data also make the free use of the data problematic. Much data is unusable by many organisations due to the refusal by the data-gatherers to allow this information to be made freely available to all. Most national recording schemes are unable to computerise their holdings of data due to a number of important factors: the size of the backlog of data available, incomplete data-sets, the reluctance of data-owners to allow full access to these data-sets, and the lack of transparency over the use and sale of the data by Local Record Centres (LRCs), as well as the perceived difficulties of allowing the transfer of data-sets to the originators themselves. It should be noted that most national recorders are unpaid volunteers and may not have the back-up of a sophisticated computer data-base or the support required to ensure that all data entered into their data-base has all the required ownership and legal titles attached. A National set of agreements need to be in place between data-owners, LRCs, the National Biodiversity Network (NBN), and all other interested parties so as to allow free access of data to and from data-gatherers. This agreement needs to be able to assure data-gatherers that their data will not be sold or used for profit.

Question 8. Most regional museums are unable to fund even the most basic research and many do not have the funding, space or expertise to place the bulk of their collections in taxonomic order. The regional collections do, however, play a major role in housing local, regional and even international collections and allowing access to these collections by local specialists and recorders, without which these people would be unable to check and verify the identifications of data submitted to LRCs and ultimately to the NBN database.

The development of the Regional Museum HUBS and the extra funding which came with this development from DCMS has made some difference but much of this extra funding has been wasted due to a lack of long-term strategic planning. Governments like "quick fixes" which gain them publicity. One of the easiest of these "quick fixes" is to spend more on educational projects, often with little co-ordinated planning and few long-term gains. The original plans for this extra funding for museums were intended, at least in the first few years, to build capacity and expertise within these institutions. This policy was discarded in favour of "quick-fixes" purely for political and publicity purposes. Funding should be allocated to correct this so that museums can fund strategic taxonomic tasks by employing trained taxonomists, as well as funding the proper storage of their collections.

The many differing documentation systems used by museums make it difficult to extract data from reference collections via these data-bases for use in national recording schemes. Some system needs to be established by which this data can be extracted and used as the historical base for the modern LRC data-bases.

Questions 9 and 10. I have combined these questions as I feel that one cannot easily be separated from the other. Although some attempts have been made to develop web-based taxonomy, the constant advances in identification techniques, particularly with the much wider use of DNA, has resulted in many changes to our knowledge about the inter-relationship of species. These modern techniques have also resulted in many changes to the nomenclature making it difficult to keep up to date. In many cases, web-based identification

systems are difficult and expensive to alter when such nomenclatural changes take place. Thus these systems, at best, are commonly out of date.

Question 11. The role of the experienced amateur naturalist has long been recognised within Britain as one of the major players in the collecting, identification and compiling of knowledge on our flora and fauna and yet, some elements of the professional taxonomic community make little effort to engage with the non-professionals. The work of the LRCs, English Nature and its regional equivalents and many other local, regional and national NGOs and other statutory bodies would be severely curtailed without the input of the non-professional enthusiast. With the pressures of global warming threatening climate change and thus the extinction of our more vulnerable species, more should be done by government to encourage the participation of people of all ages and abilities to become involved in the study and monitoring of our flora and fauna. Legislation passed in recent years covering health and safety and child protection, although very necessary in some quarters, has made things almost impossible for the non-professional to become involved in this important work. Insurance cover is difficult to obtain and expensive to acquire even to cover simple field meetings and most organisations find it difficult to involve younger people as the costs involved in getting child protection clearance is far too expensive.

Skills Base

As indicated above, most regional museums do not have the funding to employ specific staff covering systematics and taxonomy, and the lack of job opportunities within Britain has discouraged universities from training students in these subject areas. This situation contrasts sharply with that in most of the rest of Europe where a high value is accorded to taxonomy and significant resources are available even in regional museums.

Memorandum submitted by the Plant Diversity Challenge Steering Group

At The Hague in April 2002, as part of the Convention on Biological Diversity, the *Global Strategy for Plant Conservation* (GSPC) was endorsed, the long-term objective being to halt the continuing loss of plant diversity. Sixteen outcome-oriented targets for plant conservation were set, to be completed by the global community by 2010. The UK is committed to implementing the strategy and *Plant Diversity Challenge* is its response—the first by any nation.

Launched by the UK Government in 2004, *Plant Diversity Challenge* (PDC) sets out the framework for plant and fungus conservation throughout the UK. Like GSPC, it identifies sixteen targets grouped under five objectives covering: understanding and documenting plant diversity, conserving plant diversity, using plant diversity sustainably, promoting education and awareness about plant diversity and building capacity for the conservation of plant diversity. The wording of the targets was adjusted to take account of the UK situation.

We do not have a complete inventory of the plants of the world, but it is estimated that the total number may be in the order of 300,000 species. Of particular concern is the fact that many are in danger of extinction, threatened by habitat transformation, alien invasive species, pollution and climate change. The disappearance of such vital biodiversity sets one of the greatest challenges for the world community; to halt the loss of the plant diversity that is so essential to meet the present and future needs of humankind.

Of the sixteen targets in GSPC and PDC, several are of explicit relevance to the matters being considered by the House of Lords Science & Technology Committee in the inquiry on systematics and taxonomy in the UK. Here we give the wording from PDC, as we are addressing the questions from the UK (rather than global) perspective. The main relevant targets are:

- Target 1 Developing a working list of species—a widely accessible working list of known plant species, as a step towards a complete world flora.
- Target 2 Assigning conservation status to species—a preliminary assessment of the conservation status of all known plant species at national, regional and international levels.
- Target 14 Communicating and educating—the importance of plant diversity and the need for its conservation incorporated into communication, educational and public awareness programmes.
- Target 15 Training in plant conservation—the number of trained people working with appropriate facilities in plant conservation increased, according to national needs, to achieve the targets of this strategy.

In addition, several other targets require input from skilled taxonomists as illustrated by this quote from PDC (pp. 42-43):

> "One of the main drivers for achieving this target [target 15] will be providing the capacity required to meet the other targets in the Strategy. For instance, target 1 will require taxonomists trained in plant, algal and fungal taxonomy; targets 2, 5, 6 and 7 will require workers with field identification skills to provide surveillance; and target 8 will require conservationists based in botanic gardens. One of the key challenges will be promoting the subject at all educational levels in order to ensure that sufficient people are entering plant conservation careers. This is particularly urgent as the need for field identification skills increases in connection with the fields of environmental assessments and enforcement of biodiversity legislation."

In 2007, the UK published *Plant Diversity Challenge: 3 Years—16 Targets—One Challenge*, *Progress in the UK towards the Global Strategy for Plant Conservation* (PDC2). This document, resulting from a one-day conference of stakeholders in 2006, includes ten recommendations designed to focus attention on the remaining challenges needing to be addressed if we are to be successful.

The most relevant recommendations to this inquiry are:

- RECOMMENDATION 1 Focus research on improving the understanding of the importance of UK plant and fungal species in a European context, specifically the development of European Red Lists and European and UK fungal checklists.
- RECOMMENDATION 2 Increase support for the capture and handling of data at a local, regional and UK level, thereby improving the knowledge resource accessible through the National Biodiversity Network (NBN).
- RECOMMENDATION 8 Ensure young people experience plants and fungi in the field when they are learning about the natural world, alongside education in a classroom setting.
- RECOMMENDATION 9 Develop and deliver an action plan to address the need for plant and fungal skills and expertise in the UK.

In the light of the original targets and the more recent recommendations, we make the following response to the relevant questions set by the Committee as follows:

1. *What is the state of systematics research and taxonomy in the UK? What are the current research priorities? What are the barriers, if any, to delivering these priorities?*

Authoritative checklists of UK algal, fungal and plant species are essential to conservation programmes and will provide a major contribution to a complete world flora and mycota. Without such fundamental checklists, which tell us which species occur in the UK, it is clearly impossible to create meaningful Red Data Lists, Biodiversity Action Plans, and protected species lists. When additionally integrated with other, often scattered information, concerning taxonomy, systematics, nomenclature, distribution, frequency, habitat details and ecosystem function, such checklists become very powerful tools for setting priorities for conservation action and ecological research. Much progress has been made towards production of such checklists for several major groups, notably most plants and basidiomycete fungi. Further work is required as a high priority on several groups of fungi (notably Ascomycota, Chytridiomycota, Glomeromycota and Zygomycota) if we are to achieve Target 1 for these groups. As identified in other submissions, the number of trained mycologists available to work on these groups is woefully inadequate, especially when aquatic (marine and fresh water fungi) are taken into consideration.

Many Species Action Plans (SAPs) for vascular plants (http://www.ukbap.org.uk/) and other groups include calls for further research into taxonomy of problematic species or groups. Even out of the first three in the alphabetical list (*Alchemilla minima*, *Alisma gramineum* and *Apium repens*) the SAPs for the first and third identify clarification of the taxonomy of these species as a priority for further research. Understanding the UK taxa in their European context (as stated in Recommendation 1 in PDC2) is a major way forward to addressing these taxonomic issues, but this area is still under resourced.

2. *What is the role of systematics and taxonomy and, in particular, in what way do they contribute to research areas such as biodiversity conservation, ecosystem services and climate change? How important is this contribution and how is it recognised in the funding process? How is systematics integrated in other areas of research?*

Our response to this overlaps with that to Q. 1. If the UK is to achieve the goals of GSPC and PDC, in biodiversity conservation, full checklists and a better understanding of UK taxa in their continental context are essential. Systematics needs to be integrated with population genetics to establish the correct context for plants in the UK. For example, a preliminary study of the Welsh endemic *Scleranthus perennis* subsp. *prostratus* is in fact closer to English *S. perennis* subsp. *perennis* than the English populations are to continental populations of subsp. *perennis*, thus calling into question the significance of the Welsh endemic. However the low level of funding available for such studies means that this and many other similar questions cannot be adequately addressed.

3. *Does the way in which systematics research is organised and co-ordinated best meet the needs of the user community? What progress has been made in setting up a body to lead on this? What contribution do the leading systematics research institutions make both nationally and internationally?*

In relation to plant conservation, systematics research in the UK is covered by the Interagency Plant Conservation Working Group which includes a subgroup specifically addressing genetics and the interface between systematics and population genetics. This coordinated effort is appropriate to the needs of the community, but again the amount of work that is possible is limited by the funds available. Much of the work that is currently carried out on vascular plants is done by the major institutions, notably the Royal Botanic Gardens at Kew and Edinburgh. With current resources little work on fungi has been possible.

4. *What level of funding would be needed to meet the need for taxonomic information now and in the future? Who should be providing this funding?*

Clearly there is a need for an increase in funding if we are to meet the targets already agreed. The source of these funds, we believe needs to be largely from government directly or through the Statutory Agencies or the Research Councils. We note that the financial situation in the Agencies is currently difficult and that baseline taxonomic research is unlikely to be funded through the Research Councils as it is not regarded as "cutting edge" research. To overcome this latter problem will require a change in the attitude to descriptive systematic research.

5. *How does funding in other countries compare? Could there be more international collaboration? If so, what form should this collaboration take and how might it be achieved?*

Given the UK focus of PDC, we are not in a position to give a detailed answer to the first part of this question. We are in favour of international collaboration and numerous projects have gained benefit from this. It is an obvious way by which Recommendation 1 of PDC2 could be met. The will is there, but sourcing appropriate funding is difficult.

6. *What impact have developments in DNA sequencing, genomics and other new technologies had on systematics research? In what way has systematics embraced new technologies, and how can these research areas interact successfully and efficiently?*

Molecular techniques have dramatically changed the way in which systematics research is done, and the techniques now available provide the possibility to address many of the remaining questions relating to UK biodiversity. The teams at the two Royal Botanic Gardens and the Natural History Museum currently use these techniques to address such questions to the extent that funding allows, again largely on vascular plants. The techniques are applicable to fungi, but to our knowledge little work has been done.

7. *Does the way in which taxonomic data is collected, managed and maintained best meet the needs of the user community? What is the state of local and national recording schemes?*

Recommendation 2 seeks increased support for the capture and handling of data at local, regional and UK levels, thereby improving the knowledge resource accessible through the National Biodiversity Network. Whilst good progress has been made with various aspects in the UK, for instance through the development of Threatened Species Databases and the National Biodiversity Network (NBN), further effort is needed to ensure there is consistent data collection and that up-to-date data are made available through the NBN at a variety of scales. This will require considerable support and resourcing.

8. *What is the role of the major regional museums and collections? How are taxonomic collections curated and funded?*

This question falls outside our remit.

9. *What progress has been made in developing a web-based taxonomy? How do such initiatives fit in with meeting demand for systematics and taxonomy information? How do UK-led initiatives fit in with international initiatives, and is there sufficient collaboration?*

We are not in a position to answer this question, but believe that the submissions from the major institutions will address this.

10. *What needs to be done to ensure that web-based taxonomy information is of high quality, reliable and user-friendly?*

We are not in a position to answer this question, but believe that the submissions from the major institutions will address this.

11. *How does the taxonomic community engage with the non-taxonomic community? What role do field studies play?*

One of the major success stories relating to PDC is the role of voluntary/non-professional surveyors of diversity in the UK. Products such as the *New Atlas of the British and Irish Flora* and the *Checklist of British & Irish Basidiomycota* would not have been possible without this input. Tracking changes in distributions of species in response to climate change and other threats will mean that field studies providing ever more accurate pictures of species diversity changes in space and time will remain a high priority. Recommendation 10 of PDC2 (*Ensure the resources available for plant conservation activities in the volunteer and charitable sector are sufficient to cover the expectation of work to be carried out by this sector*) recognises the role of the non-professional in this area and identifies the need for adequate resourcing.

12. *What are the numbers and ages of trained taxonomists working in UK universities and other organisations?*

We are not in a position to answer this question in detail. However the 2007 report recognises that across the UK there is a continuing loss of botanical and mycological expertise from government organisations and this has coincided with a significant increase in the requirements for reporting on Biodiversity Action Plans and targets.

The UK has a history of learned societies and committed individuals who give their time and expertise. There are few young enthusiasts, and hence there is a danger that skills and expertise will not be passed from generation to generation. This trend is compounded by the loss of specialists in institutions and statutory organisations available to train and transfer skills. The Government needs to provide leadership in this area through the implementation of an action plan following a needs assessment.

13. *What is the state of training and education in systematics and taxonomy? Are there any gaps in capacity? Is the number of taxonomists in post, and those that are being trained, sufficient to meet current and future needs across all taxonomic subject areas?*

We are not in a position to answer this question in detail, but believe that the state of training needs to be dramatically improved if we are to meet the needs of UK biodiversity and its conservation. The situation is not good for vascular plants; it is worse for macro-fungi, and poor for micro-fungi.

Sources

Global Strategy for Plant Conservation:

— http://www.plantlife.org.uk/international/assets/policies/global-stategy-for-plant-conservation/Global_Strategy_for_Plant_Conservation.pdf

Plant Diversity Challenge:

— http://www.jncc.gov.uk/pdf/plantdiversitychallenge.pdf

Plant Diversity Challenge: 3 Years—16 Targets—One Challenge, Progress in the UK towards the Global Strategy for Plant Conservation:

— http://www.plantlife.org.uk/portal/assets/News%20Sue%20Nottingham/PDC.pdf

Memorandum submitted by Plantlife International

Plantlife, the UK's leading charity working to protect wild plants and their habitats, sincerely welcomes the timely follow-up inquiry on systematic biology research and taxonomy by the House of Lords Committee on Science and Technology. In particular, we are greatly concerned by the persistent lack of skills and information relating to lower plants and fungi and welcome all moves to redress this situation. Plantlife's submission to the Committee focuses on the state of affairs in Systematics and Taxonomy as it relates to fungi and lower plants, unless otherwise stated.

In summary, Plantlife believes there is a lack of taxonomical expertise that is accessible to government, conservationists and education establishments. This problem will be exacerbated as the retirement of a large proportion of current experts is imminent. Insufficient funding for training in order to support the training of new skilled mycologists and lichenologists, as well as scarce funding for systematics and taxonomic research in general, further compounds the issue. Plantlife believes the situation amounts to a crisis, particularly in mycology.

With regard to the collation and management of taxonomic data, Plantlife believes that a separate review is necessary. With rapid technological advances matched both by the increases in demand for taxonomic data and potential sources of such data, we regard a new look at best practise models to be urgently required.

Question 1. *What is the state of systematics research and taxonomy in the UK? What are the current research priorities? What are the barriers, if any, to delivering these priorities?*

1. Plantlife believes that, in general, there is lack of taxonomical expertise that is accessible to government, conservationists and education establishments. We are particularly concerned by the situation with respect to lower plants and fungi.

2. Plantlife understands that within Universities in the UK there is little taxonomic research on lichens, and only a small amount of ad hoc research on macro fungi undertaken at Liverpool John Moores and the University of Cardiff. For lichens, taxonomy and systematics research is undertaken as part of the job of two staff members at the Royal Botanic Garden Edinburgh (RBG Edinburgh), one staff member at the National Museums and Galleries of Wales, Cardiff, and one person at the Natural History Museum, South Kensington. Meanwhile, no one in Wales has a specific remit for such research relating to fungi, whilst elsewhere in the country, and only as a part of their jobs, there is just one person working on research in Scotland, a very small team (two staff and two support staff) at the Royal Botanic Gardens Kew (RBG Kew), and three at CABI Biosciences (the latter two institutions providing a world-wide service and with confirmed plans to consolidate activities and staff at RBG Kew). A limited number of specialists also offer consultancy work in this area.

3. Research priorities within conservation-based organisations are dictated by available funds that, at present, are almost exclusively linked to Biodiversity Action Plan (BAP) species and those receiving statutory protection. Furthermore, in order to gain sufficient funding for a project of British national value—such as the updating of a checklist or the creation of primers to help identify the mycelium of a fungus that occurs nation-wide—researchers may have to make a number of applications to a number of different bodies as no single source of dedicated funding that is sufficiently resourced exists. The lack of any long-term certainty over research funds compounds the problem. In this context, programmes commenced tend to stall before they can be completed.

4. Plantlife believes that the current research priorities regarding all plants and fungi involve:

— resolving outstanding taxonomic issues regarding threatened flora in order to inform and facilitate conservation efforts

— confirming that taxa considered endemic to Britain really are distinct species. This work has stalled at least on lower plants and requires more significant funding, for example, PhD studentships;

— increasing understanding of within-species diversity as a prerequisite to conserving it.

In addition, priorities for fungi-specific research are:

— combined molecular and morphological resolution of priority taxonomic issues to refine our measures of diversity;

— the design of species-specific primers for the detection of rare and threatened species;

— increased understanding of the hidden fungal diversity, distribution and links between it and other taxa diversity.

Question 2. *What is the role of systematics and taxonomy and, in particular, in what way do they contribute to research areas such as biodiversity conservation, ecosystem services and climate change? How important is this contribution and how is it recognised in the funding process? How is systematics integrated in other areas of research?*

5. Systematics and taxonomy research identifies discrete biological entities and provides the tools such as identification guides ("floras") to enable the recognition of these entities. Taxonomists also offer an invaluable service in determining the identity of problematic material and assist in the production of reference collections that are invaluable in resolving the identity of critical material. Having collected together distribution data from this identification process, conservation priorities can be developed, in particular through the process of "Red Listing". These Red Lists identify those species of conservation concern and help inform the development and implementation of protective legislation such as Schedule 8 of the Wildlife & Countryside Act, the notification of Sites of Special Scientific Interest, and the designation of National Nature Reserves. An insecure nomenclature could make the legislation unenforceable.

