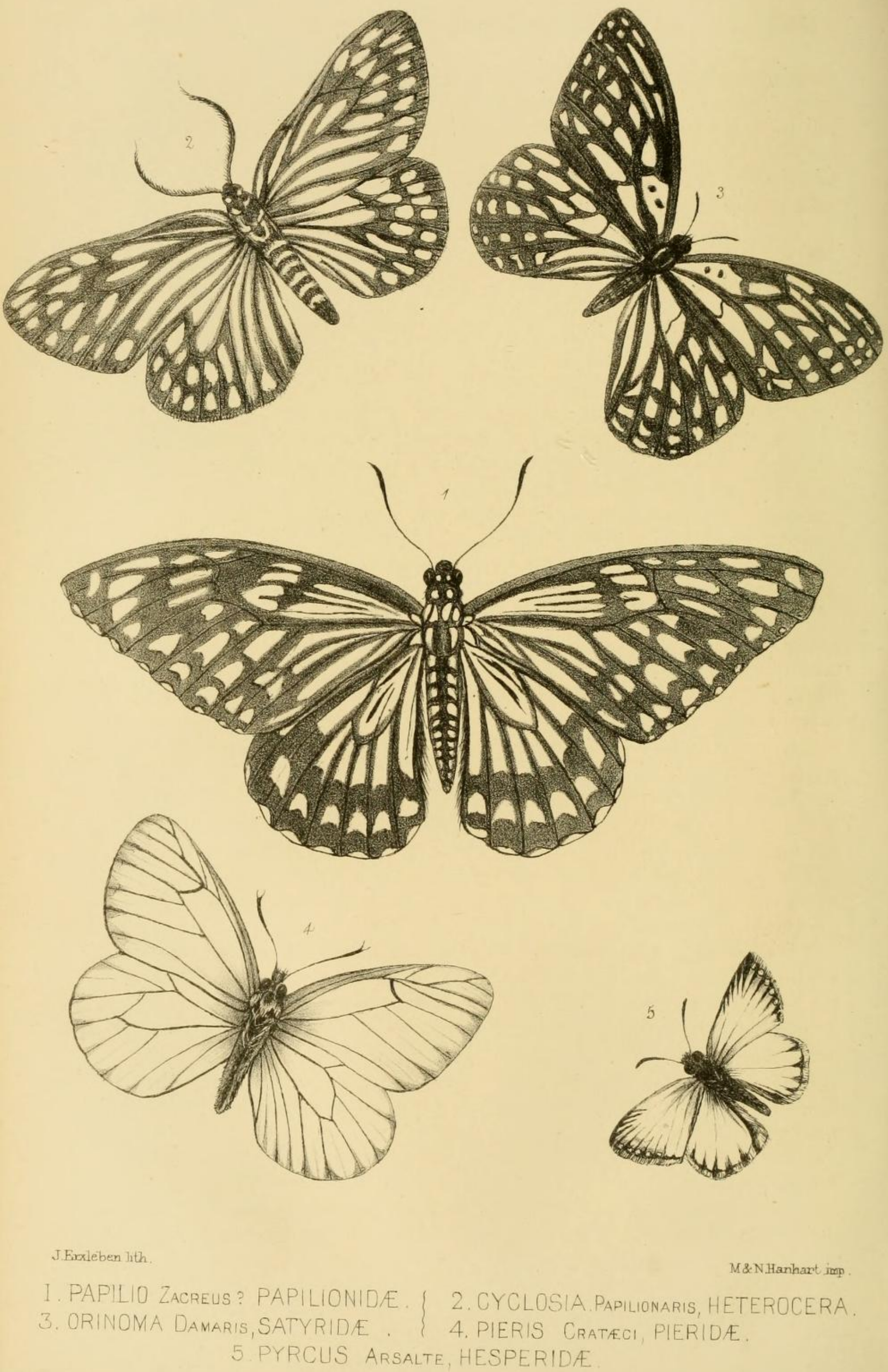

J.Erxleben lith.

M&N.Hanhart imp.

