The Iridescent Colours of Insects.

By H. Onslow.

II.—Diffraction Colours.

The structure of the scales of a number of iridescent butterflies was described and illustrated in the first article. The colours of many of these insects are undoubtedly produced by thin plates, either of chitin or of chitin and air. In a few instances, however, the structure gave no indication whatever as to how the colours were evoked.

Some definite modification of the structure gives rise to the principal colour, but all the minor details, such as the exact shade and the quality of the surface, which are so characteristic of any particular species or variety, are determined by the shape and position of the scales, the amount and form of the surface modelling, and the colour and localisation of any accompanying pigment. Consider, for instance, the shimmering appearance of the familiar Green Hairstreak (*Thecla rubi*), Fig. 1, which makes this insect so difficult to find, when it sits with its wings folded high overhead, looking like a green leaf dancing in the breeze. The appearance of the green scales is well known, 1 (Fig. 2), and a discussion on their colour, and on the cause of their characteristic reticulation, was carried on in the *Entomologist's Record*, vol. vi., p. 35, 1895.

Fig. 1.—The Green Hairstreak (*Thecla rubi*). Showing the iridescent green under-wings, which are the same colour as the leaves. (Natural size.)

When observed by reflected light under the microscope, this shimmer is seen to be due to the spangled appearance of the scale, which is divided into many small, irregular areas, *o*, which reflect a green glitter of varying intensity, like so many sequins. These areas are divided from one another by pale lines, which form a reticulation. By transmitted light the reticulation shows as a transparent line, and, moreover, the brown colour of the polygonal areas is seen to vary considerably, some being dark brown and very opaque, and others pale yellow and transparent. Now the intensity of the green light varies in exactly the same way as this brown colour, the darkest and most opaque areas reflecting the brightest green. The iridescent colour is probably caused by a periodic structure not unlike that described in *Papilio ulysses*, the normal brown colour of the scale concealing any trace of this structure that might otherwise have been visible. The explanation of the reticulation and the spangled appearance it produces becomes at once evident on cutting a transverse section, 5 (Fig. 2), through the scale. It can be seen that the network corresponds to the thin places on the scale, *b*,

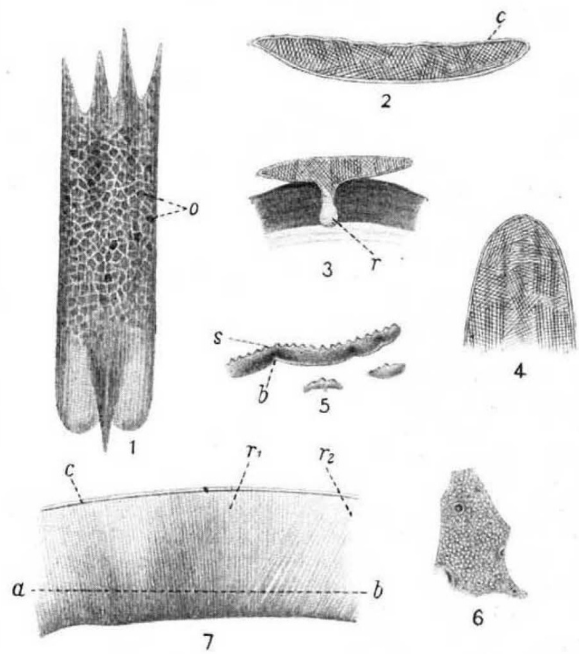

Fig. 2.

1, Green under-scale of *Thecla rubi*, showing reticulation. *o*, dark polygonal areas.
2, Section through scale of *Hypomeces squamosus*, var. *durulentus*, showing stratification. *c*, surface cuticle.
3, Scale of the same weevil, *in situ*. *r*, root.
4, Plan of scale from the same weevil.
5, Cross-section of green scale of *T. rubi*, showing places *b*, where the scale is looped up, corresponding to the reticulation in *1*. *s*, striæ.
6, Tangential section through the wing-case of *Heterorrhina elegans*, made through the plane *ab* of section 7, showing the tops of the doubly refractive rods.
7, Cross-section through the same wing-case, showing layer of rods r_1 and a deep layer r_2. *c*, the surface cuticle.
All these sections, with the exception of *5*, were drawn to the scale $\mu = 1$ mm. with Zeiss 2 mm. apochromat, N.A. 1·4, and Comp. Oc. The scale *1* has a magnification of about 100 diams.

[1] Continued from p. 152.

where it appears, as it were, to have been looped up. The bright green areas then correspond to the thickest portions of the scale. This is evidently only another example of the intensification of the colour produced by an underlying screen of dark pigment, which absorbs the excess of white light that would otherwise be reflected to the eye, causing the colour to become much desaturated.

