Physiological Colour Change in the Hercules Beetle

THE Hercules beetle, *Dynastes hercules* L., can change the colour of its elytra—horny fore-wings—from black to greenish yellow and back again to black all within a few minutes. It does this in a way previously unknown among insects. Apart from the reversible migrations of pigment granules in the iris cells, physiological or rapidly reversible colour changes are very rare in insects[1–4]. Among beetles, *Coptocyclia*[5], *Aspidomorpha*, and many other Cassidinae can change the colour of their elytra by varying the amount of water in the cuticle and thereby the thickness of the thin films responsible for the interference colours.

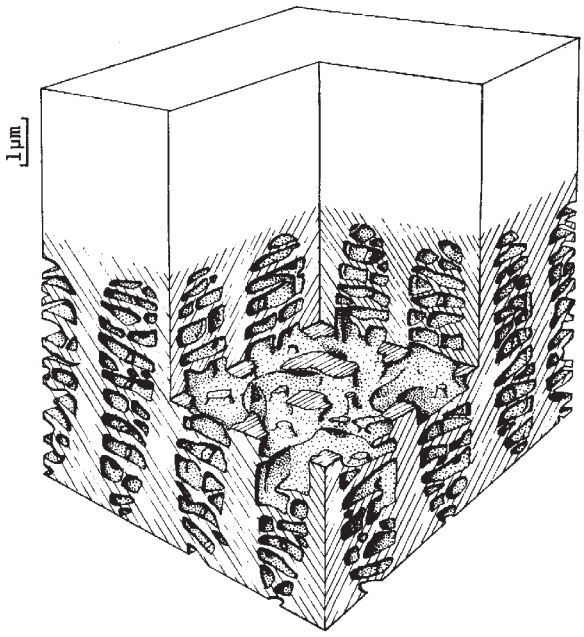

Fig. 1 The yellow spongy layer of the elytra beneath the transparent epicuticle.

The outermost layer of the cuticle of the Hercules beetle is transparent and about 3 μm thick. Below is a yellowish spongy layer generally about 5 μm thick. Below the yellowish spongy layer the cuticle is black by reflected light and reddish by transmitted light. Transmission electron micrographs show that the spongy layer consists of columns or pillars normal to the plane of the surface and usually about 0.5 to 1 μm thick. The pillars are connected to each other by irregular branches normal to their major axes (Fig. 1). When the elytra are yellowish, the spaces between the pillars are filled with air; when the elytra are black, the spaces between the pillars are filled with liquid. Scanning electron micrographs of 10 μm thick sections show that the spongy layer is much more irregular than would appear from transmission micrographs. The interstices or spaces between the branches of the pillars usually vary from 0.01 to 0.5 μm wide. Columns that are oval or circular in section and up to 1.6 mm in diameter extend vertically through the elytra to the outermost layer. When the elytra are yellowish because the interstices of the spongy layer are filled with air, the areas occupied by the columns appear as black spots.

Air can be squeezed out from the spaces in the spongy layer by exerting a little pressure with a rounded point so that the outermost transparent layer is not broken. The black layer below then shows through the now optically homogeneous spongy layer. Black lines made in this way on old museum specimens (Fig. 2) appear to be more or less permanent. The yellow colour, however, may be restored by adding water to the surface over the black areas and allowing it to evaporate. The water is absorbed by the spongy layer and restores its interstices, but the colour remains black until the water evaporates and the coloured layer again becomes optically heterogeneous. If a drop of liquid nitrogen is placed on a black elytron of either a live or a dead beetle, a yellow spot immediately appears which vanishes as soon as the nitrogen evaporates and the spongy layer once more becomes optically homogeneous.

If a live beetle that has yellowish elytra is placed in a saturated environment, the elytra become black. If the relative humidity is suddenly reduced to 80% or less, yellow patches begin to appear on the elytra, usually within 30 s–2 min. The rate of yellowing depends on both the previous history of the individual and the temperature. When an elytron was removed from a living beetle, it changed colour in just the same way as the elytron left attached when both were subjected to the same changes in relative humidity.