6. Identifications need also to be accurate. Currently, the learned societies offer a panel of referees willing to examine material relating to flowering plants, ferns, stoneworts, mosses, liverworts and lichens. This is mostly a voluntary process and for some genera a number of years may pass before a referee has time to check a specimen. Some referees are based in institutions where only a small amount of time may be allowed for such work. Plantlife considers this very unsatisfactory and believes additional central funding should be made available to these institutions in order that they may fund a proper service. The small number of professional taxonomists is also largely responsible for the initial training of voluntary referees. If we are to rely on voluntary societies, resources need to be made available to support and sustain these activities. RBG Kew, the National Museums and Galleries of Wales, Cardiff and RBG Edinburgh all provide a limited identification service, but would soon be overwhelmed by demand if this service were advertised. Plantlife does not consider systematics and taxonomy research to be adequately funded at present.

7. Understanding the functioning of ecosystems and their conservation or commercial exploitation is largely impossible if the individual taxonomic units from which they are constructed cannot be recognised. A clear understanding of evolutionary relationships of species can also provide important information as to how their populations may be managed appropriately. For example, the Cruciferae (cress family of flowering plants) do not normally form relationships with mycorrhizal fungi in their roots. In consequence they appear less susceptible to the effects of nutrient enrichment of their environment than, for instance, a member of the Fagaceae (oak and beech family), which appear to be highly dependent on such fungi and perform poorly in nutrient-rich situations.

8. Without a secure and widely accepted taxonomic base, biological data recording would become confused and unworkable. Checklists are an invaluable aid to stabilising the use of names. For plants and fungi the production and maintenance of checklists is haphazard at best. Indeed, Plantlife believes that the production and maintenance of these fundamental tools should not be left to chance and the efforts of mostly voluntary societies. Recognising this problem, the Botanical Society of the British Isles has recently set up a voluntary panel to review taxonomic developments and maintain a website with a comprehensive synonomised checklist. This model might be repeated within the other Societies with grant aid provided as an inducement. The alternative strategy is to provide ring-fenced funds to a particular institution charged with the maintenance of such lists and guided by a consultative panel. It is clear that the current situation is not sustainable. For example, the British lichen checklist is largely the work of one man, carried out mostly in his spare time. Dr Brian Coppins of RBG Edinburgh maintains the list that is available on the web. He is, however approaching retirement age and there is no obvious successor in any other British institution.

9. From time to time there are disagreements over interpretation. Unresolved taxonomic interpretations can lead to confusion during planning decisions, statutory designation or prosecution. There is at present no clear mechanism for establishing a consensus. Of even greater concern to Plantlife is the fact that the skills base in

the UK is so depleted that creating a panel to establish consensus would be difficult without recruiting assistance from abroad. On the retirement of Dr Coppins in the next two years the skill gap will be such in lichens that a professional replacement is unlikely to be found. The Natural History Museum, which has traditionally trained staff to a level where the production of checklists and the provision of nomenclatural advice was seen as part of their job, appears to pursue contracts around the world to secure funds and is the consumer not provider of this sort of support.

10. The situation within the rest of the fungus kingdom is even more unsatisfactory. The Ascomycete checklist has not been updated for 23 years. Until recently the Basidiomycete checklist was over 40 years out of date. Although this checklist was updated in 2005, this was only possible because RBG Kew took the lead with this work with outstanding contributions from experts who gave their time in a voluntary capacity. Only a small amount of grant aid was available from conservation agencies, adding to Plantlife's concerns that the importance of taxomony and systematics research is not reflected in current funding processes. Unfortunately funds could not be found to ensure that the checklist is maintained and updated.

11. In brief, without the ability to identify species correctly, research and conservation projects may be compromised. Although the use of genetic markers is a useful way forward, it depends on taxonomic expertise and the availability of good collections. Plantlife believes there is a potential misunderstanding that genetic barcoding may be used to resolve the UK's current taxonomic impediment.

Question 3. *Does the way in which systematics research is organised and co-ordinated best meet the needs of the user community? What progress has been made in setting up a body to lead on this? What contribution do the leading systematics research institutions make both nationally and internationally?*

12. There remains no methodical organisation behind systematics research. What coordination exists is provided largely through the voluntary effort of individuals mediated by conservation bodies and learned societies. For example, Plantlife coordinates and services the Fungus Conservation Forum consisting of voluntary and learned societies and statutory organisations. The Forum has developed a UK Fungi Strategy and offers a platform for inter-institutional discussion on taxonomic study. Plant Link (PLINK—the forum for all organisations with an interest in plant conservation) and its Welsh and Scottish committees, each have representatives from the major taxonomic research institutes and have, or are now developing, strategic plans that involve elements of taxonomic and systematics research

13. Some of the major taxonomic institutions such as the National Museum of Wales no longer have advisory panels. This is regrettable as these panels allowed an exchange of views regarding priorities between organisations. It is to be hoped that, provided funds persist to support PLINKCymru, this alternative forum may partly meet this need.

Question 6. *What impact have developments in DNA sequencing, genomics and other new technologies had on systematics research? In what way has systematics embraced new technologies and how can these research areas interact successfully and efficiently?*

14. With the caveat noted above in Paragraph 11, DNA sequencing has permitted for the first time the recognition of the important role fungi play in most ecosystems. Most plants and animals have formed mutualistic associations with fungi, whilst nutrient cycles and the control of pests and pathogens are effected by the presence of beneficial fungi. Traditional identification methods to identify theses fungi are of limited value and there is an urgent need to equip the existing, though limited, research facilities so as to improve our understanding of this fundamental ecosystem process and the range of new taxa that sequencing has identified. The current widespread use of artificial fertilizers threatens life-supporting fungi. It is, therefore, of vital importance we are able to describe and conserve this newly discovered genetic diversity.

15. Sequencing has also led to considerable taxonomic instability and has forced a radical review in particular of generic and higher relationships. Some traditional taxonomists reliant on morphology and chromosomes have found the use of genomics difficult to embrace. The instability of names is problematic and Plantlife fears it may dissuade people from taking up an interest in the identification of plants and fungi. It is therefore imperative that every support should be offered to those willing to accept the challenge. Plantlife recommends the development of an apprentice scheme akin to that already trialed with much success in Scotland.

Question 7. *Does the way in which taxonomic data is collected, managed and maintained best meet the needs of the user community? What is the state of local and national recording schemes?*

16. The quality and accessibility of the taxonomic data collated varies greatly between species groups, and Plantlife believes that taxonomic collections are not being used to their maximum potential. Maintenance of good-quality data requires considerable resources. Additional resources are urgently needed in order to capture electronically all the data held regarding herbarium specimens in British institutions and make them available via the National Biodiversity Network (NBN). Some herbaria such as Liverpool have electronic databases of the data taken from the labels of all their specimen, but many do not. At the National Museum of Wales, for example, only recently curated specimens are logged electronically. There are no resources to clear the backlog. Plantlife considers it unacceptable that it is now more desirable to deposit important plant and fungus specimens in overseas institutions, where the data is made immediately accessible via the web, than in some UK institutions where data is less easily accessed.

17. Plantlife believes that the current state of national and local recording schemes and the management of the data they generate (namely their provision on the web at a usable scale) should be the subject of a separate review. With rapid technological advances matched both by the increases in demand for taxonomic data and potential sources of such data, Plantlife believes that a new look at best practise models is urgently required.

18. The situation in Wales provides a good example of some of the issues. Four local record centres have been established to cover the entire country. A consortium of users funds the collection and dissemination of data and the sale of data is a significant part of their financial support. At the same time a number of organisations including the Botanical Society of the British Isles, The British Lichen Society, the British Mycological Society and the Association of British Fungal Groups have all resolved to create their own separate British national databases; some working in partnership with the NBN Trust. All of these organisations are now competing for scarce resources to assist in data input and system support with no clearly defined overall plan. The recorders of biological data are left to decide for themselves which system they will support and no one system any longer has a comprehensive data set. Quality control issues also arise.

19. The NBN provides a useful "library" through which datasets can be made available. However, the development of species dictionaries has been slow and Plantlife believes too little consideration has been given to the impact of taxonomic change on records. As an example, the species dictionary in Recorder (the most widely used biological recording database) became years out of date. This will now necessitate a large amount of work to resolve records of species split into more than one entity where one of the new entities retains the old name. Furthermore, there are examples of name swaps between species. In such cases, the true identity of a record can only be ascertained if an accurate date for the name change is known or the date at which the maker of the record took up the change. The process for deciding when, or whether, a proposed change in taxonomy will be adopted by Recorder remains undefined. The development of a global biodiversity information network will require considerable work as it necessitates the construction of synonomy lists and species dictionaries that go beyond the borders of the British Isles.

Question 8. *What is the role of the major regional museums and collections? How are taxonomic collections curated and funded?*

20. Regional museums have played a pivotal role in improving botanical taxonomic skills. Without lichenologists in RBG Edinburgh and Cardiff, lichenology would have floundered in Great Britain. The three British-trained lichenologists based in these institutions provide an important service in the identification of critical specimens and have resolved numerous taxonomic problems. Their collections are well curated and accessible (although the working facilities in Cardiff are extremely small). The staff lead workshops and field meetings and provide essential support to a small but active band of amateur lichenologists. They also provide important support to the country conservation agencies.

21. Whilst RBG Kew attempts to fill the skills gap in fungus taxonomy, their small staff combined with a worldwide remit means little specialist support is available to a country such as Wales. The merging of this team with the CABI specialists will not increase the number of experts available. Scotland has not recovered from the loss of its mycologist at RBG Edinburgh. Staff in these regional centres have been pivotal in the ongoing revision of the British Lichen Flora. This essential tool had become seriously out of date. Its revision has only been possible by the use of retired one-time professional lichenologists and much amateur help. Unless additional resources are found for these institutions to take on the work of keeping this standard flora up to date, it is very unlikely, given the age profile of the current participants and existing work programmes of those few remaining professional lichenologists, that any new edition could be contemplated in the foreseeable future.

Question 9. What progress has been made in developing a web-based taxonomy? How do such initiatives fit in with meeting demand for systematics and taxonomy information? How do UK-led initiatives fit in with international initiatives and is there sufficient collaboration?

22. The learned botanical and mycological societies have embarked on the development of websites for taxonomy alongside the NBN. Plantlife believes these sites could offer essential information such as checklists, synonomy lists, conservation evaluations and distributional data as well as supporting the means of accurate identification of species. At present, there are insufficient resources to set up such websites.

Question 10. *What needs to be done to ensure that web-based taxonomy information is of high quality, reliable and user-friendly?*

23. Plantlife believes that there needs to be a strategic review of data collection and management, and their dissemination on the internet.

Question 11. *How does the taxonomic community engage with the non-taxonomic community? What role do field studies play?*

24. The main means of engagement of the taxonomic community with the field-based community is through publications and meetings run by the learned societies. The Botanical Society of the British Isles, British Bryological Society, British Lichen Society, British Mycological Society and the Association of British Fungus Groups all hold indoor and outdoor workshop meetings where taxonomic skills can be transferred. Within Wales informal field meetings of amateurs and professionals who wish to improve identification skills are held in addition to formal meetings. Plantlife assists in their organisation as well as coordinating the PLINK groups at UK and country level. These groups provide regular, albeit limited, opportunities for both communities to engage on these and similar issues. Many of the specialist Societies offer small grants to help less fortunate members attend such meetings. A more structured approach offering financial support in the purchase of identification guides, microscopes and the wherewithal to transfer records electronically to central databases is highly desirable.

Question 12. *What are the numbers and ages of trained taxonomists working in UK universities and other organisations?*

25. In general, the issue remains that an aging body of taxonomic specialists, especially with regard to lower plants and fungi, is not being replaced let alone developed. The Basidiomycete project described in Paragraph 10 was exceptionally fortunate in securing the talents of N.W. Legon as the paid senior author, but he has now left RBG Kew to seek employment outside this field. Other key participants in the project have either retired or are likely to do so in the next few years. There appears to be no strategy within RBG Kew for the transfer of skills of trained staff approaching retirement. In consequence fungus taxonomy in Britain appears to be facing a major crisis.

26. Plantlife is extremely concerned by the persistence of the gulf between the need for taxonomic expertise and the resources being supplied to ensure the continuity of such expertise. The problem arises both from a lack of funding and a lack of training, especially as the latter may take many years before expertise is achieved. This issue may be illustrated by the experience of RBG Edinburgh where, seven years after the retirement of a mycologist of international repute, no replacement had been recruited.

27. Efforts to redress this situation have been instigated, for example the British Lichen Society lichen apprenticeship scheme in Scotland (part funded by Scottish Natural Heritage) provided training to seven individuals over three years, but current needs outweigh such initiatives to date. Funding for training is a high priority.

28. It is noticeable that in those institutions and subject areas where foreign trained staff have had to be employed due to a lack of any suitable British applicants, their skills transfer has been far less successful and almost without exception they have made little impact on the British scene.

Question 13. *What is the state of training and education in systematics and taxonomy? Are there any gaps in capacity? Is the number of taxonomists in post, and those that are being trained, sufficient to meet current and future needs across all taxonomic subject areas?*

29. There remains little capacity to train young potential taxonomists. This problem is fuelled by the lack of experts in lower plants and fungi and is compounded by their imminent retirement. Apprentices must be recruited quickly, and it is possible that it will be necessary to seek them from overseas.

30. The urgent need for an action plan to address the need for plant and fungal skills and expertise in the UK has been recognised in the progress report (2007) of the Plant Diversity Challenge.

4 February 2008

Memorandum submitted by the Royal Entomological Society

1. The Royal Entomological Society (RES), founded in 1833, is the UK's professional body for entomologists, with around 1800 members. We produce seven journals on all aspects of entomology, including *Systematic Entomology*, recognised as one of the world's leading journals for insect taxonomy. In addition we publish a series of identification guides to British insects (*Handbooks for the Identification of British Insects*, begun over 50 years ago), which includes the definitive checklists of the British species. Although we are concerned with just one group of organisms, the insects are widely regarded as the most species-rich group on earth.

2. The RES has an active programme of publishing handbooks to the British insects, yet we are unable to do so as quickly as we would like. The difficulty is not in funding the publications, nor in selling the finished products. The limiting factor is the lack of authors willing or able to write definitive accounts of many taxonomic groups. In recent years most of our authors have been amateur workers or retired professionals. Approaches to professional biologists usually result in a clear statement that their employer does not consider work on the British fauna to be a high priority, or in some cases does not consider taxonomy to be a genuine research area, even though the biologist in question may be a recognised authority on the group. There are approximately 24,000 species of insects in the UK, yet we estimate that there are no modern comprehensive identification guides for at least 6,000 of these. These gaps are not in the smaller and obscure groups, however, as there is a serious lack of information for many groups of Coleoptera (beetles), Hemiptera (bugs), Diptera (flies) and Hymenoptera (ants, bees and wasps). Among these insects groups are many plant pests and important pollinators of crops. Our inability to identify them reliably is not only a clear indicator of the lack of targeted taxonomic research, but it may also have serious implications for the future as it seems inevitable that agriculture and sourcing our own food will be increasingly important in the coming decades.

3. A study of the numbers of UK insect taxonomists who were actively undertaking research (Hopkins & Freckleton, 2002) was published in the same year as the last Select Committee's report, and so was not referred to in the evidence submitted at that time. The paper shows a clear decline in the numbers of both amateur and professional taxonomists, and our own difficulties in identifying authorities on many groups of insects confirm that the decline is continuing. Two recent editorials in *Systematic Entomology* (Cranston & Krell, 2007; Krell & Cranston, 2008) drew attention to the low numbers of authors based in the UK publishing in the journal. In the last six years (2002-2007) the number of principal authors from the UK, in relation to the total number of authors, was: 3/18, 5/26, 3/31, 1/28, 2/32, 1/40. Although this averages at about 10 per cent of authors from the UK, the decline in the last few years is cause for concern. For comparison, the same ratio in 1995 was 5/21, or about 24 per cent.

4. The UK is fortunate in having a substantial number of amateur naturalists, some of whom are the acknowledged taxonomic experts on their groups, but such a situation is not sustainable. Amateurs follow their own interests, and they do not necessarily train successors. Similarly, many of the larger UK museums rely heavily on retired staff to cover taxonomic groups; again this is an unstable situation that is an unsatisfactory substitute for long-term strategic planning of staff succession. No doubt this is partly a result of having to chase external funding, and partly because they cannot rely on finding taxonomists on certain groups, given the lack of taxonomic training at university level. However, it is clearly unsatisfactory that many agriculturally or medically important groups of insects no longer have professional specialists working on them, given the impending world food crisis.

5. The current inquiry into systematics and taxonomy is the latest in a long line of investigations extending back to the Review Group on Taxonomy of the Advisory Board for the Research Councils set up in 1974 (ABRC, 1979). That report commented (p. 45) that developments in areas like molecular biology had overshadowed taxonomy, leaving it "undeservedly under-rated and in low esteem." Sadly their optimism for future improvement was not justified. Even after the previous two inquiries by the House of Lords Select Committee, there have been numerous calls for dedicated funding for taxonomy, for recognition of its

fundamental importance, as well as suggestions for a more integrated approach to the organisation of the whole discipline (eg Claridge, 2001). There is no need to labour the point: basic taxonomy is still seen as under-resourced and poorly regarded in many circles, and this situation looks unlikely to change unless a new approach is adopted.

6. Current funding priorities for research and development in systematic biology include molecular systematics, automated identification systems and database networks. Molecular systematics, including DNA bar-coding, is a valuable new tool, but it does not replace traditional morphological taxonomy. The former Head of the Entomology Department at the Natural History Museum has said that what we need is not "DNA-exclusive or DNA-intensive classifications, but *integrative taxonomy*" (Wheeler, 2008; italics original). Automated systems for species recognition such as DAISY (Gaston & O'Neill, 2004) have the potential to remove much routine identification work from taxonomic experts, but this serves to free the specialist to do taxonomy; it does not replace need for professional taxonomists. It is important to distinguish between taxonomists and those who make use of the products of taxonomy such as keys for identification; the former is a group of innovative research workers on whom the latter group depends. Networks of taxonomic databases, whether of primary descriptive data or of collection data are attractive and popular tools, but they are essentially concerned with manipulating metadata and do not generate new information. Thus all these activities and new developments are extremely valuable and are indeed essential for the future development of systematic studies in an evolving discipline. But clearly they all depend on the continuation of basic morphological taxonomy for their relevance to be maintained. Short-term funding for the development of new techniques is no substitute for sustainable funding that will ensure the continuance of a stable taxonomic information system.

7. Clearly, another round of bemoaning the decline of taxonomy, asking for more government funding (or for existing funding to be ring-fenced) and setting up more committees to assess the decline in years to come, will be fruitless. Even if extra funding were available, the training of new taxonomists is a long-term commitment, and the current situation cannot be reversed overnight. There are already calls for traditional taxonomy to change its image, by moving from a paper-based and intractable archive to a web-based, freely accessible system that can be rapidly revised and integrated with other taxon-linked data (eg Godfray, 2002). But such innovations cannot be funded by individual institutions, nor will they attract the current funding bodies if the end result is seen to be of limited or parochial value.

