from a similar string sounding, and give out the note in a weakened degree, so a source of light of a particular colour will receive light from another source of precisely the same colour, and appear to give it out in a weakened degree—in other words, the vapour of a metal at a lower temperature will absorb exactly those rays which it will emit at a higher. This is the principle enunciated by Kirchoff, and one of his experiments in support of it was this: A continuous spectrum was obtained with the oxy-hydrogen limelight, and a yellow sodium flame was interposed between the light-source and the spectroscope, as in our experiment with the iodine and oxides of nitrogen. A dark line appeared where the yellow luminous sodium line ought to have been. The great importance of the discovery lies in this, that if we have a spectrum with a series of dark lines in it, and we find a metal whose luminous vapour gives corresponding bright lines, then we may safely say that the dark lines are produced by this metal. Turn to the figure of the solar spectrum: there is a double line lettered D. This double line is emitted by glowing sodium vapour. There is sodium vapour, then, in the atmosphere of the sun. The mystery is solved!

The Fraunhofer lines tell us that there are in the atmosphere of the sun, hydrogen, sodium, barium, calcium, magnesium, aluminium, iron, manganese, and a great many other metals. They tell us that the exceedingly hot nucleus of the sun is surrounded by cooler metallic vapours, which are yet so very hot that the metals exist in a state of vapour (p. 77).

In 1861 Huggins and Miller turned their attention to the spectroscopic study of the stars, and some of these, like the stars Aldebaran and Betelgeux, they found to give spectra of dark lines. These dark lines they compared with the bright lines produced by terrestrial substances, finding indications of hydrogen, sodium, magnesium, calcium, iron, bismuth, tellurium, antimony, and mercury, in Aldebaran; and sodium, magnesium, calcium, iron, and bismuth, in Betelgeux. These important investigations teach us something positive about the stars: that, like the sun, they have a community of matter with the earth; and that, like this centre of our system, many of them must be sufficiently hot to have metals in the vaporous state which on the earth are solid even at comparatively high temperatures. They may be worlds on the way to become like our own, cool and habitable; and doubtless untold ages ago our earth was in the same plight, this being attested by its present shape, its hot springs and lava-emitting volcanoes.

THE PROTECTIVE COLOURS OF ANIMALS.

By Alfred Russel Wallace, F.L.S., Author of "The Malay Archipelago," etc.

TO the ordinary observer the colours of the various kinds of molluscs, insects, reptiles, birds, and mammals, appear to have no use, and to be distributed pretty much at random. There is a general notion that in the tropics everything—insects, birds, and flowers especially—is much more brilliantly coloured than with us; but the idea that we should ever be able to give a satisfactory reason why one creature is white and another black, why this caterpillar is green and that one brown, and a third adorned with stripes and spots of the most gaudy colours, would seem to most persons both presumptuous and absurd. We propose to show, however, that in a large number of cases the colours of animals are of the greatest importance to them, and that sometimes even their very existence depends upon their peculiar tints.

It is an almost universal rule that each animal either has enemies which seek to feed upon it, or that it seeks itself to feed upon other animals. In the first case, it has to escape its enemies or it cannot long continue to live. This it does either by its swiftness of flight, by its watchfulness, or by hiding itself from view. Some species come abroad only at night, some burrow under ground, many hide themselves among leaves, or bark, or stones, and thus escape destruction. Their enemies, however are as swift and as watchful as they are themselves, and they can in most cases only escape them by avoiding observation. To do this, they must not be too conspicuous; and thus any kind of colouring that renders them hardly visible while seeking their food or attending to their young, actually tends to preserve their lives, and often alone enables them to secure the safety of their offspring. But the enemy who is in pursuit of them is in just the same predicament. He, too, must be concealed by his colour, or he will be seen

afar off and his prey will seek a secure concealment. In that case he will simply starve to death, and his race will cease to exist. It thus appears that almost every kind of animal requires concealment; and it might therefore be thought that colour must always be injurious, and ought never to exist. And as colour not only exists, but abounds among the various classes of animals, it may be thought that we have here a *reductio ad absurdum*, and that protective colouring cannot be of much importance.

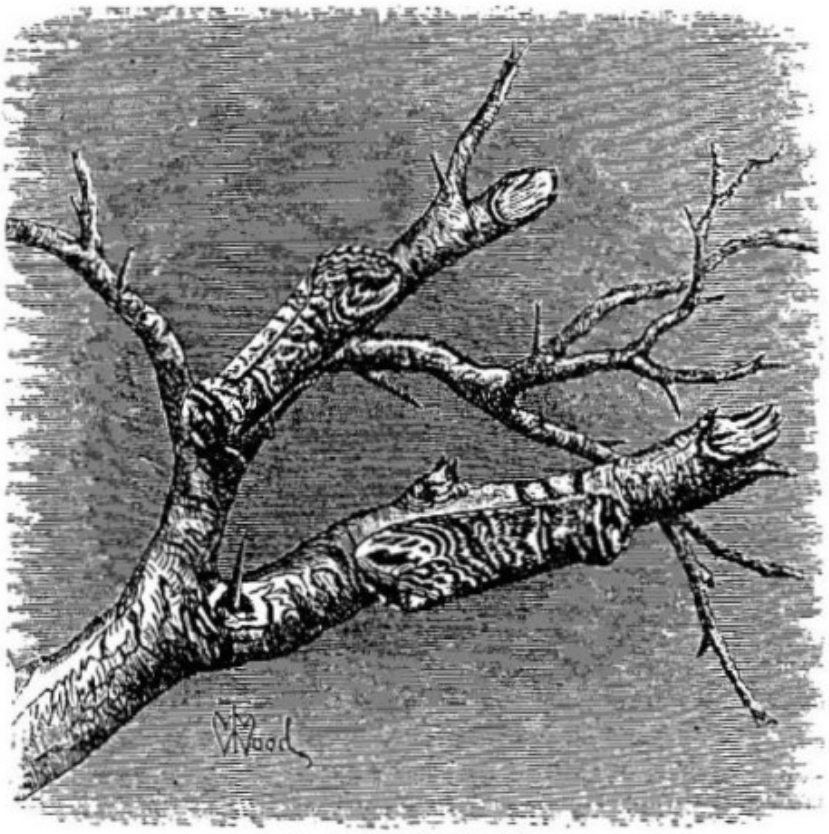

Fig. 1.—The Buff-Tip Moth.

Further examination, however, shows us that even gay colours are very often protective, because the earth and the sky, the leaves and the flowers, themselves glow with pure and vivid hues. In other cases conspicuous colouring is useful to an animal, as when it is protected by the possession of a deadly sting or a nauseous taste, and the bright or unusual colour warns its would-be enemies to avoid it. There are also a great number of animals who appear to be sufficiently able to take care of themselves without resorting to concealment, and with these the tendency to the production of colour, which seems to be inherent in organic beings, exhibits itself unchecked. Taking all these facts into consideration, we find that there is an ample field for the development of bright and conspicuous colour on the one hand, and for the display of an infinite variety of protective tints on the other, dependent on the structure, the habits, and the instincts of the different kinds of animals.

Let us now consider a few familiar examples of protective colouring. Owing to the mildness of the winter of 1877, and the dampness of the following spring, my garden was overrun with slugs, and I had to wage continual war against them. On every damp evening I would go round the borders, examining the choicest plants, and, taking the slugs off with a knife, deposit them in a jar of strong brine. While doing this, many of them, on being touched, would contract and drop to the ground, and though they fell close under my eyes, I often had some trouble to find them again, owing to their close resemblance to the small pebbles with which the soil abounded. They varied in colour from nearly white, to brown, yellow, and nearly black, and when contracted into an oval lump, they were exactly like the variously-coloured wet pebbles. One black slug with an olive-yellow under-surface, when

contracted was wonderfully like a blackish flint pebble broken in two, showing the yellowish inside so common in such stones. It may be said that this was only an accidental resemblance, and at first it did not strike me as being anything else; but when, time after time, I lost sight of a slug beneath my very eyes, and had often no other means of finding it again but by touching the various small stones with my knife till I found a soft one, the conviction forced itself upon me that here was a case of true protection by colour among animals of our own country, before proceeding to those more wonderful developments which occur chiefly in tropical lands. Every collector of beetles must have observed how many of our *Curculionidæ* or weevils are brown or speckled, and also that they have the habit, on being touched or alarmed, of falling down on the ground, drawing in their legs and antennæ, and there becoming undistinguishable from small lumps of earth or stones. Others, however, which are found

Fig. 2.—The Lappet Moth.

protection, and that what deceived me would also probably sometimes deceive the birds and other animals that feed upon slugs. In the tropical forests I had often in the same way to resort to the sense of touch to supplement that of sight, in distinguishing between the phasmidæ or "stick insects" and real pieces of stick; and as in this case it is universally admitted that the resemblance is a protection to the insects, since it saves them from the attacks of the numerous tropical insectivorous birds, we may well believe that our familiar slugs are similarly protected from the thrushes and other birds which feed upon them.

We will now consider some other cases of pro- constantly on nettles and herbage, are beautifully green, and these usually run or fly away when alarmed. A curious little beetle, *Onthophilus sulcatus*, is brown and furrowed, so as exactly to resemble the seed of some umbelliferous plant. The beautiful Musk-beetle, which usually rests upon the leaves of willows, is green; while the Saperdas and Rhagiums, which frequent timber or posts, are invariably brown or yellowish. It is, however, among our moths, which are at once more conspicuous and more defenceless, that the best examples of protective colouring in this country are to be found. The beautiful green *Agriopis aprilina* and the dusky *Acronycta psi* rest during

the day on the trunks of trees, and are often completely concealed by their resemblance to the green and grey lichens which surround them. The Lappet-moth (*Gastropacha quercı*), when at rest, so disposes its rich brown wings as to resemble, both in shape and colour, a dead leaf (Fig. 2); while the Buff-tip moth (*Pygæra bucephala*) so contracts its wings that it looks exactly like a thick piece of broken stick, the yellow patch at the extremity of the wings giving the appearance of the freshly-broken end (Fig. 1). a leaf, and, *vice versâ*, the dung for the moth. Two other moths, *Bryophila glandifera* and *B. perla*, are the very image of the mortar walls on which they rest; and in Switzerland I amused myself for some time in watching a moth, probably *Larentia tripunctaria*, fluttering about close to me, and then alighting on a wall of the stone of the district, which it so exactly matched as to be quite invisible a couple of yards off." It has also been noticed that the general tints of the moths which are on

Fig. 3.—Jacobea Caterpillars.

This is a case which well illustrates how impossible it is to decide from the appearance of a specimen in a cabinet whether the colours of an animal are or are not protective, for no one would imagine that this handsome and conspicuously-coloured moth could ever deceptively resemble a bit of dead stick, and so obtain protection from its enemies. It is a very common thing in the tropics to find beetles and moths which resemble bird's droppings, and the same occurs in this country; for Mr. A. Sidgwick, in a paper read before the Rugby School Natural History Society, says: "I have myself more than once mistaken *Cilix compressa*, a little white-and-grey moth, for a piece of bird's dung dropped upon the wing in autumn and winter correspond to the prevailing hues of nature at those seasons. The Rev. Joseph Greene states that the great majority of the autumnal moths are of various shades of yellow and brown, like those of the autumnal foliage; while the winter moths of the genera *Cheimatobia* and *Hybernia* are of grey and silvery tints.

It is among the caterpillars, however, that protective colouring is the most general and conspicuous. An immense number of these creatures are green, corresponding with the tints of the leaves on which they feed, or brown when they rest on bark or twigs; while a large number of the larvæ of

the Geometridæ or Loopers have the habit of sticking themselves out rigidly like sticks, which they exactly resemble in shape as well as in colour. Every one knows, however, that there are a number of very brightly-coloured caterpillars, and it may be asked how these are protected, or why the others need protection if these can do without it. The answer to this question is most instructive, and affords the most conclusive proof that various examples of protective tints in nature really have the effect we impute to them. It has been found by repeated observation and experiment that every green and brown caterpillar, without exception, is greedily eaten by birds, and even by frogs, lizards, and spiders, and that they endeavour to conceal themselves from these numerous enemies by feeding usually at night, while during the day they remain motionless upon leaves, twigs, or bark, of the same colour as themselves. The brightly-coloured caterpillars, on the other hand, were found to be universally rejected by birds when offered to them, and even by lizards, frogs, and spiders. None of these would touch the common spotted caterpillar of the magpie moth (*Abraxas grossulariata*), nor those of the *Cucullia verbasci*, *Callimorpha jacobeæ* (Fig. 3), or the *Anthrocera filipendulæ*. Sometimes the caterpillars were seized in the mouth, but always dropped again, as if in disgust at their taste. The same rule was found to apply to all the hairy or spiny caterpillars; and, what is very interesting, the habits of these creatures are correspondingly different from those of the green and brown eatable species. They all feed during the day; they do not conceal themselves, but feed openly, as if courting observation, and secure in the knowledge of their safety from all enemies.*

This connection of gay colours and bold habits with non-edibility, throws light on many other cases of bright colouring which might otherwise be adduced as opposed to the theory of protection. Thus, among our beetles we have such conspicuous creatures as the lady-birds (*Coccinellidæ*) and the "soldiers and sailors" among the Malacoderms, which are all conspicuous and defenceless insects, never hiding themselves, or seeking concealment, or feigning death, as do so many other beetles. The reason is now found to be that, like gaudy caterpillars, they are generally unfit for food. The same explanation may be given of the conspicuous whiteness of certain moths. One of these, *Spilosoma menthrasti*, is very common, but when given by Mr. Stainton to a brood of young turkeys among hundreds of other worthless moths after a night's "sugaring," it was always rejected, each bird in succession picking it up and then throwing it down again, as if too nasty to eat. The same thing has been observed with the showy butterflies forming the family *Danaidæ*. Insect-eating birds were observed by Mr. Belt in South America, catching butterflies which they brought to their nest to feed their young; yet during half an hour they never brought one of the Danaidæ, which were flying lazily about in great numbers.

But there are other modes of protection, besides a nauseous taste which renders concealment unnecessary. Either weapons or armour have the same effect, if they are sufficiently perfect of their kind to render it useless or dangerous for their enemies to attack them. The best example of armed insects are the bees and wasps, and among these conspicuous colours are the rule, while they usually fly about and seek their food without any attempt at concealment. Other insects have so hard a covering, or such awkward spines, as to be practically uneatable, and among tropical insects many of these are conspicuously or gaudily coloured. One of the few examples we have of this group are the little Ruby-tail wasps (*Chrysis*) which have no stings, but have the power of rolling themselves up into a ball, which is very hard; and they are so gorgeously coloured as to appear like some curious jewels. Others, again, obtain protection by extreme rapidity of flight, and by concealing themselves in holes or among flowers when at rest, and these are often brilliantly coloured, as in the case of the common Rosechafer. These few examples are merely intended to show that it is no argument against the use of protective colours in some animals, that many others have brilliant and clearly non-protective hues. In those cases, the creatures have certainly some substitute which enables them to live and continue their race. What this substitute is we can in some cases find out, but in many others we are too ignorant of the habits and surroundings of the species to determine whether its peculiar colours are or are not protective, or, if they are not, to determine what are the peculiar conditions which enable it to dispense with this particular kind of safeguard. An excellent example of a brilliantly-coloured insect, which yet obtains protection by its colours, is afforded by the caterpillar of the Emperor moth (*Saturnia pavoniaminor*). The green body adorned with pink spots

* For a full account of these interesting experiments, see "Contributions to the Theory of Natural Selection," 2nd Ed., p. 117.

is pre-eminently beautiful, and in most situations conspicuous; but it feeds on the common heather, and its colours then so completely harmonise with the young green shoots and small pink flowers, that it is with difficulty detected.

Leaving now these familiar examples, to be found everywhere around us, let us cast a glance over a wider field, and see how the general conditions of existence, affecting many different groups of animals at once, influence their coloration for protective purposes. And first let us transport ourselves to the great deserts of the earth, and inquire what kind of animal life we find there. Canon Tristram has travelled much in the Sahara, and he thus describes the characteristic colours of its animal life: "In the desert, where neither trees, brushwood, nor even undulations of the surface, afford the slightest protection against its foes, a modification of colour which shall assimilate an animal to that of the surrounding country is absolutely necessary. Hence, without exception, the upper plumage of every bird, whether lark, chat, sylvian, or sand-grouse, and also the fur of all the smaller mammals, and the skin of all the snakes and lizards, is of one uniform isabelline or sand colour." This is not a characteristic of one desert, but of all. In a recent account of the Steppe of Erivan in Asia Minor, it is said that "a remarkable feature of the animal inhabitants of the Steppe, insects and reptiles, and especially of the lizards, is the most perfect coincidence of their colouring with the colouring of the Steppe." More prominent examples of this prevalent tint are such animals as the camel and the lion, which are exactly of the usual tints of sand and sandy rock.

Let us go now to the arctic regions, and we find these reddish-yellow tints entirely wanting, and instead of them pure white, or in a few cases dark-brown or black, where conspicuousness seems of more importance than concealment. All the bears of the globe are brown or black, except the polar bear, which is white. The polar hare, the snow-bunting, the snowy-owl and the jer-falcon, are also white or nearly so; while the arctic fox, the ermine, and the Alpine hare, change white in winter, as does our own Highland ptarmigan. This last bird is a fine example of protective colouring, for its summer plumage so exactly harmonises with the lichen-covered stones among which it delights to sit, that a person may walk through a flock of them without seeing a single bird; and when it changes to white in winter it is equally protected amid the snow which covers the mountains. A striking exception to the usual white covering of arctic animals is the Musk-sheep, or Musk-ox as it is often erroneously called. This animal is of a dark-brown colour, easily seen among the snow and the ice, but the reason of this is not difficult to explain. The Musk-sheep is gregarious, and derives its protection from this habit. A solitary strayed animal would soon become the prey of the polar bears or even of the arctic foxes; it is therefore of more importance that it should see its comrades at a distance, and so be able to rejoin them, than that it should be concealed from its few enemies. Another case is that of the sable, which retains its rich brown fur throughout the severity of a Siberian winter, but at that season it frequents trees, feeding on fruits and berries, and is so active that it catches birds among the branches. Again, the common raven is found in the extreme arctic regions, but is always black; and this is probably because it has no enemies, while, as it feeds on carrion, it does not need to be concealed from its prey. These three cases are exceedingly valuable from a theoretical point of view, for they prove the incorrectness of a common notion that animals may change to white in the arctic regions either from the direct effect of cold, or from some influence of the white reflections from the snow; and they teach us that only those animals become white to whom that colour is useful, while those which either do not require protection or to whom dark colours are actually beneficial, remain totally unaffected. The cause of change must therefore be sought, not in the direct action of external conditions, but in the same general laws of variation and selection which have modified all the other characters of animals in the way most beneficial to them.