Colour changes were not affected when male beetles were kept in the light or in total darkness, or by blackening their eyes, or by prodding them or exposing them to sounds of different intensities and frequencies.

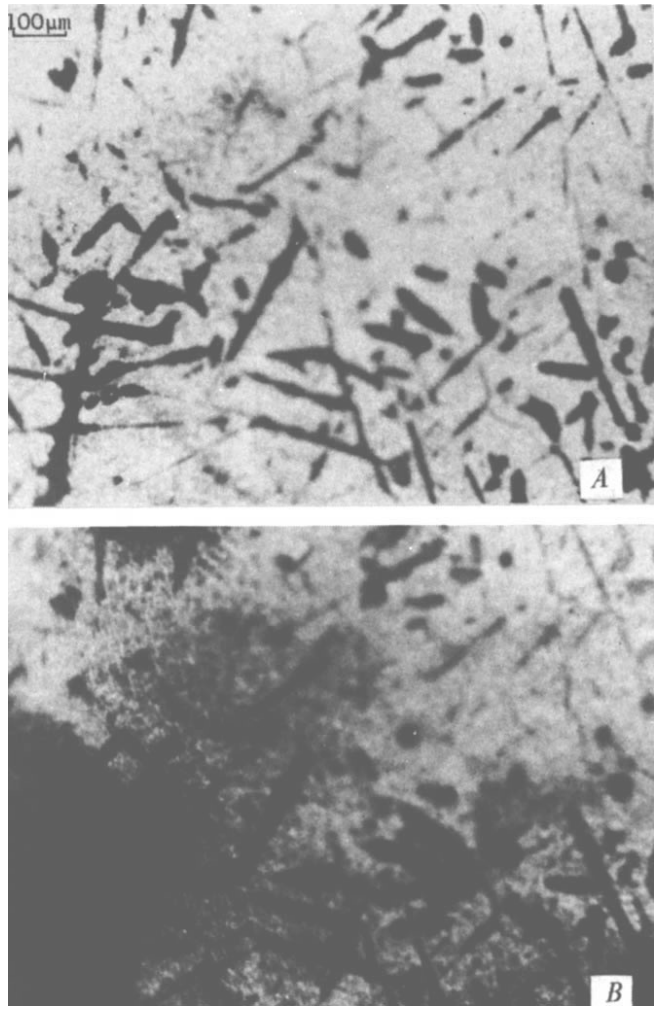

Fig. 2 The gradual flooding of the yellow spongy layer when a piece of an elytron is immersed in gum chloral. *A*, Shortly after immersion and (*B*) about 30 min later when many more of the air spaces in the spongy layer are filled with the liquid.

Live beetles kept at a constant humidity invariably became black in time. In one series of experiments, pairs of glass tubes were attached by their open ends, with chewing gum, to the elytra of beetles that were black in saturated air. One tube was filled with silica gel and the other with moist filter paper. The circle under the tube with the silica gel yellowed

immediately but then blackened over a period of many hours. The silica gel remained blue, which is difficult to explain. Perhaps after absorbing a small amount of water, enough lipids were transferred to the area to render it relatively impermeable to water: the hydrocarbons that can be washed with hot chloroform from the surface of the elytra suggest a lipid layer several hundred molecules thick. When the beetles were transferred to a relative humidity of 80%, the elytra became yellowish. When the tube with moist filter paper was removed, the area beneath was always black but then yellowed at about the same rate as the exposed parts of the elytra had done. When the tube with silica gel was removed, the circle beneath it stayed black, perhaps because that area was then subjected to an increase in the ambient relative humidity.

From both the experiments with dead elytra and living beetles, it appears that the level of hydration of the spongy layer, and therefore the colour, is determined by (1) the level of hydration of the spongy layer under direct control, presumably by the epidermal cells of the elytra, and (2) the amount of water that condenses on the surface of the epicuticle and is then absorbed by the spongy layer below.

Experiments with museum specimens suggest that *D. hyllus* Chevr., *D. granti* Horn, and *D. tityrus* L. change colour in the same way. In the latter two species the structure of the cuticle of the pronotum is like that of the elytra. Neither the American *D. neptunus* Quenzel nor any of the African or Oriental species of *Dynastes* seem to be able to change colour.