8. The current downward spiral of reducing funding for traditional taxonomy, no training of taxonomists, difficulties in recruiting specialists and lack of taxon-based succession planning is the result of a feedback-loop with each decline influencing the others; it is unlikely to be solved by addressing just one of these issues. The way forward, if all interested parties are serious about reforming the situation, is an integrated approach to bring taxonomy into the 21st century, and this will require cooperation between learned societies, taxonomic institutions, universities and funding bodies. But this collaborative effort must lead to action, not merely more words, and this will only happen if one of these groups acts as a champion of the cause. In general, the societies such as the Linnean Society and Systematics Association do not have the resources to undertake this, though the broad-ranging expertise of their members will be invaluable. It therefore seems that, with their existing resources of staff, collections and libraries, the UK's major museums are the only contenders for this championing role. In the longer term the establishment of a national systematics body may be realised (Claridge, 2001).

9. Moving in this integrated and collaborative direction will bring the initiative back to the taxonomists themselves, enabling them to set their own scientific priorities, rather than having these dictated by external funding pressures. Even the "New Taxonomy" (NERC, 1992), while actively promoting the funding of new techniques in systematic biology, still recognised that "the case for working on a group should be made on the basis of scientific arguments" and that there should be "flexibility in funding to support this kind of taxonomy."

10. The continued decline in numbers of both amateur and professional taxonomists is rapidly leading to the marginalisation of the UK as a world-class taxonomic power. We have large and irreplaceable natural history collections held in a wide range of institutions in the UK, which collectively comprise a unique resource. Failing to make good use of these species-rich and historically unique collections and failing to encourage our existing taxonomic experts is not just a missed scientific opportunity; it is a betrayal of our heritage. In order to fill the important gaps in our knowledge of British insects indicated above (para 2) an integrated approach to the planning of basic taxonomic research is thus an urgent necessity. Such a coordinated effort is essential for the future of UK taxonomy as a whole, and is a vital component of the UK Biodiversity Action Plan in response to the Rio Convention of Biological Diversity.

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January 2008

Memorandum submitted by the Royal Horticultural Society

The Royal Horticultural Society is a charitable organization with the purpose of encouraging and improving the science, art and practice of horticulture in all its branches. It is a membership organization with over 360,000 members from the UK and overseas. Its vision is to be the leading organization demonstrating excellence in horticulture and promoting gardening. As a learned society it has a remit for furthering the science of horticulture, including the systematics of plants in cultivation and organisms that affect plants. As a membership organization an important aspect of its work is providing an interface between the specialists and the wider public and therefore has a role in conveying the benefits of systematic research.

The RHS submitted evidence to the previous inquiry in 2002 and welcomes the opportunity to do so again. As both a provider and user of systematics, it regards the UK's capabilities in systematic research as critical in supporting its work, and is keen to support any initiative that sustains or improves the research base in this country.

The state of systematics and taxonomy research

1. *What is the state of systematics research and taxonomy in the UK? What are the current research priorities? What are the barriers, if any, to delivering these priorities?*

1.1 Over the past five years there has been a continuing emphasis on research addressing evolutionary relationships of organisms, and more specifically on functional or developmental significance of component parts or molecules (generally referred to as –omics studies). It is still the case that the underpinning studies of organism diversity (whole organism biology) are still under-resourced.

1.2 Systematics research is largely confined now to the established institutions (RBG Kew, RBG Edinburgh, Natural History Museum, Central Science Laboratories) with very little now being carried out in the universities with the conspicuous exceptions of Cambridge, Oxford and Reading who still have active taxonomy research programmes. Major regional museums, such as Cardiff, Manchester and Liverpool have some systematics capabilities but not a critical number to foster a healthy climate for research.

1.3 The RHS has a small team (see 12.1) of taxonomists and is internationally recognized the centre in the UK for horticultural taxonomy.

1.4 There remains a conspicuous difference in the concentration of expertise. The "higher organisms" such as flowering plants and insects and mammals still have a significant number of specialists, whereas those groups that have not enjoyed the support of a single institution (such as fungi and protozoa), continue to decline in the number of experts. Mycology is of particular concern given the significance of fungi to plant and animal health, to industry and the environment. At present there are fewer than 10 fungal taxonomists in the UK in a group, where new taxa frequently come to light and the diversity of which is still poorly known.

1.5 A huge positive impact has been made by the sharing of taxonomic data on the internet, which reduces the amount of time spent by taxonomists in resolving basic queries. Notable amongst many such sources are the International Plant Names Index (IPNI), GenBank, Species 2000, Index Fungorum and Tropicos.

1.6 The priority for systematics and taxonomy is to document and make widely available what is known of our diversity, and to describe what is not known.

1.7 The principal barrier to delivering the requirement for systematics is the funding environment, where support is provided through an unstable mix of core funding, research grants, collaboration with industry, fundraising (and a tax regime that does not encourage large-scale donations in the way that this operates in the USA).

2. *What is the role of systematics and taxonomy and, in particular, in what way do they contribute to research areas such as biodiversity conservation, ecosystem services and climate change? How important is this contribution and how is it recognised in the funding process? How is systematics integrated in other areas of research?*

2.1 The ever-increasing threat to organism diversity through habitat loss and climate change, means that the emphasis must be on conservation and the understanding of ecosystems; both these depend upon a thorough knowledge of diversity. This is of particular relevance in horticulture, as the horticultural world seeks to meet its responsibilities under the Convention on Biological Diversity (CBD), Access & Benefit Sharing agreements and the Global Strategy for Plant Conservation.

2.2 A demonstration of the use of taxonomy in support of conservation is the research carried out into the systematics of *Cyclamen*, a genus of horticultural importance all species of which are listed in Appendix II of CITES. This research was aimed at gaining a better understanding of localized populations and therefore contributing to the conservation of threatened populations and the monitoring of their importation. This work was co-funded by the RHS and the Cyclamen Society.

2.3 A further application in relation to conservation is research now being carried out at RBG Edinburgh on hybridization in China between species in *Rhododendron* Subsect. *Taliensia*. This PhD study will help to understand the effects on species boundaries arising from the increased potential for hybridization to occur following habitat degradation and loss. This work is funded the RHS Rhododendron & Camellia Group.

2.4 RHS plant names data are currently being used to construct a measure of genetic diversity of cultivated plants in the UK. It is the basis of any recording scheme to monitor the conservation status of cultivated plants. The impact of climate change can be detected through changes in what can be grown in gardens but the correct identification of these plants is essential for a robust, evidence-based documentation of these changes

2.5 The taxonomic input to determining the effects of climate change are still developing, but it is anticipated that it will have a key role in characterizing the impact of change on wildlife and cultivated plants as well as assisting in assessing the true threat of organisms coming into the UK that may prove to be invasive. The RHS already contributes, through its advisory service, in detecting the early appearance of new organisms entering through gardens and providing data on their spread. Recent examples include the Horse Chestnut leaf miner, Rosemary beetle and Fuchsia gall mite, as well as the spread of sudden oak death (*Phytophthora ramorum*). Our ability to do this is dependent upon the taxonomic expertise at the RHS and in other institutions.

3. *Does the way in which systematics research is organised and co-ordinated best meet the needs of the user community? What progress has been made in setting up a body to lead on this? What contribution do the leading systematics research institutions make both nationally and internationally?*

3.1 The RHS is both a provider of systematics and a user of the outputs of systematics research. The Society also sees itself as having an important role in promoting a wider appreciation and understanding of the benefits of systematics through its publications, provision of an advisory service and through information on its website. It also provides advice to the Government through consultations on future legislation in the areas of wildlife and conservation.

3.2 The RHS benefits from linkages with major UK research organizations through its Science & Horticultural Advice Committee, and through collaborative research with RBG Kew and RBG Edinburgh. It has Associate Institute status with the University of Reading. The RHS places great value on the work of the leading systematics research institutions, whose collections, data and literature resources are of international importance.

4. *What level of funding would be needed to meet the need for taxonomic information now and in the future? Who should be providing this funding?*

4.1 The RHS has no evidence on the level of funding required. It would re-iterate the point made above (1.6) about the problems inherent in the nature of the funding for systematics in the UK, and the need for more support for descriptive taxonomy.

4.2 The RHS, as a provider of systematic research, is principally involved with mycology, entomology and botany (horticultural taxonomy). Its work is not directly funded by the Government and is dependent upon funds raised by the Society and on grants awarded for specific projects and collaborations with other organizations. This means that most of our research is small-scale although there is a greater capacity for longer term studies than is the case in some other organizations.

5. *How does funding in other countries compare? Could there be more international collaboration? If so, what form should this collaboration take and how might it be achieved?*

5.1 The RHS has no data on the level of funding for systematics funding in other countries. However, although the situation is not directly comparable to the UK, it is worth noting that Beijing Botanic Garden employed 100 new taxonomists in 2007.

5.2 International collaboration in systematics research has increased over time, especially through EU initiatives. Investigating organisms with a wide distribution and the need to consult collections in other countries also encourages such collaborations. The need to recognize our responsibilities under the Convention on Biological Diversity also means that collaboration with workers in relevant countries is essential. However, the point needs to be made that building large teams of collaborators should not suppress the opportunity for independent research. Taxonomy, like any science, depends upon the robust testing of hypotheses and consensus only arrived at, if at all, through widespread acceptance of well founded research.

6. *What impact have developments in DNA sequencing, genomics and other new technologies had on systematics research? In what way has systematics embraced new technologies and how can these research areas interact successfully and efficiently?*

6.1 DNA sequencing and other molecular characterization methods have been shown to have tremendous potential in systematics and the RHS has been keen to apply these to its work where possible.

6.2 For its advisory service, the RHS makes use of sequencing to identify isolates of the fungal pathogens *Pythium* and *Phytophthora*, which is dependent upon the sequence database of *Phytophthora* species built up by the Scottish Crops Research Institute. For these taxa identification based on morphology is problematic and use of sequence data far more reliable. It has, in turn, revealed a hidden diversity of these organisms in our gardens.

6.3 For horticultural taxonomy, it offers the possibility of providing an objective method for characterizing cultivars distinguished normally by subjective and possibly unreliable features. This is significant, not only for conservation, but also for commercial reasons where Plant Breeders' Rights are being assigned or where the identity of a plant is disputed (for instance in cases taken to Trading Standards). The RHS is aware that a significant amount of research in this area is being carried out in some European countries and in the Far East but little, so far, in the UK.

Data collection, management, maintenance and dissemination

7. *Does the way in which taxonomic data is collected, managed and maintained best meet the needs of the user community? What is the state of local and national recording schemes?*

7.1 As stated in 1.4 above, the provision of large scale data sets on the internet has been and continues to be a major benefit to others, not just taxonomists, world-wide. This kind of information can be greatly enhanced by linking to other related datasets, creating a seamless reference for users (a "portal", "gateway" or "repository"). This is the approach that the RHS aims to develop when linking its plant names data to data sources provided by other collaborating organizations, to provide a portal for cultivated plant conservation.

7.2 The increasing availability of scanned taxonomic literature online is to be much welcomed. Much of this literature is rare, only being found in a few institutions around the world and is difficult to obtain, especially for those working in less developed countries. Ready access to these scanned images, just as with scanned

images of specimens (8.2 below) will do much to increase efficiency in research. Institutions holding such literature need to be encouraged to do more to make it available.

7.3 The RHS supports the efforts of TDWG (the Taxonomic Databases Working Group), which is an international group, to promote standardization of data structure to facilitate the exchange and linkage of taxonomic data.

8. *What is the role of the major regional museums and collections? How are taxonomic collections curated and funded?*

8.1 The UK has an almost unique tradition of maintaining extensive collections of specimens and has more herbaria listed in *Index Herbariorum* than any other country in the world. Some of these, especially the regional museums (such as Liverpool, Manchester, Glasgow etc.) contain collections of international significance. These museums now have an important role of take on collections from smaller herbaria when these are no longer supported and need to be re-housed. While some universities have disposed of their herbaria as taxonomic expertise has been lost or is no longer a priority (for instance most recently at Leeds) others, such as Oxford, have invested heavily in upgrading facilities and has an active research programme. Funding for regional museums should reflect the importance of being able to absorb such collections without any deleterious effect on curation.

8.2 An important consideration is access to collections. The widespread availability of digital imaging means that it is now conceivable to database and create images of all specimens, or in larger collections the significant specimens, in a herbarium. These can be provided on the internet as a resource for researchers and can, potentially, reduce the need for physical examination of specimens, reducing costs and possible damage to the specimens. However, while digital imaging can greatly enhance research, it cannot be seen as a substitute for the physical preservation of specimens. A priority for collections must be to undertake this work and for collections in the UK to link their images in a virtual herbarium. This has already been achieved in Australia (see http://www.anbg.gov.au/avh).

8.3 The RHS has the leading horticultural herbarium in the UK, containing over 58K specimens, connected to images (over 30K). The herbarium is databased and well curated, but is constrained in its capacity to expand and meet its remit to document plants in cultivation in the UK (especially NCCPG national collections) and in other temperate regions. The herbarium is core-funded by the RHS and receives no financial support from external sources.

9. *What progress has been made in developing a web-based taxonomy? How do such initiatives fit in with meeting demand for systematics and taxonomy information? How do UK-led initiatives fit in with international initiatives and is there sufficient collaboration?*

9.1 The RHS has no evidence to offer on this question.

10. *What needs to be done to ensure that web-based taxonomy information is of high quality, reliable and user-friendly?*

10.1 The RHS has no evidence to offer on this question.

11. *How does the taxonomic community engage with the non-taxonomic community? What role do field studies play?*

11.1 The need for greater understanding of need for systematics amongst the public, as users of names of organisms, is critical for the future of systematic research. It seems widely accepted that taxonomists do not communicate their work effectively to a non technical audience, but there are good examples where the public can be engaged in taxonomic effort, and there is a continuing interest in finding out more about particular groups of organisms. One example that highlights this is the Natural History Museum's bluebell survey, to clarify the question of the status of the supposed invasive hybrid. Through their website, the public have been provided with a simple means to identify the three types of bluebell and send in their results.

11.2 As noted in 3.1, the RHS sees itself as having an important role in engaging with the non-taxonomic community. As Britain's leading horticultural charity with over 360,000 members, and linked to over 2,000 affiliated societies, the Society is in a good position to put systematic research to practical use. One particular area can be highlighted but it should be emphasized that the RHS uses taxonomic outputs for all the kinds of organisms that affect gardens and plants. A specific output from the RHS horticultural database is the *RHS Plant Finder*, published every year as a book and on the website. Not only is it a source on where plants can

be found it is now seen as a source on the correct nomenclature of cultivated plants, not just in the UK either. This is an important service for the users of systematics (ie plant names) and acts as a means to stabilize and harmonize cultivated plant names.

Skills base

12. *What are the numbers and ages of trained taxonomists working in UK universities and other organisations?*

12.1 The RHS employs 8 trained botanists (6 at PhD level, 2 at MSc level) that are involved to varying degrees with taxonomic research. It is a relatively young age range (mid 20s to early 50s) for systematics in the UK. It also employs 2 entomologists and 3 plant pathologists who are involved in identification work but do not generally undertake taxonomic research.

The Sir Harold Hillier Arboretum in Hampshire employs one botanist who is a skilled horticultural taxonomist, but is in his late 50s.

13. *What is the state of training and education in systematics and taxonomy? Are there any gaps in capacity? Is the number of taxonomists in post, and those that are being trained, sufficient to meet current and future needs across all taxonomic subject areas?*

13.1 This is a complex situation and, in some ways, is a vicious circle: the lack of jobs, clear career structure and recognition for systematists do not encourage young people to pursue their vocation in this area; the schools, where this kind of interest should be nurtured, have little information or idea of how to support students wishing to develop their interests in taxonomy (and the future taxonomists generally show some inclination in that direction by GCSE and A level stage); and the universities have tended to move away from what is regarded as traditional kinds of knowledge and merge whole-organism departments (zoology, botany etc.) into more generalist departments such as biomedical sciences. This is undoubtedly stimulated by the Research Assessment Exercise (RAE) which does not favour systematics. The principal difficulty remains, however, the lack of employment in systematic research in the UK which leads to the loss of trained systematists to other kinds of employment or to pursue their careers overseas.

13.2 The contraction of expertise over the past two or three decades, the increasing age of existing taxonomists and the low levels of recruitment mean that expertise is being lost which should be passed onto younger taxonomists. This will become critical where major groups have such small numbers of experts (see 1.3 above) and the total loss of this expertise is now becoming a distinct possibility. Once lost, it is hard to regain and the effects may only become apparent at a later stage.

13.3 The RHS works with the University of Reading, through the Plant Diversity MSc, by sponsoring a place on the course, to promote horticultural taxonomy and provide training for new taxonomists. We also contribute to the funding of two PhDs at RBG Edinburgh, to support horticultural taxonomic elements to botanical research. Given the relatively large number of cultivated plants and the importance of horticulture in the UK, the RHS considers that the current level of capacity is insufficient to meet current or future needs. Horticultural taxonomy is still an actively developing discipline, benefiting from the advances made in related research but the resources are needed to make best advantage of these opportunities.

4 February 2008

Memorandum submitted by the School of Computer Science, Cardiff University

This submission from the School of Computer Science at Cardiff University, is made by staff who are members of the School's Knowledge and Information Systems Research Group, whose work provides design research and practical software and database resources to support the Species 2000 Catalogue of Life, a UK-led international programme constructing and making available, in digital form, the first comprehensive listing of all the world's species of biological organisms (animals, plants, fungi and micro-organisms). The edition of the Catalogue of Life to be released in April 2008 documents 1.1 million of the estimated 1.8 million known species. The Catalogue is an essential tool for organising biodiversity data, improving retrieval and minimising the loss of data which can occur because of the necessary changes in the names and classification of organisms as knowledge improves, and is an essential core component of international biodiversity knowledge organisations such as GBIF (Global Biodiversity Information Facility) and the Encyclopedia of Life.

As non-taxonomists ourselves, we wish to emphasise some of the ways in which systematics and taxonomy research in the UK is linked to other kinds of research, and to the sources of information used by scientists and professionals in other disciplines. We have become associated with the Species 2000 Catalogue of Life and

its Secretariat at the University of Reading through such linkages. Richard White is a member of the Species 2000 Project Team (the Executive), and is the Convenor and Andrew Jones is a member of the Species 2000 Information Systems Group, which oversees the technical computing aspects of the Catalogue of Life, such as its adherence to international standards to enhance its interoperability with other information and knowledge systems. Alex Gray is a Director of Species 2000 which, although an international co-operative programme, is registered as a UK not-for-profit organisation in order to handle matters of finance and ownership.

Response to question 9

There are two interpretations of the phrase "web-based taxonomy", deriving from the dual meaning of "taxonomy" as both the science and process of carrying out taxonomic revisions and also the result of carrying out these processes on a particular group of organisms, which usually results in revised and improved classifications. To make a mechanism for carrying out taxonomic revisions accessible on the Web to those actually performing it (taxonomists and other providers of the information they use), is different from and more challenging than the delivery of the results of a taxonomic revision on the Web (to scientists, professionals and the general public). It is important to make this distinction clear in the context of what is meant by "web-based taxonomy". We will refer to them as "web-based revision" and "web-based delivery" respectively.

Carrying out taxonomic revisions on the Web

Web-based revision is in its infancy, and working taxonomists are not all convinced of its value. But research in progress shows how it could be done. It has many parallels with performing other complex collaborative tasks on the Web. It will be able to make use of principles and practice being developed in other disciplines, especially in commerce and education. Unlike web-based blogs, wikis and the like to create what are essentially simple documents collaboratively, the process of taxonomic revision requires rigorous recording of "provenance" (the originators, dates and details of data values, analyses, decisions and changes) and the ability to back-track to substantiate or reverse past decisions. The NERC CATE project is beginning to tackle these issues.