1. PAPILIO Zacreus? PAPILIONIDÆ. { 2. CYCLOSIA. Papilionaris, HETEROCERA.
3. ORINOMA Damaris, SATYRIDÆ . { 4. PIERIS Cratæci, PIERIDÆ.
5. PYRCUS Arsalte, HESPERIDÆ.

when it amounted to 15,000,000*l.* sterling, since which period the production of California has steadily declined, and the present annual return of the precious metal does not much exceed 5,300,000*l.*

The total value of the gold produced in the state, from the time of the discovery of that metal in 1848 to the close of 1866, is estimated at 167,260,000*l.*

III. ON THE COLOUR-PATTERNS OF BUTTERFLIES.

By Rev. H. H. Higgins, M.A.

The petals of flowers, the plumage of birds, the surfaces of shells, the hides of quadrupeds, the integuments of polyps, and the wings of insects, are some of the chief objects distinguished by a great variety of natural colour-patterns.

All that I propose to attempt in the present instance is to offer a few remarks on the proximate origin and general configuration of the patches, bands, and spots of colour which adorn the wings of the Rhopalocera.

By the use of the term "proximate origin," the inquiry is limited to the appliances immediately engaged in producing the results under consideration; an inquiry which cannot conveniently be separated from the question, whether amidst the apparently capricious and endless varieties of colour-patterns on the wings of butterflies, may be recognized the elements of a prevailing arrangement.

An example of the kind of agency contemplated may be found in the serrated edge of the leaf of a Potentilla, which, it is said, is the result of a certain configuration of organs discernible in the leaf-bud; or, again, the spines on the shell of a Murex, which may be shown to be the result of tentacular appendages periodically developed in the mollusc.

The physical conditions which have preceded so delicate a result as the shading of the colours on the wing of a butterfly, require a kind of investigation which must be attended with corresponding difficulties. But it will be admitted that in no case is a spot or a band added or obliterated except through the instrumentality of antecedents sufficient to produce the result in question. How far these antecedents are capable of being investigated has yet to be determined.

The rudiments of wings, according to Burmeister, may be observed when the caterpillar has completed its third moulting and has attained its full size. "They at first present themselves as short viscous leaves, the substance of which greatly resembles that

of the mucous tunic, and to which many delicate tracheæ pass which distribute themselves throughout them."

The wings in an imperfect condition, whilst still enclosed by the shell of the chrysalis, are closely folded together with many plications. Can any clue to the subsequent arrangement of the colours be found in the manner in which the wings are folded in the pupa state? If a scrawl of any kind be made on paper with a pen, and if the paper be folded, the ink being inside and still wet, a symmetrical pattern is produced, the sides of which, like the markings on the wings of a butterfly, exactly correspond. And it is manifest that under certain conditions of folding, colouring matter of any kind might, by a comparatively simple process of arrangement, produce patterns remarkable for symmetry and regularity.

In the limited number of instances in which I have been able to examine the sufficiently advanced chrysalis of a butterfly, nothing of this kind has been indicated: the like spots on the right and left wings do not, in the pupa state, coincide; the folds do not bisect the markings; that which becomes a beautifully formed band, begins as a mere line, or a shapeless spot; and this stage of the metamorphosis, if watched, conveys a decided impression that the resulting colour-pattern is not dependent on the folding of the wings in the immature condition.

The perfect wing of a Lepidopterous insect consists of a delicate double membrane, traversed between the folds by nerves or veins ramifying from the base. The wings are covered with minute scales of various shapes and colours, which, in combination, form a pattern much after the manner of the materials used by an artist in constructing a piece of mosaic work.

Three elements then are essential to the wing, the double membrane, the veins, and the scales covering both.

The simplest type of colour presents itself in the plain uniform tint, exhibited when the scales are all exactly alike. Examples of this are rare in nature. A variety of *Pieris rapæ* is almost wholly white; *Gonepteryx rhamni* is almost wholly yellow.