Diffraction of Light by "Gratings."

Colours due to barred structures, or "gratings," which diffract light in the usual way, cannot be said, in Lepidoptera at least, to be of very great importance. They do, however, often produce effects which, though of secondary value, contribute a good deal to the final result. The fact that most scales appear to be marked with striæ, which form gratings of suitable dimensions, has sometimes given rise to the idea that most insect colours are produced in this way. This is evidently not the case, for iridescent scales are sometimes smooth, and, moreover, plain black and white ones are often striated. Impressions or replicas were therefore taken of many scales in a special preparation of collodion, in order to isolate the effect of the surface structure from any other colour-producing factors. Good "gratings," showing normal lateral spectra, were obtained from most insects, such as the Large White (*Pieris brassicae*), but if the film was dyed, the colours became feeble or disappeared. This indicates that diffraction colours are, as might be expected, discernible only on very pale or colourless scales. The existence of diffraction colours can be clearly demonstrated by the following experiment. An impression was made from the pale blue surface scales of *Morpho achilles,* in such a way that at least one patch adhered to the collodion film. On tipping the grooved film so as to cause the spectrum colours to pass across the patch of scales, it could be seen that their normal blue colour became intensified in the violet region of the spectrum, changed to mauve or pink in the red region, and returned to its original shade on passing into the infra-red. When this effect has once been seen, a very similar play of pale mauve and pink diffraction colours can be discerned on examining the wings of *M. achilles* itself, and of certain similar insects.

Very brilliant colours are shown by scale-bearing beetles or weevils, like the Brazilian Diamond Beetle (*Entimus imperialis*) (Fig. 3). Michelson admits these colours to be an exception to the general rule, by which he attributes all insect colours to selective metallic reflection, or surface colour. He believes the colours of these beetles to be due to gratings within the scale itself, since as soon as a fluid can enter the scales through a rent or tear the colour vanishes. Moreover, since the light is concentrated in a single spectrum, he is obliged to assume that the grating has bars, which are asymmetric or prism-shaped, so that they refract the incident rays in the same direction as the diffracted rays of the lateral spectra. For several reasons it is difficult to believe that such saw-tooth-shaped gratings are responsible for the total colour effect. For instance, the very saturated complementary colours seen by transmitted light, and the monochromatic character of the reflected colours at different angles, demand a form of grating structure even more complicated than that described by Michelson, such, for instance, as that named by Prof. R. W. Wood the "échelette grating." Moreover, though as a rule no structures are seen, a very well-defined stratification, 2 (Fig. 2), sometimes appears in cutting sections of certain scales, as in the pink weevil, *Hypomeces squamosus,* var. *durulentus.* This stratification can be seen in plan, 4 (Fig. 2), and appears to exist throughout the scale, giving it in section the crossed appearance of the strings of a tennis racquet. It seems probable that such a structure would contribute a large share to the total colour effect. Further, a suitable irregularity in the periodicity or thickness of the plates

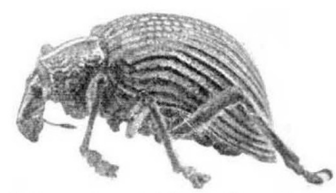

FIG. 3.—The Brazilian Diamond Beetle (*Entimus imperialis*), a large, iridescent weevil. The black pits on the wing-cases are lined with gem-like scales. (Natural size.)

would account for the existence of the very saturated colours of some weevils, and of the very pale and desaturated colours of others.

Dispersion of Light by Prisms.

If Michelson's hypothetical prism- or saw-tooth-shaped gratings are omitted, no case of prismatic structure has been met with. It is true that Dr. H. Gadow has explained how the colours of certain feathers might be the result of the roughly prism-shaped structure of the barbules. He supposed that these were placed in such a way, in respect to each other, that each barbule obscured part of the spectrum formed by the preceding one, so that partially monochromatic colours would result. Numerous theoretical and practical considerations, however, make this suggestion highly improbable.

The Scattering of Blue Light due to Small Particles.

The investigations of the late Lord Rayleigh, and others, have shown that the blue of the sea, sky, snow and even tobacco smoke is caused by particles which, being very small compared with the wave-length of light, scatter the blue waves to a much greater extent than the longer red waves. Several colours can be produced in this way, as, for instance, the blue, green, and purple of certain feathers, which are matt, and do not change colour with the angle of incidence.

such feathers show a faint yellow colour by transmitted light, and any pressure which destroys the structure also destroys all colour. The small bodies which scatter the light are in this case said to be exceedingly minute air-canals, which, on being filled with fluid, lose this property. In the case of feathers, as well as of certain animals, such as green frogs and many reptiles, the green is said to be due to the additional effect of a yellow pigment which is superimposed on the blue colour, as in the case of *Ornithoptera poseidon*, already described. There are also some exceedingly brilliant marine copepods which owe their colours to a prismatic layer of minute rods, said to be small enough to scatter coloured light.