Nocturnal animals offer equally good examples of protective colouring. Mice, rats, bats, and moles, are all of dusky or blackish hues, and are therefore very difficult to be seen at night; when alone they move about, while during the day they conceal themselves in holes or underground. When concealment by day as well as by night is required, as in the case of owls and goatsuckers, we find dusky mottled tints, assimilating with bark or earth during the day, and not very conspicuous at night. In some few cases nocturnal animals are conspicuous, a striking example of which is the North American skunk, which has much white about it and a large white tail which it carries erect in the most conspicuous manner possible. But the horrible odour emitted by this animal makes it universally dreaded, and its conspicuous tail is thus a signal-flag to all carnivorous animals not to attack it—a parallel case, in fact, to the white moth,

which we have already seen was rejected by birds which eat so many other moths.

Equally striking as a proof that colour is largely protective is the fact, that nowhere but among the evergreen forests of the tropical and sub-tropical zones do we meet with birds the ground-colour of whose plumage is green. Parrots, which are confined to such countries, are generally green, with small patches of vivid colours. In the Eastern tropical islands many pigeons are as green as parrots, and there are numbers of other groups which are of the same colour. Such are the barbets, a family of fruit-eating birds, especially abundant in tropical Asia; the green bulbuls (*Phyllornithidæ*); the Bee-eaters; the Turacos of tropical Africa; the little White-eyes (*Zosterops*) of the eastern tropics; and many other groups. These all frequent thick foliage, with which their colours so exactly harmonise that it is most difficult to detect them.

Contrast these with the ordinary colouring of the birds of the region of deciduous trees, of which our own country is a fair example. Here anything approaching a pure green is unknown, while brown or olive is the almost universal body-colour of the plumage. This is the tint which is least conspicuous among the leafless trees and bushes, which prevail for so large a part of the year, and when the need of protection is greatest.

Among reptiles these protective tints are very apparent. Our lizards and snakes are all more or less brown or olive tinged, while in the tropics alone they are often of a vivid green, exactly corresponding with the vegetation they dwell among. The curious geckos—flat lizards with dilated toes, which cling to the trunks of trees or to rocks—are often finely marbled with green and grey, so as exactly to resemble the lichen-covered surface on which they cling. Some arboreal snakes of the genus *Dipsas* are, however, nocturnal; and these, like all other nocturnal animals which require to be concealed, are of dusky colours, being of various shades of black, brown, and olive.

Many fishes even, present clear examples of protective colouring. Such as rest on the bottom, like the flounder, skate, sole, or Miller's Thumb, are invariably of the colour of the bottom, and often singularly speckled, so as to resemble sand or gravel. Such as swim near the surface of the water are almost always dark-bluish or greenish above, and white beneath, colours which evidently tend to their concealment from enemies in the air above them or in the water below. The brilliantly-coloured fishes from warm seas are many of them well concealed when surrounded by the brilliant sea-weeds, corals, sea-anemones, and other marine animals, which make the sea-bottom sometimes resemble a fantastic flower-garden. The pipe-fish and sea-horses (*Hippocampus*) are excellent examples of this style of colouring. Some of them are greenish, resembling floating sea-weed; but in Australia there is a large species which is covered with curious leafy appendages, and all of a brilliant red colour, and this lives among red sea-weed, and is then perfectly concealed.

It is, however, among tropical insects that the most perfect and wonderful cases of protection by colour and marking are to be found, and a very few examples of these must now be given. The best known and most celebrated are the leaf-insects of the genus *Phyllium*—curious large insects, whose wings and wing-covers are broad and flat, shaped and veined exactly like leaves, while their legs, head, and thorax have all flat dilatations, like the stipules of many plants; and the whole being of the exact green tint of the foliage of the plant they live on, it is actually impossible to detect them when they are not in motion. The walking-stick insects, or spectres, are equally curious. These are long cylindrical insects, often nearly a foot long, and of the exact colour of pieces of greenish or brown sticks. If they have wings, these fold up closely, and are concealed under wing-covers of the same stick-like appearance; while the head and legs are so shaped and jointed as either to fit closely on to the stick-like body, or to appear like branched twigs. These creatures hang about shrubs in the forests, and can seldom be distinguished from small twigs and branches which have fallen from the trees overhead. They remain quite motionless during the day, and feed at night, and they hang anyhow across the foliage, holding on by two or three of their legs only, while the others are closely fitted to the body, and they thus give themselves that unsymmetrical appearance which belongs to accidentally-broken twigs. A few of the species are still further protected by curious green, leafy excrescences all over the body, so as to look exactly like a piece of dead twig overgrown with a delicate moss. Such a one was brought to the present writer in Borneo by a Dyak, who assured him that moss had grown over the insect while alive, and it was only by very close examination that it could be discovered that the supposed moss was really part of the integument of the insect.

Even among butterflies, whose gay colours seem

only adapted to render them conspicuous, there are equally wonderful examples of protective marking. It was first pointed out by Mr. T. W. Wood (to whose skilful pencil we are indebted for the illustrations to this paper) that our beautiful little Orange-tip butterfly (*Anthocharis cardamines*, Fig. 4), although so conspicuous when on the wing, is perfectly concealed when resting in the evening in its favourite position among the flower-heads of the wood parsley (*Anthriscus sylvestris*). Its

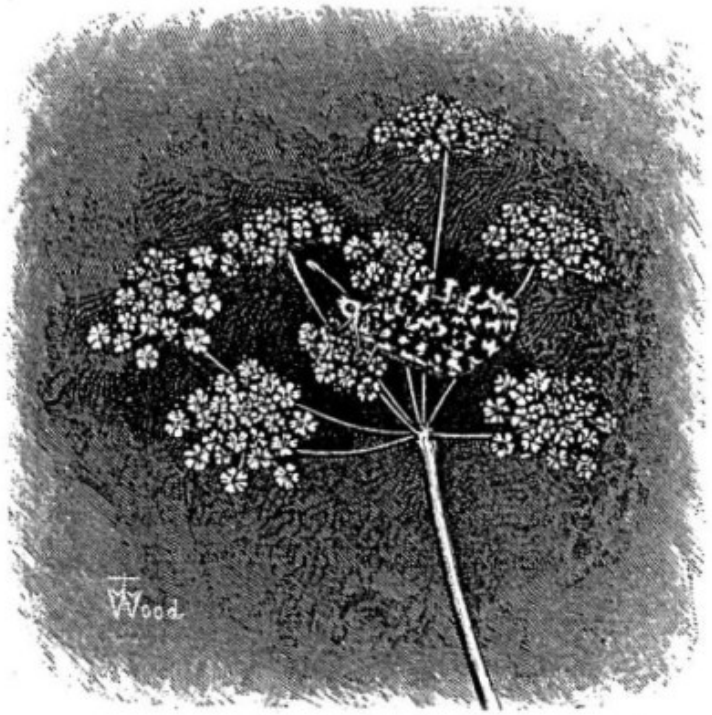

Fig. 4.—The Orange-tip Butterfly.

under surface is beautifully mottled with white and green, which strikingly assimilate with the white and green flower-heads of this plant. Much more wonderful, however, and perhaps the most wonderful of all imitative insects, is the leaf-butterfly of India (*Kallima inachis*, Fig. 5). This is a rather large and handsome butterfly, of a deep bluish colour, with a broad orange band across the wings. It is thus sufficiently conspicuous; but it flies very quickly, and in a zigzag manner, so as to be caught with great difficulty. It is when at rest that it requires protection, and this it obtains by its colour and markings on the under surface, and by its peculiar habits. The upper wings have an acute lengthened apex, which is exactly the shape of the tip of the leaf of many tropical trees and shrubs; while the hind wings are produced into a short narrow tail, which well represents the stalk of a leaf. Between these points runs a dark curved line, representing the mid-rib, and from this radiate a few oblique markings for the veins of the leaf. The colour of the under side of the wings closely imitates that of dead leaves, but it varies almost infinitely through shades of bright yellow, reddish, ochre, brown, and ashy, just as leaves vary in their different stages of drying and decay. Even more remarkable is the manner in which the diseases and decay of leaves are represented by powdered dots and blotches, often gathered into little groups, so as to imitate in a most marvellous way the various fungi which attack decaying leaves. But to render the disguise effective, it is necessary that the insect should assume the position of a leaf, and this it does most perfectly. It always settles on an upright twig or branch, holding on by its fore legs, while its body (concealed between the lower margins of the wings) rests against the stem which the extremity of the tail, representing the stalk, just touches. The head and antennæ are concealed between the front margins of the wings,

and thus nothing is seen at a little distance but what appears to be a dead leaf still attached to the branch. Yet further, the creature seems to have an instinct which leads it to prefer to rest among dead or decaying leaves, which are often very persistent on bushes in the tropical forests; and this combination of form, colour, marking, habit, and instinct, produces a degree of concealment which is perfectly startling. You see this gay butterfly careering along a forest path, and suddenly rest upon a shrub not three yards from you. Approaching carefully, you look for it in vain, and you may often have to touch the branches before it will dart out from under your very eyes. Again you follow it, and mark the very branch on which it has seemed to rest; but in vain you creep forward, and scan minutely every twig and leaf. You see nothing but foliage—some green, some brown and decaying—till the insect again starts forth, and you find that you have been actually gazing upon it without being able to see any difference between it and the surrounding leaves. After repeated experiences of this kind, and knowing exactly what to look for, you are able sometimes to detect it in repose, and are then more than ever amazed at the completeness of the deception, and at the same time profoundly impressed with the protection that must be afforded by this wonderful disguise—a protection whose effect is seen in the wide range and extreme abundance of the species.

In this case, and in that of the moss-covered stick-insect, we see the extreme perfection of imitative colouring; and we can only understand how this has been produced, by always keeping in mind the very much more numerous cases of slight or partial protection by colour or marking. We can only now briefly indicate some of the steps by which such protection is brought about.

Fig. 5.—Leaf Butterfly of India.

None of the characters of animals are more variable than their colours, though this may appear doubtful when we look at the constant tints and markings of so many animals in a state of nature. There is, however, good reason to believe that even, in cases, these variations are constantly occurring, but, owing to the fact that the tint of each animal is useful to the species, all important deviations from it soon die out. Certain it is that almost every domesticated animal varies in colour, and

these varieties, not being hurtful as in a state of nature, are increased and multiplied without end. Now, if we suppose an animal to suffer from being too conspicuous, any variation of colour or marking tending to make it less conspicuous will give it a better chance of life; and as offspring tend to be like their parents, these less conspicuous varieties will often leave successors similarly endowed; but these again varying, some among them will be still more protected; and thus the protective tints will tend to become more and more perfect in each succeeding generation, till their enemies, finding the pursuit too difficult, will confine their attention chiefly to other species. Then there will be no more change till some new enemy appears, when a further advance may take place till the protection becomes sufficiently perfect to place our supposed animal in a slightly better position than its neighbours.

It has been a difficulty to many persons to understand how such variations could explain the curious cases of the Alpine hare, the ptarmigan, and many other animals which become white in winter only, when the ground is covered with snow and that colour serves as a protection. It has, however, been observed, that a slight seasonal change takes place in many animals. Thus, in Siberia, the wolf, the horse, the cow, the roe, elk, reindeer, and two kinds of antelope, all become paler in colour during winter. Now, if either of these species migrated northward, till it came to inhabit a country where the winter snow remained on the ground for half the year, varieties in which the seasonal change was more and more pronounced would have an advantage, and thus, in the course of many generations, an animal might be produced which changed colour as completely as do the arctic fox or the ptarmigan.

We must now conclude this very brief outline of one of the most curious chapters in natural history. We have shown how varied and how widespread are protective colours among animals; and, if we add to these the cases in which conspicuous colours are useful, sometimes to warn enemies from such as are distasteful or are possessed of dangerous weapons, at other times to aid wandering species to recognise their companions or to find their mates, we shall become satisfied that we have a clue to much of the varied coloration and singular markings throughout the animal kingdom, which at first sight seem to have no purpose but variety and beauty.

GREAT SEA REPTILES.

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In a former article (Vol. I., p. 198) we gave some consideration to those ancient and extinct reptiles which were organised for flight, and are known to geologists as *Pterodactyles;* and on the present occasion we propose to glance at some of the equally strange types of reptilian life which accompanied these forms. If we go back to that epoch of the earth's history which geologists know as the Secondary Period, we find that at that time the great class of the Reptiles had attained its maximum of complexity. It was truly an "Age of Reptiles." Not only was the air tenanted by the weird and spectral Pterosaurs, but huge lizards, of forms now no longer represented, crawled upon the land, and the waters of the ocean swarmed with special and gigantic types of the same class. It is to these last that we intend to confine our attention at present. To study these, the reader must pay a visit to some good zoological collection, or, best of all, to the long and richly-stored galleries of the geological department of the British Museum, where he will find ample material for the reconstruction of these old and monstrous forms of life, and will be able to obtain a clearer idea of their true characters than can be afforded by any mere description. There are not many places in this country where one could hope to collect the remains of these ancient reptiles for one's self, and we must content ourselves here with the endeavour to obtain some general idea of their construction and of their most important peculiarities.

If we take the reptiles which are known to be in existence at the present moment, we find few of these, comparatively speaking, to be organised for a life in the water. Perhaps the most thoroughly aquatic of these are the great sea-turtles, the compressed bodies and flattened paddles of which enable them to make their way through the waters

PROTECTIVE MIMICRY IN ANIMALS.

By Alfred Russel Wallace, F.L.S., Author of "The Malay Archipelago," etc.

In a former article (pp. 128—137), on the "Protective Colours of Animals," we endeavoured to illustrate the purpose and origin of all those peculiarities of colouring which tend to conceal animals from their enemies or from the prey which they wish to capture; we showed how widespread were such colours in nature, and how often it happened that what seem showy colours when we examine the species in confinement, or when preserved in a museum, are really protective when the animal is seen in its native haunts and in the attitude it usually assumes when at rest. We referred to many cases of special imitation by insects of vegetable substances — of leaves or flowers, bark or moss—sometimes so wonderfully accurate as to deceive the eye of the experienced naturalist as well as that of the hungry bird. But besides all these, we called attention to a totally different kind of protection, always associated with conspicuous instead of protective colouring. A number of insects (and some of the higher animals) possess secretions which are so nauseous as to render them generally uneatable. This is a perfect protection against being devoured, but it would be no protection against being hunted, and caught, and often killed, if there was nothing to distinguish these from the great majority of eatable insects. But eatable insects (if soft and defenceless) are almost always protected by obscure or green tints harmonising with their surroundings. Evidently, therefore, the best way to distinguish the uneatable kinds would be that they should be of gay and brilliant tints, strongly contrasted with their surroundings, and readily distinguishable from a considerable distance. Marvellous to relate, this is actually the case; and the uneatable insects are, almost without exception, gaudily and conspicuously coloured. A number of such cases were adduced, especially among our native caterpillars, and proofs of their non-edibility were given.

We now propose to deal with this part of the subject more fully, in order to explain what is meant by "protective mimicry"—perhaps the most interesting and the most wonderful of all the phenomena of colour among animals. It is only among the teeming forms of life of tropical forests that the best cases of mimicry are to be met with, and we shall therefore now have to deal with objects for the most part unfamiliar to the British collector. We hope, however, by means of numerous illustrations, to make the subject intelligible to our readers, and especially to such as have some knowledge of our native insects.

Mimicry is the term applied to the phenomenon presented by certain species which, being themselves eatable, and belonging to groups which are attacked and devoured by numerous enemies, obtain protection by their close resemblance to some of the brightly coloured species which are free from attack on account of their nauseous odour or general inedibility. In most cases it is not a general but a special resemblance which serves this purpose, sometimes carried so far that the mode of flight and general habits are imitated, as well as colour and marking. The most numerous examples of mimicry occur among butterflies, but there are almost equally remarkable cases among beetles and other orders of insects, as well as a few among reptiles and birds. We will, therefore, first describe the groups of butterflies which are the subjects of mimicry by other groups.

In all tropical forests butterflies are abundant, and very varied in size, form, colouring, and mode of flight. Some fly with great rapidity, others have a zigzag, jerking mode of flight, and many such are adorned with brilliant colours. Great numbers of Satyridæ and Erycinidæ keep near the ground, with a slow hovering flight, and these have generally a sober style of coloration; while many of the showy species have their under-sides adorned with rich dark marblings, which render them inconspicuous as soon as they settle on a leaf or branch. But there are three great families—the Danaidæ, Heliconidæ, and Acræidæ—one or other of which is everywhere abundant both in species and individuals, and which are always remarkable, for their beauty or their conspicuousness; for their slow and lazy flight; for never trying to conceal themselves, and never flying high up in the air. The under-sides of their wings, too, are always coloured nearly the same as the upper, or, at all events, never present markings tending to concealment. These three families are closely allied to each other, and should, perhaps, form sub-divisions of one family, and they are believed to be most nearly related to the Nymphalidæ (to which family belong our tortoiseshells and fritillaries), of which they are a special development. They all have

the cell of the hind-wings closed, whereas in the Nymphalidæ it is always open; but they agree with the latter family in having the first pair of legs short and imperfect in both sexes, but more especially in the males, and in the pupæ being freely suspended by the tail.

All three groups have the peculiarity of possessing a powerful odour, which appears to pervade the whole body. When a specimen is caught and pinched between the fingers, a yellow fluid oozes out, which has a strange pungent smell and stains the skin. This has been observed with the Heliconidæ of South America, the Acræidæ of Africa, and the Danaidæ of Asia and Australia, and it appears to be of a very similar nature in all these groups. This pungent yellow secretion is very distasteful to birds and other insectivorous animals, so that the butterflies in question are never persecuted as others are. Some persons have doubted whether birds catch butterflies at all. Swallows, however, have been seen chasing white butterflies even in England; but in the tropics insectivorous birds belonging to many distinct families are much more numerous, and no eatable insects escape them. Mr. Belt, when in Brazil, watched a pair of puff-birds catching butterflies during half an hour, capturing many and carrying them to their young; but though numbers of Heliconidæ were flying slowly about, the birds neither noticed nor made any attempt to catch them. Neither Mr. Bates nor myself ever saw these butterflies attacked by birds, or lizards, or predacious insects, though they often rest exposed, hanging on the tips of leaves where they would be easily captured; and though the wings of butterflies that have been caught and eaten are often found lying in the forest paths, those of the Heliconidæ are never found among them. Dragon-flies were seen to catch Pieridæ in Natal, but never the slower-flying Acræidæ; while among the wings of butterflies found under certain trees where they assemble to feed on the exuding sap, and are captured by mantises and other insectivorous creatures, no Acræidæ or Danaidæ were ever found. We may consider it, therefore, to be an established fact that these three groups of butterflies enjoy almost perfect immunity from attack, owing to their offensive taste and odour; and their peculiarities of form and colour as well as their mode of flight, seem to be so well known to all insectivorous creatures, that they are recognised at a considerable distance, and thus not only escape being devoured, but are generally free from all pursuit or molestation. No doubt young birds or lizards sometimes make the trial, but the result is so disagreeable that they very soon learn what to avoid.

