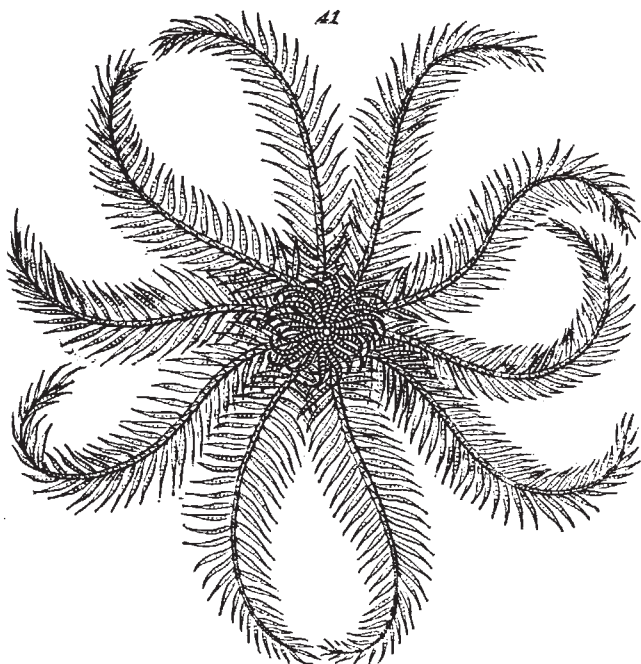


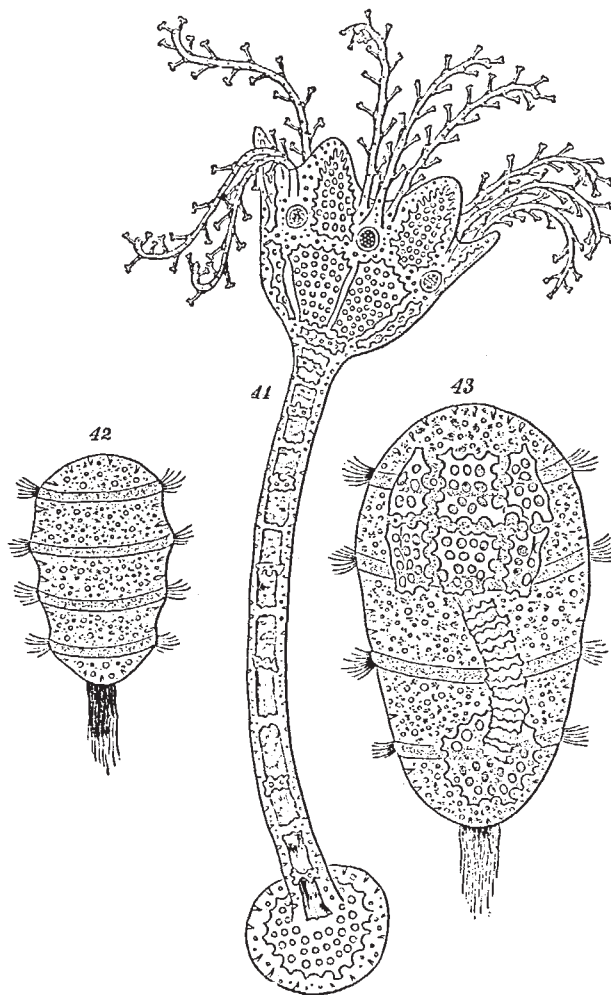
ON THE ORIGIN AND METAMORPHOSES OF INSECTS*

V.

THE development of the beautiful *Comatula rosacea* (Fig. 41) has been described in the "Philosophical Transactions," by Prof. Wyville Thomson.* The larva quits

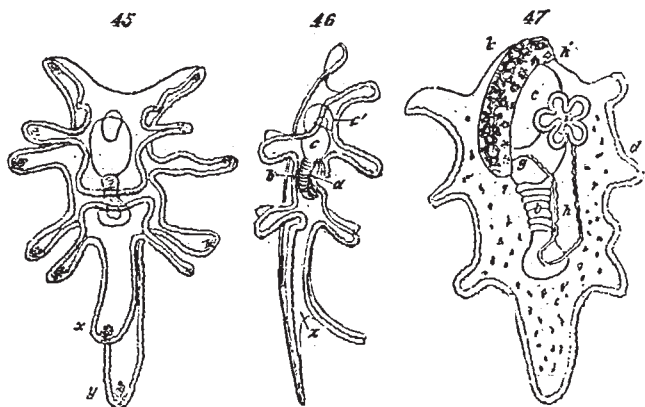
FIG. 41.—*Comatula rosacea* (after Forbes).

the egg, as shown in Fig. 42, in the form of an oval body about $\frac{3}{16}$ inch in length, something like a small barrel, surrounded by four bands or hoops of long vibratile hairs or ciliae. There is also a still longer tuft of hairs at the narrower posterior end of the body. Gradually a number of minute calcareous spines and plates make their appearance (Fig. 43) in the body of this larva, and at length

FIG. 42.—Larva of *Comatula rosacea* (after Thomson). 43, Larva of *Comatula rosacea*, more advanced. 44, Larva of *Comatula rosacea*, in the Pentacrinus state.

first supposed to be a Crinoid, and was named *Pentacrinus*, though we now know that it is only a stage in the development of *Comatula*. The so-called *Pentacrinus* increases considerably in size, and after various gradual changes, which time does not now permit me to describe, quits the stalk, and becomes a free *Comatula*.