In most beetles the metallic colours are seen to come from the surface, and the slightest scratch on the elytron removes all the colour. In the case, however, of certain emerald-green and blue Cetoniids, the colour appears to come from underneath the surface, which gives the wing-case a curious enamelled appearance. This peculiarity can be instantly recognised, and, moreover, the colour, though matt, is seen to persist, even when the surface layer has been removed with a scalpel. This layer has been called the "*Emailschicht*," and when sections are cut from it tangentially to the surface, 6 (Fig. 2), they give a bright green colour by reflected light, even when mounted in fluid media. A transverse section, 7 (Fig. 2), was cut from this layer of a beetle called *Heterorrhina elegans*; it is seen to be made up of very fine rods of chitin, r_1, about 1μ apart, and arranged at right angles to the surface; r_2 represents a second layer of rods at a lower depth. The section, 6 (Fig. 2), made through the line *ab* of section 7, reveals the cut ends of the rods. Thus the light, on striking the wing-case, is reflected from the tips or ends of a large number of these rods or pillars, and it seems possible that they may scatter the light in the same way as the air-canals do in the case of birds' feathers. It must, however, be pointed out that the above theory demands that the rods, or other bodies which scatter the light, should be appreciably smaller than the wave-length of light; that is to say, not much larger than a complex molecule. It is, however, uncertain whether bodies of the same order of magnitude as light waves (*i.e.* $0{\cdot}5$–$1{\cdot}0\mu$) can produce analogous colours. A very remarkable point about these rods of chitin is that under crossed Nicols they appear to be doubly refractive. This suggests that there may be some analogy with doubly refractive striated crystals like the tourmaline.

(*To be continued.*)

Physical Anthropology of Ancient and Modern Greeks.

By L. H. DUDLEY BUXTON.

IN classical times a clear distinction was drawn between Greek and Barbarian; Aristotle, indeed, claimed that they differed physically. To a certain extent it may be shown that in detail Aristotle had right on his side, but it can also be shown that Greek differs physically from Greek, so that his general thesis is untenable. It is true that most of our evidence rests on measurements made on modern Greeks, but there are data to prove that the latter possess physical characteristics not differing essentially from those of the former.

Among recent writers it has been generally admitted that at least two races are represented in Greek lands—the "Mediterranean" and the "Alpine." The former are short in stature, dark in colouring, and long-headed, typically represented by the Spaniards; the latter are fairer, and often, but not invariably, have auburn hair and hazel eyes, and vary very much in stature. The Eastern branch of the Alpines are usually known as "Armenoids." They are distinguished by their short, high heads, which are extremely flattened in the occipital region. It has also been suggested that long-headed, blond giants—Nordic—have contributed to the population of Greek lands.

Of the aboriginal population there is little evidence at present. Von Luschan believes that, at any rate in Anatolia, the earliest people were Armenoids, and in the Morea Prof. Myres considers that the Alpine strain is certainly ancient and may even be primitive. Early material is, however, so rare that it is easier, in stating the problem before us, to reverse the time process and to study the ancient people after the modern, about whom we are better informed.

The mean cephalic index in Greek lands to-day varies from 79 in Crete to 84 in the island of Leukas. None of the Greeks are as long-headed as the pure Mediterranean type, such as we find in a comparatively pure form in Corsica or Spain and in a less pure form in Egypt; nor, again, are they as broad-headed as the Lycian gipsies, who certainly represent pure Armenoids. If we group such cephalic indices on the living as are available, we obtain three classes: (1) Under 81, Cretans, Peloponnesians, Lycians (Greeks and Turks); (2) intermediate, Messenians and Cypriots; (3) more than 84, Leukadians, Albanians, Lycian gipsies. It would appear unlikely that this grouping is of any significance, if we turn from these figures to the variation, conveniently measured by taking the square root of the average square deviation from the mean (standard deviation). The Lycian Greeks and Turks have a very high standard deviation, suggesting considerable mixture, and the standard deviation of the cephalic indices of all the Greeks is sufficient to suggest a greater or less degree of intermixture. The condition of intermixture in Cyprus can be seen in Fig. 1—a photograph of a Cypriot woman and her three children. The elder boy might easily have been taken for an almost