The peculiar odour is found in the caterpillar and the chrysalis of these butterflies, as well as in the perfect insects, and the result of this freedom from persecution is that they swarm in the forests to a greater extent than any other butterflies. The Heliconidæ of South America and the Danaidæ of the Malay Islands may always be found, even when other butterflies are very scarce, and there are many places where hardly any other kinds can be seen. It is evident, therefore, that if any other butterflies, belonging to eatable groups, should closely resemble any of these inhabiting the same districts, they would certainly be mistaken for them, and so obtain protection. Wherever these groups are found there are such cases of mimicry, of which we will now give some of the more interesting examples.

In tropical America the Heliconidæ* are immensely abundant, about 400 species having been described up to 1871, while, as many new ones are discovered every year, the number cannot be now much less than 500 species. They are also, as already stated, very abundant in individuals, and as all these are, without exception, uneatable, it is not surprising that insectivorous creatures have got to know them well and avoid them. They differ wonderfully among themselves in colour, some being black or blue, banded with yellow or white; others rich red, with yellow bands and rays; others rich brown and yellow spotted; while an immense number have transparent wings, either simply veined or delicately tinged with yellow, brown or purplish. Yet, amid all this variety, the general form, the style of marking, and the

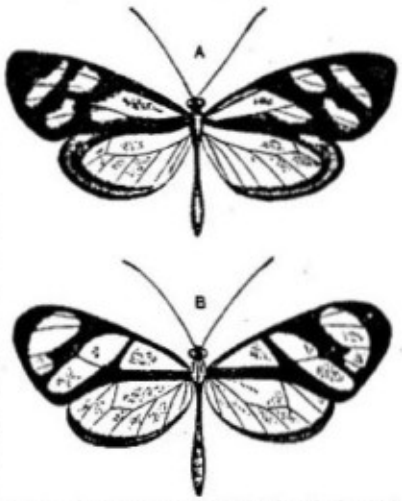

Fig. 1.—Leptalis theonoë (A); Ithomia flora (B).

* They have now been divided into two families, Heliconidæ and Danaidæ; but I keep the old nomenclature for simplicity.

mode of flight are so peculiar, that even species never seen before are recognised at a glance as belonging to this family.

In the same forests are found a considerable number of the totally distinct family of Pieridæ, to which belong our well-known "cabbage," "orange-tip," and "brimstone" butterflies. Most of these are white or yellow, variously marked and shaded, but still unmistakably Pieridæ; but there is one genus—*Leptalis*—which has more elongate wings than usual and a weaker flight, and these vary greatly in colour, some being white, others yellow or yellow and black, while others are coloured exactly like the Heliconidæ. The wonderful thing is, that the resemblance is not general but special. The coloured *Leptalis* does not look like a new species of Heliconidæ, but exactly imitates an existing species, and *always a species which inhabits the same locality*. Thus the transparent-winged, black-banded *Ithomia flora* (one of the Heliconidæ) is accompanied, at Cupari on the Tapajos river, by *Leptalis theonoë* (Fig. 1), which so closely resembles it that it cannot be distinguished when on the wing; while in other parts

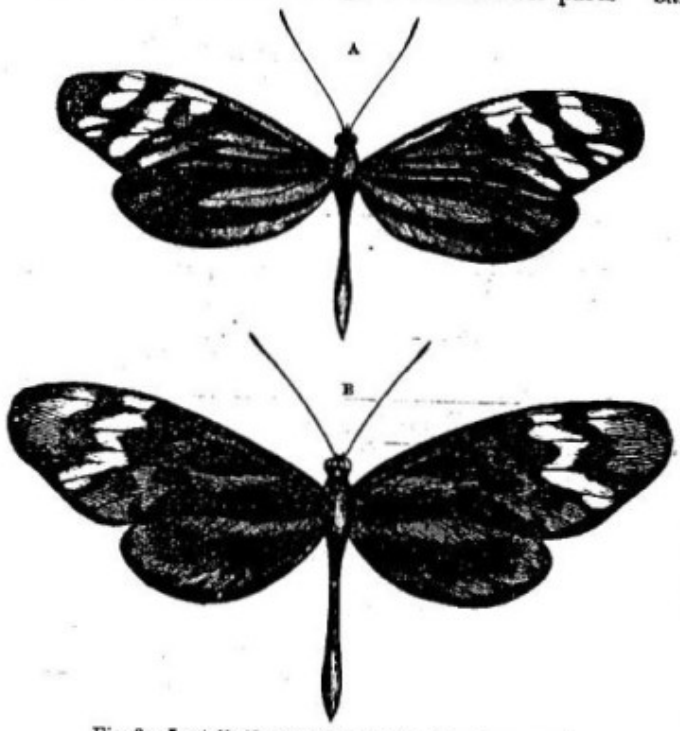

Fig. 2.—Leptalis Egaëna (A); Mechanitis obscura (B).

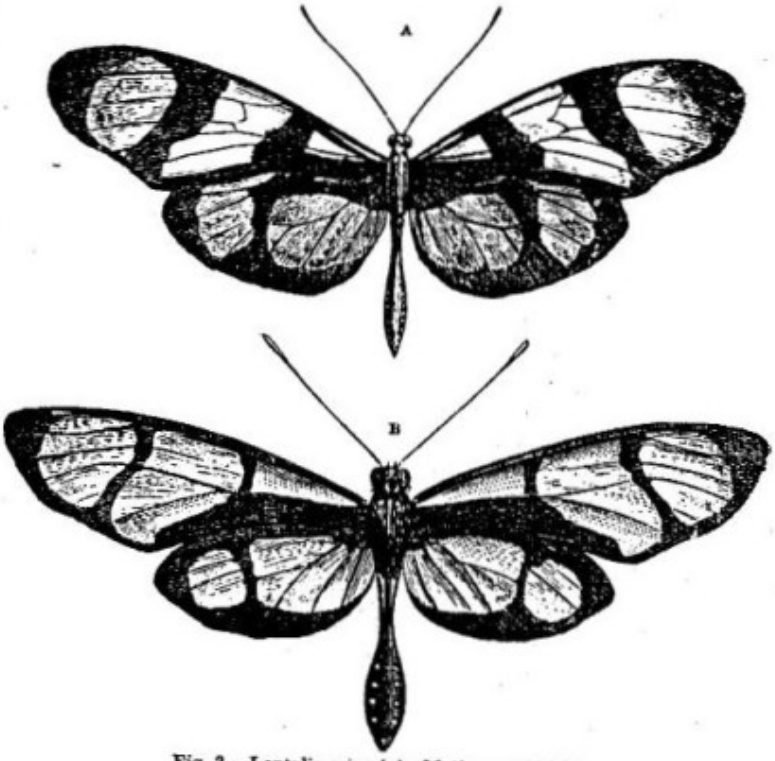

Fig. 3.—Leptalis orise (A); Methone psidii (B).

of the Amazon valley distinct species of *Ithomia*, with orange-red bands and spots, are imitated by varieties of this *Leptalis*. At Ega, on the Upper Amazon, the handsome brown-black and yellow-banded *Mechanitis obscura* (one of the Heliconidæ) is accompanied by *Leptalis Egaëna*, closely resembling it in size, colours, and markings, and both have long yellow antennæ (Fig. 2). Still more remarkable is the large and handsome yellow-and-black *Methone psidii* (one of the Heliconidæ), accompanied by *Leptalis orise*, equally large and very similarly marked and coloured; and in this case both have long black antennæ with a yellow club (Fig. 3).

These are only a few out of many examples that might be referred to, but it is necessary to see the specimens themselves in order to appreciate the wonderful change that has taken place from the usual style of colouring of the Pieridæ (still prevalent even in the genus *Leptalis* itself) to these richly-coloured and strangely-marked forms. Before going further, however, it will be well to show how greatly the two groups, *Leptalis* and *Ithomia*, really differ. The accompanying figures (Fig. 4) show the anterior feet, the pupæ, and the larvæ of the two families Pieridæ and Heliconidæ. In the former the feet are long and perfect, with five-

jointed tarsi and bifid claws; the pupa is always supported by a looped thread, and the larva, or caterpillar, is smooth, slightly downy, but without spines or processes of any kind. In the latter the anterior legs are short and imperfect, having no tarsi in the male, and only one or two joints in the female; the pupa is always freely suspended, without any brace or loop, and the larvæ are always furnished with fleshy processes. These combined differences are so important that we may consider the two families to be at least as distinct as deer are from goats, or robins from finches.

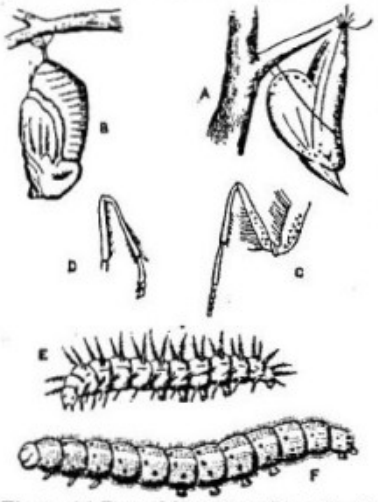

Fig. 4.—(A) Pupa of Gonepteryx Rhamni; (C) Leg of Gonepteryx; (B) Pupa of Danais plexippus; (D) Leg of Danais plexippus♀; (E) Larva of Acræa violæ; (F) Larva of Pontia brassicæ.

Besides the genus *Leptalis*, several other groups imitate the Heliconidæ in an equally extraordinary manner. A true Papilio (*P. pausanias*) has the exact colouring of *Heliconius clytia*—rich steel-blue with yellow bands; while another most remarkable species (*P. zagreus*) is richly marked with stripes and spots of yellow, brown, and black, so as closely to resemble the Heliconoid *Lycorea atergatis*. Two genera of Erycinidæ (*Ithomeis* and *Stalachtis*), and moths of the genera *Castnia*, *Dioptis*, and *Pericopis*, also resemble species of Heliconidæ in their respective districts in an equally remarkable manner.

In all, or almost all these cases, it has been observed that the mimicking species are much less plentiful than the Heliconidæ which they resemble; and a little consideration will show us that this is essential to the success of the imitation. For if the eatable Pieridæ and other groups were as abundant as the uneatable Heliconidæ, insectivorous animals would soon find it out, and would systematically capture them both, on the chance of getting at least one that they could eat for every one that they were obliged to reject. The fact seems to be, however, that the imitating species are usually very scarce indeed: often not one to a hundred, and sometimes not one to a thousand of the species they imitate; so that they are quite secure among the crowd of uneatable creatures so much resembling them. It may be asked, however, why, as they have the same protection, they do not increase and become nearly as numerous as the uneatable kinds. The answer is, undoubtedly, because their larvæ and pupæ are not protected, and thus suffer great destruction; and this was probably the reason why certain species acquired protection by mimicry in the perfect state as the only means of escaping impending extermination. It is evident that those species which had long and delicate wings and a slow flight, and which, owing to the thinning out of the larvæ and pupæ, were never very abundant, would be most liable to extermination. But these long-winged kinds would in form resemble the Heliconidæ, and any variations of colour tending to make them more like any of the species of that group would be an advantage. Such varieties would therefore have a better chance of escape, and in a long series of generations some of them might at least come to have the wonderful resemblances we now find, while many others, failing to vary sufficiently, have no doubt become extinct.

We will now pass to the African continent, where Acræidæ abound both in species and individuals, while Danaidæ, though few in species, are still sufficiently plentiful in individuals. These take the place of the Heliconidæ of South America, enjoying the same advantages; and they are mimicked in an equally remarkable manner by butterflies of three distinct families—Papilionidæ, Nymphalidæ, and Eurytelidæ; but not by any Pieridæ, which form the bulk of the mimicking species in South America. As an example we may take the *Acræa Eurya*, a common but remarkable butterfly of West Africa, numerous varieties (or allied species) of which are figured in Mr. Hewitson's "Exotic Butterflies," Vol. IV., Pl. IV., V. (Acræa); and in the same volume under Diadema (a genus of Nymphalidæ), Pl. III., are a series of insects, which it is hard to believe, at first sight, are not also varieties of the same species (Fig. 5). There is also a species of *Melanitis* (Fam. Eurytelidæ) that resembles the same species of *Acræa*. Another species, *Acræa zetes*, has a different style of marking, being red with numerous black spots, and this is very well imitated by another species of *Diadema* inhabiting the same districts.

But the most remarkable case known in Africa is presented by a true *Papilio* which, in several varieties and allied species, mimics the common *Danais echeria* with its varieties and allied species.

Danais Echeria (Fig. 7, A) is an elongate-winged black butterfly with a group of spots, either buff or white on the front wings, and a broad buff band across the hind wings; varying considerably in different parts of South Africa. Another species, *Danais niavius* (Fig. 8, A), is larger and handsomer, being deep black with two very large white patches, occupying more than half the surface of the wings. Yet another species, *Danais chrysippus*, perhaps the commonest of all, is rich orange-red, bordered with black on the hind wings, while nearly the outer half of the upper wings is black crossed by a broken band of pure white. These three butterflies may be said to be totally unlike each other in colour and markings, and each of them is accompanied by a Papilio closely imitating it, which have all been described as distinct species. A gentleman resident in Cape Town (Mr. Roland Trimen), who in 1861 published a book on the butterflies of South Africa, had his attention called to these cases of mimicry by the papers of Mr. Bates and myself, and especially to the fact that very often the females only have protective or imitative colours. He then observed that all these Papilios were, without exception, females, and no male specimen was to be found in any of the rich museums or private collections of this country. He also observed that wherever these butterflies were found, there was also found the large and handsome *Papilio merope* (Fig. 6), conspicuous by its pale sulphur-yellow colour, the anterior wings black bordered, while the tailed hind wings are crossed by a broken black band. This insect is as completely unlike all the others as possible; but it was always of the male sex, no female being known in any collections, and it was only found in districts where some one or other of the mimicking female Papilios were also found. The two sorts were also seen flying together and chasing each other, just as males and females of the same species often do; so, putting all these things together, he ventured to announce his belief that *all were one and the same species.*

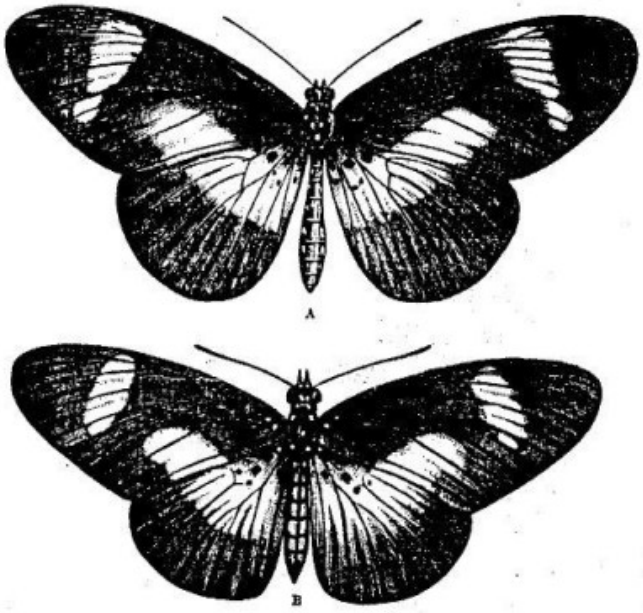

Fig. 5.—Acræa gea (A); Diadema Hirce (B).

On close examination it was found that there were many minute points of resemblance between these very different-looking insects, and a number of entomologists who were already acquainted with similar facts in other countries, concurred in Mr. Trimen's view. Others, however, strongly opposed it, especially Mr. Hewitson, who possessed the finest collection of butterflies in England. When figuring some of these female Papilios in his work on "Exotic Butterflies,"

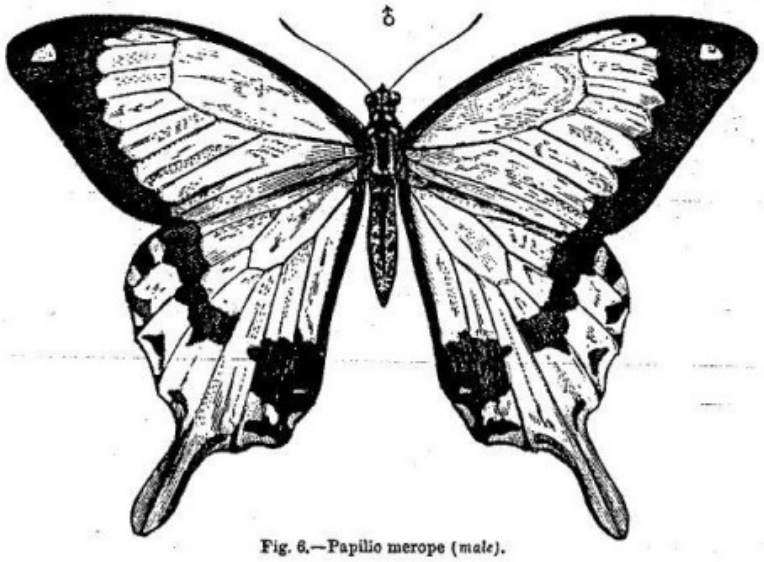

Fig. 6.—Papilio merope (*male*).

he wrote thus:—"That the butterflies now figured are all females, there cannot, I think, be a doubt; but that they are the females of *P. merope*, as suggested by Mr. Trimen, I do not for one moment believe." And he supported his disbelief by what is certainly a most remarkable fact, that in the adjacent island of Madagascar there is a slight variety of *Papilio merope*, which has a female almost exactly like itself, while nothing resembling the other females is found there.

In order to settle the question, Mr. Trimen requested his friend Mr. Mansel Weale to endeavour to obtain the eggs or caterpillars of one of the disputed females, and raise therefrom the perfect insect. This was done. Mr. Weale found eggs and larvæ of *Papilio cenea* (which was the name hitherto given to the female which resembled *Danais echeria*), and succeeded in raising from them thirteen butterflies. Of these butterflies, seven were males—the well-known yellow-and-black tailed *Papilio merope*; four were buff-banded females, mimicking *Danais echeria* (Fig. 7); one was a black-and-white female like *Danais niavius* (Fig. 8); and one was a red-winged female like *Danais chrysippus*. Here was positive proof that all these strangely different butterflies are one and the same species, the females mimicking distinct species of Danais!