The metamorphoses of the true star-fishes are also very remarkable. Sars discovered in the year 1835 a curious little creature about an inch in length, which he named *Bipinnaria asterigera*, and which he then supposed to be allied to the ciliograde Medusæ; subsequent observations however, made in 1844, suggested to him that it was the

FIG. 45.—Larva of Starfish (*Bipinnaria*), $\times 100$ (after Muller). 46, Larva of Starfish (*Bipinnaria*), $\times 100$, seen from the side. *a*, mouth; *b*, oesophagus; *c*, stomach; *c'*, intestine. 47, Larva of another *Bipinnaria*, showing the commencement of the starfish. *g*, canal of the ciliated sac; *i*, rudiments of tentacles; *d*, ciliated band.

arrange themselves in a definite order, so as to form a bent calcareous club or rod with an enlarged head.

* Continued from p. 70.

† Philosophical Transactions, 1865, vol. clv. . 513.

larva of a star-fish, and in 1847 MM. Koren and Danielson satisfied themselves that this was the case.

Figs. 45 and 46 represent the front and side view of a *Bipinnaria* found by Muller* near Marseilles. *a* is the mouth, *b* the œsophagus, *c* the stomach, *c'* the intestine. Fig. 47 represents a somewhat older specimen in which the Starfish (*k*) is already beginning to make its appearance.

But while certain Starfishes thus go through metamorphoses, similar in character to, and not less remarkable than, those of sea-eggs; there are others, as, for instance, the genus *Asteracanthium*, in which the organs and appendages special to the Pseudembryo, are in abeyance, while in *Pteraster* "the zooid is reduced to an investing sheet of sarcode."†

Even in the same species the degree of development attained by the larva differs to a certain extent according to the state of the temperature, the supply of food, &c. Thus in *Comatula*, specimens which are liberally supplied with sea-water, and kept in a warm temperature, hurry as it were through their early stages, and the free larva becomes distorted by the growing *Pentacrinus*, almost before it has attained its perfect form. On the other hand under less favourable conditions, if the temperature is low, and food less abundant, the early stages are prolonged, the larva is longer lived, and reaches a much higher degree of independent development. Weissmann has observed similar differences in the larvæ of Flies,‡ and it is obvious that these facts throw much light on the nature and origin of metamorphoses as we see them among insects, but the latter question we shall now proceed to consider.

ON THE ORIGIN OF METAMORPHOSES

The question still remains, Why do insects pass through metamorphoses? Messrs. Kirby and Spence tell us they "can only answer that such is the will of the Creator;"§ which, however, is rather a general confession of faith than an explanation of metamorphoses. And this they appear to have felt themselves; for they immediately proceed to make a further suggestion. "Yet one reason," they say, "for this conformation may be hazarded. A very important part assigned to insects in the economy of nature, as I shall hereafter show, is that of speedily removing superabundant and decaying animal and vegetable matter. For such agents an insatiable voracity is an indispensable qualification, and not less so unusual powers of multiplication. But these faculties are in a great degree incompatible; an insect occupied in the work of reproduction could not continue its voracious feeding. Its life, therefore, after leaving the egg, is divided into three stages."

But there are some insects, as, for instance, the Aphides, which certainly are not among the least voracious, and which grow and breed at the same time. There are also many scavengers among other groups of animals, such, for instance, as the dog, the pig, and the vulture, which undergo no metamorphosis.

It is certainly true that, as a general rule, growth and reproduction do not occur together; and it follows, almost as a necessary consequence, that in such cases the first must precede the second. But this has no immediate connection with the occurrence of metamorphoses. The question is, not why an insect does not generally begin to breed until it has ceased to grow, but why, in attaining to its perfect form, it passes through such remarkable changes. And in addition to this, we must consider, first, the sudden and apparently violent nature of these transitions, and, secondly, the immobility of the animal in its pupa state; for undoubtedly the quiescent and

deathlike condition of the pupa is one of the most remarkable characteristics of insect-metamorphosis.

In the first place, it must be observed that many species which differ considerably in their mature state, agree more nearly when young. Thus birds of the same genus, or of closely allied genera, which, when mature, differ much in colour, are often very similar when young. The young of the lion and the puma are often striped, and foetal whales have teeth. Leidy has shown that the milk-teeth of the genus *Equus* resemble the permanent teeth of the ancient *Anchitherium*, while the milk-teeth of *Anchitherium* again approximate to the dental system of the still earlier *Merychippus*. Rutimeyer, while calling attention to this interesting observation, adds that the milk-teeth of *Equus caballus* in the same way, and still more those of *E. fossilis*, resemble the permanent teeth of *Hipparion*.

