XLII.—*On the various Modes of Coloration of Feathers.* By M. VICTOR FATIO*.

THE various plumages of birds have been studied in all times, and their difference of coloration has been in the present day the subject of many interesting works. The question of changes of plumage has presented itself in various ways. Is a new coloration always the peculiarity of a new feather? or may the coloration sometimes undergo alteration in the same tissues? Each of these notions has had its defenders; but the second gradually increasing in probability, it has become necessary to find out how and by what means these internal modifications take place.

Schlegel†, in 1852, supposed a new life in the feather at the approach of spring; and most of the naturalists who have paid attention to the subject since his time have sought rather to throw over this first hypothesis than to substitute for it a new and plausible explanation of the phenomenon.

Nevertheless some theories put forward during the last few years have still further subdivided the question. Weinland‡, supposing that a pigmented fat came from the body to colour the dead feather afresh, did not believe in the presence of what may be called a latent colouring principle beneath the apparent colour.

Severtzof§ believed in this primitive inherence of the new colouring matter, and put forward the ozone of the air as the modifying agent of the coloration in general.

As none of these methods satisfy the mind, and especially as none of them can sustain a careful observation, I have taken up the question by commencing with the study of the growth and anatomy of the feather, which must hereafter facilitate that of the ulterior developments.

I shall not enter here upon the details of these preliminary researches, but will confine myself to citing briefly the points most indispensable for the comprehension of my subject. I shall state, in the first place, that each feather consists of—

1. A central stalk, or primary axis.
2. Numerous barbs arranged on the sides of this first stem, and forming, as it were, branches or secondary axes.
3. Numerous barbules regularly implanted upon the barbs, and forming tertiary axes.

* Translated by W. S. Dallas, F.L.S., from the 'Bibliothèque Universelle,' March 25, 1866, Archives des Sciences, pp. 244–254.

† Naumannia, vol. ii. 1. p. 2.

‡ Zur Verfärbung der Vogelfeder ohne Mauserung, Cabanis, iv. 1856.

§ Mikroskopische Untersuchungen über die Verfärbung der Federn, &c.

4. Small lateral hooklets, forming, as it were, the branches of the latter, or quaternary axes.

I may then indicate that each of these parts is also composed of an exterior *epidermis* with flat and irregular cells, of a *cortical matter* formed of cells more or less elongated into fibres, of a coloured *medullary substance* in rounded or polygonal cells in the interior, and of *pigment-granules* scattered or grouped in the centre of each segment of each axis.

Lastly, I may state that the feather is formed in the interior of the corium at the expense of plastic cells which become organized in a protective sheath, and that, in growing, they push before them the down which prepared their path in the young bird.

Cuvier*, Reclam†, Engel‡, Holland§, and many others have written so much upon the development of feathers, that I may abstain from touching upon this point. When once grown, the feather has already received all the coloured principles that it can ever derive from the body; the bloodvessels which have nourished it become gradually obliterated, and its interior medulla dries up by degrees.

This being established, I commenced by studying the modifications due to actual moultings, or to changes of feathers; but I shall not enter here into any details, in order to arrive more speedily at the true purpose and actual result of my investigation—namely, the various modes of coloration in the same feather.

Every bird presents different aspects according to its age and sex and the season; but it also varies according to the localities which it inhabits, and the food which it finds there. The blood, modified by these various internal or external influences, furnishes the new feathers with diversely elaborated pigments.

A young bird, for example, at its first moult, will not receive either the same quantity or the same quality of pigment as an older individual. A male will not receive the same colouring matter as his female, or, rather, he will receive a substance which, although at first analogous, will be capable of modification in a different manner. Lastly, an old individual will always receive only the same quantity of the same pigment, so as constantly to present a similar plumage.

* F. Cuvier, Observ. sur la Structure et le Développement des Plumes (Mém. du Musée d'Hist. Nat. tome xiii.).

† C. Reclam, De Plumarum Pennarumque Evolutione. Leipzig, 1846.

‡ Jos. Engel, Ueber Stellung und Entwickelung der Feder (Wiener Sitzungsber. Bd. xxii., 1857, pp. 376–393).

§ F. Holland, Pterologische Untersuchungen (Journal für Ornithologie, 1864, vol. xi.).

A feather grown in autumn becomes modified in the spring, if it is not renewed; but at the same time it passes by degrees from a death which was only apparent to a more and more real death, until a moment will arrive when it must be expelled and replaced by another, presenting certain forms and proportions and a determinate coloration.

At the approach of cold, a new feather, longer and warmer because it has been less worn, comes to replace the old one; in the spring a more brilliant plumage decorates the bird, which is preparing for its nuptials.

When, in the spring, a bird cannot cover itself with a new clothing, it refreshes its old plumage by picking off the worn ends and retaining what still remains good. It is precisely this refreshing, and the new tint thus produced, that I have more particularly endeavoured to study in the present memoir. I have attempted, in taking up the question, always to reproduce artificially what I supposed must have taken place in nature.