It seems probable, however, that the scales growing on the membrane upon or near the veins would be distinguished from the scales growing on other parts of the membrane by a freer development of pigmentary matter, and that in this manner would arise a kind of primary or fundamental pattern, namely, a pale ground with darker linear markings following the course of the veins, *e. g. Pieris cratægi.*

For the present we shall notice only the upper surface of the wings, in which the prevalence of the primary pattern is more clearly indicated.

Most butterflies exhibit some traces of the *black-veined white* pattern; and the pattern itself, with slight modifications, is found

in species belonging to eight of the fourteen families into which the butterflies are divided.* (See Plate.)

The fundamental character of this dark-veined pattern is confirmed by the closeness of the gradations connecting it with others apparently altogether distinct. For example, *Pieris brassicæ*, and some other insects of the same family, which are wholly white with the exception of a broad black tip at the apex of the fore-wing. Now several exotic species of *Pieris* present the dark veins expanded at the outer margin of the fore-wing into a deeply scalloped black border; others show the gradual fading of the lower portions of the border, together with attenuation of the venous markings in the disc of the wing, till the passage from the pattern of *P. cratægi* to that of *P. brassicæ* is made by almost imperceptible steps.

In the genus *Hestia*, the primary pattern is diversified by a great variety of black spots and blotches, which are all evidently dependent on the venation: the spots occupy a central position between the veins, or they are bisected by a false vein, or they are in pairs contiguous to a vein. In one fine species there is a broad, black band across the wing; but here (as in almost every other instance) the outlines of the black markings are strongly affected by the veins. We shall see, presently, that this is not the case with the brighter colours; but the black markings are very generally thrown nearer to or farther from the base by the passage of a vein, as geological strata are disturbed by the occurrence of a fault. Even where, as in *Euplæa Treitschkei*, only a small spot or two of white is shown on the wings, it is pretty plain that the ground-colour of the wings is white, almost wholly obscured by a greater development of the dark scales belonging to the veins.

The scalloped border has been referred to; and as the scalloped band, nearer to or farther from the margin of the wing, is one of the most prevalent kinds of markings, it may be well to see how readily it may arise from the primary pattern. Let it be supposed that at a given distance from the base a portion of the dark scales begin to diverge on each side from the veins. The dark lines thus formed will meet in the middle of the areas between the veins, producing a band of scallops having their concavities towards the base of the wing. If the divergence takes place towards the base, scallops are formed having their convexities in the same direction. If the latter mode of divergence be quickly followed by the former, a row of annular markings between the veins is the result. In this manner may be obtained the simplest and most elementary form of the annular or ocellate spot, which in the higher stages of development becomes distinguished for its variety and exquisite beauty. Of this, more hereafter.

* Even in the less likely families, *Nymphalidæ* and *Satyridæ*, it occurs in *Penthema Lisarda*, *Orinoma Damaris*, and other species.

Before leaving the subject of the dark vein scales, it may be desirable again to refer to the folding of the wings in the pupa state; for although the pattern is not supposed to be the result of the plications, yet the compressed condition of every part of the wing, whilst in the chrysalis, must be borne in mind. The divergence of a portion of the vein scales to form scallops is difficult to be conceived if we regard the process as wrought in the fully expanded wing; but the whole scallop is a microscopic speck, and the direction of the divergence quite indistinguishable in the pupa state. Yet in this state, whilst the vessels are soft and permeable, the scheme of the future pattern is, no doubt, fully organized, so that the most minute extension this way or that from the incipient vein, of the dark pigment bearing germs of scales, when inflated, expanded, dried and hardened in the wing of the imago, becomes a band, or a scallop, or a ring, according to the original construction and direction.

From the vein scales, then, are supposed to arise all the darker markings which limit and sometimes enclose the areas occupied by the paler ground-tint; frequently, in fact, extending over the greater portion of the surface of the wing. These darker markings are manifestly affected by the passage of the veins, and very commonly, though not always, are distinguished by an outline more or less sharp and distinct.