These requirements can in turn be addressed, for example, by a suite of techniques collectively known as "virtual organisation" facilities, which are being developed in collaborations between computer scientists and business and commercial organisations. The overall goal is to allow partners to discover each other and work together in a secure Internet environment to achieve more through their collaboration than they could have achieved separately. There is much here of potential mutual benefit to taxonomic practitioners and computer scientists, and this is one of the reasons for the joint activities of our group with those who are creating and distributing taxonomic products such as the Catalogue of Life. In Cardiff, we are involved in initiatives and programmes which will put in place elements of a system which may make web-based taxonomic revision widely available in the future.

Delivering taxonomic outputs on the Web

At its simplest, web-based delivery of taxonomic results is a much easier task, and many organisations, projects and individuals are doing this already. Web pages are much easier for scientists, other professional users and the general public to find than the printed publications in which taxonomic revisions and classifications are traditionally published. The Species 2000 Catalogue of Life is delivering taxonomic outputs (the Catalogue of Life itself) on the web, at http://www.sp2000.org.

However, there is a translation and packaging process which is necessary if user communities are to make full use of the results of taxonomic revisions. This point also addresses questions 2 and 3 in the request for submissions. What most users want to use is not the taxonomic revisions themselves but improved and reliable resources based on them: outputs and services such as stable nomenclature, checklists and improved classifications which can be used as the framework for assembling information. What is important to them is a stable framework of classification and nomenclature organised and made available on top of the foundation established by the taxonomic revisions. These resources are often not created by the taxonomists themselves, but by organisations such as Species 2000 who understand the need for them and the data, information and knowledge they will help to organise.

In delivering these outputs and services, the Catalogue of Life supports an increasing variety of user communities, and also demonstrates the need for continuing taxonomic and computing activities to complete them. It provides a consensus view of the taxonomic outputs which makes them easier to use, by effectively

filtering out the "noise" in the process of delivering taxonomic summary outputs to the users, so that they need not consider individually every revision and name change or worry about whether it is accepted by all taxonomists before they adopt it.

Despite the vital role of the Species 2000 Catalogue of Life in helping to organise biodiversity knowledge, it currently receives little funding for either its data content (filling in the taxonomic groups which still lack reliable checklists) or its computing infrastructure; improved techniques and the software to implement them can accelerate its completion and increase its usability for many users).

Response to question 10

Both of our interpretations of "web-based taxonomy" involve processes which encourage the full exposure to scrutiny that always tends to improve quality, reliability and user-friendliness. If web-based, every step in the processes of both taxonomic revision and delivery can be made open and accessible to scrutiny. Taxonomy should not be seen as an impenetrable process of preparation carried out by experts before their conclusions are finally revealed. What makes information useful is not hiding it away until it is deemed to be complete and finished, but providing the right access methods to give taxonomists and users the views of the data that they individually want and can understand, even while the taxonomists are still working on it. After all, many taxonomic revisions take a long time, but the data which is being used by the taxonomists and their preliminary conclusions may be of use to users, who may even be able to add to them. The intermediate layer of "resources" between the taxonomic revisions and the knowledge layers that user communities are building, described in the previous section, can be seen as a set of tools to provide the views that the users need.

Openness encourages the development of these tools. Standards for the various levels of data and computing interoperability are important to encourage diversity and innovation in tool development, rather than dependence on one supplier of tools, and diversity of use of the tools and data will lead to broad knowledge development.

International organisations, especially GBIF and the Biological Information Standards organisation (TDWG), have a vision for the delivery of taxonomic information to users as part of a complete, organic, dynamic, distributed information system. This will facilitate the growth of both interpretations of web-based taxonomy. They have activities and plans for assisting with the growth of such a system, involving the Catalogue of Life, and are also encouraging the development of open standards for data and information exchange and the use of software tools to create and deliver the resources that users need. This was very clear at the recent European EDIT project's Symposium "Future Trends of Taxonomy" and General Meeting in January 2008, both in the talks and in the corridors. There is a clear and timely opportunity for the UK to maintain and demonstrate its lead in these areas, with relatively small amounts of additional funding.

4 February 2008

Memorandum submitted by the Scottish Environment Protection Agency

The Scottish Environment Protection Agency (SEPA) welcomes the opportunity to provide its views to the House of Lords Science and Technology Committee's follow-up inquiry on systematic biology research and taxonomy. As the Agency is principally an end-user or beneficiary of the process of taxonomic development and the production of trained taxonomists, our comments are confined to the issue of a taxonomic "Skills Base".

As the Committee will be aware, SEPA is the environmental regulator in Scotland responsible for control of emissions to land, air and water, for the regulation of the storage, transport and disposal of waste and for the licensing of the keeping and disposal of radioactive substances. SEPA is responsible for the relevant chemical, biological and microbiological monitoring, river basin management planning, Flood Risk assessment and Flood Warning, reporting on the state of environment, and is a joint competent authority for Strategic Environmental Assessments. The strong scientific element of SEPA's remit is reflected in SEPA's 2002 Management Statement from the then-Scottish Executive, which states that one of SEPA's main objectives is

> "…to operate to high professional standards, based on sound science, information and analysis of the environment and of processes which affect it;"

As such, we have a strong business need for access to a pool of trained, experienced taxonomists. Traditionally, the taxonomic skills required by the UK's environment protection agencies would have been almost exclusively in the aquatic ecology fields, both freshwater and marine, and this remains a key skill set for our work. Latterly, however, the growth in importance of the biodiversity policy arena and the need to assess and

monitor the impacts of aerial deposition on habitats and species, have begun to drive the requirement for staff with more terrestrial taxonomic skills.

Even within the aquatic sciences, where in the past SEPA's taxonomic skills have been strong in relation to particular taxonomic groups, our taxonomic requirements are expanding as a result of the wider range of aquatic taxa we will be required to monitor, as a result of the European Water Framework Directive. This covers both freshwater and marine taxa. We have recently developed a new monitoring programme and network for Scotland. Implementation of this, and other elements of WFD, has also seen a significant increase in the absolute number of scientific staff employed by SEPA who require taxonomic skills, for example, for diatoms, freshwater and marine phytoplankton aquatic macrophytes, freshwater fish.

As a prospective employer advertising for specialist staff to cover a wide range of taxonomic bases, SEPA's finds it increasingly difficult to recruit trained taxonomists, and access to certain taxonomic specialisms is particularly limited (eg for phytoplankton, phytobenthos/ diatom and macrophyte specialisms). As such, SEPA has to devote increasing resource to training in these areas, where it would previously have expected to recruit already-experienced, trained taxonomists. SEPA has also participated in a small way in the taxonomic apprenticeship scheme run by the British Trust for Conservation Volunteers (BTCV) and supported by the funding from the National Lottery. The BTCV scheme, while extremely worthwhile for both the apprentices and the hosting organisations, is, however, unlikely to stem the decline in the taxonomic skill base in the UK.

We have discussed this issue informally with colleagues in the Environment Agency. Their requirement for ecologists with good taxonomic and diagnostic skills is similar to our own. Their recent experience is that the introduction, within the Agency, of rigorous quality assurance, better identification keys, improved training and mentoring has made a tremendous difference to the skills base of ecologists employed by the Agency, compared with the situation in predecessor organisations 20 years ago. The key concern is maintaining the taxonomic capacity and skills in technical centres of expertise (eg Natural History Museum, Freshwater Biological Association, NERC Institutes) that allow the mentoring and training of ecologists recruited by the Agency to continue into the future. It is this particular concern of a decline in the taxonomic capacity in these specialist organisations, a critical issue that was highlighted by the Freshwater Biological Association—Centre for Ecology and Hydrology review of freshwater biology in the UK:

(http://www.fba.org.uk/pdf/ReviewOfFreshwaterEcology.pdf).

So, the real problem lies in combination of (i) the difficulty of recruiting candidates with a deep understanding of aquatic ecology generally, and (ii) a decline in the taxonomic capacity of specialist institutions. Both are having an impact on the ability to maintain and develop specialists within the environment and nature conservation agencies.

As a public body committed to openness and transparency, SEPA feels that it is appropriate that this response be placed on the public record.

Memorandum submitted by the Society for General Microbiology

About the Society for General Microbiology

The Society for General Microbiology (SGM) was founded in 1944/1945 and is now the largest microbiological society in Europe. It has over 5000 members of whom 75 per cent are in the UK. The remainder are located in more than 60 countries throughout the world. Most members are qualified to PhD; MB ChB or equivalent level. There are 1000 postgraduate student members and 450 schools are corporate members.

The Society provides a common meeting ground for scientists working in academic centres and in a number of fields with applications in microbiology, such as medicine, dentistry, veterinary medicine, pharmaceuticals, numerous industries, agriculture, food and beverages, the environment and education. The main activities of the Society are organizing scientific conferences, publishing learned journals, promoting microbiology education and careers, and promoting understanding of the importance of microbiology to government, the media and the general public.

The Society is governed by a Council of 24 comprising appointed officers and representatives elected by the membership. Its headquarters office has a staff of more than 30 and an annual turnover in excess of £3.5m.

Systematics and taxonomy of micro-organisms: more differences under the sun than meet the eye

The science of microbiology covers a great diversity of life forms: disease-related molecular structures such as prions and viruses; archaea, bacteria, fungi, protozoa and microscopic algae. Microbiology is important because:

- Microbes represent a greater proportion of the biomass on the planet than plants and animals combined, and exist in a wider range of environments, such as deep within the Earth's crust, where plants and animals are absent.
- Microbes are crucial in a number of processes affecting all life on Earth: the cause and control of disease; fertility of soils and aquatic environments; nutrient, gas and mineral cycling; fermentation; biodegradation of waste materials and dead biomass; food and drink production; bioprocessing steps in drug and antibiotic production, and molecular biotechnology. Life on this planet would grind to a halt without micro-organisms. Extend this to "derived prokaryotes" and we have mitochondria and chloroplasts as essential components of eukaryotic cells.
- Changes in microbial-influenced processes such as CO_2 and CH4 cycling will potentially play significant or dominant roles in determining the effects of climate change.

An examination of the systematics and taxonomy of microbes provides a number of fascinating contrasts with the state of knowledge and development for plants and animals. Because plants and animals are visually and practically so much more accessible, and have inherent attractiveness to amateur enthusiasts, the general public and indeed the entertainment industry, they have been studied far more than the Earth's microbes. It's easier, and to many more pleasant, to do it with the butterflies and buttercups, than it is with the bugs (in the microbiological rather than entomological sense of the word). And for a number of reasons, it has been easier to develop systematic research and theory with the larger organisms. However, given the importance of microbes in controlling global processes, and the fact that they have been doing so for 3.5 billion years, this is an imbalance that should be considered when allocating resources to future research.

Some key contrasts between the systematics of microbes and other organisms are now listed. Most of these refer to prokaryotic microbes (*Archaea* and *Bacteria*), but many of the points made are relevant to the numerous types of eukaryotic micro-organisms, especially the diverse groups encompassed by the term "fungi". The viruses are another world of complexity and diversity in their own right,

- The number of prokaryotic species isolated, described and validly named within the rules of the *International Code of Nomenclature of Prokaryotes*, currently ca 7,000, is vastly smaller than the numbers of species known for plants and animals. For example, more than 1,000,000 species of insect have been described and named; more than 20,000 orchids.
- However, the number of prokaryotic species *remaining* to be discovered is immense. Modern methods of DNA analysis (eg "gene dredging") indicate that probably 99 per cent or more of prokaryotic species are out there, probably doing very important things in their ecosystems, but as yet uncharacterized. In contrast, it is likely that for many well-studied groups of plants and animals, the majority of existing species have already been described.
- Many of these unknown prokaryotic organisms form lineages containing no named or well-studied member. Many of these groups would be at the level of order or higher in animal or plant taxonomy: there is at least one lineage (the Korarchaea) equivalent to Kingdom level containing no known cultivar.
- The overall biological diversity of the micro-organisms (prokaryotic plus eukaryotic), as measured by molecular methods, is immensely greater than that of the higher plants and animals. See for example the three domain model for the universal tree of life, pioneered by Carl Woese, where higher plants and animals represent small, recent branches.
- The "species" concept for prokaryotes is quite different from that for plants and animals, and much more a matter of debate. If the current pragmatic definitions of prokaryotic "species" such as *Escherichia coli*, based on DNA hybridization were applied to animals, then arguably all of the *Insecta* would be in a single species, as would humans, chimpanzees and lemurs in another.
- Characterization and naming the as yet undescribed species of prokaryotes is hindered by the fact that many of them can be difficult to isolate and grow in pure culture for further study; indeed many may only grow in complex communities with other organisms and substrates. Their existence can be detected, and biodiversity quantified, by sequencing techniques, but there is a major block in moving them up to the next stage of taxonomic description and systematic analysis.

— Morphological diversity of Prokaryotes is very limited, compared with that of Eukaryotes. This has perhaps led to an anthropocentric perception that the Prokaryotes are less interesting. However, the physiological and metabolic diversity of the Prokaryotes far exceeds that of the plant and animal worlds. The physiology of plants and animals is mainly limited by oxygenic photosynthesis and aerobic respiration respectively, whereas a tremendous metabolic diversity is found in the different groups of bacteria. They include aerobic and anaerobic chemo-organotrophs, able to degrade just about any naturally occurring organic compound on Earth, different types of photoauxotrophs (oxygenic as well as anoxygenic) and photoheterotrophs, and chemolithotrophs that obtain their energy from the oxidation of reduced inorganic compounds.

— Descriptions and names of new species of plants and animals are published in hundreds of journals, which has lead to much fragmentation and duplication. In contrast, the great majority of new prokaryotic species are published in a single journal, the *International Journal of Systematic and Evolutionary Microbiology (IJSEM)*. Furthermore, where new prokaryotic species are published in other journals, the names of the new species must be validated by publication in *IJSEM*, with checks that rules for description of new species and deposit in culture collections have been complied with. The title is formally owned by the International Committee on Systematics of Prokaryotes. *IJSEM* is published by the Society for General Microbiology on behalf of ICSP, as a service to the international prokaryotic and microbial eukaryotic systematics community. It should be recognised that the journal's highly experienced editorial staff make a major contribution to the quality and consistency of descriptions of new taxa, and that this is ultimately funded from income to the journal from institutional subscriptions. The journal currently operates at close to break-even point financially, although when SGM took it over as publisher it made a significant loss. Current moves by major research funders such as NIH, the Wellcome Trust and Research Councils UK, to require journals to make articles "open access" at the time of publication for work they have funded, sometimes in exchange of an author-side payment, could impact adversely on journals such as *IJSEM*, where authors generally do not have sufficient grant funding to support such author-side payments.

Responses to specific questions raised by the inquiry

1. *What is the state of systematics research and taxonomy in the UK?*

As a central resource, *IJSEM* provides a ready source of accurate statistical information about the level of prokaryotic systematics research in the UK. In the years 2000–2002, some 8–9 per cent of papers had corresponding authors from the UK. By 2007 this had fallen to 2 per cent. Examination of the January 2008 issue of *IJSEM* showed that only two papers describing new species came from UK laboratories. Perhaps more notably, of the 55 papers describing new taxa emanating from laboratories overseas, not a single one had a UK co-author.

The message is quite clear, that the number of active prokaryotic taxonomists in UK institutions is declining. Specifically, two very active (and internationally renowned) university groups have been lost in recent years, one due to retirement of the group leader, and one due to the group being disbanded because of suspected RAE pressures.

A professor of systematic bacteriology at another UK university comments:

> "A fair number of eminent prokaryotic systematists based in the UK are contributors to the world's most highly respected reference text upon the subject—*Bergey's Manual of Systematic Bacteriology* (publishing between 2001 and 2009); this demonstrates considerable UK interest and expertise in the field, a field that is much better regulated in terms of its proposal of new taxa and emendations, and its regulation of nomenclature, than are other areas of biology.
>
> However, few young bacteriologists working within systematics at present will be able to contribute to subsequent editions of the *Manual,* or to other works or bodies in this field, because the emphasis in training now has to be upon techniques to be learned, rather than upon the organisms that they may be applied to, and so the long-term study of a genus or species for its own sake appears to be a thing of the past; we therefore no longer have a generation of prokaryote systematists growing up with the knowledge and experience of individual groups of organisms. This is not just a problem for the UK, but it is acutely felt here on account of many years of underfunding. As a result, publications from UK scientists are dwindling at an alarming rate. Most students working on systematics in my

laboratory are from overseas, often from outside the EU, and all my funding comes from outside the UK.

This loss of expertise is a most worrying matter, as the UK will lose what little presence it has in what is now becoming a more widely appreciated field—for example, a systematic approach to *Mycobacterium tuberculosis* and its relatives, and an understanding of these organisms' relationships, has a key role in our progress in understanding and controlling tuberculosis. Knowing how to diagnose and treat the individual patient has never been enough, and currently this shortcoming is repeatedly emphasised. In addition to natural diseases, we also now have major concerns over biosecurity and bioterrorism, where this increasing need for prokaryote systematists also applies."

2. *What is the role of systematics and taxonomy…….how do they contribute to research areas such as biodiversity, ecosystem services and climate change?*

The importance of microorganisms in the biodiversity and ecological stability of this planet is undisputed and acknowledged by acclaimed zoologists such as E.O.Wilson. We know very little about the prokaryote species diversity within the UK and we know virtually nothing about their roles on maintaining habitats favourable for plant and animal communities. The fact that they are not visible does not mean that they do not play a crucial role. Recent work in agricultural areas, for example, indicates how the compacting of soil can be monitored by the change in the microflora in favour of anaerobes. Changes in the way fields are fertilised will also cause changes in the microflora and influence the plant and animal communities.

Changes in microbial communities and their activities are likely to be critical in Earth responses to climate change. Examples include CO_2 fixation by phytoplankton, release of fixed CO_2 from soils by microbial activity, and release of methane. Studies of all of these processes depend on an understanding of what microbial communities are involved.

3. *Does the way in which systematics research is organized and coordinated best meet the needs of the user community?*

The recommendations by the UK government in the last report do not seem to have done anything for the acute problems in prokaryote systematics. Supplying extra funding to specialist units does not solve the problem in prokaryote systematics, because such units currently do not exist in prokaryote systematics. There are no equivalents to the NHM, RBG Kew or the RBG Edinburgh in the area of prokaryotes. Equally well there are far too few scientists active in either universities or other research establishment with an appreciation/experience in prokaryote systematics to provide an effective lobby for prokaryote systematics within the UK. The situation in other European countries varies from marginally better to significantly worse.

4. *What level of funding would be needed to meet the need for taxonomic information? Who should be supplying it?*

Prokaryotic systematics has different requirements in terms of infrastructure and funding to those perceived as important in botany and zoology. As such, solutions tailored to meet the needs of botany and zoology do not solve problems in prokaryotic systematics.

It is perceived that the current UK Research Assessment Exercise has led to a concentration on a smaller number of areas of research that can be published in high impact factor journals, to the detriment of those engaged in long-term scholarship in specialized fields. UK research funders should recognize the value of systematics and taxonomy, which apart from their own scientific merit, underpin so many other research areas.