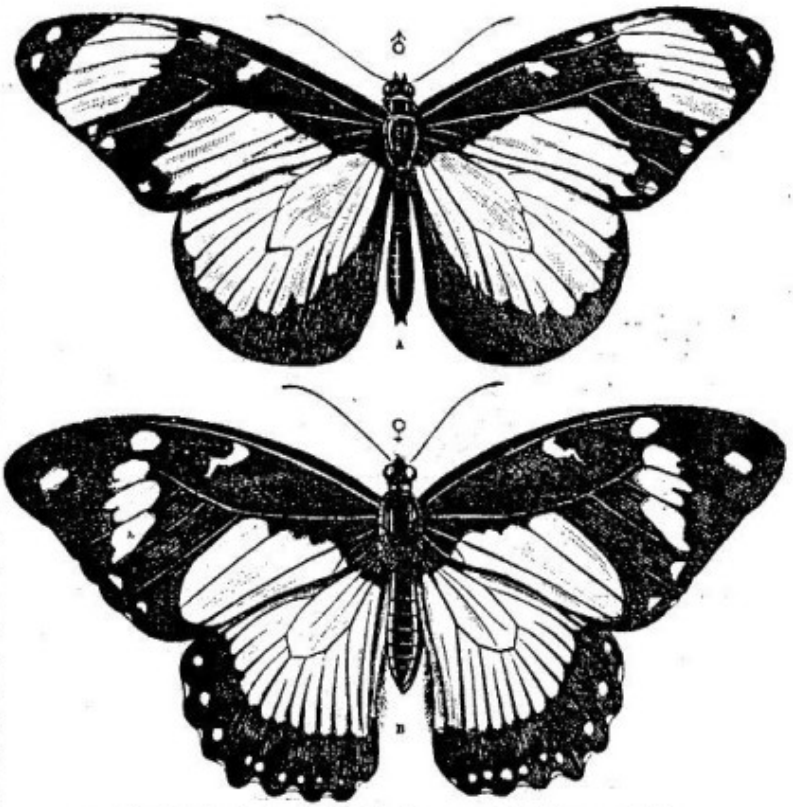

Fig. 8.—Danais niavius (A); Papilio merope ♀ (P. hippocoon [B]).

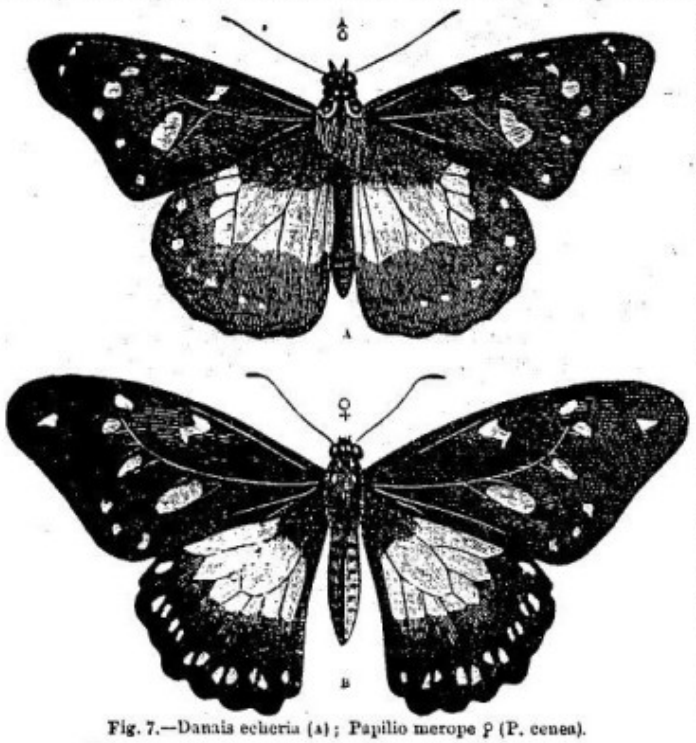

Fig. 7.—Danais echeria (A); Papilio merope ♀ (P. cenea).

There are several other interesting facts connected with this butterfly. The caterpillar is the exact colour of the leaves it feeds upon, and is thus protected; the chrysalis is of a remarkable, broad shape, so as exactly to resemble a leaflet of the same plant, and the under side of the male butterfly is of mottled brown tints, and when at rest closely resembles a dead leaf. The perfect male is subject to the attacks of birds, since Mr. Weale saw one actually captured by a large crested fly-catcher; but they fly strongly, darting up and down with great rapidity, and thus no doubt many escape. The flight of the females is, on the other hand, heavy and

slow, and while laying their eggs on the proper food-plant they are especially subject to attack. We may well suppose, then, that they were once near extermination, when some ancestral form varied sufficiently to become something like one of the Danaidæ, and thus obtained the protection necessary for the preservation of the race. Why the Madagascar form of the species did not produce similarly diverse females is not quite clear; but it is certain that in such islands as this, where the number of species both of birds and insects is much less than on continents, the struggle for existence is not nearly so severe. Forests also are denser and more extensive in Madagascar, and thus offer better concealment for insects, which, therefore, may not need the same amount of extraneous protection as on the continent. Having devoted so much space to *Papilio merope*, we must pass by the many other cases of mimicry that occur in Africa, in order to notice a few of those of India and the Malay Archipelago.

In these countries three genera of Danaidæ, *Danais*, *Euplœa*, and *Idea*, are very abundant, each having a peculiar style of colouring. *Danais* has elongate wings, and is very varied in colour, but is often semi-transparent greenish or bluish-white with black stripes, and often suffused with yellow or brown. *Euplœa* has more rounded wings, and is usually dark coloured, with white bands or spots, but is often richly glossed with metallic blue, and very handsome. *Idea* is very large, with thin papery wings of a whitish semi-transparent colour, marked with round spots or with bands of black. All these forms are closely imitated by various species of *Papilio* and *Diadema*, of which only a few of the more remarkable can be here noticed.

One of the most common Danaidæ in Malacca and Borneo is *Euplœa midamus* (Fig. 10), the male of which has the fore wings of a brilliant metallic blue, with faint bluish-white spots, while the hind wings are uniform brownish black. The female differs considerably, the hind wings being covered with narrow white lines radiating from the body, and having a marginal row of white spots. This is exactly imitated in the two sexes of *Papilio paradoxa* (Fig. 9), which inhabits the very same districts, but is, comparatively, rare; but the two species are so much alike that I could hardly ever distinguish them when on the wing. The almost equally common *Euplœa rhadamanthus* is very distinctly coloured, with sharply defined white patches and blue spots on a black ground, very unlike any other butterfly except the *Papilio caunus*, which imitates

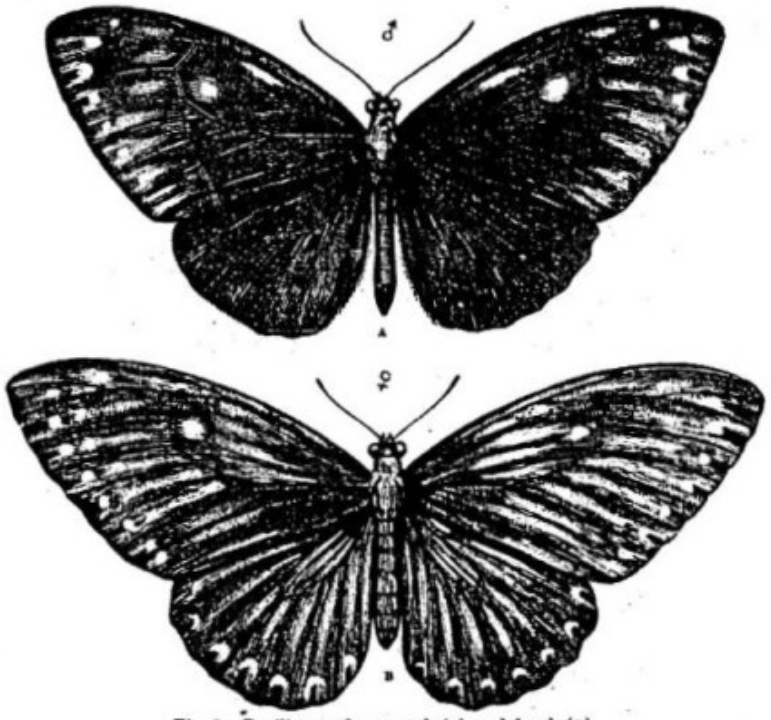

Fig. 9.—Papilio paradoxa: *male* (A), and *female* (B).

it with wonderful accuracy both in markings and in mode of flight. In the Philippine Islands the large white-and-black *Idea leuconoe* is closely imitated by the fine *Papilio idæoides* of the same islands.

We have here also two examples of female butterflies being modified for protection, so as to be quite unlike their males. The male of the very common *Diadema misippus* (Fig. 11) is black, with four conspicuous oval white spots margined with glossy blue. The female is a totally different-looking insect, of a rich orange-brown colour, margined with black and white, and with a white band crossing the black apex of the anterior wings. The idea of their being two sexes of the same species would never strike any one, and would seem utterly preposterous if it were told them for the first time. It is, however, undoubtedly the fact, and the female is an

accurate mimic of the excessively common *Danais chrysippus*. The male *Diadema misippus* flies rapidly, and often mounts into the air, while the female flies slowly and keeps low down; and as the species frequents open grounds rather than forests, she would be in great danger of extermination while hovering over the plants on which she lays her eggs, and thus has great need for the protection gained by her resemblance to the uneatable *Danais chrysippus* which swarms everywhere (Fig. 11).

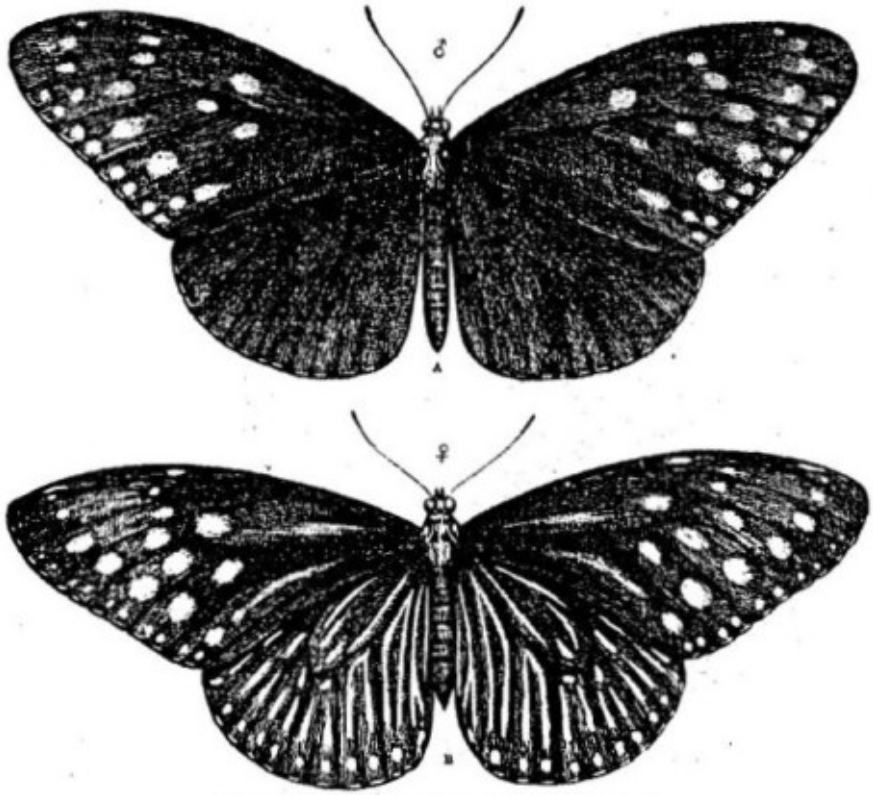

Fig. 10.—Euplœa midamus: male (♂), and *female* (♀).

The other case is that of a *Diadema* from the larger Malay islands, which, owing to its rich metallic blue gloss, had been described, thirty years ago, as the male of another species. On close examination, however, I found it to be a female, while the male is a comparatively dull insect, with hardly any blue gloss and much whiter spots. The two differ, in fact, just as do the sexes of many butterflies, but in a reverse way, the female being here the more brilliant, the male far less so, for which reason I named the species *Diadema anomala*. The explanation of the anomaly is, that the female mimics the male *Euplœa midamus* with great accuracy, and thereby acquires the protection which her slow flight and exposure while egg-laying renders necessary. This is a most interesting case, as proving the great power of the need of protection to lead to modifications of colour in the female sex. For purposes of concealment, females generally have less conspicuous tints than their mates, but when protection can be more readily secured by resemblance to species absolutely free from molestation, they can acquire distinct or even brilliant colours, and such as are generally characteristic of the male sex.

Cases of true mimicry among Lepidoptera, such as we have here described, are almost unknown in temperate lands, where the forms of insect life are so much less varied; but there is one very good case in temperate North America, and there are also a few in our own country. In the United States the handsome red-and-black *Danais erippus* is very common, and there occurs with it one of the Nymphalidæ, *Limenitis archippus*, which closely resembles it in colour and markings, and is totally unlike all the other species of its own genus. The white moth, *Spilosoma menthrasti*, mentioned in our former paper as being uneatable, is very abundant; but there is another moth, *Diaphora mendica*, of which the female only is white, which appears at the same time of the year, and is much less common, so that it is very probable that this species is secure from enemies by being mistaken for the uneatable kind. Our clear-wing moths of the families Sesiidæ and Ægeriidæ are, however, undoubted mimickers, many of the species resembling bees, wasps, or ichneumons, as their names imply. *Sphecia crabroniformis*, for example, imitates the wasp, *Odynerus antilope* (Fig. 12); and the common little currant moth, *Trochilium tipuliforme*, resembles a small black wasp, *Odynerus sinuatus*, which is abundant in gardens at the same season.

Coming to the order Coleoptera, or beetles, we find numerous cases of the mimicry of protected

by defenceless species. Some extensive groups have an offensive taste like that of the Danaidæ among butterflies. Such are the Eumorphidæ and Hispidæ, and especially many of the Malacoderms, our own red-and-black species of *Telephorus*, commonly called "soldiers and sailors," being refused by most, if not all, birds. These groups have all conspicuous colours and fly slowly, and many of the species are mimicked by Longicorns, a group of beetles which seems to be particularly subject to the attacks of insectivorous creatures, since a large number of the species have acquired protection, either by their colours, markings, and rugosities, causing them to resemble bark or foliage, or by their habits of concealment, feigning death, or feeding at night. Another group of beetles are protected by the excessive hardness of their integuments, which render them uneatable to most insectivorous birds. Such are many of the Curculionidæ and Anthribidæ, and both these groups are often mimicked by Longicorns in a most perfect manner. The most curious example is, perhaps, that of the Longicorns—*Doliops curculionides* and *D. geometrica* of the Philippines, which, both in shape and colours, closely resemble weevils of the genus *Pachyrhynchus*, peculiar to the same islands. This is the more remarkable, because the insects imitated are marked in a most unusual manner with geometrical patterns, and possess the most brilliant metallic colours. The Eastern tiger-beetles of the genera *Collyris* and *Therates* are also mimicked, the former by a Longicorn, *Collyrodes Lacordairei*, the latter by a species of Heteromera, and in both cases the imitation is very exact.

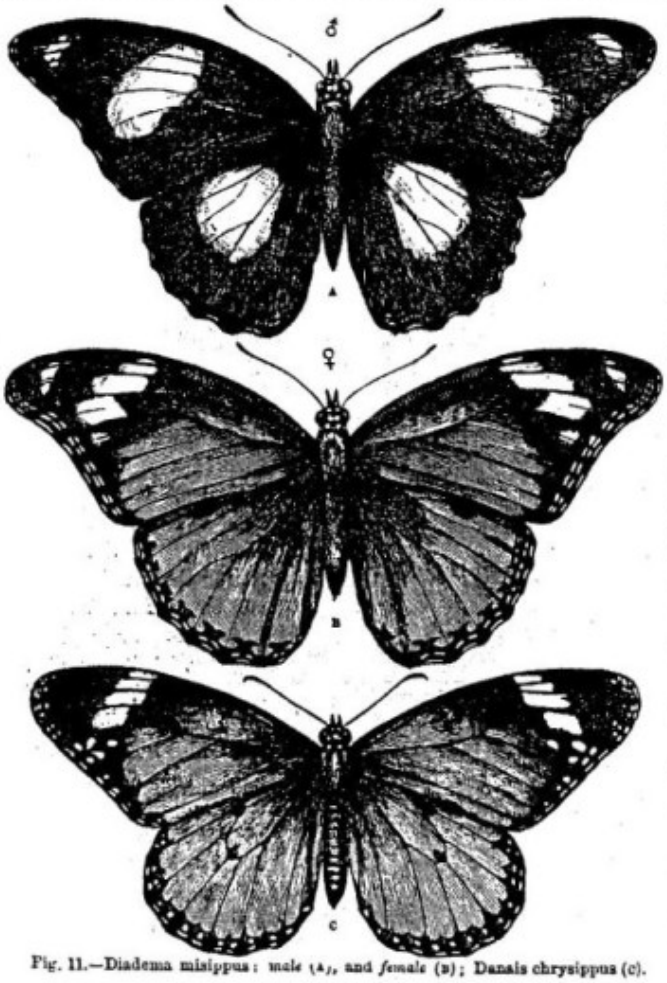

Fig. 11.—Diadema misippus: male (A), and female (B); Danais chrysippus (C).

The same group—Longicorns—also mimic many other insects which it is to their advantage to be mistaken for. Different species resemble bees, wasps both blue and yellow, saw-flies, ants, and the strong-smelling Hemiptera. Our illustration (Fig. 13) represents one of these beetles, which exactly resembles a large blue wasp, both inhabiting the same districts in South America. The reason why cases of mimicry occur so much more frequently in this family of beetles than in any other, is, probably, because their enormous numbers and endless modifications of form and structure offer facilities for natural selection to work upon, some of them more or less closely approximating to the form and colouring of every other family of the order.

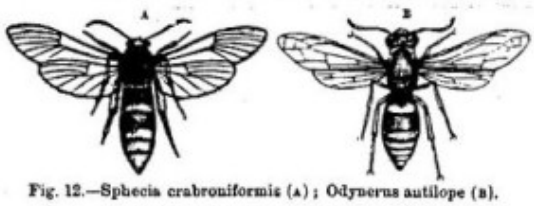

Fig. 12.—Sphecia crabroniformis (A); Odynerus antilope (B).

There are also many cases in which distinct orders of insects mimic each other. Moths which imitate bees and wasps have already been mentioned. In the Philippine Islands two very singular cases occur. An insect of the cricket family (*Condylodera*

tricondyloides) is so exactly like a tiger-beetle of the genus *Tricondyla*, that so old and learned an entomologist as Professor Westwood placed it among them in his cabinet, and kept it there for a long time before he found out his mistake. An-

Fig. 13.—Sphecomorpha chalybea.

other species of the same cricket family (*Scepastus pachyrhynchoides*) mimics a species of Pachyrhynchus (*P. venustus*), a beetle as totally unlike a *Tricondyla* as it is possible to find.

We cannot now do more than refer to the numbers of two-winged flies which mimic bees and wasps,* or the spiders which resemble ants; but we must just mention the Mantis which Mr. Bates found on the banks of the Amazon exactly resembling the white ants it feeds upon, and the crickets of the genus *Scaphura*, which accurately mimicked sand-wasps, the reason being that the sand-wasps are especially fond of crickets with which to provision their nests. These defenceless creatures have, therefore, in many distant countries, been preserved, by acquiring the form and colouring of stinging Hymenoptera, carnivorous Cicindelidæ, or hard-shelled Curculionidæ.