The selective advantage of the colour change may have to do with the fact that whereas a large entirely black beetle is not easily visible at night, it would be more conspicuous than a beetle with yellowish elytra in most situations in a tropical forest during the day. Thus the beetle would be entirely black during the night when the humidity was high, but its elytra would become yellowish as the humidity fell during the day.

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[1] Griesberg, H., *Z. Vergl. Physiol.*, **7**, 657 (1928).
[2] Key, K. H. L., and Day, M. F., *Austral. J. Zool.*, **2**, 309 (1954).
[3] Kopenec, A., *Z. Vergl. Physiol.*, **31**, 490 (1949).
[4] O'Farrell, A. F., *Austral. J. Sci.*, **25**, 437 (1963).
[5] Mason, C. W., *Entomol. News*, **40**, 52 (1929).

Scanning Electron Microscope Study of Jane Austen's Hair

JANE AUSTEN (1775–1817) bequeathed a lock of her hair to her niece Fanny Knight. In 1949 this lock, mounted between two glass disks in a gilt frame, came into the possession of the Jane Austen Society and since then has been exhibited in the museum at Chawton in Hampshire. Recently we were approached by the society to examine the hair, for it was thought that some deterioration had occurred. Certainly some bleaching by light had taken place because the side of the lock which was exhibited uppermost was a light straw colour, whereas the underside was mid-brown. As it was desired to preserve the majority of the hair lock intact, our studies have been restricted to the examination of a few of the fibres with the aid of the scanning electron microscope.

Hairs for examination were stuck to double-sided 'Sellotape' on a standard scanning electron microscope mount and vacuum coated with a 10 nm-thick layer of carbon followed by a 30 nm-thick layer of metallic silver. These were examined in a Cambridge 'Stereoscan Mk II' scanning electron microscope operated in the secondary electron emissive mode and at an accelerating potential of 10 kV.

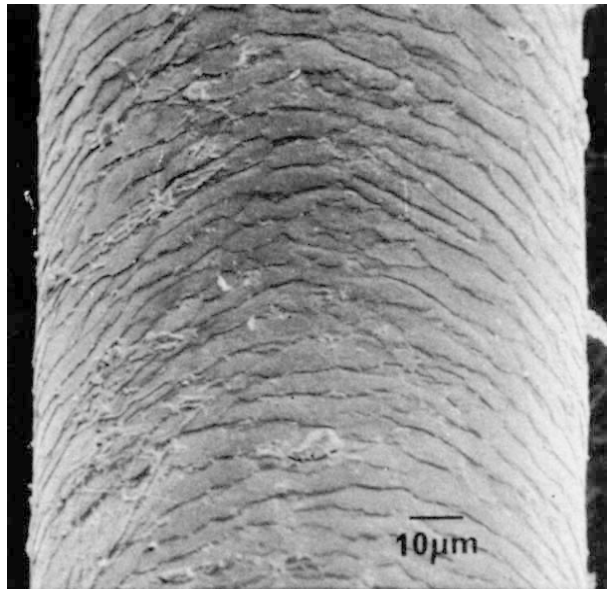

Fig. 1 A typical Jane Austen hair.

The hairs varied in length up to 40 cm, were from 50 to 80 μm in diameter, slightly elliptical and their surfaces covered with a pattern of overlapping scales as is typical of contemporary Caucasian head hair[1]. A most unusual feature was that for at least three-quarters of the length of each hair the scale margins were of smooth contour and the scale surfaces relatively flat (Fig. 1). In recent years we have examined many thousands of hairs from women who apply normal grooming, and the scale margins within the first 2 to 5 cm of the scalp surface are usually of smooth contour, but beyond this the scale margins break away to give highly irregular edges. In addition to this, the scale surfaces, although smooth in the first 2 to 5 cm from the scalp, are punctuated by occasional low ridges and depressions. These changes are normally brought about by the action of brushing, combing and mechanical handling. It must be concluded, therefore, that within the last three years of her life Jane Austen did little to tend her

Fig. 2 An engraved portrait of Jane Austen which appeared in Edward Austen-Leigh's memoir[3].