The long-term financial stability of culture collections is critical not only for microbial systematics and taxonomy, but also for their service to wider areas of research and industry. There has been long-term failure to invest properly, which has endangered the quality of the service on offer, and failure to appreciate the underlying value of systematics. One may cite the recent issues concerning the use of the wrong cell lines in cancer research as examples of inadequately maintained and verified primary biological material in research institutions/universities, and the dangers of uncoupling from important secondary information. The costs associated with maintaining verified collections are often seen as being too high, but are negligible when compared with the costs associated with entire research programmes based on incorrect biological material."

5. *How does funding in other countries compare?*

Again, *IJSEM* provides some interesting statistics. The number of papers published from South Korea increased from 10—15 in 2000—2002, to 140 published in 2007. This was the result of a major research programme funded by the Korean Government to discover and characterize new bacterial species in Korean environments. There have also been significant increases in papers published from China, Japan and India.

6. *What impacts have developments in DNA sequencing, genomics and other new technologies had on systematics research?*

These developments have revolutionised the science of prokaryotic systematics. New and relatively inexpensive sequencing and related technology has increased the rate of characterization of new taxa, and the molecular approach has led to radical new thinking about the structure of the tree of life, and the early evolution of life on Earth. In some ways, a gap is opening up, in that the other taxonomic information required as part of the description of new species has still to be collected, accurately, and this is more dependent on experienced "wise heads" than on automated technology.

Nowhere is the gap more clearly shown that where "gene dredging" can indicate millions of new bacterial species in particular environments, but where completing proper taxonomic descriptions for all but a few would be an enormous task.

The use of gene-based systems has helped to crystallise our appreciation of prokaryote diversity, but it has not solved the problem alone. Co-relation with other data was a significant factor some 30 years ago and provided a widely based system, with a greater chance of it being stable on the long-term. The availability of full genomes potentially opens the way to understanding individual strains completely. However, we already know that transcriptomics and proteomics are already necessary to complement this area. Other topics will follow, that require an in-depth appreciation of cellular structure, function and organisation. Genomics alone cannot achieve this goal.

7. *Does the way in which taxonomic data is collected, managed and maintained best meet the needs of the user community? What is the state of local and national recording schemes?*

Prokaryote diversity is rarely tackled at this level, although there is no reason why this should not be the case.

8. *What is the role of the major regional museums and collections?*

We know of no microbial taxonomy being undertaken in any regional museum and no prokaryotic taxonomy in any museum. The role of the culture collections is crucial to disseminate strains and provide continuity between short-term research projects in (typically university) research laboratories.

The major collections in the UK continue to be hit by reductions in financial support. As such their contribution to taxonomy hit an all time low some years ago, from which they have not been able to recover. One should also qualify the fact that "major" in terms of collections of micro-organisms in the UK means no more than 10 staff (often significantly less).

9. *What progress has been made in development of a web-based taxonomy?*

The internet plays an increasingly important role in microbial systematics given the central role that molecular data play. Major culture collections also make their catalogues web-accessible and some journals (notably those of the SGM and the American Society for Microbiology) make their journals open access after a one-year commercial period. SGM is currently providing funding for the entire back archive of *IJSEM* and its predecessors, back to 1946, to be digitized and made freely available to all on the internet.

There are microbial components to initiatives such as the Tree of Life <http://www.tolweb.org> but there is no co-ordinated push to develop a web-based taxonomy. Prokaryote systematics is largely defined by *Bergey's Manual* <http://www.bergeys.org> which is published by a Trust whose income is derived from sales of the resulting books. There is no obvious business model to transfer this resource to the web as current academic web servers (including JANET in the UK) currently prohibit advertising to generate a replacement revenue stream.

Prokaryote taxonomy and nomenclature has played a pioneering role in a number of web-based areas, dating back to the late 1960s. mid 1970s, largely without any significant funding and dependant upon one or two dedicated individuals. However, much of this was done in the past and due to the current flood of data cannot continue on this basis. The pioneering work has included:

- the compulsory registration of all new names and combinations from 1.1.1980
- the setting up of web based sites reflecting the registered names as well as indication of synonymies, location of type material, etc., such as

  http://www.dsmz.de/microorganisms/main.php?contentleft_id = 14

  http://www.taxonomicoutline.org/

  http://www.bacterio.cict.fr/ This excellent website, a listing of bacterial names with standing in nomenclature, was set up and is maintained by Jean Euz€by, who also pioneered the listing of names and taxonomic opinions on the web. It is hosted and supported by SGM through *IJSEM*.
- The *IJSEM* serves as the central registry for all names and a current project (Names 4 Life) will attempt to extract taxonomically relevant information from the manuscripts submitted using a markup language. Further and more rapid progress in this area of prokaryote systematics is largely hampered by lack of funding to meet the needs of the end users, who are microbiologically orientated and are currently not served by initiatives such as GBIF, EoL, GTI, etc.
- SGM is a supporter and research partner in the Names4Life project.

Online catalogues for the major collections, listing their holdings, have been implemented rapidly in the early to mid-1990s and data set standardisation tackled early on among European collections via the MINE project. The European collections have also pioneered close co-operation, which has resulted in the CABRI and EBRCN projects.

On a global scale the establishment of the World Data Centre (WDC) and World Federation for Culture Collections (WFCC) have played pioneering roles in listing and linking the global culture collection community, which were also closely tied to the International Committee on the Systematics of Prokaryotes, all of which are now web-based.

The prokaryotic community invented the registration of names and have shown that (within limits) it works. It was set up without major funding and continues to operate on this basis, but the failure to invest in the system could eventually result it its demise.

10. *What needs to be done to ensure that web-based taxonomy is of high quality, reliable and user-friendly?*

A web-based taxonomy depends on the availability of experts, both in the way the Code works and in the way taxonomic information is handled. The number of Code experts world-wide has always been small in prokaryote systematics, but at present there are 3 active experts, all of whom are between 50-60 and none are resident in the UK. Without experts in the relevant areas a web-based system cannot fulfil a long-term function. This is evident in web-based systems that do not draw on the available expertise and are starting to swamp the accurate sites with contradictory and inaccurate information. The lack of scientists trained in this area also has a major impact on the role of peer review of the original articles. The effect is a dangerous spiral where inaccurate information can be perpetuated and added to because expertise is lacking to evaluate the original work properly.

11. *How does the taxonomic community engage with the non-taxonomic community? What role do field studies play?*

In the sense of field studies as undertaken in botany and zoology, microbiology often takes a different approach. However, even clone libraries and metagenomic studies require an underlying taxonomy on which to base their identification. Given the vast number of prokaryote taxa that have yet to be described one is often left with vague identifications that rely solely on per cent sequence similarities of the 16S rDNA gene, with little to no information on what the organisms is, nor what it is actually doing in the environment:

12. *What are the number and ages of trained taxonomists working in UK universities and other organizations?*

"Can't answer this one, but does one need more than two hands to count them!"

See also comments on other questions.

13. *What is the state of training and education in systematics and taxonomy? Are there gaps in capacity? Are the numbers in training enough to meet current and future needs?*

In order to teach systematics or taxonomy an important pre-requisite is that one should have at least some training in that area oneself. Traditionally there have been very few centres in the UK where such qualified staff could be found. However, their students have rarely found suitable positions in UK establishments, with the consequence that as these experts retire they are leaving a vacuum. The consequences are that with the short term lack of interest in systematics/taxonomy there is no perceived need for such trained individuals. However, discussions are already underway that highlight that there is a desperate need for experts that understand and appreciate where the current deficits are. If the present decline continues one need not consider the future, because there will not be one.

Conclusion

Prokaryote systematics has always been a poor relation to botanical and zoological systematics—no David Attenborough-type programmes on television or radio, or glossy magazine articles, are devoted to the microbes, and no member of the public or any politician is likely to be aware of this fundamental part of the biosphere on a day-to-day basis. Who will weep when a bacterium becomes extinct, and how will we know that it has happened? Does the average biologist—or politician—appreciate the fact that our body harbours ten to 100 times more microbial cells than our own human cells, or that the healthy development of the human gut is highly dependant upon an amazing consortium of microorganisms that may be composed of as many as 800 different species?

The public perception of bacteria is little better than the ill-informed and demeaning media and advertising images that "all germs are bad", or, at best, that there are "good" and "bad" bacteria. As part of the overall drive to improve the nation's health, some better understanding than this is vital, and bacterial systematics and taxonomy is a fundamental part of any such educational advance; without it, it is akin to attempting to teach a language without a vocabulary. And again, don't forget the amazing diversity of viruses.

The last House of Lords Science and Technology Committee report did not address the viral and prokaryote systematics and taxonomy issue adequately; it is a matter that needs to be addressed specifically, because its moribund state will not be resolved by measures that consider only the larger forms of life. Indeed, a holistic approach that considers each special part of the biosphere is the approach that is most likely to be efficient and effective in terms of conservation and human knowledge.

4 February 2008

Memorandum submitted by the UK Biodiversity Research Advisory Group & the Global Biodiversity Sub-Committee of the UK GECC[31]

The UK BRAG exists to

(1) identify, promote and facilitate biodiversity research to support UK and individual country biodiversity action plan commitments;

(2) coordinate effective and efficient UK engagement with European biodiversity research issues;

(3) contribute to effective biodiversity research networking in the UK, leading to increased interdisciplinary capacity; and

(4) support knowledge transfer activities in relation to biodiversity research.

The membership of the UK BRAG represents UK biodiversity researchers, funders and practitioners.

The GBSC exists to:

(1) ensure that Government policy on global biodiversity conservation is both sufficiently informed by, and informs the work undertaken to develop the science base;

(2) identify significant gaps in scientific understanding of global biodiversity change and propose options for addressing them, including through collaborative programmes with EU and other international players;

(3) identify and review emerging scientific questions concerning global biodiversity, evaluate their significance and make recommendations;

(4) review the effectiveness of the national capacity, capability and performance in this area;

[31] The UK Global Environmental Change Committee www.ukgecc.org

(5) recommend a lead Department/Agency in areas of science and technology, where responsibility is unclear;

(6) improve the evidence base and promote wider understanding across Government of global biodiversity science issues;

(7) recommend strategic priorities for UK and EU science relating to global biodiversity, and

(8) advise on and facilitate collaborative scientific investigation of global biodiversity change.

Both the UK BRAG and the GBSC are under Defra Chairmanship, with a Secretariat based in the Joint Nature Conservation Committee. Their membership represents UK biodiversity researchers, funders and practitioners, including members from statutory conservation agencies, academia, the collections, the Research Councils and government departments (Defra, DfID, FCO).

The State of Systematics and Taxonomy Research

1. *What is the state of systematics research and taxonomy in the UK? What are the current research priorities? What are the barriers, if any, to delivering these priorities?*

Introductory remarks

1.1 Taxonomy and systematics research in the UK addresses:

— molecular techniques to establish phylogenetic relationships of animal or plant families,

— stabilising the names used for species, thus supporting those who use those names,

— establishing whether a set of organisms justify specific or sub specific status and consequently how they should be treated under UK conservation law,

— developing field-guides to British organisms to assist students, amateurs and environmental managers.

The current state of taxonomy and systematics

1.2 The considered view of members of the two groups is that the status of taxonomy and systematics has continued to deteriorate overall, but there is limited quantitative evidence (ie publication data, numbers of specialists, total expenditure) to back this up (but see Q12). As an example, the situation with respect to cryptogamic plants, lichens and fungi is described in Annex 1.

Box 1 *Lichenology in Scotland: a case study in revival*

Mycology is a discipline that has significantly declined with an ageing cohort of expertise and no new recruitment. However, it is possible to make significant improvements with relatively small investments, as demonstrated by the revival of lichenology in Scotland. In 2002, RBGE employed only one lichen taxonomist, insufficient to deliver national conservation targets for lichens in Scotland. Succession planning at RBGE has capitalised on the opportunity for collaboration between its lichen taxonomist and a lichen ecologist, invigorating research in conservation biology and climate impacts; the two lichenologists have since won external funding for post doctoral research and studentships. SNH provided funds to the British Lichen Society to support the training of lichen apprentices by the RBGE taxonomist, which has provided a core of individuals capable of making conservation assessments and delivering site condition monitoring on lichens.

Research

1.3 There is no UK-wide strategic plan for systematics and taxonomic research as such, but UK BRAG has considered requirements and identified priority topics for action by its members (see box 2). The three major taxonomic institutions (NHM, RBGK, RBGE) continue to maintain taxonomy and systematics capability, and apply this expertise, eg to provide some support to national and international conservation strategies. While they are funded through different areas of government (DCMS, Defra and Scottish Government), and each institution has its individual research priorities, they have a long tradition of cooperation.

1.4 *The Taxonomic Needs Assessment for Conservation in the UK* (Taylor, 2006[32]) was based on survey responses from ninety-nine organisations in the UK and its Overseas Territories, and identified needs in relation to habitat requirements of animals/plants; information on local species distributions; information on regional species distributions; GIS data; information on name changes; lists of invasive alien species; specialised taxonomic identification services. These were identified as "very important" by more than a third of respondents, and as "not accessible" by a fifth or more of respondents.

Box 2 *UK BRAG priorities in relation to taxonomy and systematics research*

The UK BRAG has identified an urgent need, in the face of environmental change, to improve our knowledge of the contribution of biodiversity to the functioning, resilience and stability of ecosystems, and the delivery of goods and services on which we depend. Taxonomy and systematics are essential underpinning to such research. UK BRAG priorities requiring direct or indirect taxonomic and/or systematic research input include:

- microbial community structure and function in a range of ecosystems
- the impact of environmental changes (climate change, land use change, non-native species, over-exploitation, pollution) on ecosystem functions through changes in biodiversity
- the response of species and populations to large-scale environmental change
- the effect of loss of species from systems
- key indicators and surrogates of biodiversity status
- the fitness consequences of genetic isolation v population networks in the context of different population sizes, environmental gradients and species attributes
- conservation of divergent intra-specific endemic lineages
- high-throughput genetic tools for species identification and discovery
- action plans to cope with the challenges for taxonomically complex groups and those undergoing diversification
- novel techniques (eg DNA bar-coding) for tracing the origin of introduced species
- impacts of climate changes on soil biodiversity
- the functional role of biota in marine and freshwater sediments
- whether local genetic adaptation within species limits adaptation to climate change

Barriers to be overcome

1.6 We consider that recent technological advances enable us to address any of these problems and that advances will be dependent on funding and capacity (for an example, see the UK BRAG submission concerning mycology in the UK). The funding issues are taken up in section 2.

2. *What is the role of systematics and taxonomy and, in particular, in what way do they contribute to research areas such as biodiversity conservation, ecosystem services and climate change? How important is this contribution and how is it recognised in the funding process? How is systematics integrated in other areas of research?*

The contribution of systematics and taxonomy

2.1 BRAG / GBSC consider that taxonomy is a necessary underpinning for biodiversity conservation and sustainable use, ecosystem services and climate change in the UK and globally. The Convention on Biological Diversity (CBD) uses the term "taxonomic impediment [to implementing the Convention]", and the decisions accepted by the Parties to the CBD, including the UK, aim to address provision of taxonomic information, infrastructure and expertise.

2.2 The benefits of taxonomy to non-taxonomic sectors are considerable; some case studies can be accessed at http://www.bionet-intl.org/opencms/opencms/caseStudies/caseStudies/list.jsp. Where the financial impact of use of taxonomic information has been assessed in these case-studies, the benefits routinely run into millions of pounds and cost benefit ratio ranges from 1:50 to 1:700! Examples are listed in Annex 2.

[32] Taylor, A. (2006) *United Kingdom Taxonomic Needs Assessment*. Natural History Museum/Defra. 23/02/2006. Taxonomy for Ghana's development and conservation—assessing the needs. Ghana-UK Project 2006-7. Supported by the WSSD Implementation Fund of Defra (UK).

2.3 It is appropriate to note that none of these benefits could have been delivered without pre-existing taxonomic infrastructure, research and skills. Furthermore, without a reliable inventory, efforts to conserve biodiversity are greatly hampered. The *Encylopedia of Life* project (http://www.eol.org/home.html) aims to address this, and is supported through the Biodiversity Heritage Library (http://www.biodiversitylibrary.org/) in which both NHM and RBGK are partners.

Recognition in the funding process

2.4 Research funding can come either from the Research Councils, government departments and agencies, or the voluntary sector. The Research Councils' mandates prioritise innovative research at the cutting edge of science; systematics and taxonomic research rarely fall in this category. Consequently, research is largely funded through various mechanisms in association with the users, such as the conservation agencies and the Darwin Initiative.

2.5 We are concerned that there is a lack of clarity concerning 'cutting edge' and 'basic' science, in terms of who the users are, who funds each, and how they rate as institutional priorities. As a consequence of this confused picture, UK research on genetic barcoding has slipped behind progress made elsewhere, eg the Canadian Centre for DNA barcoding (http://www.dnabarcoding.ca/).

2.6 In the review of eligibility to Research Council funding in 2006, NHM, RBGK and RBGE became ineligible for responsive mode funding from BBSRC. This put a halt on proposals submitted or under development. On appeal, all three institutes have now regained access to this funding stream; both NERC and BBSRC have clarified their commitment to biodiversity research and are keen to engage with the taxonomic community, as evidenced through their co-funding of the Systematics Research Fund and the Collaborative Scheme for Systematics Research. This is greatly welcomed.

2.7 There is little recognition of the need for systematics in the European Union Framework Programmes. There are no relevant topics under the latest EU FP7 call for Theme 2: Food, Agriculture and Fisheries, and Biotechnology. Under the latest call for Theme 6: Environment, Area 6.2.1.4: Biodiversity, there is a provision for coordination and support actions on *Rehabilitation of data from biodiversity-related projects funded under previous framework programmes.* While this project should contribute to initiatives to develop biodiversity related data infrastructures, eg LIFEWATCH, there is no specific reference to taxonomy or systematics research.

Integration in other research areas

2.8 The integration of taxonomy with other sectors is vital, and it is significant that biodiversity is now a key area for funding within both NERC and BBSRC. Taxonomy and systematics are well integrated across a wide range of research activities, underpinning work on biodiversity, climate change and the provision of ecosystem goods and services. In many cases, advances cannot be made without taxonomic knowledge.

2.6 Taxonomic expertise plays an important role in agriculture, in the identification of non-native invasive species (such as plant and animal pests & pathogens). Taxonomic data have also been applied in climate change research, where modelling capabilities of programmes such as MONARCH have been restricted by limited biological information.

2.7 There are significant national gaps in taxonomic knowledge needed to underpin research in the marine environment (for example, relevant to the proposed Marine Bill) particularly in relation to marine fungi, which are important in terms of impacts of increased acidification (an issue highlighted by the GBSC) and microbial communities in marine sediments (an issue highlighted by UK BRAG).

3. *Does the way in which systematics research is organised and co-ordinated best meet the needs of the user community? What progress has been made in setting up a body to lead on this? What contribution do the leading systematics research institutions make both nationally and internationally?*

Meeting the needs of the user community

3.1 The needs of the user community have been reviewed in the *UK Taxonomic Needs Assessment,* undertaken by NHM as a contribution to the Global Taxonomy Initiative. The UK BRAG and the GBSC also provide for identification of user needs and priorities for conservation and sustainable use of biodiversity in the context of the UK Biodiversity Action Plan and international commitments. The needs of other users, at regional or local level, including the public, are more difficult to identify and coordinate.

3.2 A number of positive steps have already been taken by the individual institutions, eg RBGE has carried out a review of priorities, and has had increased funds for more effective communication (to both the public and to other scientific sectors).