A new coloration may appear in a feather, slowly, and even commencing in the autumn, or more rapidly, only in the spring; it may also consist in a simple augmentation of the intensity of the former coloration, or be in complete contrast with it.

The external or internal conditions which may act upon the feather are *the humidity of the air, temperature, light, movements, and the grease of the bird.* The modifications produced by these agents are *the various development of certain parts, the solution and diffusion of the internal pigment,* and *the rupture of the external parts.*

The humidity of the air causes the cortical substance of a feather to swell, and thus facilitates the communication between the constituent cells and fibres. A colourless liquid fat, arriving either by the interior or the exterior of the feather, dissolves the latent colouring fatty matter in the centres; the intensity of the colour is then simply augmented in certain cases, whilst in others the old colour is replaced and driven outwards by the new one, which spreads and forces it to become extravasated throughout in the form of an external powder. A slightly elevated temperature facilitates these chemical actions; winter slackens them; great cold arrests them almost entirely. Light seems, as it were, to direct the deposit towards those surfaces which are most exposed to it.

A feather thus becomes coloured more or less rapidly, but always from the periphery to the centre, as the extreme parts of the new feather are the first and the most exposed to the influences of the circumambient air.

Moisture, which in course of time injures the cortical substance which it at first inflated, weakens and deteriorates the ends of all the feathers; the latter, torn off by friction at each movement of the bird, by degrees make way for the coloration manifested in other feathers beneath them.

During this time the lowest parts of the feather are gradually decolorized, not, as might be supposed, in consequence of an ascending current of colouring matter, but simply by the fall of the greater part of the coloured downy barbules.

All this takes place without any introduction of new blood, without any resurrection of the "soul of the feather," and solely, as I have just said, under the influence of moisture externally and of the fat in the interior. I have produced and studied under the microscope both the development of the cortical substance and the internal solution of the different pigments in the barbs and barbules.

Conditions of climate and food produce varieties in nature, just as the different influences and the more or less abnormal diet to which we subject birds in captivity cause their plumage to vary. We may, for example, obtain albinism, either by an impoverishment of the blood so that it may no longer furnish colouring matters to the feathers, or by a complete extravasation of all the internal pigment. Nevertheless, although the solution takes place everywhere in the same way, the coloration is not developed in the same manner in all feathers.

Bogdanow *, who has occupied himself with the chemical solution of the pigments of feathers, has distinguished in them two groups, in accordance with differences in their pigmentation. He has given the name of *optical* feathers (*optiques*) to those which always furnished him with a brown pigment and owed their variety of colours to light alone; and that of *ordinary* feathers (*ordinaires*) to those which contained variously coloured pigments. I have retained this primitive division, which the microscope has shown to be natural; but a deeper study has forced me to establish two new subdivisions—the *mixed* feathers (*mixtes*), dependent on the ordinary feathers, and the *enamelled* feathers, dependent on the optical. The comparative distribution of the cortical substance, combined with the different pigmentation, give these feathers their principal distinctive characters.

In the *ordinary* feathers, which contain various pigments, it is the barbs that possess the thickest layer of cortical substance. These barbs, in swelling, throw off their useless barbules, and in spring form as it were clubs, of which the coloration is the same both by transmitted and reflected light. These first feathers present plenty of brilliancy of colour, but never reflections.

* Étude sur les Causes de la Coloration des Oiseaux (Revue Zoologique, 1858, vol. x. p. 183).

In the *mixed* feathers the barbules are persistent, because the cortical substance is equally distributed in the two axes. In them the latent coloration is concentrated principally in the barbs, and these possess ready communication with the barbules. These second feathers, like the ordinary feathers, contain various pigments and sometimes present much brightness of colour; but they never possess reflections, and rarely so much brilliancy as the preceding ones.

In the *optical* feathers it is the barbule alone that can develope itself. It swells enormously, and very often swallows up in its mass its lateral hooklets, when it acquires a cylindrical or prismatic form. Sometimes in spring it may actually measure three or four times as much in diameter as in the previous autumn.

These feathers always contain brown pigments, and the separative septa of the superposed segments which compose each barbule are in them much stronger than in any other feathers. These third feathers present themselves under all forms, and of all the colours of the spectrum, but always with metallic reflections.

Lastly, in the *enamelled* feathers, it is again the barb that is developed and throws off the barbule, although these are nevertheless optical feathers, invariably furnished with dark pigments. In them the cortical substance has not been developed into fibres,—on the contrary, it presents itself in the form of large polygonal cells with the nuclei strongly coloured brown. On the dorsal surface of the barbs the cells, much less strongly coloured, are elongated and vertical, and form as it were a transparent external varnish of greater or less thickness. To this fourth kind belong some green feathers, and especially all the blue feathers without metallic lustre.