Owing to the comparative stability of the external form of the higher animals, and the important outward differences between the various groups, the facilities for the production of mimicry rarely exist in their case. Yet there are a few undoubted examples of very great interest. The chief venomous snakes of America belong to the Crotalidæ or "Pit-vipers" (of which the rattlesnake is the most remarkable), and are known by their broad and almost triangular heads; but there is one genus of poisonous snakes in America—*Elaps*, which belongs to a totally distinct family, and has a small oval head just like many harmless snakes. These, therefore, would be attacked and occasionally killed by snake-eating birds and quadrupeds, unless they had some distinctive mark as a notice of their possessing poison-fangs; and they have got this mark in a peculiar style of colouring different from that of any other snakes. They are all coloured with alternate black, red, or yellow rings from head to tail, giving them a most elegant and altogether peculiar appearance—a distinctive livery pointing them out as uneatable, in the same way that the Heliconidæ are pointed out amid the host of eatable South American butterflies. Now, just as the eatable and defenceless butterflies of the genera *Leptalis* and *Stalachtis* have taken on the livery of the Heliconidæ as a protection, so there are two or three genera of harmless snakes which have taken on the peculiar livery of those poisonous snakes, at least seven or eight species being known, each accurately mimicking in different parts of the

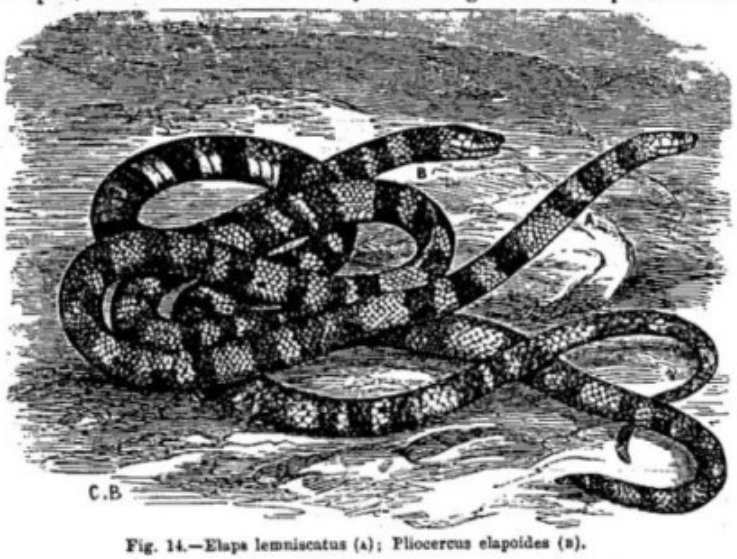

Fig. 14.—Elaps lemniscatus (A); Pliocercus elapoides (B).

country the particular species of Elaps found there. As an example we may name the deadly *Elaps*

* This is often so remarkable as to deceive the best observers. One of our first entomologists, Mr. McLachlan, informs me that once when out with a party of collectors he captured what he took to be a pair of humble-bees, and gave them to the late Mr. Frederick Smith, the greatest authority on bees, who carefully secured them in his collecting-box; and it was only on reaching home and proceeding to set them out that he discovered that they were not bees at all, but flies of the genus Volucella, which are parasitic on humble-bees, and are thus disguised in order that they may enter their nests with impunity in order to deposit their eggs.

lemniscatus, of Mexico, which has broad black bands on a red ground, each band divided into three parts by narrow yellow rings; and this very peculiar colouring is exactly copied in the harmless *Pliocercus elapoides* of the same country (Fig. 14). We can hardly have more wonderful and more conclusive cases of warning colour and protective mimicry than are afforded by these various species of American snakes.

Birds offer a few undoubted cases of mimicry, the most perfect being that of some species of *Mimeta*, a genus of brown orioles, which mimic *Philedon*, a genus of honeysuckers (Fig. 15). The latter birds, it may be remarked, are the largest of their family, and are very noisy and pugnacious; they are also very plentiful, and will band together to drive away crows and even hawks that intrude among them. We may presume, therefore, that they are generally unmolested, and it would thus be of use to any weaker bird to be mistaken for them. The orioles, though nearly as large, are decidedly weaker birds, and are far less numerous, and thus correspond to the general character of mimicking species. In the island of Bouru, one of the Moluccas, there is a peculiar species of *Philedon* (*P. bouruensis*), and in the same island a peculiar species of *Mimeta* (*M. bouruensis*), which are so much alike that in a great French work, the "Voyage de L'Astrolabe," the oriole is figured and described as a honeysucker under the name of *Philedon bouruensis!* the two birds belonging to families at least as distinct as thrushes and crows. The manner in which the imitation is effected is very curious. The *Philedon bouruensis*, as in almost all the species of the genus, has a large bare patch of black skin round the eyes; this is copied in the *Mimeta bouruensis* by a patch of black feathers. The narrow scale-like feathers on the crown of the *Philedon* are imitated by a dark line on the broader feathers of the *Mimeta*. On the neck of the *Philedon* the feathers are recurved, showing their pale under-surfaces and forming a kind of ruff or cowl which has given to them the name of friar-birds, and this is represented by a pale band in the *Mimeta;* and lastly, the bill of the *Philedon* has a protuberant keel at the base, and the *Mimeta* has the same character, though it is not found in the allied species. The colours of this pair of birds are simply brown, darker above and lighter below; but in the adjacent island of Ceram there is another species, *Philedon subcornutus*, which has a great deal of ochre-yellow in its plumage, and this is exactly imitated by the corresponding *Mimeta forsteni*, both being confined to this single island. If it could be thought that the resemblance in the one case might be accidental, and that their occurring in the same island was also a coincidence, the occurrence of another pair in another island renders this explanation inadmissible; but to any one who has comprehended the general principles of mimicry already set forth, it will be clear, that these are of exactly the same nature in the case of these birds, and can be explained only in the same way.

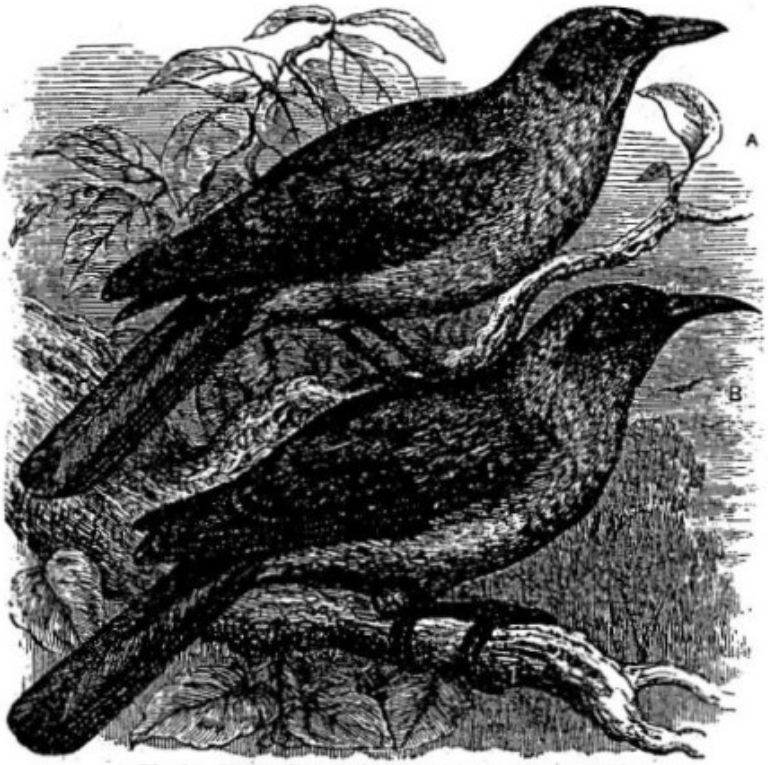

Fig. 15.—Mimeta bouruensis (A); Philedon bouruensis (B).

The family of birds which presents the greatest number of cases of mimicry is undoubtedly that of the cuckoos, the reason being that the species are

all of very weak structure and utterly defenceless. Many of the true cuckoos are coloured exactly like hawks, and this is particularly the case with those of the genus Hierococcyx, which are named hawk-cuckoos. Dr. Jerdon states that *H. varius*, a common Indian species, undergoes changes of plumage exactly corresponding to that of an Indian sparrow-hawk, *Micronisus badius*, and that it is often mistaken for that species by other birds. Another Indian cuckoo (*Surniculus dicruroides*) is black with a deeply-forked tail, and is so exactly like the common King-crow (*Dicrurus macrocercus*) as to be mistaken for it. It is believed that it lays its eggs in the nest of the latter bird, and that this is the reason of its remarkably perfect mimicry; but no doubt it is also thereby protected from the attacks of hawks, as the king-crows are very pugnacious and aggressive birds, which attack and drive away hawks, kites, and crows, a habit from which they have obtained their popular name. In Sumatra and Borneo there is a large ground cuckoo (*Carpococcyx radiatus*) handsomely coloured with metallic purple and red, so as to resemble the pheasants of the country of the genus *Euplocamus*.

Among mammalia there are hardly any examples of one species imitating another of a different group for the purpose of protection, the best perhaps being the curious insectivorous Tupaias of the Malay countries, which almost exactly resemble squirrels both in their colours and their bushy tails, but which belong to a totally distinct order. If this resemblance is not accidental it must be for the purpose of enabling them to approach their insect prey under the guise of harmless squirrels. Another case is that of the Aard-wolf (*Proteles*), which has weak jaws, and feeds on white ants and carrion, but which is coloured and spotted exactly like the savage hyæna; and it may avoid the attacks of the more powerful carnivora, owing to the very general fear of the terrific bite of the animal it resembles.

In describing the phenomena of mimicry it is difficult to avoid conveying the impression, that there is some voluntary action in the creatures that thus seem to disguise themselves in order to be mistaken for quite different creatures; but those who have understood the explanation given in our former paper, of the mode in which ordinary protective resemblances have been brought about, will not fall into this mistake. If an Arctic bird has become white, and a forest bird green; if one insect is coloured like a leaf, another like the bark it clings to, we can easily see that it is only a step further in the same process for one insect to become exactly like another insect.

Some persons, however, have objected, that so many steps are required in the process of making a white *Leptalis* resemble a highly coloured *Ithomia*, that the chances against the necessary variations occurring are infinite. It is forgotten, however, that both the groups to which these genera belong have been undergoing constant changes for countless generations. Many Pieridæ have dusky, or yellow, or red markings, and many Heliconidæ have comparatively little colouring; and if we go back to the remote epoch when the Heliconidæ and Pieridæ were both much nearer to their common lepidopterous ancestor, we can have no difficulty in believing that species of one family might sometimes not be very unlike species of the other family. Now if at this remote period the Heliconidæ began to acquire the peculiar nauseous secretion which became a protection to them, and allowed them to increase and vary greatly, and to acquire the brilliancy of colour, length of wings, and slowness of flight which now distinguish them, it is not improbable that here and there one of the Pieridæ should be sufficiently like them to be mistaken for one of the group, and thus acquire a partial protection. This protection would inevitably increase by the simple action of natural selection, those variations of the ancestral *Leptalis* or *Enterpe* having the advantage which followed the variations of the ancestral *Ithomia* or *Mechanitis*, and thus, in the course of thousands or perhaps millions of generations, that close resemblance which we now see would be brought about. It must be remembered too, that the imitation would be rendered more accurate as time went on, owing to the increased acuteness of the insectivorous enemies of the butterflies. An imperfect resemblance would, after a time, be found out, and this would lead to the selection and perpetuation of more and more perfect mimicry. It may be asked, how do so many species of *Leptalis* still survive, which are yellow and white and not at all like Heliconidæ? and we can only give a guess in reply. Many of them are more rapid fliers; some may have different habits, and in some the larvæ may have better means of concealment and protection. As Mr. Darwin has remarked, we can seldom say why one of our native insects should be very common while another is very rare, and to answer similar questions regarding tropical insects is, of course, impossible. Our ignorance in this respect does not, however, prevent us from acquiring knowledge in other directions, and does not in the least affect the

extraordinary facts of mimicry, only a small selection of which have here been laid before our readers. These facts are so varied and so extraordinary, they occur in so many distinct groups of animals, and in so many different parts of the world, and they have been so carefully studied by several good observers, that not a doubt remains as to their reality; while no theory but that of Natural Selection affords—in my opinion—any intelligible explanation of them.

THE PHYSICS OF MUSIC.

By Professor F. R. Eaton Lowe.

THERE are few ears anatomically perfect that are altogether insensible to the charms of music. Its power to soothe or to excite, to soften and to refine, to move to sadness or to rouse to passion, is no mere visionary sentiment conjured up by poets and musicians, but an actual potential influence, which has been felt and appreciated by mankind from time immemorial. As education advances, music becomes more generally regarded as an essential and integral part of it, and the "concourse of sweet sounds," from being a source of mere sensuous enjoyment, becomes a subject of intellectual study. It is the cultivated musician alone, however, who can extract from music all the enjoyment it is capable of affording.

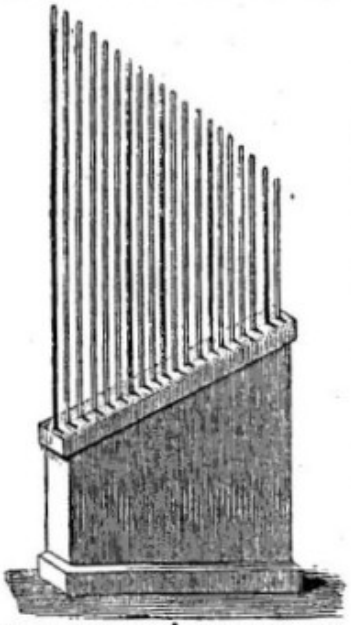

Fig. 1.—Marloye's Harp of Wooden Rods.

His disciplined ear alone can unravel the intricacies of the combined counterpoints, appreciate fully the resolution of chords, comprehend the working out of a theme, or detect the unity of idea pervading an entire composition. But it is reserved for the physicist to explain to the musician the various phenomena which accompany the production of those sounds with which he is so much enraptured; and the admiration which he feels for his favourite art cannot but be heightened by the knowledge thus acquired of the physical laws which operate in its exercise and development.

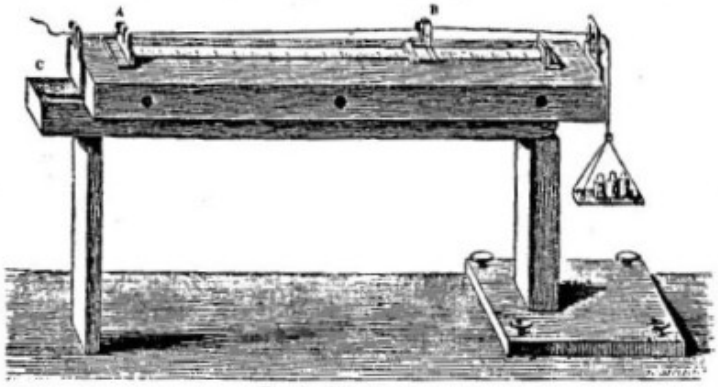

Fig. 2.—The Sonometer.

The general laws relating to the propagation of sound through air have already been discussed in these pages (Vol. I., p. 124), so that, in this paper, we shall confine ourselves to the consideration of those vibrations which, simply or compounded, are concerned in the production of those multifarious acoustic effects included under the general term *music*.

Musical sounds are produced by the vibration of strings or wires, in a state of tension, of rods of metal or wood, metallic plates or tongues, and by air-pulsations within tubes or pipes; thus we have stringed instruments, as the harp, violin, and piano; wind instruments, as the organ, trumpet, and cornet; reed instruments, in which a peculiar quality is imparted to the sound by the vibration of narrow slips or tongues of metal, as the oboe, bassoon, harmonium, and the reed pipes of organs; and, lastly, instruments of a more primitive character, in which solid rods or plates—either of metal or wood—are

PROTECTIVE MIMICRY IN ANIMALS.

By Alfred Russel Wallace, F.L.S., Author of "The Malay Archipelago," etc.

In a former article (pp. 128—137), on the "Protective Colours of Animals," we endeavoured to illustrate the purpose and origin of all those peculiarities of colouring which tend to conceal animals from their enemies or from the prey which they wish to capture; we showed how widespread were such colours in nature, and how often it happened that what seem showy colours when we examine the species in confinement, or when preserved in a museum, are really protective when the animal is seen in its native haunts and in the attitude it usually assumes when at rest. We referred to many cases of special imitation by insects of vegetable substances — of leaves or flowers, bark or moss—sometimes so wonderfully accurate as to deceive the eye of the experienced naturalist as well as that of the hungry bird. But besides all these, we called attention to a totally different kind of protection, always associated with conspicuous instead of protective colouring. A number of insects (and some of the higher animals) possess secretions which are so nauseous as to render them generally uneatable. This is a perfect protection against being devoured, but it would be no protection against being hunted, and caught, and often killed, if there was nothing to distinguish these from the great majority of eatable insects. But eatable insects (if soft and defenceless) are almost always protected by obscure or green tints harmonising with their surroundings. Evidently, therefore, the best way to distinguish the uneatable kinds would be that they should be of gay and brilliant tints, strongly contrasted with their surroundings, and readily distinguishable from a considerable distance. Marvellous to relate, this is actually the case; and the uneatable insects are, almost without exception, gaudily and conspicuously coloured. A number of such cases were adduced, especially among our native caterpillars, and proofs of their non-edibility were given.

We now propose to deal with this part of the subject more fully, in order to explain what is meant by "protective mimicry"—perhaps the most interesting and the most wonderful of all the phenomena of colour among animals. It is only among the teeming forms of life of tropical forests that the best cases of mimicry are to be met with, and we shall therefore now have to deal with objects for the most part unfamiliar to the British collector. We hope, however, by means of numerous illustrations, to make the subject intelligible to our readers, and especially to such as have some knowledge of our native insects.

Mimicry is the term applied to the phenomenon presented by certain species which, being themselves eatable, and belonging to groups which are attacked and devoured by numerous enemies, obtain protection by their close resemblance to some of the brightly coloured species which are free from attack on account of their nauseous odour or general inedibility. In most cases it is not a general but a special resemblance which serves this purpose, sometimes carried so far that the mode of flight and general habits are imitated, as well as colour and marking. The most numerous examples of mimicry occur among butterflies, but there are almost equally remarkable cases among beetles and other orders of insects, as well as a few among reptiles and birds. We will, therefore, first describe the groups of butterflies which are the subjects of mimicry by other groups.

In all tropical forests butterflies are abundant, and very varied in size, form, colouring, and mode of flight. Some fly with great rapidity, others have a zigzag, jerking mode of flight, and many such are adorned with brilliant colours. Great numbers of Satyridæ and Erycinidæ keep near the ground, with a slow hovering flight, and these have generally a sober style of coloration; while many of the showy species have their under-sides adorned with rich dark marblings, which render them inconspicuous as soon as they settle on a leaf or branch. But there are three great families—the Danaidæ, Heliconidæ, and Acræidæ—one or other of which is everywhere abundant both in species and individuals, and which are always remarkable, for their beauty or their conspicuousness; for their slow and lazy flight; for never trying to conceal themselves, and never flying high up in the air. The under-sides of their wings, too, are always coloured nearly the same as the upper, or, at all events, never present markings tending to concealment. These three families are closely allied to each other, and should, perhaps, form sub-divisions of one family, and they are believed to be most nearly related to the Nymphalidæ (to which family belong our tortoiseshells and fritillaries), of which they are a special development. They all have

the cell of the hind-wings closed, whereas in the Nymphalidæ it is always open; but they agree with the latter family in having the first pair of legs short and imperfect in both sexes, but more especially in the males, and in the pupæ being freely suspended by the tail.