The need for a coordination body: progress

3.3 We believe that there remains a need for improved mechanisms to make user needs known to the taxonomic community and funding bodies. To some extent this can be achieved through existing bodies; UK BRAG and the GBSC, have both addressed taxonomic issues but their remits extend only to biodiversity conservation, rather than wider issues concerned with agriculture, fisheries or health.

3.4 Individual taxonomists communicate well, as do their institutions. For example, the Systematics Association promotes collaborative research and organises a varied programme of international conferences on key themes where taxonomy and systematics have an important role to play. A number of institutions contribute to the Plant Conservation Working Group, genetics sub-group (http://rbg-web2.rbge.org.uk/pcwg/), which has served as a model example of how to bring together conservation geneticists and practitioners. It should be noted that the intellectual capacity exists to do more, but this is limited by a shortage of staff resources (see comments in answer to Q12 and Q13).

3.5 Much taxonomic support for non-academic research and environmental activities still comes from the amateur community. However, it is difficult to discern the extent, and also how it may be managed sustainably. Since users rely on this resource, there is a risk if no attempt is made to understand or coordinate it. Some progress has been made to support the volunteer community in the UK, through development of the National Biodiversity Network (NBN), although here the focus is on information exchange rather than taxonomic skills.

Making a contribution to policy

3.6 The UK Darwin Initiative (http://www.darwin.gov.uk/) is aligned to CBD implementation, and has so far funded over 50 projects with a strong taxonomic component, more or less aligned with the Global Taxonomy Initiative (http://www.darwin.gov.uk/downloads/briefing_notes/taxonomy.pdf). The projects have generally included a strong element of capacity building in taxonomy, and produced both field guides and papers, and also improvements to collections of specimens and recommendations to governments on protected areas and conservation.

4. *What level of funding would be needed to meet the need for taxonomic information now and in the future? Who should be providing this funding?*

4.1 Supplying the needs identified by the *UK Taxonomic Needs Assessment* (see box 2 above), would probably require significant funding but this work has not been costed. Provision of additional funding for 'taxonomy' would need to be clearly targeted & prioritised. Priorities are identified below.

4.2 Digitising the UK collections of flora and fauna would clearly be of value for example in relation to the important link between climate change and invasive alien species, or the use of digitised data and appropriate modelling to predict distributions under different scenarios. Some limited investments are being made through the Global Biodiversity Information Facility (GBIF) and the NBN, but here the UK funders have put more emphasis on sharing information about biological records than collections.

4.3 Identification keys and field guides were noted as being of high importance in the *UK taxonomic needs assessment* by 70 per cent of respondents (Taylor, 2006), but many respondents noted they were not accessible or, are out of date. About half of the British insect fauna has never been covered by an identification guide. Funding for their production is critical in an environment of increasing numbers of Invasive Alien Species, and where taxonomic names change.

4.4 European funding sources support good networking activities, but their support for actual research is less good. The work of the Australian Virtual Herbarium, which includes both digitising and databasing activities, is an integral part of their science funding (see http://www.chah.gov.au/avh/avh.html for details). In contrast, databasing projects in the UK tend to be funded by charities and involve the use of volunteers.

5. *How does funding in other countries compare? Could there be more international collaboration? If so, what form should this collaboration take and how might it be achieved?*

Funding comparisons

5.1 We provide some examples below:

Box 3 *Mexico's commitment to CONABIO, and the Swedish Taxonomy Initiative*

In Mexico, CONABIO has been set up to create a national inventory of biodiversity and to "advise governmental agencies, as well as social and private sectors on technical and applied research aspects regarding the use and conservation of biological resources.". The Mexican Government is a major user of CONABIO, although Business also makes use of their data. The financial resources of CONABIO are mainly provided by the Federal Government, and are administrated through a private trust fund. This trust fund can receive national and foreign deductible donations, monetary or non-monetary contributions. CONABIO's annual budget has been on average US$3 million, plus about 30 percent extra in earmarked grants from a variety of national and international agencies.

The Swedish Taxonomy Initiative (STI) is an All Taxon Biodiversity Inventory (ATBI) of Sweden, coordinated by the Swedish Species Information Centre (ArtDatabanken) in collaboration with Swedish universities and natural history museums. Started in 2002 and fully funded from 2005, the project aims to completely chart the flora and fauna of Sweden within 20 years. The budget in 2006 was ca $9.3 million.

Greater international collaboration

5.2 More collaboration would facilitate an improved understanding of the UK flora in its continental context. As an exemplar of good practice, the Euro + Med Plantbase project (http://www.euromed.org.uk/), which draws together different nomenclatures and uses accepted standards, demonstrates many of the characteristics needed for successful future collaboration.

6. *What impact have developments in DNA sequencing, genomics and other new technologies had on systematics research? In what way has systematics embraced new technologies, and how can these research areas interact successfully and efficiently?*

6.1 The impact of developments in DNA sequencing, genomics and other new technologies has been better quality results than 10 years ago, eg angiosperm phylogeny, leading to reorganisation of herbaria (Haston, 2007[33]). Such new technologies are needed to create a rate-change in our work, but the technologies must be accompanied by the funding to put them to use, not just develop them.

Embracing new technologies

6.2 The major taxonomic institutions are using molecular techniques to both hypothesise phylogeny and using DNA barcoding, to provide novel identification methods and enable association of morphologically very different life stages. These techniques may enable us to greatly increase the rate of discovery of biodiversity. There will still be a need to apply traditional methods to provide in-depth information and output tailored to certain user needs, and also to link units discovered through molecular means to currently known taxa.

6.3 The growth of bioinformatics techniques means that we have the potential to digitise data and link disparate data sources together to greatly increase access and analytical efficiency, and remove some of the blocks and barriers to taxonomic information generation and dissemination. The global importance of bioinformatics is described in Annex 3.

[33] Haston, E., Richardson, J. E., Stevens, P. F., Chase, M. W., Harris, D. J. (2007). "A linear sequence of Angiosperm Phylogeny Group II families". *Taxon* 56 (1): 7–12

Data collection, management, maintenance and dissemination

7. *Does the way in which taxonomic data is collected, managed and maintained best meet the needs of the user community? What is the state of local and national recording schemes?*

7.1 The state of local and national schemes is good for some taxa, but less so for others. The UK is well-served by the Biological Record Centre (hosted by the Centre for Ecology and Hydrology), many Local Record Centres (hosted by local authorities and/or local volunteer organisations) and brought together by the NBN (http://www.nbn.org.uk/). The NBN is specifically designed to meet the needs of users at national and local scales. A huge diversity of contributions are made to NBN, largely by volunteers, backed up (in some cases) by taxonomic specialists, who provide verification. NBN contributes nearly 15million records to the GBIF from 113 different datasets / recording schemes around the UK. The NBN receives funding from a number of government departments and agencies. It employs a distributed data model, whereby data are held and maintained by the data provider organisations. This can be more efficient than alternative models, but carries risks of data loss and orphan datasets. Problems with identification can mean that some taxa are not covered.

8. *What is the role of the major regional museums and collections? How are taxonomic collections curated and funded?*

8.1 This is not a question on which the UK BRAG and the GBSC can provide an answer. However, if amateur taxonomists are to provide a component of UK taxonomic resources, local museums are likely to have an important role in supporting and sustaining this community.

9. *What progress has been made in developing a web-based taxonomy? How do such initiatives fit in with meeting demand for systematics and taxonomy information? How do UK-led initiatives fit in with international initiatives, and is there sufficient collaboration?*

Developing a web-based taxonomy

9.1 There are a number of different aspects of web-based taxonomy: revisionary taxonomy; specialist taxonomic pages; public-use pages; taxon-centred sites; databases. A number of examples are given in Annex 4, and illustrate how some of these are being addressed, at a national, European and global scale.

10. *What needs to be done to ensure that web-based taxonomy information is of high quality, reliable and user-friendly?*

10.1 Crucially, datasets need to improve ease of use and accessibility for end-users. At present, many web-based systems are of only limited help in identifying a specimen. Good examples are the *Discover Life* project and the BSBI online keys (see comments in answer to Q9).

11. *How does the taxonomic community engage with the non-taxonomic community? What role do field studies play?*

11.1 The taxonomic community engages widely with the non-taxonomic and user community. However interactions are limited by available resources. Engagement is a two-way process, requiring the non-taxonomic community to look for and exploit opportunities for collaboration. We acknowledge that there are very real benefits from such interactions (eg engagement with ecologists, the public etc.).

11.2 Examples include: The Global Strategy for Plant Conservation, CITES enforcement (eg CITES timbers—see box, below), the Forensic Science Service, the National Poisons Information Service, etc.

Box 4 *Taxonomic expertise and traded or poisonous species*

Taxonomic support to the Convention of Trade in Endangered Species (CITES, http://www.ukcites.gov.uk/default.asp) can be especially important in terms of identification of timbers such as ramin and mahogany, and also in policing the global trade in orchids. Without taxonomic expertise, enforcement would be impossible. Taxonomic expertise is also called upon to advise the National Poisons Information Service, while some major institutions give advice on poisonous plants and fungi to appropriate medical institutions, eg Guys hospital, London.

Skills base

12. *What are the numbers and ages of trained taxonomists working in UK universities and other organisations?*

12.1 In a separate submission, the UK BRAG has provided some figures for mycology. The UK Systematics Forum report, *The Web of Life: a Strategy for Systematic Biology in the United Kingdom* (http://www.nhm.ac.uk/hosted_sites/uksf/web_of_life/summary/index.htm) provides figures on training and education (see Q13). Numbers have undoubtedly declined further since the late 1990s, when this report was written.

13. *What is the state of training and education in systematics and taxonomy? Are there any gaps in capacity? Is the number of taxonomists in post, and those that are being trained, sufficient to meet current and future needs across all taxonomic subject areas?*

13.1 *The UK Taxonomic Needs Assessment* (Taylor, 2006) pointed out that training & education were insufficient to meet current or future needs:

- too few staff are coming through the education system with whole-organism biology training;
- obtaining research grants to support taxonomic PhDs is difficult;
- a need for early training in taxonomy, from Key Stages 2 and 3 upwards;
- the National Curriculum shows a lack of commitment to the natural sciences, and fieldwork in particular; and
- a reliance on the amateur community for delivery of taxonomic information, the sustainability of which depends in part on training in secondary and tertiary education.

13.2 In addition to a need for a greater commitment to the teaching of taxonomy and systematics, both through the National Curriculum and within the university sector, there need to be opportunities for career progression for graduates.

Appendices

Annex 1: *The current state of taxonomy and systematics—cryptogamic plants, lichens and fungi*

With respect to cryptogamic plants (algae, mosses liverworts, ferns), lichens and fungi, as an important example, UK systematics research and taxonomy is patchy in coverage, quality and achievements. Many individuals and small groups are highly respected, both nationally and internationally. They make valued contributions to the discovery, description and cataloguing of cryptogam diversity, they examine the evolution and speciation of cryptogams, to provide basic understanding of the origins and maintenance of cryptogam biodiversity, and they provide identification tools and services for fellow professionals and amateurs. Current research priorities are more diverse than in flowering plants. Aspects that have approached consensus in many macroscopic organisms (such as the nature and circumscription of species) remain controversial in most cryptogam groups and they therefore remain the focus of research. However, it has also been important for the health of the subject to engage with advances in molecular technology, for classification and identification. Outside the principal taxonomic research institutes and in the universities, taxonomic and systematic research on cryptogams and fungi is almost defunct; with the principal exceptions being a few species (eg among phytoplankton) that have reached 'model system' status because of their perceived ecological or economic importance.

Annex 2: *Examples of the benefits of taxonomy to non-taxonomic sectors*

- Identification of a mealybug attacking cassava in Africa and its natural enemy in South America, a project involving UK taxonomists and which has led to savings of between $8 and $20 billion (case study #2).
- Development of identification and monitoring tools for marine micro-algae as a response to regulations linked to marketing seafood products has led to considerable benefits, and is a good example of governments working together and with funding bodies to secure a benefit from taxonomy (case study #11).
- Use of intensive surveys and authoritative identifications of the specimens enabled a marine biodiversity hotspot to be recognised off New Zealand in 1999, and its subsequent preservation (case study #25)

— Floating water fern (*Azolla filiculoides*) has been a problem in South African waterways, increasing flood risks, threatening livestock and aquatic biodiversity. Fragmentation of the weed fronds made control by mechanical means virtually impossible. A weevil species was found to feed only on *Azolla*, and since its release the weevil has brought even the most heavily infested sites under control within a matter of months, without the need for chemicals or further control measures. Identification of an effective biological control agent for *Azolla* depended on expert taxonomic work. (case study #26)

— Data from specimens in museums have been used to assess the efficiency of protected areas to conserve all the significant biodiversity, eg Ortega-Huerta, M.A. & Peterson, A.T., 2004, Modelling spatial patterns on biodiversity for conservation prioritization in North-eastern Mexico. *Diversity and Distributions,* 10, 39-54.

Annex 3: *The global importance of bioinformatics*

The threats posed by climate change and invasive alien species, mean that the global biota is of potential interest to every country in the world, and thus we need a global system. This will include converting specimen data into digital form and geo-referencing them, digitising images and linking them to appropriate names, creating digital catalogues of names. UK institutions have provided hundreds of thousands of verified names and associated taxonomic / nomenclatural data to the world, names, for example, mediated through the UK-founded *Species 2000* and thence to GBIF and specimen data through NBN and GBIF. Other activities including digitising legacy taxonomic literature (the Biodiversity Heritage Library project includes UK partners), and applying XML schemas to this to itemise the information and data included in an interoperable manner to other data sources (INOTAXA, Integrated Open Taxonomic Access is a UK-USA partnership, in which a web workspace allows resources to be accessed simultaneously according to user-defined needs), using international standards—see TDWG, Biodiversity Information Standards http://www.tdwg.org/, which includes significant UK participation. Although the technology is improving impressively, resources to populate the systems with data to capitalise on their efficiency are not increasing in step.

Annex 4: *Examples of the development of a web-based taxonomy*

— NERC has provided funding through its e-science initiative to support the CATE project (Creating a Taxonomic e-Science), which involves a consortium comprising NHM, RBGK, the University of Oxford, and Imperial College London. The objective is to test the feasibility of a web-based, consensus taxonomy using two model groups.

— EDIT, the European Distributed Institute of Taxonomy (http://www.e-taxonomy.eu/) is an EU-funded Network of Excellence bringing together 27 European, North American and Russian institutions to reduce fragmentation in taxonomic research and expertise and coordinate the European contribution to the global taxonomic effort, particularly the Global Taxonomy Initiative (GTI).

— IPNI, the International Plant Names Index (http://www.ipni.org/) provides a global database of the names and bibliographical details of all seed plants, ferns and fern allies; and is a product of collaboration between RBGK, The Harvard University Herbaria and the Australian National Herbarium.

— The point needs to be made, however, that such initiatives do not necessarily help people to identify things. To this end, the *Discover Life* project (hosted by the University of Georgia, the Missouri Botanical Garden, and the Smithsonian Tropical Research Institute) is particularly valuable (http://www.discoverlife.org/). In the UK, the Botanical Society of the British Isles (BSBI) online keys are a good example of a web-based system designed for a variety of end-users (http://www.botanicalkeys.co.uk/flora/).

Memorandum submitted by Dr John Waland Ismay

I am an entomological consultant and taxonomist specialised in Flies (Diptera), in particular Chloropidae. I am one of the leading world experts in this family of about 2400 described species. My research interest in systematics, taxonomy and Chloropidae dates back to 1970. I am a Fellow of the Royal Entomological Society and am on the editorial board of the Entomologist's monthly Magazine. Also, I am an Honorary Associate Curator of the Oxford University Museum of Natural History.

I am also currently Chairman of Dipterists Forum, a non-profit-making NGO concerned with the study of Diptera, particularly in the UK but also more widely, with more than 300 members. There are about 7000 species of Diptera recorded from the UK. However, due to time constraints this submission is a personal one. Paragraphs are numbered after the question to which they refer.

Submission

The state of systematics and taxonomy research

1. In my opinion systematics and taxonomy research in the UK is moribund, with very little funded work ongoing. Taxonomy as a science deals with finding, describing and naming organisms, while systematics deals with the relationships between taxa (singular: taxon), eg species, genera or families, especially at the higher levels. These may lead to the production of identification keys. However, identifying specimens is not taxonomy, but taxonomy is vital for this latter task. In Diptera most of the published work is done by a small group of non-professionals, nearly all of whom are of advanced age. In the Diptera there are many groups where we have no recent UK identification literature. This means that in order to identify a specimen one must use original published papers, sometimes several hundred papers for one family. Examples are Cecidomyiidae (600 species, many plant pests), Ceratopogonidae (150 species, including the vector of blue-tongue disease in cattle etc), Agromyzidae (300 + species, many plant pests). Within Diptera, the current research priority is and must be to improve coverage of groups. The barriers are the lack of employment prospects for taxonomists and funding for research projects. There is hardly any training for new taxonomists, so that as workers cease research their knowledge is lost.

2. There is a perception in the wider scientific community that systematic and taxonomic work has been done and published. In the Diptera this is not the case. Systematics and taxonomy are vital to almost all whole organism research, but funding for work on Diptera is almost non-existent. Biodiversity conservation and ecosystem services are still focused on "cuddly" groups such as birds, mammals, butterflies and bumble bees, all of which have a low number of species in the UK. For example, there are 39 BAP mammals (out of 98 species) but 35 Diptera (out of 7000 species). A considerable number of Diptera have conservation status, but without adequate identification literature there is a risk that many of these will become extinct. Diptera are an important component of most ecosystems, eg woodland, wetland etc. Several species are good indicators of climate change. Without proper taxonomy no identification keys will be produced and identification of samples will be difficult.

3. I am not aware of a single body which co-ordinates systematic and taxonomic research in the UK. Systematic and taxonomic research in the UK is conducted by museums, some societies and some universities, as well as private individuals. In entomology (insects) the Royal Entomological Society publishes Handbooks for the Identification of British Insects, with wide coverage but a low production of new works. The Freshwater Biological Association also publishes keys. In all cases, there is a problem with inadequate funding causing delays in publication and causing high prices. There is a clear case for subsidising publication of such works, as happens in many other countries. In Diptera, almost all the work is conducted by private individuals or freelance consultants, who have no funding. As a result identification keys do not get completed. New museums posts, more time allocated for existing staff and funding for freelance researchers are needed.

4. It is almost impossible to acquire funding purely for an identification handbook or pure taxonomic work. The councils controlling funding do not regard systematics and taxonomy as high priority. However, compared to other, more popular subjects such as biochemistry, the preparation of identification keys is cheap. Many such works could be produced by the allocation of 1 or 2 years salary, at Senior Scientific Officer or equivalent grade. This presumes that the chosen author already has extensive experience in the group. In the future, more taxonomic posts need to be created and increased training for younger scientists provided. This should be funded by central government.

5. In most other countries the situation is even worse than in the UK and the UK fauna is regarded as the best known in the world. This was only possible to achieve due to the high level of non-professional experts. There is enormous scope for collaboration, particularly with experts from other European countries. Some of the problems with identification of UK species can only be solved by research on a European basis, while some experts from other European countries are better placed than their UK counterparts to produce keys. The EU has already funded activities aimed at increasing European collaboration. In my view some research is better funded on a European basis, while promoting identification guides to UK species is best funded by the UK but may require overseas collaboration. However, as many experts in the UK are non-professionals, due to the low number of posts, this funding should not be confined to experts associated with an institution.