We come now to inquire into the modifications observable in the paler ground-colour, proper to the scales growing on the spaces between the veins, and often extending over the veins themselves. The first and most obvious modification is the deepening or intensifying of the colour in certain parts of the wing: thus, yellow becomes bright orange; white becomes yellow or scarlet; a pale buff becomes bright testaceous, &c. The transition is generally gradual, the richer being shaded off at its edges into the paler colour. Indeed, so characteristic of the ground-pattern is this kind of shading, that I propose to call the area occupied by the brighter and more intense hue, the "blush." A very satisfactory example of the blush is seen in *Gonepteryx Cleopatra*.

Belonging essentially to the membranous portions of the wing, the blush should not in its contour be affected by the veins, and for the most part it seems to be remarkably independent of them. It occurs in all parts of the wing, at the tip or in the disc, at the margin or, less frequently, near the base, often at the anal angle of the hind wing; but wherever it occurs, it seems to be neither limited nor extended by the veins. It is of course liable, like the ground-colour to which it belongs, to be parted into bands or spots by the dark vein scales; in fact, the whole area of the blush is seldom seen, and more frequently than otherwise the junction of the blush with the pale tint, or rather the space where the junction

might have been, is occupied by expanded parts of the black venous pattern.

The blush is not always shaded at its junction with the paler tint, especially where it takes the form of a patch or a spot; as in the tip of the fore-wing of the male of *Anthocharis Cardamines*, the spot in the fore-wing of *Gonepteryx Rhamni*, and that on the anal angle of the hind-wing of *Papilio Machaon*.

In *Vanessa Cardui* the blush is suffused over the greater part of the fore and hind wings, the pale ground colour appearing in spots towards the tip of the fore-wing, on the under side of which the "blush" character of the rose-tint is more plainly exhibited.

In *Vanessa Atalanta* a similar disposition of colours is observable, but the black vein-scales cover a larger portion of the wings, the bright scarlet of the blush being shown in a band on the fore-wing and on the margin of the hind-wing.*

The shading of the paler into the brighter hue is well seen in *Vanessa Urticæ*.

The testaceous colour of the *Fritillaries* I am inclined to regard as a blush, uniformly suffused over the whole area of the wings. The dependence of the black scales on the veins is seen throughout the tribe.

In *Papilio Hector* the blush is exhibited in the crimson spots on the hind wings.

In *Thais Rumina* the blush is broken up into spots, but it will be observed that the crimson spots have black edges, and are rarely bordered by the yellow ground-colour.

We have now observed three important elements in the colour patterns of butterflies: the pale ground-colour; the dark markings due to the vein scales; and the more or less richly-tinted blush; a fourth remains to be noticed.

Hitherto, the scales themselves have presented no very marked distinctions; the black scales, colour excepted, are in appearance exactly similar to the adjacent white or red ones. Under a magnifying power and by transmitted light, all are found to contain appropriate colouring matter; thus, an orange band is made up of orange-coloured scales, and a black marking of dark and nearly opaque scales.

But conspicuous on the wings of butterflies are certain other hues, and these the most splendid of any, which when examined by transmitted light are found to be produced by scales not of corresponding colours. *Lycæna Adonis*, the most brilliant of the British "Blues," has scales altogether colourless; the deep purple on the wings of *Apatura Iris* is produced by scales the colouring matter of

* That the scarlet band is a blush, shown as it were through an opening in the black scales, appears from the under-side of the fore-wing. This is seen still more plainly in the allied species *Pyrameis Gonerilla* from New Zealand.

which is brownish black. A similar hue on *Thecla Quercus* is formed by scales the colour of a dark cloud. The brightest scales on *Lycæna Phlæas* are of a watery burnt-sienna hue. Far more striking discrepancies between the transmitted and reflected hues of scales might be quoted from exotic butterflies: I have selected these because the insects are more familiarly known. Viewed as opaque objects, even under a moderately high magnifying power, at the proper angle the reflected hue comes out superbly, but when the light is sent through the scales, a pale, or dull dark tint is all that is observable.