All three groups have the peculiarity of possessing a powerful odour, which appears to pervade the whole body. When a specimen is caught and pinched between the fingers, a yellow fluid oozes out, which has a strange pungent smell and stains the skin. This has been observed with the Heliconidæ of South America, the Acræidæ of Africa, and the Danaidæ of Asia and Australia, and it appears to be of a very similar nature in all these groups. This pungent yellow secretion is very distasteful to birds and other insectivorous animals, so that the butterflies in question are never persecuted as others are. Some persons have doubted whether birds catch butterflies at all. Swallows, however, have been seen chasing white butterflies even in England; but in the tropics insectivorous birds belonging to many distinct families are much more numerous, and no eatable insects escape them. Mr. Belt, when in Brazil, watched a pair of puff-birds catching butterflies during half an hour, capturing many and carrying them to their young; but though numbers of Heliconidæ were flying slowly about, the birds neither noticed nor made any attempt to catch them. Neither Mr. Bates nor myself ever saw these butterflies attacked by birds, or lizards, or predacious insects, though they often rest exposed, hanging on the tips of leaves where they would be easily captured; and though the wings of butterflies that have been caught and eaten are often found lying in the forest paths, those of the Heliconidæ are never found among them. Dragon-flies were seen to catch Pieridæ in Natal, but never the slower-flying Acræidæ; while among the wings of butterflies found under certain trees where they assemble to feed on the exuding sap, and are captured by mantises and other insectivorous creatures, no Acræidæ or Danaidæ were ever found. We may consider it, therefore, to be an established fact that these three groups of butterflies enjoy almost perfect immunity from attack, owing to their offensive taste and odour; and their peculiarities of form and colour as well as their mode of flight, seem to be so well known to all insectivorous creatures, that they are recognised at a considerable distance, and thus not only escape being devoured, but are generally free from all pursuit or molestation. No doubt young birds or lizards sometimes make the trial, but the result is so disagreeable that they very soon learn what to avoid.

The peculiar odour is found in the caterpillar and the chrysalis of these butterflies, as well as in the perfect insects, and the result of this freedom from persecution is that they swarm in the forests to a greater extent than any other butterflies. The Heliconidæ of South America and the Danaidæ of the Malay Islands may always be found, even when other butterflies are very scarce, and there are many places where hardly any other kinds can be seen. It is evident, therefore, that if any other butterflies, belonging to eatable groups, should closely resemble any of these inhabiting the same districts, they would certainly be mistaken for them, and so obtain protection. Wherever these groups are found there are such cases of mimicry, of which we will now give some of the more interesting examples.

In tropical America the Heliconidæ* are immensely abundant, about 400 species having been described up to 1871, while, as many new ones are discovered every year, the number cannot be now much less than 500 species. They are also, as already stated, very abundant in individuals, and as all these are, without exception, uneatable, it is not surprising that insectivorous creatures have got to know them well and avoid them. They differ wonderfully among themselves in colour, some being black or blue, banded with yellow or white; others rich red, with yellow bands and rays; others rich brown and yellow spotted; while an immense number have transparent wings, either simply veined or delicately tinged with yellow, brown or purplish. Yet, amid all this variety, the general form, the style of marking, and the

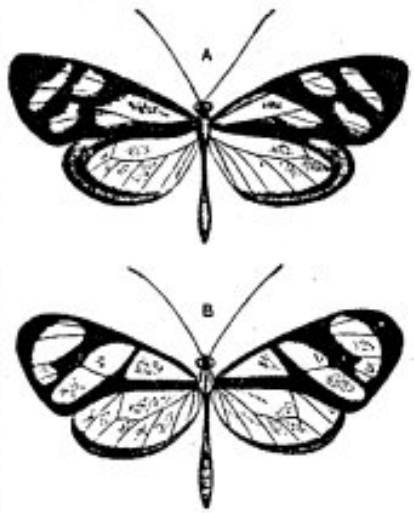

Fig. 1.—Leptalis theonoë (A); Ithomia flora (B).

* They have now been divided into two families, Heliconidæ and Danaidæ; but I keep the old nomenclature for simplicity.

mode of flight are so peculiar, that even species never seen before are recognised at a glance as belonging to this family.

In the same forests are found a considerable number of the totally distinct family of Pieridæ, to which belong our well-known "cabbage," "orange-tip," and "brimstone" butterflies. Most of these are white or yellow, variously marked and shaded, but still unmistakably Pieridæ; but there is one genus—*Leptalis*—which has more elongate wings than usual and a weaker flight, and these vary greatly in colour, some being white, others yellow or yellow and black, while others are coloured exactly like the Heliconidæ. The wonderful thing is, that the resemblance is not general but special. The coloured *Leptalis* does not look like a new species of Heliconidæ, but exactly imitates an existing species, and *always a species which inhabits the same locality*. Thus the transparent-winged, black-banded *Ithomia flora* (one of the Heliconidæ) is accompanied, at Cupari on the Tapajos river, by *Leptalis theonoë* (Fig. 1), which so closely resembles it that it cannot be distinguished when on the wing; while in other parts

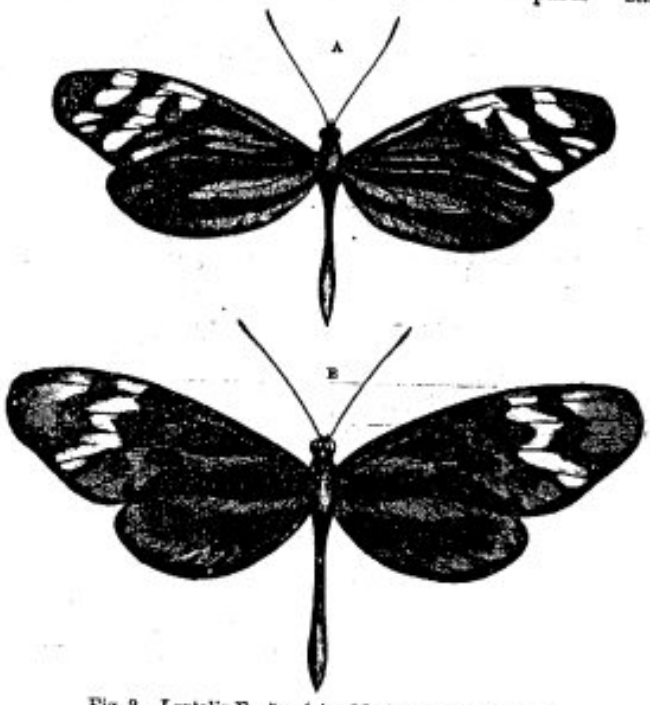

Fig. 2.—Leptalis Egaëna (A); Mechanitis obscura (B).

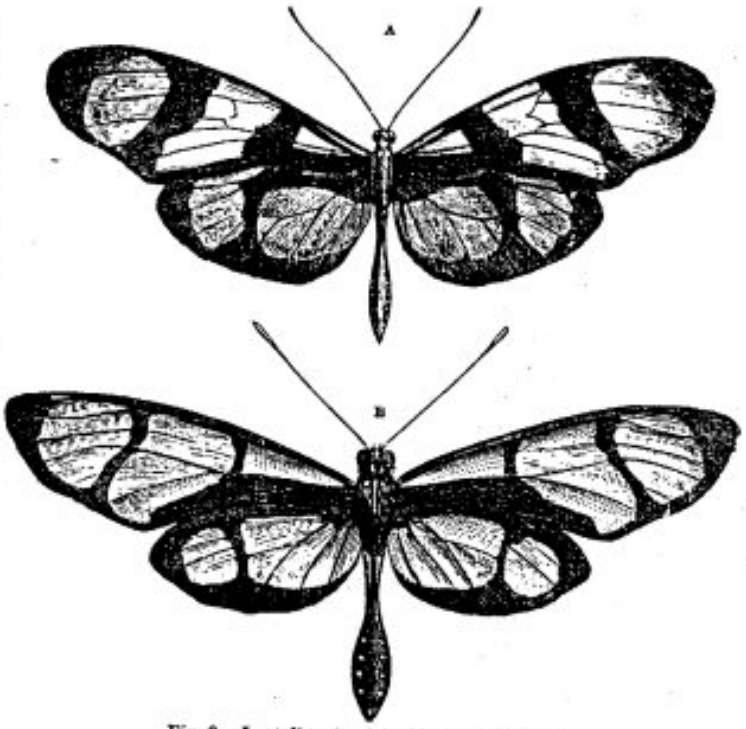

Fig. 3.—Leptalis orise (A); Methone psidii (B).

of the Amazon valley distinct species of *Ithomia*, with orange-red bands and spots, are imitated by varieties of this *Leptalis*. At Ega, on the Upper Amazon, the handsome brown-black and yellow-banded *Mechanitis obscura* (one of the Heliconidæ) is accompanied by *Leptalis Egaëna*, closely resembling it in size, colours, and markings, and both have long yellow antennæ (Fig. 2). Still more remarkable is the large and handsome yellow-and-black *Methone psidii* (one of the Heliconidæ), accompanied by *Leptalis orise*, equally large and very similarly marked and coloured; and in this case both have long black antennæ with a yellow club (Fig. 3).

These are only a few out of many examples that might be referred to, but it is necessary to see the specimens themselves in order to appreciate the wonderful change that has taken place from the usual style of colouring of the Pieridæ (still prevalent even in the genus *Leptalis* itself) to these richly-coloured and strangely-marked forms. Before going further, however, it will be well to show how greatly the two groups, *Leptalis* and *Ithomia*, really differ. The accompanying figures (Fig. 4) show the anterior feet, the pupæ, and the larvæ of the two families Pieridæ and Heliconidæ. In the former the feet are long and perfect, with five-

jointed tarsi and bifid claws; the pupa is always supported by a looped thread, and the larva, or caterpillar, is smooth, slightly downy, but without spines or processes of any kind. In the latter the anterior legs are short and imperfect, having no tarsi in the male, and only one or two joints in the female; the pupa is always freely suspended, without any brace or loop, and the larvæ are always furnished with fleshy processes. These combined differences are so important that we may consider the two families to be at least as distinct as deer are from goats, or robins from finches.

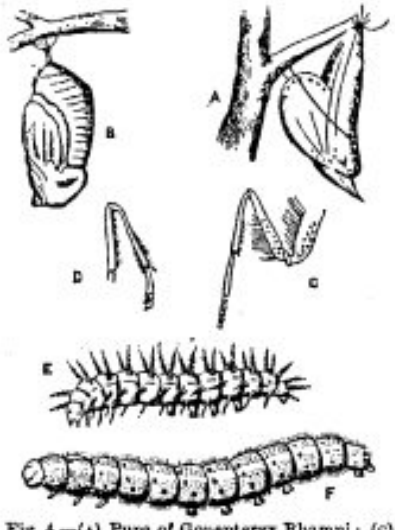

Fig. 4.—(A) Pupa of Gonepteryx Rhamni; (C) Leg of Gonepteryx; (B) Pupa of Danais plexippus; (D) Leg of Danais plexippus♀; (E) Larva of Acræa violæ; (F) Larva of Pontia brassicæ.

Besides the genus *Leptalis*, several other groups imitate the Heliconidæ in an equally extraordinary manner. A true Papilio (*P. pausanias*) has the exact colouring of *Heliconius clytia*—rich steel-blue with yellow bands; while another most remarkable species (*P. zagreus*) is richly marked with stripes and spots of yellow, brown, and black, so as closely to resemble the Heliconoid *Lycorea atergatis*. Two genera of Erycinidæ (*Ithomeis* and *Stalachtis*), and moths of the genera *Castnia*, *Dioptis*, and *Pericopis*, also resemble species of Heliconidæ in their respective districts in an equally remarkable manner.

In all, or almost all these cases, it has been observed that the mimicking species are much less plentiful than the Heliconidæ which they resemble; and a little consideration will show us that this is essential to the success of the imitation. For if the eatable Pieridæ and other groups were as abundant as the uneatable Heliconidæ, insectivorous animals would soon find it out, and would systematically capture them both, on the chance of getting at least one that they could eat for every one that they were obliged to reject. The fact seems to be, however, that the imitating species are usually very scarce indeed: often not one to a hundred, and sometimes not one to a thousand of the species they imitate; so that they are quite secure among the crowd of uneatable creatures so much resembling them. It may be asked, however, why, as they have the same protection, they do not increase and become nearly as numerous as the uneatable kinds. The answer is, undoubtedly, because their larvæ and pupæ are not protected, and thus suffer great destruction; and this was probably the reason why certain species acquired protection by mimicry in the perfect state as the only means of escaping impending extermination. It is evident that those species which had long and delicate wings and a slow flight, and which, owing to the thinning out of the larvæ and pupæ, were never very abundant, would be most liable to extermination. But these long-winged kinds would in form resemble the Heliconidæ, and any variations of colour tending to make them more like any of the species of that group would be an advantage. Such varieties would therefore have a better chance of escape, and in a long series of generations some of them might at least come to have the wonderful resemblances we now find, while many others, failing to vary sufficiently, have no doubt become extinct.

We will now pass to the African continent, where Acræidæ abound both in species and individuals, while Danaidæ, though few in species, are still sufficiently plentiful in individuals. These take the place of the Heliconidæ of South America, enjoying the same advantages; and they are mimicked in an equally remarkable manner by butterflies of three distinct families—Papilionidæ, Nymphalidæ, and Eurytelidæ; but not by any Pieridæ, which form the bulk of the mimicking species in South America. As an example we may take the *Acræa Euryta*, a common but remarkable butterfly of West Africa, numerous varieties (or allied species) of which are figured in Mr. Hewitson's "Exotic Butterflies," Vol. IV., Pl. IV., V. (Acræa); and in the same volume under Diadema (a genus of Nymphalidæ), Pl. III., are a series of insects, which it is hard to believe, at first sight, are not also varieties of the same species (Fig. 5). There is also a species of *Melanitis* (Fam. Eurytelidæ) that resembles the same species of *Acræa*. Another species, *Acræa zetes*, has a different style of marking, being red with numerous black spots, and this is very well imitated by another species of *Diadema* inhabiting the same districts.

But the most remarkable case known in Africa is presented by a true *Papilio* which, in several varieties and allied species, mimics the common *Danais echeria* with its varieties and allied species.

Danais Echeria (Fig. 7, A) is an elongate-winged black butterfly with a group of spots, either buff or white on the front wings, and a broad buff band across the hind wings; varying considerably in different parts of South Africa. Another species, *Danais niavius* (Fig. 8, A), is larger and handsomer, being deep black with two very large white patches, occupying more than half the surface of the wings. Yet another species, *Danais chrysippus*, perhaps the commonest of all, is rich orange-red, bordered with black on the hind wings, while nearly the outer half of the upper wings is black crossed by a broken band of pure white. These three butterflies may be said to be totally unlike each other in colour and markings, and each of them is accompanied by a Papilio closely imitating it, which have all been described as distinct species. A gentleman resident in Cape Town (Mr. Roland Trimen), who in 1861 published a book on the butterflies of South Africa, had his attention called to these cases of mimicry by the papers of Mr. Bates and myself, and especially to the fact that very often the females only have protective or imitative colours. He then observed that all these Papilios were, without exception, females, and no male specimen was to be found in any of the rich museums or private collections of this country. He also observed that wherever these butterflies were found, there was also found the large and handsome *Papilio merope* (Fig. 6), conspicuous by its pale sulphur-yellow colour, the anterior wings black bordered, while the tailed hind wings are crossed by a broken black band. This insect is as completely unlike all the others as possible; but it was always of the male sex, no female being known in any collections, and it was only found in districts where some one or other of the mimicking female Papilios were also found. The two sorts were also seen flying together and chasing each other, just as males and females of the same species often do; so, putting all these things together, he ventured to announce his belief that *all were one and the same species.*

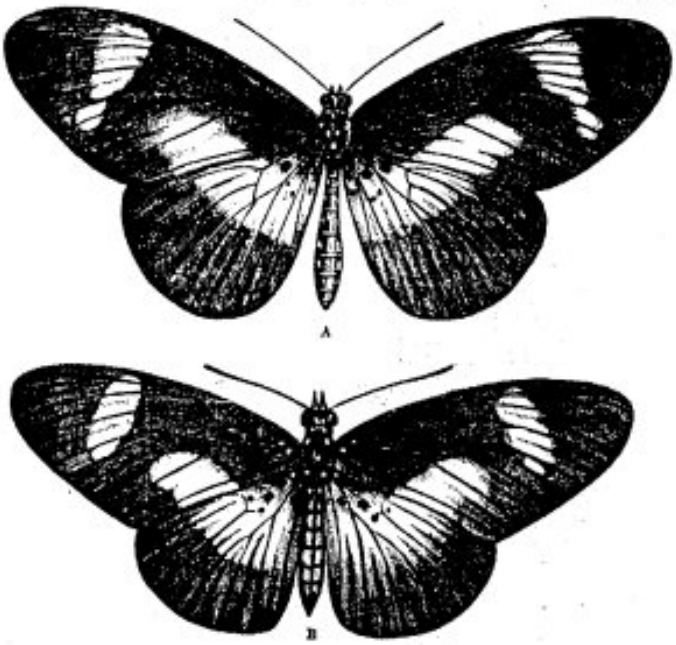

Fig. 5.—Acræa gea (A); Diadema Hirce (B).

On close examination it was found that there were many minute points of resemblance between these very different-looking insects, and a number of entomologists who were already acquainted with similar facts in other countries, concurred in Mr. Trimen's view. Others, however, strongly opposed it, especially Mr. Hewitson, who possessed the finest collection of butterflies in England. When figuring some of these female Papilios in his work on "Exotic Butterflies,"

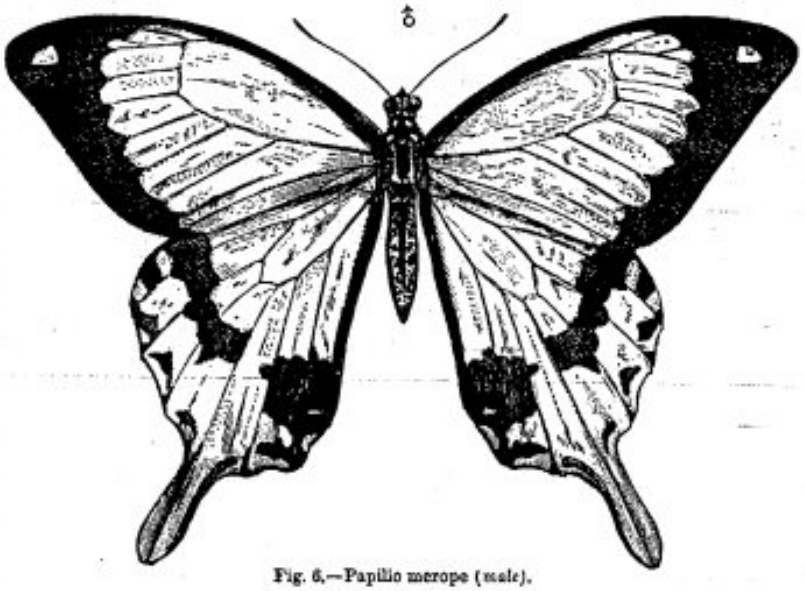

Fig. 6.—Papilio merope (male).

he wrote thus:—"That the butterflies now figured are all females, there cannot, I think, be a doubt; but that they are the females of *P. merope*, as suggested by Mr. Trimen, I do not for one moment believe." And he supported his disbelief by what is certainly a most remarkable fact, that in the adjacent island of Madagascar there is a slight variety of *Papilio merope*, which has a female almost exactly like itself, while nothing resembling the other females is found there.