6. Systematics has always utilised new discoveries and incorporated them into the greater body of knowledge. Examples from Linnaeus onwards include external morphology, internal anatomy, embryonic development, early stages, behaviour, biogeography, phylogenetics and now DNA sequencing. It is the aim of the systematist that these and other aspects be combined into a unified whole, which allows prediction of the possible properties of a taxon. For example, knowing the properties of the disease and the vector, we could predict that blue tongue disease is likely or unlikely to spread in the UK by considering the presence and distribution of the fly vector. DNA sequencing is another, possibly more powerful, tool for taxonomists; but it is useless without an "old fashioned" taxonomist to relate the sequence to the classical taxon.

Data collection, management, maintenance and dissemination

7. i. Taxonomic data and biological recording are two separate fields. Data used in taxonomy exists in various forms; it can, for example, be a precise description of a species, the locality where a particular specimen was found, or the range in which a species exists. Taxonomic recording includes listing the taxa known from a region, for example the UK or Wales or Oxfordshire. Diptera are exceptionally well covered at world and UK level, much less so at county level. There are Catalogues for all zoogeographical Regions, in varying states of accuracy and age. No other major order of insects has such complete coverage. There is a 1998 Checklist of all known British and Irish species of Diptera, including all names which have appeared in British literature. The Dipterists Forum has produced updates on this list (6668 species in 1998, about 7000 currently). Much of this information is available on the web. In other orders these checklists either do not exist or only include current names. This makes it very difficult for non-experts to relate the names in older publications to modern works. One of the main priorities in British entomology should be to reach this level for the other large orders of insects, such as Lepidoptera, Coleoptera and Hymenoptera. Current efforts are making slow progress and could be funded. This is an attainable objective.

ii. Biological recording is the recording of the distribution of species at national or local level, plus associated data such as date, habitat, host etc. National and local recording schemes are highly variable in size and coverage. Groups such as birds and butterflies are well recorded at national and local level and changes in distribution are reliably indicated. National schemes exist for many groups of Diptera, most under the umbrella of Dipterists Forum, but there are many gaps. In many families the first stage must be to provide adequate identification literature, but almost no funding is available for this purpose. Some funding is becoming available to computerise a large body of distributional information in the Diptera, but this facility could be increased. Local and national recording schemes (mostly run by volunteers) and local government Record Centres are developing fast and a national coordination scheme is running. Many of these Record Centres have problems due to cutbacks in local government funding. Much remains to be done, particularly to ensure even coverage. Much of this recording is done by non-professionals and there is further scope for encouraging this skills base by training new participants.

8. i. Collections are important because they form a data bank, containing the original specimens from which a species was described (types), voucher specimens identified by earlier workers, and the specimens referring to published records. Where these specimens have been lost, for example by museum pests or acts of war, this information is lost for ever. Descriptions of species and records by earlier workers are often inadequate or unreliable without the specimens available for examination. Specimens from many collections are used frequently for current research in the UK and abroad.

ii. Collections can be broken down into national, local, university and private collections. National collections (London, Cardiff, Edinburgh, Liverpool) have inadequate core funding for their remit and need better facilities. Local museums are dependant on local government funding and many are hopelessly under funded. University museums vary greatly in size and coverage and can be considered an anomaly in the system. They require special consideration to maintain some of our most important collections (eg Oxford University Museum of Natural History, second in importance to the Natural History Museum but with two entomological staff). Private collections are a most under-rated resource, with many non-professional experts who maintain private collections. In the USA such individuals can claim tax breaks to encourage good curation and proper arrangements for the future of the collection. Museums used to employ experts in entomology, often curating whole collections but researching one group. Other museums employed experts in different groups, so that good overall coverage was achieved. Very few taxonomists are currently employed in museums in the UK. The Natural History Museum had eight world experts in Diptera taxonomy in the 1960's, who could identify a wide range of taxa worldwide. The current staff are valued colleagues, but their research is focused on much smaller projects, often externally funded, and their taxonomic expertise is focused on smaller groups. Funding for taxonomic collections is erratic and many do not have sufficient funding for core activities, let alone the routine curation and rehousing activities which are essential to the care of

collections. They are dependant on grant funding, which was always erratic, but now almost impossible due to the reduction in funding from the National Heritage Lottery Fund.

9. Taxonomy is the description of species and higher taxa and the International Commission on Zoological Nomenclature excludes descriptions of new taxa on the web. This is because the date of last revision of webpages is not always clear, but printed works can be accurately dated. However, there are many resources available on the web and this area will grow and should be encouraged. The Diptera Checklist noted above is on the Dipterists Forum webpage. The most important advantage of web versus printed works is that web resources can be constantly updated. There has been some collaboration within the international scientific community in developing web based initiatives. A world checklist of Diptera is in development (based in the Smithsonian, Washington) and in Europe a web based Fauna Europaea has listed the species present in each European country. Much remains to be done, but I am optimistic about these developments.

11. As indicated above (6), good taxonomy unifies the information available on a taxon. Good taxonomists therefore are constantly interested in new developments in their field; new rearing records, new distributional data, chemistry, behaviour, as all relate to taxonomy. Non-taxonomists need taxonomists, especially in the little known or difficult groups, to identify their specimens (see 12 for the time to train a new taxonomist). Most taxonomists undertake some training at some level, from "Bug days" in infant schools, to training experts in related groups and to training replacements in their specialised field. Field studies and university courses in field ecology are an essential aspect of taxonomy, at many levels. Field studies train students in sampling methods to collect specimens for research, to learn identification skills and to find species new to science.

Skills base

12, 13. In my opinion, the skills base of taxonomists in the UK is a time bomb. Most experts on a group are retired or near retirement and have no replacement in training. During the last thirty years many positions for taxonomists were lost. University teachers often find students who wish to become taxonomists and their general advice is to take a different job, as there is no money and precious few jobs in taxonomy. As a general guide, someone starting with a higher degree but no experience would take 8-12 years to become expert (ie have a good working knowledge) of a group and might be expected to cover around 10,000 species, depending on the difficulty of the group. Thus when the current experts cease to be actively involved, there will be a great gap in expertise. Knowledge is already being lost, as many still active taxonomists have to earn their living as freelance consultants and do not have the time to describe species new to science or write identification keys. The lack of funding and positions in this field is the greatest constraint.

3 February 2008

Memorandum by Professor Roy Watling MBE, PhD., DSc., F.R.S.E., F.I.Biol., C.Biol., F.L.S.

This is a personal response from a retired Head of Mycology and Plant Pathology, Royal Botanic Garden Edinburgh and former Acting Regius Keeper of the Royal Botanic Garden; from a former President of the British Mycological Society and Member of the Scientific Advisory Committee for the earlier National Conservancy Council. I am an Honorary Member of the American Mycological and German Mycological Societies, the North American Mycological Association and a Corresponding member of the Dutch Mycological Society.

I wish to address the problem of mycological systematics and taxonomy in the framework of the UK as I fear over the last decade the UK base has been almost irreversibly damaged.

Fungi are an important element of our everyday life, food and the food industry, pharmaceuticals, industry at large and human, animal and plant diseases; indeed fungi in their activities are extremely important in the health of all ecosystems even giving indications as to climate change and environmental degradation. Fungi range from sea-level to mountain tops and to Antarctica even in the depths of the maritime abysses—even aviation fuel! In order to alleviate error as with other organisms an accurate identification of fungi is paramount. New species of fungi are found in their hundreds each year world-wide, and the British Isles does not surprisingly escape and that is despite a long tradition of natural sciences in these islands.

Since the retirement of senior members of staff at both Edinburgh and Kew, there is no longer a macromycetologist in the UK dedicated to the mushroom and toadstools and their allies, one of the most important ectomycorrhizal groups, as well as edibles and those causing poisoning, especially in children and numbering over 2,500 in the British Isles alone. There are even more micro-fungi!. At Kew a remaining member of staff has to double up on these fungi which is not a healthy situation and Scotland with a rather different mycodiversity and in need of a macromycologist, has only an ornamental plant pathologist.

The barriers to the employment of mycologists is two-fold, being a lack of the teaching of systematic mycology in tertiary education and its importance, and in the world of botany, the overwhelming emphasis being placed on flowering plants, but our rainforests, the lungs of the globe, are in fact dependent heavily on fungi for their continuation. This imbalance needs to be addressed. Fungi should be an integral part of any countries research funding. Even in developing countries such as China, Thailand and Malaysia of which I have personal knowledge they put a high value on an understanding of their, and the world's mycodiversity. I fear for the future of the western mentality as molecular techniques although exceedingly useful in solving some problems has to be underpinned by basic field work and systematics however archaic that may seem and something which laboratory based workers tend to forget. Molecular work is thought to be at the cutting edge of science but if it is not supported by clear ecological and identificatory data it will flounder, and with the lack of young people coming along to undertake fungal systematics this so called state of the art science which calls on much of the funding available, will hesitate and fall. At the moment mycololgy relies heavily on the participation of amateurs but they can only do a certain amount of work themselves; they need professional back-up, follow-up and importantly encouragement. The training of partaxonomists directed in some countries is certainly a way forward and I am glad to see some NGOs have seen the light whereas central Government turns a blind eye.

The natural collections collectively in Britain are the world's best and are not in any danger of being lost, but why have collections especially if many were obtained during the Empirial era of Britain when no one in Britain works on them today to forward our knowledge. There are over 10,000 collections of fungi from Malaysia and Singapore alone in Edinburgh, yet we have to rely on foreign visitors, who value these collections, examining them during their studies and working with retired or elderly mycologists. The experience of the latter gained over many years and paid for initially by the British public, through taxes, will be lost when so much can be passed on. That is why developing countries are welcoming us to teach their under- and post-graduate students and researchers; what a waste of British money! Even our own Scottish collections of fungi are not even available to the National Biodiversity Data base, because money is not available for them to be accessed digitally.

The costs of even some of the items I have covered in the above, eg data-basing Scottish fungal collections costs pennies, compared with the money which has been put into molecular work let alone astronomy. Would it not be just as important to know what our own British natural heritage, and that of the world involves.

Memorandum submitted by the Wellcome Trust

I am writing to you on behalf of the Wellcome Trust in response to the Science and Technology Select Committee's call for evidence to their inquiry into systematics and taxonomy.

The Wellcome Trust is the largest charity in the UK. It funds innovative biomedical research, in the UK and internationally, spending around £600 million each year to support the brightest scientists with the best ideas. The Wellcome Trust supports public debate about biomedical research and its impact on health and wellbeing.

The Trust feels that systematics and taxonomy are fundamental to the understanding of biodiversity and the ways that biodiversity may be changing, particularly in the context of climate change and global health threats. They are also crucial to an understanding of basic biology. It is therefore important that taxonomy and systematics continue to be supported in the UK research base, given their importance in underpinning research addressing key global challenges.

Taxonomy is particularly important for the study of emerging diseases and disease surveillance. Genetic sequencing of disease organisms and the analysis of their development and mutation in humans is proving increasingly important. The current threat of pandemic flu, for example, shows the importance of being able to identify and track variants of flu in both animals and humans. It is crucial that taxonomical expertise is maintained to enable the development of robust, transferable tools for the identification of emerging diseases.

The Trust notes that there is a current funding gap for research in the areas of systematics and taxonomy, and would emphasise the necessity of ensuring sustainable funding from a diversity of sources.

The Trust would emphasise that it is important to consider animal, plant and microbial systematics separately, given the substantial differences in practice for each. However, although the diverse needs of each field should be recognised, this should not give rise to disparity between them.

The Trust recognises the enormous potential of using new sequencing technologies as a powerful tool for genetic analysis and defining variation between and within species. The Wellcome Trust Sanger Institute is participating and leading in international projects using these technologies to understand and catalogue human variation (the 1000 Genomes project) and the International Microbiome project to characterise microbial species present in the human body. The Trust is confident that this and other research undertaken by the Sanger Institute will form an important contribution to systematics and taxonomy research.

The Trust recognises that DNA barcoding, for example through the Barcode of Life initiative, represents important developments in both systematics and taxonomy. It will be particularly interesting to see the impact of DNA barcoding on traditional taxonomy practices, and how newer techniques can be used alongside more traditional taxonomical tools and practices. It will be important to continue to monitor developments in this area and in particular, to ensure that DNA barcoding complements traditional taxonomy tools to provide accurate classification of species (including using barcoding alongside more traditional tools).

The Trust is aware of a number of initiatives in existence around barcoding data collection and sharing, including the Consortium for the Barcode of Life, the Fish Barcode of Life, the All Birds Barcoding Initiative and the Polar (Flora and Fauna) Barcodes of Life. The Trust has also previously supported the International Commission on Zoological Nomenclature in its development of Zoobank, a free to access web-based register of all the scientific names of animals. Whilst such initiatives undoubtedly make a valuable contribution to the field, it is not always clear what stage they have reached; what data is collected and how it is managed and validated; or if and how they interlink. There is an apparent lack of collaboration between different barcoding initiatives which makes for significant confusion.

The Trust would emphasise that it is important that any data collection and data-sharing initiatives should operate according to shared standards and practices. It will be important to consider how validation of data could best be achieved. It would also be helpful to consider how such initiatives might better join up for the benefit of the taxonomy and systematics community. Given the current confusion, it would be helpful to review those current initiatives in order to identify progress to date, likely future developments, and opportunities for future collaboration and joint working.

The Trust would suggest that an international approach is crucial, if the taxonomic community is to achieve successful data collection and sharing. It is necessary to have internationally agreed standards and processes on data collection, classification, validation and sharing to enable high-quality, accurate data sharing. It will also be necessary to have leadership at an international level to sustain momentum and ensure that diverse initiatives are joined up. The Committee may wish to consider during the course of its inquiry, how work could be taken forward to develop international standards.

With regard to the skills base for taxonomy, the Trust would argue that as well as supporting the training of DNA specialists, it will be important to continue to train and develop more traditional taxonomists. As noted above, it is important to maintain taxonomically expertise to support the study of emerging diseases. Links between wet molecular scientists and taxonomists should be strongly encouraged to ensure that the full range of taxonomical skills is maintained, and that the UK has the skills base to continue to deliver high-quality taxonomy. The Trust would also highlight the importance of ensuring that science teachers remain up-to-date with the latest developments in genetics and knowledge of species, given the importance of an understanding of biodiversity to science education.

Memorandum submitted by The Wildlife Trust for Lancashire, Manchester & North Merseyside

Locus standi of The Wildlife Trust for Lancashire, Manchester & North Merseyside

We are part of the Wildlife Trusts partnership, which is the UK's leading partnership dedicated to all wildlife. The network of forty-seven local Wildlife Trusts and our junior branch, Wildlife Watch, work together with local communities to protect wildlife in all habitats across the UK, in towns, countryside, wetlands and seas.

The Wildlife Trust for Lancashire, Manchester and North Merseyside was formed in 1962 by a group of local naturalists who wanted to help protect the wildlife of the old county of Lancashire. It is now the leading local environmental charity covering the sub-region defined by Greater Manchester, Lancashire and Merseyside and the adjacent Irish Sea.

Our Mission

— To work for a region richer in wildlife by the protection and enhancement of species and habitats, both common and rare.

— To work towards public recognition that a healthy environment rich in wildlife and managed on sustainable principles, is essential for continued human existence.

Our Vision

- To be the key voice for nature conservation within our region
- To use our knowledge and expertise to help the people and organisations of Lancashire, Manchester and North Merseyside to enjoy, understand and take action to conserve their wildlife and its habitats.

Responses

Our responses to some of the questions you have raised appear below, using your headings and numbering.

The state of systematics and taxonomy research

2. What is the role of systematics and taxonomy and, in particular, in what way do they contribute to research areas such as biodiversity conservation, ecosystem services and climate change? How important is this contribution and how is it recognised in the funding process?

The role of taxonomy is fundamental to the delivery of the Species Action Plans (SAP) that forms the bulk of the United Kingdom Biodiversity Action Plan and the Local Biodiversity, Action Plans (LBAPs) that derive from it. In our sub-region these are the Greater Manchester LBAP, the Lancashire LBAP and the North Merseyside LBAP. (There is currently no functional LBAP or equivalent for the Irish Sea.)

Without knowledge of what identifies a particular species and the expertise and facilities to identify it in the field a decision that the population of such a species is so rare, or in such steep decline that such a SAP is justified is essentially impossible. The production and delivery of that plan is then, self-evidently, severely compromised.

Two particular cases are pertinent here:

Jennings' Proboscis-worm

The only known population of Jennings' Proboscis-worm (*Prostoma jenningsi*) on Earth occurs in a flooded former clay pit in Chorley Borough, Lancashire. The pit is managed for recreational angling.

Dr J. O. Young of Liverpool University discovered the proboscis-worm as a new species in 1969. It was described by him and by Professor Ray Gibson of Liverpool John Moores University in 1971 [(1)].

Intensive searches of more than 200 other ponds in North West England (Lancashire, North Merseyside and Wirral) have failed to reveal other populations. Beyond sporadic local searches for the species there are no current research activities on it. Previous studies are limited to the original description of the species [(1)] and preliminary ecological investigations [(2)].

Certain identification of the species requires detailed histological study of its internal morphology. Consequently, actions to conserve this species or confirm its occurrence anywhere else on Earth are entirely dependent on specialist taxonomic expertise and laboratory facilities, which are at a premium.
Further information may be found in the Lancashire Biodiversity Action Plan [(3)].

Common Pipistrelle & Soprano Pipistrelle

Until relatively recently, the UK's pipistrelle bats were believed to belong to a single species (*Pipistrellus pipistrellus*), estimated to have declined in numbers by 70 per cent between 1978 and 1993[(2)]. "The Pipistrelle" was therefore included on the list of Priority Species in the UK BAP.

It is now known that there are two species of this bat; the "Common Pipistrelle", (*Pipistrellus pipistrellus*) and the "Soprano Pipistrelle" (*Pipistrellus pygmaeus*), the Soprano Pipistrelle being new to science. The two species are distinguishable mainly by the pitch of their echolocation calls though they are also, of course, genetically distinct.

The UK Pipistrelle Species Action Plan has a target to restore both species to their 1970s population levels and geographical ranges. Estimating these historic levels will require taxonomic genetic analysis of historic "Pipistrelle" specimens to discover to which of the two species they in fact belong.

A third species, Nathusius' Pipistrelle (*Pipistrellus Nathusii*), has now been discovered in the UK. It has been recorded from locations across the UK but appears to be very rare.

Data collection, management, maintenance and dissemination

7. *Does the way in which taxonomic data is collected, managed and maintained best meet the needs of the user community? What is the state of local and national recording schemes?*

Local government has no statutory obligation to maintain a biological records centre in the way that it must maintain an up-to-date archaeological Sites and Monuments register. There here has been no effective Local Biological Record Centre or Network for Greater Manchester, Lancashire and Merseyside since the local government reform of 1974. As a result we have been without an integrated system for the deposition, management, analysis and retrieval of biological records for our sub-region for a generation. In our opinion, the very lack of such a system has very likely led to a decline in local taxonomic expertise and biological recording as there is no resourced institution charged with encouraging the taxonomic skills necessary or supporting the recorders in validating their identifications.

We hold some biological records that we have gathered ourselves over time, and some records that have been shared by other local organisations, However, when we, or other nature conservation practitioners, or ecological consultants working for prospective developers, or educational institutions, or interested members of the public wish to acquire a knowledge of the distribution of a particular species or variety of species for a particular locality in our sub-region, we and they are obliged on each occasion to contact numerous local and national institutions and individuals to achieve a comprehensive and up-to-date picture. The time "wasted" in such protracted searches must add up to a significant economic cost.