These scales therefore exhibit the phenomena of iridescence, and their hues are derived, not from the colouring matter present in them, but from striations upon their surfaces; not, however, from the striæ which under a microscope may be seen on all Lepidopterous scales, but from others far more minute, surpassing, probably, in delicacy and uniformity, anything elsewhere to be found in nature. The surfaces of iridescent bodies, such as mother-of-pearl and some of the ores of iron and copper are often very gorgeously tinted, but their hues are mixed and irregular, whereas nothing can exceed the purity of colour exhibited by patches of these iridescent scales, indicating a wondrous exactness in the intervals between the striæ.

For convenience, I shall call the feature produced in the colour-pattern by these iridescent scales, the "gloss."

The gloss seems to have towards the dark vein scales the same kind of relation which the blush has towards the pale ground-colour, except that it seems to be rather charged upon, than shaded off into, the venous scales, being sometimes, as it were, sprinkled or dusted upon them, as in *Papilio Paris* and *Teinopalpus imperialis*.

The gloss is rarely seen to form sharply-defined bands or patches, nor does it often come in contact with the ground-colour or the blush, being almost always surrounded by a black border: it frequently suffuses the whole wing,* and is often pierced by the black vein scales, which show themselves as spots in the midst of it.

In rare instances, highly-coloured scales, belonging to the blush, exhibit iridescence; when this occurs the result is exquisitely beautiful. Thus, in *Papilio Vertumnus*, a patch of carmine scales on the hind-wing is glossed so as to show an amethystine hue when seen obliquely; and in one rare species of *Ornithoptera* the yellow patch on the hind-wing has similar reflections. In these butterflies the carmine and yellow hues are the results of corresponding pigment granules; the amethystine gloss arising from iridescent striæ on the surfaces of the scales which contain the pigment grains.

It is a source of much gratification in all branches of natural history, to observe the modifications of an organ through a series of

* As in some *Morphos* and many of the *Lycænidæ*.

species, in one or other of which it may become so changed in appearance, that its identification is possible only by a close comparison between the many links which connect its most abnormal forms with those in which it is ordinarily found.

I have often felt the want of a *rationale* of this kind, in admiring the colour-patterns of butterflies, and have endeavoured to trace a kind of homology between their respective constituents.

For a long time the case seemed hopeless; but opportunities having been afforded me of examining a moderately large number of *Rhopalocera* from most parts of the world where they abound, many apparent anomalies were found to be so only because intermediate forms had not previously been known to me. Thus, for instance, I have ventured to speak of the red spot at the anal angle of the hind-wing of our British Swallow-tailed Butterfly as a form of the "blush." British butterflies alone considered, this must appear to be simply fanciful; but any one who will examine even a limited number of species of the large genus *Papilio* will, I think, be satisfied that the red spot on the hind wing of *P. Machaon* is a modification of the richer tinting of the pale ground-colour, such as may be seen in its more ordinary form in *P. Zagreus* (Doubleday), and in a striking intermediate form in *P. Iswara* (White).

I have only touched on the elementary portion of the subject; more minute details must be reserved for another occasion; but I venture to hope that the present very imperfect account of an attempt to classify the colour-patterns of butterflies may not be uninteresting to their admirers, and may lead to further investigations by more able observers.

IV. THE MODERN ASPECTS OF PHYSICAL SCIENCE.

If we examine with thoughtful deliberation the aspects of Physical Science as they are now presented to our mental vision, we arrive at the conclusion that much uncertainty surrounds them, and we feel that with the advance of knowledge we shall have to modify many a pet hypothesis and, possibly, to abandon some favourite theories which have held their position by the weight of the great names by which they have been supported.

We have before us ten works, each one of them excellent in its class,* and in their entirety fairly representing the conditions of the

* 1. 'The Elements of Natural Philosophy; or, an Introduction to the Study of the Physical Sciences.' By Charles Brooke, M.A., M.B., F.R.S. Churchill.

2. 'Heat considered as a Mode of Motion.' By John Tyndall, F.R.S. Longmans.

3. 'Faraday as a Discoverer.' By John Tyndall. Longmans.