In order to settle the question, Mr. Trimen requested his friend Mr. Mansel Weale to endeavour to obtain the eggs or caterpillars of one of the disputed females, and raise therefrom the perfect insect. This was done. Mr. Weale found eggs and larvæ of *Papilio cenea* (which was the name hitherto given to the female which resembled *Danais echeria*), and succeeded in raising from them thirteen butterflies. Of these butterflies, seven were males—the well-known yellow-and-black tailed *Papilio merope*; four were buff-banded females, mimicking *Danais echeria* (Fig. 7); one was a black-and-white female like *Danais niavius* (Fig. 8); and one was a red-winged female like *Danais chrysippus*. Here was positive proof that all these strangely different butterflies are one and the same species, the females mimicking distinct species of Danais!

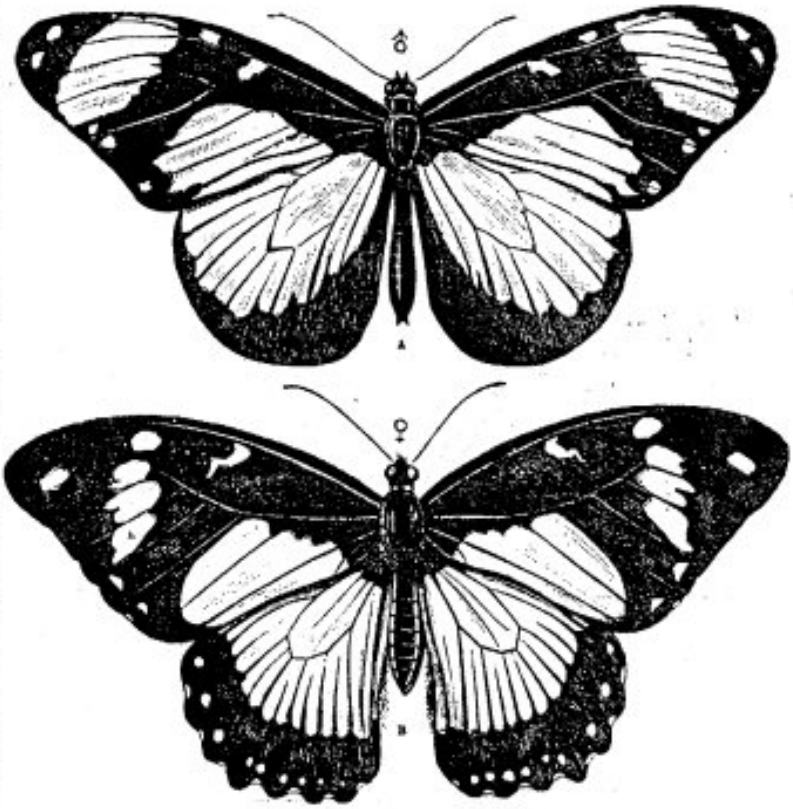

Fig. 8.—Danais niavius (♂); Papilio merope ♀ (P. hippocoon [♂]).

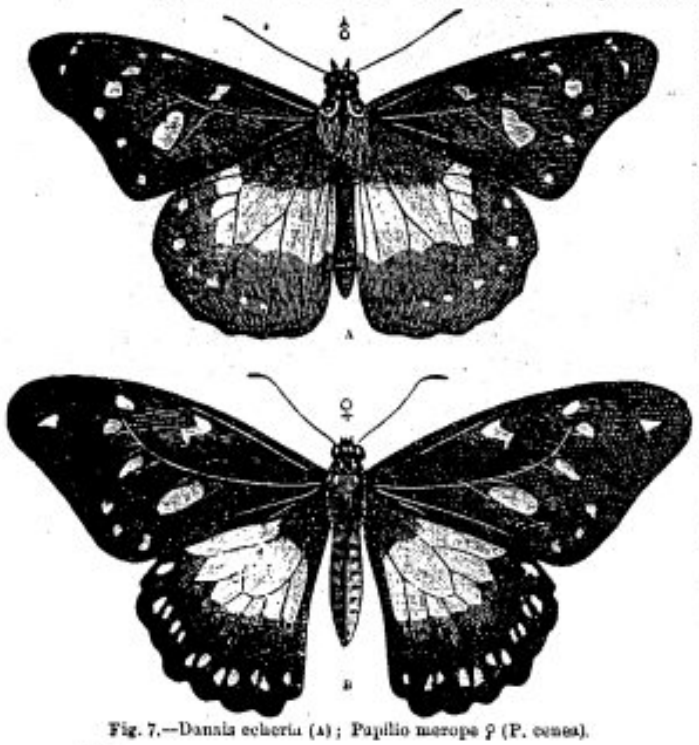

Fig. 7.—Danais echeria (♂); Papilio merope ♀ (P. cenea).

There are several other interesting facts connected with this butterfly. The caterpillar is the exact colour of the leaves it feeds upon, and is thus protected; the chrysalis is of a remarkable, broad shape, so as exactly to resemble a leaflet of the same plant, and the under side of the male butterfly is of mottled brown tints, and when at rest closely resembles a dead leaf. The perfect male is subject to the attacks of birds, since Mr. Weale saw one actually captured by a large crested fly-catcher; but they fly strongly, darting up and down with great rapidity, and thus no doubt many escape. The flight of the females is, on the other hand, heavy and

slow, and while laying their eggs on the proper food-plant they are especially subject to attack. We may well suppose, then, that they were once near extermination, when some ancestral form varied sufficiently to become something like one of the Danaidæ, and thus obtained the protection necessary for the preservation of the race. Why the Madagascar form of the species did not produce similarly diverse females is not quite clear; but it is certain that in such islands as this, where the number of species both of birds and insects is much less than on continents, the struggle for existence is not nearly so severe. Forests also are denser and more extensive in Madagascar, and thus offer better concealment for insects, which, therefore, may not need the same amount of extraneous protection as on the continent. Having devoted so much space to *Papilio merope*, we must pass by the many other cases of mimicry that occur in Africa, in order to notice a few of those of India and the Malay Archipelago.

In these countries three genera of Danaidæ, *Danais*, *Euplœa*, and *Idea*, are very abundant, each having a peculiar style of colouring. *Danais* has elongate wings, and is very varied in colour, but is often semi-transparent greenish or bluish-white with black stripes, and often suffused with yellow or brown. *Euplœa* has more rounded wings, and is usually dark coloured, with white bands or spots, but is often richly glossed with metallic blue, and very handsome. *Idea* is very large, with thin papery wings of a whitish semi-transparent colour, marked with round spots or with bands of black. All these forms are closely imitated by various species of *Papilio* and *Diadema*, of which only a few of the more remarkable can be here noticed.

One of the most common Danaidæ in Malacca and Borneo is *Euplœa midamus* (Fig. 10), the male of which has the fore wings of a brilliant metallic blue, with faint bluish-white spots, while the hind wings are uniform brownish black. The female differs considerably, the hind wings being covered with narrow white lines radiating from the body, and having a marginal row of white spots. This is exactly imitated in the two sexes of *Papilio paradoxa* (Fig. 9), which inhabits the very same districts, but is, comparatively, rare; but the two species are so much alike that I could hardly ever distinguish them when on the wing. The almost equally common *Euplœa rhadamanthus* is very distinctly coloured, with sharply defined white patches and blue spots on a black ground, very unlike any other butterfly except the *Papilio caunus*, which imitates

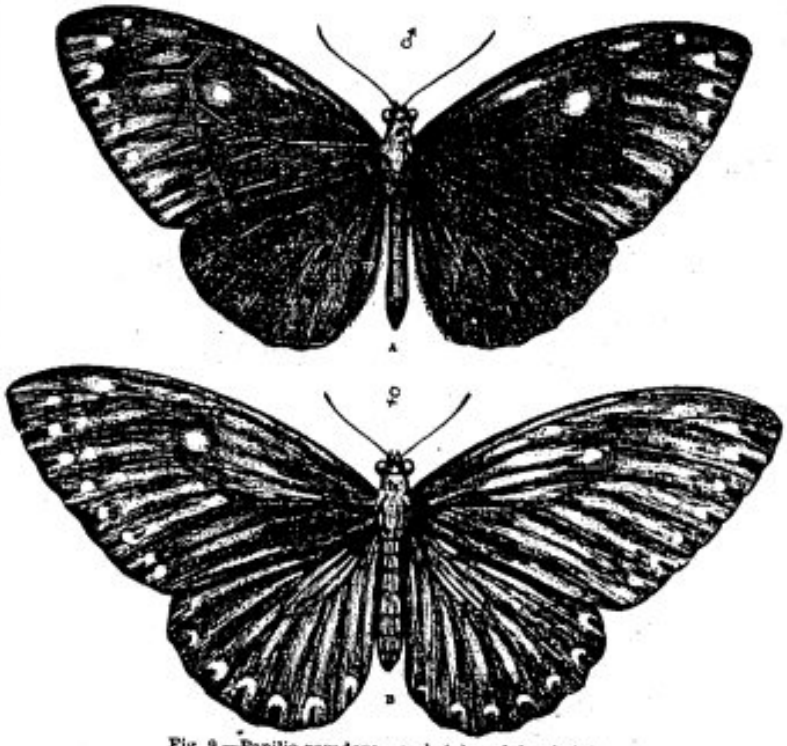

Fig. 9.—Papilio paradoxa: male (A), and female (B).

it with wonderful accuracy both in markings and in mode of flight. In the Philippine Islands the large white-and-black *Idea leuconoe* is closely imitated by the fine *Papilio ideoides* of the same islands.

We have here also two examples of female butterflies being modified for protection, so as to be quite unlike their males. The male of the very common *Diadema misippus* (Fig. 11) is black, with four conspicuous oval white spots margined with glossy blue. The female is a totally different-looking insect, of a rich orange-brown colour, margined with black and white, and with a white band crossing the black apex of the anterior wings. The idea of their being two sexes of the same species would never strike any one, and would seem utterly preposterous if it were told them for the first time. It is, however, undoubtedly the fact, and the female is an

accurate mimic of the excessively common *Danais chrysippus*. The male *Diadema misippus* flies rapidly, and often mounts into the air, while the female flies slowly and keeps low down; and as the species frequents open grounds rather than forests, she would be in great danger of extermination while hovering over the plants on which she lays her eggs, and thus has great need for the protection gained by her resemblance to the uneatable *Danais chrysippus* which swarms everywhere (Fig. 11).

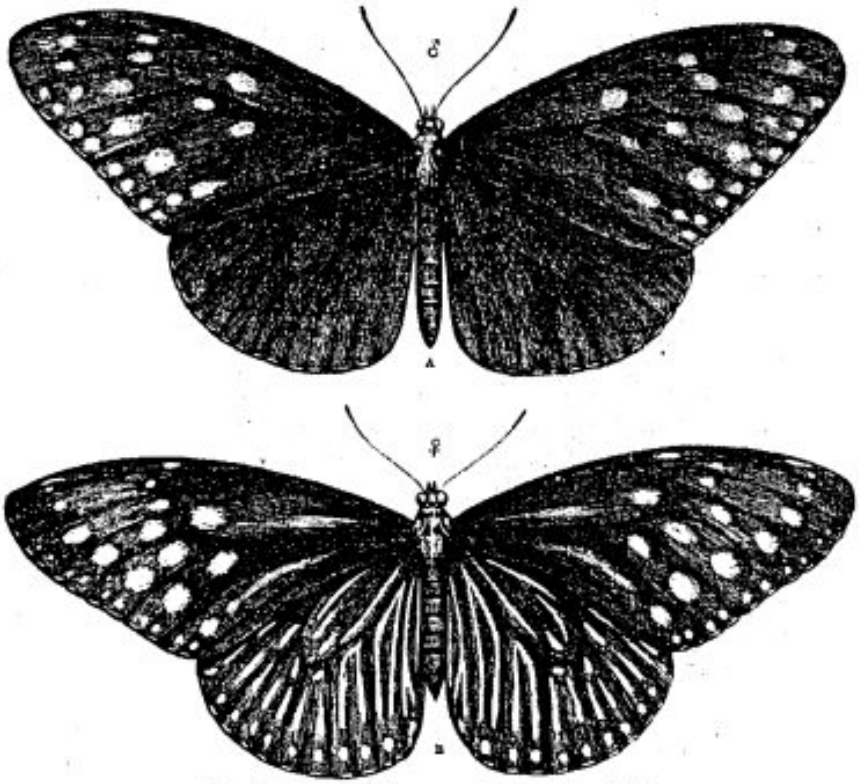

Fig. 10.—Euplœa midamus: male (♂), and female (♀).

The other case is that of a *Diadema* from the larger Malay islands, which, owing to its rich metallic blue gloss, had been described, thirty years ago, as the male of another species. On close examination, however, I found it to be a female, while the male is a comparatively dull insect, with hardly any blue gloss and much whiter spots. The two differ, in fact, just as do the sexes of many butterflies, but in a reverse way, the female being here the more brilliant, the male far less so, for which reason I named the species *Diadema anomala*. The explanation of the anomaly is, that the female mimics the male *Euplœa midamus* with great accuracy, and thereby acquires the protection which her slow flight and exposure while egg-laying renders necessary. This is a most interesting case, as proving the great power of the need of protection to lead to modifications of colour in the female sex. For purposes of concealment, females generally have less conspicuous tints than their mates, but when protection can be more readily secured by resemblance to species absolutely free from molestation, they can acquire distinct or even brilliant colours, and such as are generally characteristic of the male sex.

Cases of true mimicry among Lepidoptera, such as we have here described, are almost unknown in temperate lands, where the forms of insect life are so much less varied; but there is one very good case in temperate North America, and there are also a few in our own country. In the United States the handsome red-and-black *Danais erippus* is very common, and there occurs with it one of the Nymphalidæ, *Limenitis archippus*, which closely resembles it in colour and markings, and is totally unlike all the other species of its own genus. The white moth, *Spilosoma menthrasti*, mentioned in our former paper as being uneatable, is very abundant; but there is another moth, *Diaphora mendica*, of which the female only is white, which appears at the same time of the year, and is much less common, so that it is very probable that this species is secure from enemies by being mistaken for the uneatable kind. Our clear-wing moths of the families Sesiidæ and Ægeriidæ are, however, undoubted mimickers, many of the species resembling bees, wasps, or ichneumons, as their names imply. *Sphecia crabroniformis*, for example, imitates the wasp, *Odynerus antilope* (Fig. 12); and the common little currant moth, *Trochilium tipuliforme*, resembles a small black wasp, *Odynerus sinuatus*, which is abundant in gardens at the same season.

Coming to the order Coleoptera, or beetles, we find numerous cases of the mimicry of protected

by defenceless species. Some extensive groups have an offensive taste like that of the Danaidæ among butterflies. Such are the Eumorphidæ and Hispidæ, and especially many of the Malacoderms, our own red-and-black species of *Telephorus*, commonly called "soldiers and sailors," being refused by most, if not all, birds. These groups

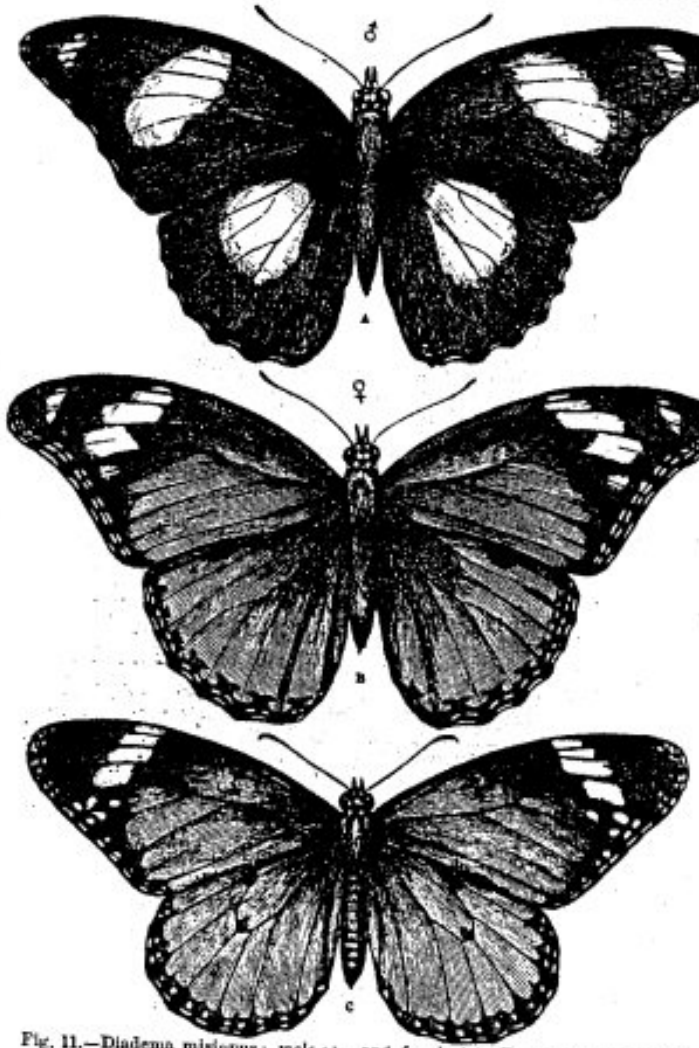

Fig. 11.—Diadema misippus: male (A), and female (B); Danais chrysippus (C).