Skills base

12. *What are the numbers and ages of trained taxonomists working in UK universities and other organisations?*

13. *What is the state of training and education in systematics and taxonomy? Are there any gaps in capacity? Is the number of taxonomists in post, and those that are being trained, sufficient to meet current and future needs across all taxonomic subject areas?*

It is our general experience that trained taxonomists in all fields, with the possible exception of ornithology, are becoming progressively scarcer. As infirmity and death overtakes them it will be difficult to replace the lost expertise of the current, elderly generation of taxonomists for many years—even if training courses (at degree and post graduate level) started today.

Amongst our own conservation staff (aged between 25 and 50), such taxonomic expertise as there is has largely been gained despite rather than as a result of the content of the degree courses they attended, mainly in the 1970s-1990s.

References

1. Gibson, R. & Young, J. O. (1971). *Prostoma jenningsi* sp. nov, a new British freshwater hoplonemertean. Freshwater. Biology. 1, pp. 121-127.

2. Gibson, R. & Young, J. O. (1976) Ecological observations on a population of the freshwater hoplonemertean *Prostoma jenningsi* Gibson and Young 1971. Arch. Hydrobiol. 78, pp. 42—50.

3. Lancashire Biodiversity Action Plan (www.lbap.org.uk)—Species Action Plan for *Prostoma jenningsi* (a ribbon worm).

Thank you for this opportunity to contribute, it is much appreciated.

Memorandum submitted by the Yorkshire Naturalists' Union

The Yorkshire Naturalists' Union (YNU) is a registered charity and was founded in 1861. Its aims are to promote the scientific investigation of the fauna, flora and physical features of the historic county of Yorkshire and to encourage the conservation of these by means of a) the Union's publications and b) the holding of field and indoor meetings in the Yorkshire Watsonian vice-counties 61-65. In the terms of the Charities Act 2006, the Union qualifies for charitable status as a charity, for the advancement of environmental protection and improvement of nature.

The Union has two categories of membership:

i. the natural history societies of Yorkshire (or strictly, the historic county of Yorkshire). Excluding the Yorkshire Wildlife Trust which is not a natural history society, there are 43 affiliated societies with about 5000 members;

ii. individual members of whom there are currently about 400. Not all individual members are resident in Yorkshire but they will mostly have some association with the historic county.

The Union has twenty-eight Recorders covering various taxonomic groups and the membership is organised into sections covering these groups. Union membership includes a number of very eminent naturalists. Many of the specialists however are elderly and are difficult to replace.

The Union works closely with the Yorkshire and Humber Region's Biological (Ecological) Record Centres and was a founding partner in the Yorkshire and Humber Environmental Data Network. Our Recorders are available to assist the Record Centres with refereeing critical groups. Our Ornithological Section deals with refereeing rare birds in line with national guidelines.

The Charity employs no staff and is managed by ten trustees elected for a period of three years. Our General Secretary, who undertakes nearly all administration, performs day-to-day management.

We publish:

1. The *Naturalist* – a peer reviewed quarterly journal.
2. The *Bulletin* in the spring and autumn. This contains articles on natural history and conservation together with the business of the Union and notices of meetings.
3. An annual *Bird Report*. We are about to publish one for 2005.
4. An annual *Lepidoptera Report* jointly with Butterfly Conservation (Yorkshire)
5. An *Annual Report* containing not only the statutory requirements, but natural history highlights.
6. From time to time specialist works on aspects of the flora and fauna of Yorkshire. A recent example is PP Abbott (2005) *Plant Atlas of Mid-West Yorkshire.*

The Natural Sciences Committee composed of the trustees, representatives of the sections and representatives of the Union's Vice Presidents manages scientific affairs of the Charity. Through this committee, field meetings are organised, projects considered and reports are received. The Union organises around 20 field meetings each year. The Union organises a major conference on a biodiversity or regional theme each year. In 2007 the theme was *Biodiversity of the North York Moors*, in 2008 the theme will be *Monitoring Biodiversity in Yorkshire* and in 2009 the proposed theme will be T*he role of linear continuities in Biodiversity*. The sections organise indoor meetings during the winter months.

Following a special conference in September 2003 to consider *Recruiting and Training the Next Generation of Field Naturalists* (a copy of the *Conference Proceedings* is appended as part of this evidence), the Union set up an Education Committee. We comment on our education work in our answer to question 13 below.

Evidence

We present our evidence in the form of answers to the questions you have asked.

Questions 1-6 The State of systematics and taxonomy research

As a society we will not comment on these issues but we believe that some of our members will comment in a personal capacity.

Questions 7-11 Data collection, management, maintenance and dissemination

7. Does the way in which taxonomic data is collected, managed and maintained best meet the needs of the user community? What is the state of local and national recording schemes?

Members of the YNU are principal providers of taxonomic data to the user community. Through its various activities, reports and publications the YNU has also long been a major user of the data that its members collect. The YNU also provides an official data verification service to the Regional Biological Records Centre (LRC) and many of our members give assistance to other LRC's outside of Yorkshire. Our members are also members of many national societies and recording schemes.

The composition of the user community and its needs has changed drastically over recent years and data collection and management is being adapted to meet the new circumstances. With the adoption by Ordnance Survey of the National Grid, field naturalists initially collected data on a 10km square basis. This is no longer adequate. To meet the needs of local land-use planning, the requirements of special land management tools (Biological Action Plans, Water Level Management Plans etc.) and to provide the data base needed for monitoring the distributional consequences of climate change, requires, in comparison with past practice, data on a much finer geographic scale, for a broader range of taxa and with more frequent and regular collection. Future data will need to be provided and stored electronically using accessible and flexible software. The YNU is fully committed to a programme of improvements in data supply and is cooperating with the regional biological records centres to meet these requirements. However there are a number of problems:

I. A back-log of both recent and historic data exist for many taxa. Some of the material held (this includes both two and three-dimensional material) has been collected in great detail over extended time periods and has great scientific value. However, much of it is not at present in electronic format and will often not meet the full desiderata of the regional LRC's, without considerable work by knowledgeable recorders. For the most part these data have been collected for private, not social purposes. To put it onto national and regional databases requires verification and interpretation. Making past data suitable for present and future purposes, is an expensive and time consuming process. Most LRCs lack the funding and staff resources to input the backlog of available data. There is a very real risk that some of these data will be lost, or so scattered (most of it is in paper format) that it will not be possible to utilise it.

II. For the future, data gatherers, many of whom are unpaid volunteers, will need to be supplied with the requisite software and to be trained in the use of that software. We see this as a responsibility jointly of Natural England and the regional record centres. The YNU has neither the resources nor the expertise necessary to take on this responsibility. For the field naturalist the opportunity cost of providing detailed electronic records is time spent on field work. Electronic record creation must thus be an efficient process that takes no more time and effort for the recorder than is absolutely necessary. Proper training in the use of well-designed software is in the interest of both users and suppliers of data.

III. Transferring past and future data to regional record centres is not simply a technical problem. Difficulties arise because those who generate the data are unwilling to make the data freely available to all. This is in part an issue of trust. In the past data generators have known what their data was to be used for and who would use it. They shared common attitudes with the traditional users of the data (national and regional recorders; Natural England and its predecessors) on the importance of species protection and stewardship. Thus the data gatherer had confidence that data which could place biota at risk (eg by revealing the location of rare lepidoptera or plants to unscrupulous collectors, or placing sensitive breeding birds at risk of disturbance) or could damage relationships with land owners and hence future site access, would be safeguarded. It cannot be assumed that new classes of users (eg local authorities and commercial consultancies) will share the values of the data collectors and, to safeguard legitimate interests, controls are needed. We note the moves by the National Biodiversity Network to improve standards of data supply and user agreements and their work in encouraging Local Record Centres to provide data suppliers and end users with standard agreements. We note also the difficulties placed by the Environmental Information Regulations on Charities such as ours. The degree of distrust by the voluntary sector may mean that significant information is not being made available to the public sector, who may well be in a position to enhance the conservation status of the species/ habitat concerned. The solution being explored is a common contract between data providers and the record centres. While we are in favour of this, it is our view there is a prior need for more dialogue between data providers and record centres. The YNU will play its part in facilitating this dialogue.

8. *What is the role of the major museums and collections? How are the taxonomic collections curated and funded?*

YNU members have long been major users of the natural history collections held within Yorkshire's Museum. They are also an important source of the material deposited in both in these collections and collections held further afield. In addition the YNU regularly assists in the identification and verification of material for museums within the region.

Most regional museums are unable to fund even the most basic research and many do not have the funding, space or expertise to place the bulk of their collections in taxonomic order. The regional museums do, however, play a major role in housing local, regional and even international collections and allowing access

to these collections by local specialists and recorders, without which these people would be unable to check and verify the identifications of data submitted to LRCs and ultimately to the NBN database.

The development of the Regional Museum HUBS and the extra funding which came with this development from DCMS, has made some difference but much of this extra funding has been wasted due to a lack of long-tern strategic planning. Governments like "quick fixes" which gain them publicity. One of the easiest of these "quick fixes" is to spend more on educational projects, often with little co-ordinated planning and few long-term gains. The original plans for this extra funding for museums were intended, at least in the first few years, to build capacity and expertise within these institutions. Funding should be allocated to museums to fund strategic taxonomic tasks by employing trained taxonomists, as well as funding the proper storage of their collections.

The many differing documentation systems used by museums make it difficult to extract data from reference collections via these data-bases for use in national recording schemes. Some system needs to be established by which this data can be extracted and used as the historical base for the modern LRC data-bases.]

9. *What progress has been made in developing a web-based taxonomy? how do such initiatives fit in with meeting demand for systematics and taxonomy information? How do UK-led initiatives fit with international initiatives?*

We do not have any significant experience of web based initiatives, although we have members who are working on the development and testing of identification keys downloaded from the web.

10. What needs to be done to ensure that web-based taxonomy information is of high quality, reliable and user-friendly?

In our view we are a long way from a situation with any taxon where a web-site will replace the verification and teaching functions currently performed by YNU.

For taxa where the taking of specimens is not permitted, such as birds, or not practised, good identification sources, whether paper or web-based, can make the recorder's life harder not easier. In the construction of a description of a scarce species they assist in supplying key identification features which may have been missed in the initial observation!

Although the web can be used to rapidly update taxonomic identification points, the observer must check that the observation follows the key anatomical points of the species under consideration. It takes experience to do this, particularly where examination of the genitalia is essential. In other species in both the plant and animal kingdom, the species may only be identified by a professional with access to DNA analysis.

11. *How does the taxonomic community engage with the non-taxonomic community? What role do field studies play?*

Taxonomy has declined considerably in recent years. It is no longer a core element in biology degrees and there are few taxonomists in university biology departments and regional museums. In contrast to the past, those trained taxonomists that remain are, for the most part, not members of the YNU and do not interact with it.

The YNU's principal concern is with biological recording which requires a combination of taxonomic and field skills. In the UK these skills are combined in its community of amateur naturalists. This community has long played a major role in the collection, identification, recording, and developing knowledge of, flora and fauna. It is a major strength of the UK system that has resulted in a wealth of detailed knowledge of its biota and its distribution that substantially exceeds that of almost any other country. It has meant in the past, and for the future will continue to mean, that the needs of users for biological data can be met at an amazingly low cost. In our judgement maintaining the vigour of this community of amateur naturalists means that any increase in biological recording to aid understanding, *inter alia* of the impacts of climate change, can be met at low (but not zero) social cost.

Amateur naturalists acquire, usually by private study, the taxonomic skills necessary to identify specimens of the taxa they study. Many naturalists are able to read a scientific description and use it to identify specimens, but may not have the ability or the confidence to make such a description. The taxonomic skills needed for successful and reliable recording vary widely between taxa. At one extreme, taking specimens of birds is illegal and the bird recorder does not need the ability to produce a full plumage description in order to create reliable records. At the other extreme taxonomic skills are essential for botanists and mycologists.

The identification of live non-captive specimens, normal practice with birds, is spreading among the *Insecta* assisted by improved optics. Capture is generally seen as unnecessary for identification of *Odonata,* most *Orthoptera* and many families of *Lepidoptera*. Capture and release is even more widespread. Current thinking

is that routine taking of specimens should be confined to taxa where identification is not otherwise possible. Where closely related species require dissection, recording at the level of the genus may be accepted practice, supplemented from time to time by the taking of specimens to monitor intra-generic distribution. This is the case with *macro-Lepidoptera*.

The ability to identify outside of the laboratory is an important component of field skills. Our experience is that students leaving universities with biology degrees, even at the Masters level, have few field skills and have no ability to identify. We view this with grave concern. Our educational activities discussed below are in part directed at giving field skills to biological science graduates holding posts where field skills are need; countryside wardens and managers; ecologists in local authorities and ecological consultancies; museum staff; biology teachers in schools.

Questions 12 and 13. Skills base

12. What are the numbers and ages of trained taxonomists working in UK universities and other organisations?

See our answer to Q.11. We are unable to answer this question even for Yorkshire, but our view is that the number is declining and that it is below what is needed. We are particularly concerned about the lack of trained taxonomists in the major regional museums. Our diagnosis of the problem is that the museums services lack the funding to employ staff and that the lack of job opportunities has discouraged the universities from training them. The UK situation contrasts unfavourably with the rest of Europe where taxonomic skills are seen as necessary even in regional museums. The base of amateur naturalists in the UK has meant that the shortage of taxonomists has not undermined biological recording.

13. *What is the state of training and education in systematics and taxonomy? Are there any gaps in capacity? Is the number of taxonomists in post, and those that are being trained, sufficient to meet current and future needs across all taxonomic subject areas?*

See our answers to questions 11 and 12. The shortage of trained taxonomists would be seen as severe were the supply of experienced field naturalists to decline. However in that event it would probably be impossible to meet the UK's demand for biological data at acceptable cost. Some simple economic analysis underlying this proposition is appended.

Training the next generation of Field Naturalists June 2007, © J.A. Newbould

In the face of widespread concern that the long UK tradition of amateur field naturalists might, in fact, be under threat, YNU organised a conference in 2003 with the title of *Training the Next Generation of Field Naturalists.* There were several reasons for this concern:

- the age profile of the current stock of experienced field naturalists. The average age appeared to be above 60 and was particularly high for specialists in some important taxa, with difficult identification problems (eg diptera; coleoptera; hemiptera)
- declining and aging membership of local natural history societies
- a perception that the number of school biology teachers possessing field skills was declining

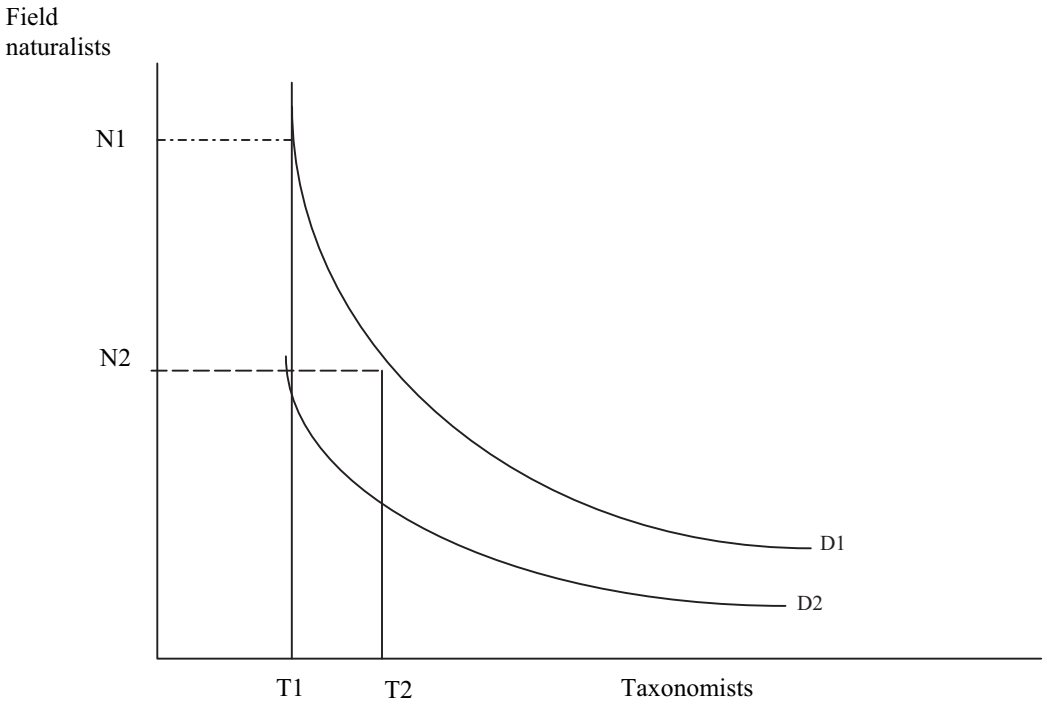
While the evidence is open to alternative interpretations, it was felt that there was sufficient basis for concern to warrant the launch of a training initiative. Accordingly, in 2006, in a partnership with the Yorkshire and Humber, Museums, Libraries and Archives Association, Union members provided seven training days in different aspects of taxonomy to over 70 people. These workshops aimed at imparting the skills and knowledge necessary for recording specific taxa (eg *Odonata*; *Bombus* species; insects in general; marine biology; mollusca; birds) or habitat types (eg hedgerows; grasslands). Workshop design embraced elements of class-room, laboratory and field work and utilised museum collections. As an unfortunate by-product of child protection legislation, participation was restricted to adults. Participants included staff from museum services, local authority environmental services departments; ecological consultancies, environmental NGO's, teachers and amateur naturalists wishing to extend their skills to cover new taxa.

Because of changes in Museums, Library and Archives Associations functions we were unable to continue this partnership in 2007. However we continued to provide training in the same format but with lower numbers of participants. It is our intention to extend the scope and coverage of this programme in future years.

Our training programmes have been extended to provide field skills training to some current university students. At the request of the course director we provide field training sessions for students on an MSc in conservation. In addition we have offered weekend training days for post-graduates and also training in wild flowers and habitat identification. The feed-back from these endeavours has been strongly positive (eg recent graduates saying that they learnt more about taxonomy from our training days than in three years at University).

Additional note:

Some Simple Economics of Biological Data Gathering



Production of biological data, D, requires the services of field naturalists N, and taxonomists T. The services of field naturalists and taxonomists can be substituted for each other but the substitution possibilities are limited. The extent to which field naturalists can acquire taxonomic skills is limited, so some trained taxonomists are required if a given level of data recording is to be maintained. Equally, however many taxonomists sit in the laboratories and museums, some one has to be in the field collecting specimens.

The services of field naturalists are available free to society but the training of taxonomists has a positive cost. Level D1 of biological data will be provided using the minimum possible level of taxonomists T1 and using N1 services of field naturalists. This is efficient; since they are available for free, field naturalists are used to the point where their marginal product is zero.

Now assume that the supply of field naturalists is restricted as a result of a failure to train the next generation. The available supply of their services falls to N2. Society can only maintain D1 level of biological data by expanding the amount of taxonomists to T2 at the cost of training them and retaining their services. Because the price of the services of field naturalists is zero the socially efficient response to the problem is to maintain the level of taxonomists at T1 and reduce the amount of biological data generated to D2 using the price mechanism to ration the demand for data.

Rationing data via the price mechanism, will squeeze out the public goods elements in the demand for data, such as university research into the consequences for biodiversity of climate change.

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