The observation of these four divisions allows us to establish the following general laws:—

1. *Of two successive axes, one is always developed at the expense of the other.*

2. *In the ordinary feathers, properly so called, the secondary axis predominates over the tertiary.*

3. *In the optical feathers, properly so called, the tertiary axis, on the contrary, predominates over the secondary.*

A. *The mixed feathers present a mean condition.*

B. *The enamelled feathers are optical in their pigmentation, and ordinary in their development.*

The *mixed* character is very often met with in a feather together with a development of another kind; but no feather can be at once ordinary and optical, any more than ordinary and enamelled or enamelled and optical.

The influence of humidity and light upon the development and coloration of the parts which are most exposed to them, readily explains why the dorsal surface of a feather is usually more highly coloured than its ventral or inferior surface.

Besides the coloration seen by transmitted light and produced by various pigments, which act the same part with light as any other coloured bodies, I explain the brilliancy of ordinary feathers, the coloration of enamelled feathers, and the varying metallic lustre of optical feathers by the following phenomena of interference.

The development of the cortical substance increases the brilliancy by multiplying the reflecting surfaces, and at the same time increasing their distance. The meeting of these rays, reflected at various distances, produces an effect nearly similar to that described by Dove * in some bodies. I should even be tempted to ascribe the production of the blue colour by the enamelled feathers to a phenomenon analogous to that by which the above learned physicist endeavours to explain the brilliancy and lustre of some bodies,—namely, to the superposition of a transparent reflecting layer (in my case slightly coloured) upon a base covered with dark-coloured designs. In fact, if I scrape away this external varnish at some point, the blue feather appears black or brown at this part.

In the lustrous optical feathers a new complication is added to these first effects. It indeed recalls the designs and streaks of Dove, but seems nevertheless to approach more nearly to the phenomenon of the coloured rings. This is a series of transverse lines, sometimes brilliant, sometimes obscure, corresponding with the strongly marked segmentation of the barbules, as may be easily ascertained by examining an opticalfeather with a low power under direct light. The effect of each barbule is added to that of the following one, and we always find a much more regular arrangement of the barbules in the feathers which have the strongest metallic lustre.

We must not confound the coloration extravasated in powder, of which I have spoken above, with another coloration deposited in the same form, but from the outside, upon the feathers of some birds. In the latter case, it is by rubbing against foreign bodies, vegetable or mineral, that some species cover certain parts of their bodies with a truly external and more or less solid coloration.

Nor must we confound the decolorization which takes place upon a living individual with that which occurs slowly in our museums. The decolorization in collections arises most frequently from a saponification of the coloured fatty matters, produced in course of time by air and light, as also from a disintegration

* Abhandlungen der Akad. der Wiss. zu Berlin, 1855.

of the epidermis and cortical substance, produced either by too great dryness or, especially, by too much moisture.

A closer investigation of feathers would perhaps explain the geographical distribution of colours modified by climatic influences, the formation of local varieties, or the parallel effects, often so curious, of captivity upon coloration.

XLIII.—*Contributions to an Insect Fauna of the Amazons Valley.* Coleoptera : Longicornes. By H. W. Bates, Esq.

[Continued from p. 303.]

Group *Astatheinæ.*

Genus Phæa, Newman.

Newman, Entomologist, p. 13.

Syn. *Lamprocleptes,* Thomson, Arch. Entom. i. 377.

The chief character which distinguishes this genus from *Tetraopes* (the chief American representative of the group Astatheinæ) is the form of the tooth of the claws. The tooth in *Tetraopes* is long and acute, running parallel to the claw itself, but much shorter; in *Phæa* it is very broad and short, adhering only to the base of the claw, as in the Callianæ. The eyes, as in the rest of the Astatheinæ, are completely divided. The body is more or less elongate and linear.

Phæa coccinea, n. sp.

P. linearis, brevis, coccinea, pube pallida sericea vestita; femoribus apice, tibiis, tarsis et antennis (basi exceptis) nigris. Long. $3\frac{1}{2}$ lin.

Head as broad as the middle part of the thorax, bright red; eyes moderately prominent, black. Antennæ about as long as the body, filiform, hirsute, black, basal half of the first joint red. Thorax constricted near the front and hind margins, surface strongly elevated and smooth in the middle, clothed with long erect hairs; bright red. Elytra linear, bright red, clothed with fine pale silky pubescence (visible only in certain lights), and with erect hairs, strongly punctate-striate, the punctures fainter and more confused towards the apex. Body beneath and thighs yellowish red; apex of thighs, tibiæ, and tarsi black.

Santarem.

Group *Amphionychinæ.*

[The Amphionychinæ are distinguished from the Phytœciinæ (both having bifid claws) by the sides of the elytra having a longitudinal carina extending from the shoulders.]