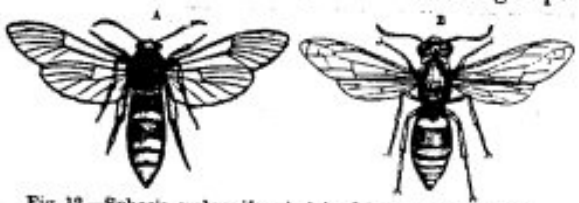

Fig. 12.—Sphecia crabroniformis (A); Odynerus antilope (B).

have all conspicuous colours and fly slowly, and many of the species are mimicked by Longicorns, a group of beetles which seems to be particularly subject to the attacks of insectivorous creatures, since a large number of the species have acquired protection, either by their colours, markings, and rugosities, causing them to resemble bark or foliage, or by their habits of concealment, feigning death, or feeding at night. Another group of beetles are protected by the excessive hardness of their integuments, which render them uneatable to most insectivorous birds. Such are many of the Curculionidæ and Anthribidæ, and both these groups are often mimicked by Longicorns in a most perfect manner. The most curious example is, perhaps, that of the Longicorns—*Doliops curculionides* and *D. geometrica* of the Philippines, which, both in shape and colours, closely resemble weevils of the genus *Pachyrhynchus*, peculiar to the same islands. This is the more remarkable, because the insects imitated are marked in a most unusual manner with geometrical patterns, and possess the most brilliant metallic colours. The Eastern tiger-beetles of the genera *Collyris* and *Therates* are also mimicked, the former by a Longicorn, *Collyrodes Lacordairei*, the latter by a species of Heteromera, and in both cases the imitation is very exact.

The same group—Longicorns—also mimic many other insects which it is to their advantage to be mistaken for. Different species resemble bees, wasps both blue and yellow, saw-flies, ants, and the strong-smelling Hemiptera. Our illustration (Fig. 13) represents one of these beetles, which exactly resembles a large blue wasp, both inhabiting the same districts in South America. The reason why cases of mimicry occur so much more frequently in this family of beetles than in any other, is, probably, because their enormous numbers and endless modifications of form and structure offer facilities for natural selection to work upon, some of them more or less closely approximating to the form and colouring of every other family of the order.

There are also many cases in which distinct orders of insects mimic each other. Moths which imitate bees and wasps have already been mentioned. In the Philippine Islands two very singular cases occur. An insect of the cricket family (*Condylodera*

tricondyloides) is so exactly like a tiger-beetle of the genus *Tricondyla*, that so old and learned an entomologist as Professor Westwood placed it among them in his cabinet, and kept it there for a long time before he found out his mistake. An-

Fig. 13.—Sphecomorpha chalybea.

other species of the same cricket family (*Scepastus pachyrhynchoides*) mimics a species of Pachyrhynchus (*P. venustus*), a beetle as totally unlike a *Tricondyla* as it is possible to find.

We cannot now do more than refer to the numbers of two-winged flies which mimic bees and wasps,* or the spiders which resemble ants; but we must just mention the Mantis which Mr. Bates found on the banks of the Amazon exactly resembling the white ants it feeds upon, and the crickets of the genus *Scaphura*, which accurately mimicked sand-wasps, the reason being that the sand-wasps are especially fond of crickets with which to provision their nests. These defenceless creatures have, therefore, in many distant countries, been preserved, by acquiring the form and colouring of stinging Hymenoptera, carnivorous Cicindelidæ, or hard-shelled Curculionidæ.

Owing to the comparative stability of the external form of the higher animals, and the important outward differences between the various groups, the facilities for the production of mimicry rarely exist in their case. Yet there are a few undoubted examples of very great interest. The chief venomous snakes of America belong to the Crotalidæ or "Pit-vipers" (of which the rattlesnake is the most remarkable), and are known by their broad and almost triangular heads; but there is one genus of poisonous snakes in America—*Elaps*, which belongs to a totally distinct family, and has a small oval head just like many harmless snakes. These, therefore, would be attacked and occasionally killed by snake-eating birds and quadrupeds, unless they had some distinctive mark as a notice of their possessing poison-fangs; and they have got this mark in a peculiar style of colouring different from that of any other snakes. They are all coloured with alternate black, red, or yellow rings from head to tail, giving them a most elegant and altogether peculiar appearance—a distinctive livery pointing them out as uneatable, in the same way that the Heliconidæ are pointed out amid the host of eatable South American butterflies. Now, just as the eatable and defenceless butterflies of the genera *Leptalis* and *Stalachtis* have taken on the livery of the Heliconidæ as a protection, so there are two or three genera of harmless snakes which have taken on the peculiar livery of those poisonous snakes, at least seven or eight species being known, each accurately mimicking in different parts of the

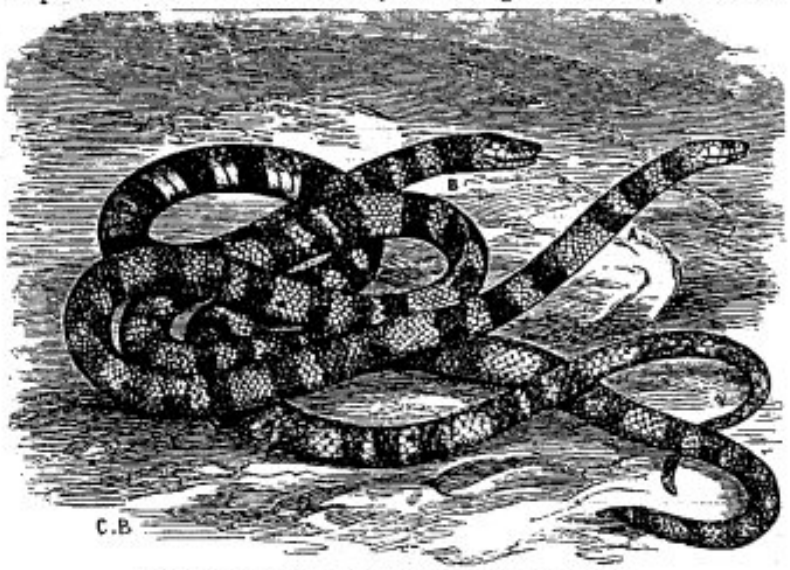

Fig. 14.—Elaps lemniscatus (a); Pliocercus elapoides (b).

country the particular species of Elaps found there. As an example we may name the deadly *Elaps*

* This is often so remarkable as to deceive the best observers. One of our first entomologists, Mr. McLachlan, informs me that once when out with a party of collectors he captured what he took to be a pair of humble-bees, and gave them to the late Mr. Frederick Smith, the greatest authority on bees, who carefully secured them in his collecting-box; and it was only on reaching home and proceeding to set them out that he discovered that they were not bees at all, but flies of the genus Volucella, which are parasitic on humble-bees, and are thus disguised in order that they may enter their nests with impunity in order to deposit their eggs.

lemniscatus, of Mexico, which has broad black bands on a red ground, each band divided into three parts by narrow yellow rings; and this very peculiar colouring is exactly copied in the harmless *Pliocercus elapoides* of the same country (Fig. 14). We can hardly have more wonderful and more conclusive cases of warning colour and protective mimicry than are afforded by these various species of American snakes.

Birds offer a few undoubted cases of mimicry, the most perfect being that of some species of *Mimeta*,

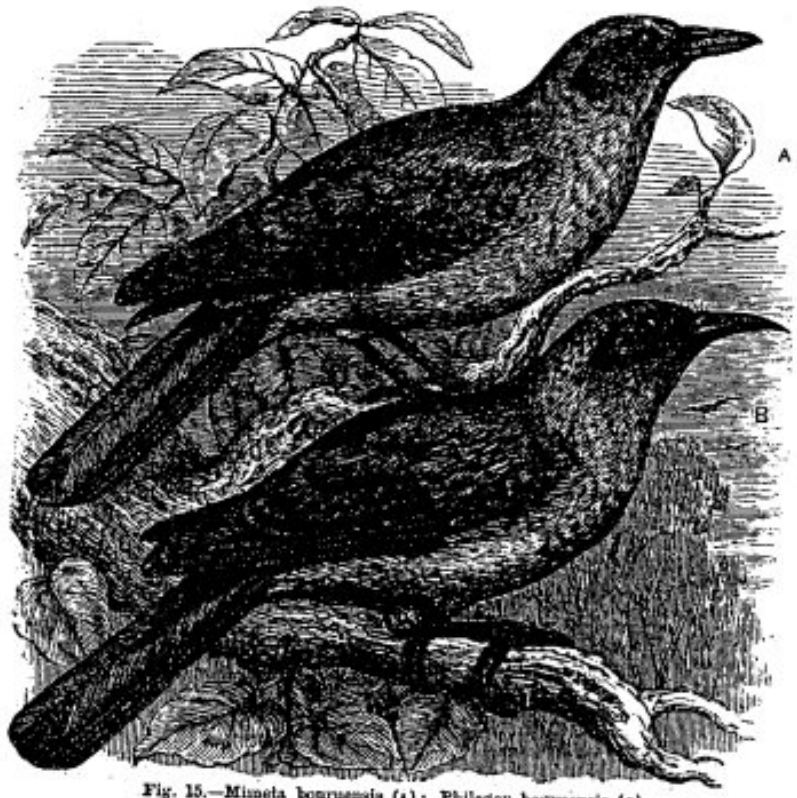

Fig. 15.—Mimeta bouruensis (A); Philedon bouruensis (B).

a genus of brown orioles, which mimic *Philedon*, a genus of honeysuckers (Fig. 15). The latter birds, it may be remarked, are the largest of their family, and are very noisy and pugnacious; they are also very plentiful, and will band together to drive away crows and even hawks that intrude among them. We may presume, therefore, that they are generally unmolested, and it would thus be of use to any weaker bird to be mistaken for them. The orioles, though nearly as large, are decidedly weaker birds, and are far less numerous, and thus correspond to the general character of mimicking species. In the island of Bouru, one of the Moluccas, there is a peculiar species of *Philedon* (*P. bouruensis*), and in the same island a peculiar species of *Mimeta* (*M. bouruensis*), which are so much alike that in a great French work, the "Voyage de L'Astrolabe," the oriole is figured and described as a honeysucker under the name of *Philedon bouruensis!* the two birds belonging to families at least as distinct as thrushes and crows. The manner in which the imitation is effected is very curious. The *Philedon bouruensis*, as in almost all the species of the genus, has a large bare patch of black skin round the eyes; this is copied in the *Mimeta bouruensis* by a patch of black feathers. The narrow scale-like feathers on the crown of the *Philedon* are imitated by a dark line on the broader feathers of the *Mimeta*. On the neck of the *Philedon* the feathers are recurved, showing their pale under-surfaces and forming a kind of ruff or cowl which has given to them the name of friar-birds, and this is represented by a pale band in the *Mimeta*; and lastly, the bill of the *Philedon* has a protuberant keel at the base, and the *Mimeta* has the same character, though it is not found in the allied species. The colours of this pair of birds are simply brown, darker above and lighter below; but in the adjacent island of Ceram there is another species, *Philedon subcornutus*, which has a great deal of ochre-yellow in its plumage, and this is exactly imitated by the corresponding *Mimeta forsteni*, both being confined to this single island. If it could be thought that the resemblance in the one case might be accidental, and that their occurring in the same island was also a coincidence, the occurrence of another pair in another island renders this explanation inadmissible; but to any one who has comprehended the general principles of mimicry already set forth, it will be clear, that these are of exactly the same nature in the case of these birds, and can be explained only in the same way.

The family of birds which presents the greatest number of cases of mimicry is undoubtedly that of the cuckoos, the reason being that the species are

all of very weak structure and utterly defenceless. Many of the true cuckoos are coloured exactly like hawks, and this is particularly the case with those of the genus Hierococcyx, which are named hawk-cuckoos. Dr. Jerdon states that *H. varius*, a common Indian species, undergoes changes of plumage exactly corresponding to that of an Indian sparrow-hawk, *Micronisus badius*, and that it is often mistaken for that species by other birds. Another Indian cuckoo (*Surniculus dicruroides*) is black with a deeply-forked tail, and is so exactly like the common King-crow (*Dicrurus macrocercus*) as to be mistaken for it. It is believed that it lays its eggs in the nest of the latter bird, and that this is the reason of its remarkably perfect mimicry; but no doubt it is also thereby protected from the attacks of hawks, as the king-crows are very pugnacious and aggressive birds, which attack and drive away hawks, kites, and crows, a habit from which they have obtained their popular name. In Sumatra and Borneo there is a large ground cuckoo (*Carpococcyx radiatus*) handsomely coloured with metallic purple and red, so as to resemble the pheasants of the country of the genus *Euplocamus*.

Among mammalia there are hardly any examples of one species imitating another of a different group for the purpose of protection, the best perhaps being the curious insectivorous Tupaias of the Malay countries, which almost exactly resemble squirrels both in their colours and their bushy tails, but which belong to a totally distinct order. If this resemblance is not accidental it must be for the purpose of enabling them to approach their insect prey under the guise of harmless squirrels. Another case is that of the Aard-wolf (*Proteles*), which has weak jaws, and feeds on white ants and carrion, but which is coloured and spotted exactly like the savage hyæna; and it may avoid the attacks of the more powerful carnivora, owing to the very general fear of the terrific bite of the animal it resembles.

In describing the phenomena of mimicry it is difficult to avoid conveying the impression, that there is some voluntary action in the creatures that thus seem to disguise themselves in order to be mistaken for quite different creatures; but those who have understood the explanation given in our former paper, of the mode in which ordinary protective resemblances have been brought about, will not fall into this mistake. If an Arctic bird has become white, and a forest bird green; if one insect is coloured like a leaf, another like the bark it clings to, we can easily see that it is only a step further in the same process for one insect to become exactly like another insect.

Some persons, however, have objected, that so many steps are required in the process of making a white *Leptalis* resemble a highly coloured *Ithomia*, that the chances against the necessary variations occurring are infinite. It is forgotten, however, that both the groups to which these genera belong have been undergoing constant changes for countless generations. Many Pieridæ have dusky, or yellow, or red markings, and many Heliconidæ have comparatively little colouring; and if we go back to the remote epoch when the Heliconidæ and Pieridæ were both much nearer to their common lepidopterous ancestor, we can have no difficulty in believing that species of one family might sometimes not be very unlike species of the other family. Now if at this remote period the Heliconidæ began to acquire the peculiar nauseous secretion which became a protection to them, and allowed them to increase and vary greatly, and to acquire the brilliancy of colour, length of wings, and slowness of flight which now distinguish them, it is not improbable that here and there one of the Pieridæ should be sufficiently like them to be mistaken for one of the group, and thus acquire a partial protection. This protection would inevitably increase by the simple action of natural selection, those variations of the ancestral *Leptalis* or *Euterpe* having the advantage which followed the variations of the ancestral *Ithomia* or *Mechanitis*, and thus, in the course of thousands or perhaps millions of generations, that close resemblance which we now see would be brought about. It must be remembered too, that the imitation would be rendered more accurate as time went on, owing to the increased acuteness of the insectivorous enemies of the butterflies. An imperfect resemblance would, after a time, be found out, and this would lead to the selection and perpetuation of more and more perfect mimicry. It may be asked, how do so many species of *Leptalis* still survive, which are yellow and white and not at all like Heliconidæ? and we can only give a guess in reply. Many of them are more rapid fliers; some may have different habits, and in some the larvæ may have better means of concealment and protection. As Mr. Darwin has remarked, we can seldom say why one of our native insects should be very common while another is very rare, and to answer similar questions regarding tropical insects is, of course, impossible. Our ignorance in this respect does not, however, prevent us from acquiring knowledge in other directions, and does not in the least affect the

extraordinary facts of mimicry, only a small selection of which have here been laid before our readers. These facts are so varied and so extraordinary, they occur in so many distinct groups of animals, and in so many different parts of the world, and they have been so carefully studied by several good observers, that not a doubt remains as to their reality; while no theory but that of Natural Selection affords—in my opinion—any intelligible explanation of them.

THE PHYSICS OF MUSIC.

By Professor F. R. Eaton Lowe.

THERE are few ears anatomically perfect that are altogether insensible to the charms of music. Its power to soothe or to excite, to soften and to refine, to move to sadness or to rouse to passion, is no mere visionary sentiment conjured up by poets and musicians, but an actual potential influence, which has been felt and appreciated by mankind from time immemorial. As education advances, music becomes more generally regarded as an essential and integral part of it, and the "concourse of sweet sounds," from being a source of mere sensuous enjoyment, becomes a subject of intellectual study. It is the cultivated musician alone, however, who can extract from music all the enjoyment it is capable of affording.

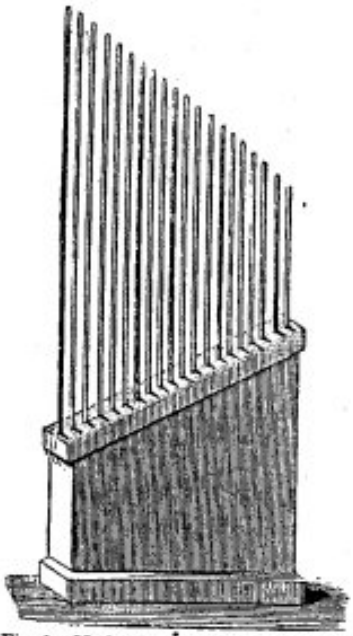

Fig. 1.—Marloye's Harp of Wooden Rods.

His disciplined ear alone can unravel the intricacies of the combined counterpoints, appreciate fully the resolution of chords, comprehend the working out of a theme, or detect the unity of idea pervading an entire composition. But it is reserved for the physicist to explain to the musician the various phenomena which accompany the production of those sounds with which he is so much enraptured; and the admiration which he feels for his favourite art cannot but be heightened by the knowledge thus acquired of the physical laws which operate in its exercise and development.

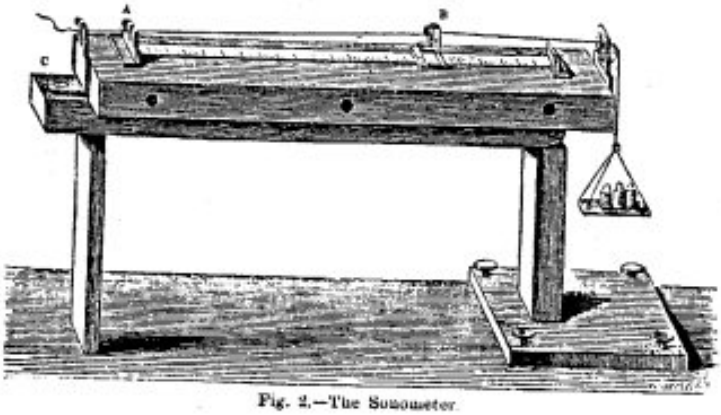

Fig. 2.—The Sonometer.

The general laws relating to the propagation of sound through air have already been discussed in these pages (Vol. I., p. 124), so that, in this paper, we shall confine ourselves to the consideration of those vibrations which, simply or compounded, are concerned in the production of those multifarious acoustic effects included under the general term *music*.

Musical sounds are produced by the vibration of strings or wires, in a state of tension, of rods of metal or wood, metallic plates or tongues, and by air-pulsations within tubes or pipes; thus we have stringed instruments, as the harp, violin, and piano; wind instruments, as the organ, trumpet, and cornet; reed instruments, in which a peculiar quality is imparted to the sound by the vibration of narrow slips or tongues of metal, as the oboe, bassoon, harmonium, and the reed pipes of organs; and, lastly, instruments of a more primitive character, in which solid rods or plates—either of metal or wood—are