In fact, the great majority of animals do go through well-marked metamorphoses, though in many cases they are passed through within the egg, and thus do not come within the popular ken. "La larve," says Quatrefages, "n'est qu'un embryon à vie indépendante."* Those naturalists who accept in any form the theory of evolution, consider that "the embryonal state of each species reproduces more or less completely the form and structure of their less modified progenitors."† "Each organism," says Herbert Spencer,‡ "exhibits within a short space of time a series of changes which, when supposed to occupy a period indefinitely great, and to go on in various ways instead of one way, give us a tolerably clear conception of organic evolution in general.

The naturalists of the older school do not, as Darwin and Fritz Muller have already pointed out, deny the facts, though they explain them in a different manner—generally by the existence of a supposed tendency to diverge from an original type. Thus Johannes Muller says "the idea of development is not that of mere increase of size, but that of progress from what is not yet distinguished, but which potentially contains the distinction in itself, to the actually distinct,—it is clear that the less an organ is developed, so much the more does it approach the type, and that, during its development, it more and more acquires peculiarities. The types discovered by comparative anatomy and developmental history must therefore agree."

And again, "What is true in this idea is, that every embryo at first bears only the type of its section, from which the type of the class, order, &c., is only afterwards developed."

Agassiz also observes that "the embryos of different animals resemble each other the more the younger they are." There are, no doubt, cases in which the earlier states are rapidly passed through, or but obscurely indicated; yet we may almost state it as a general proposition, that, whether before or after birth, animals undergo metamorphoses. The maturity of the young animal at birth varies immensely. The kangaroo (*Macropus major*), which attains a height of seven feet, ten inches, does not when born exceed one inch and two lines in length; the chick leaves the egg in a much more advanced condition than the thrush; and so among insects the young cricket is much more advanced, when it leaves the egg, than the fly or the bee; and it is a familiar fact, that in this respect, though not of course to anything like the same extent, differences occur even within the limit of one species.

In oviparous animals the condition of the young at birth depends much on the size of the egg; where the egg is large, the abundant supply of nourishment enables the embryo to attain a higher stage of development; where the egg is small, and the yolk consequently scanty, it is soon exhausted, and the embryo requires an addi-

* 1c Zweif. Abb. Pl. 1, Figs 8 and 9.

† Thomson, on the Embryology of the Echinodermata, *Natural History Review*, 1863, p. 415.

‡ Zeits. für Wiss. Zool. 1864, p. 228.

§ Introduction to Etymology, 6th Ed. i. p. 6r.

* *Metamorphoses de l'Homme et des Animaux*, p. 133.

† Darwin, *Origin of Species*, 4th Ed. p. 532.

‡ *Principles of Biology*, vi. p. 349.

tional supply of food. In the former case the embryo is more likely to survive; but, on the other hand, when the eggs are large, they cannot be numerous, and a multiplicity of germs is, in some circumstances, a great advantage. Even in the same species the development of the egg offers certain differences.*

The metamorphoses of insects depend then primarily on the fact that they quit the egg in a very early condition; many—as, for instance, flies and bees—before the thoracic segments are differentiated; others—as locusts, dragon flies, &c., after the formation of the legs, but before that of the wings.

We may now pass to the second part of the subject, that is to say, the sudden and abrupt instance of the changes which insects undergo. The development of an Orthopterous insect, indeed—say, for instance, of a grasshopper—from birth to maturity is so gradual, that but for the influence on our nomenclature exercised by the most striking changes which occur in insects of the Heteromorphous series, they would perhaps never have been classed as metamorphoses. But though the changes from the caterpillar to the chrysalis, as from the chrysalis to the butterfly, are apparently sudden and abrupt, this is in reality more apparent than real; the changes in the internal organs, though rapid, are in reality gradual; and even as regards the external form, though the metamorphosis may take only a few moments, this is but the change of outer skin—the drawing away, as it were, of the curtain; and the new form which then appears has been in preparation for days or, perhaps, weeks before.

Swammerdam, indeed, supposed (and his view was adopted by Kirby and Spence) that the larva contained within itself “the germ of the future butterfly, enclosed in what will be the case of the pupa, which is itself included in three or more skins, one over the other, that will successively cover the larva.” This is a mistake; but it is true that, if a larva is examined shortly before it is full grown, the future pupa may be traced within it. In the same manner, if we examine a pupa which is about to disclose the butterfly, we find the future insect, soft indeed and imperfect, but still easily recognisable, lying more or less loosely within the pupa-skin.

One important difference between an insect and a vertebrate animal is, that whereas in the latter, as for instance in ourselves, the muscles are attached to an internal bony skeleton, in insects no such skeleton exists. They have no bones, and their muscles are attached to the skin. Hence the necessity for the hard and horny dermal investment of insects, so different from the softness and suppleness of our own skin. Moreover the result is, that without a change of skin a change of form is impossible. The chitine, or horny substance, forming the outside of an insect, is formed by a layer of cells lying beneath it, and, once secreted, cannot be altered. From this it follows that every change of form is necessarily accompanied by a change of skin. In some cases, as for instance in *Chloëon*, each change of skin is accompanied by a change of form, and thus the perfect insect is more or less gradually evolved. In others, as for instance in caterpillars, several changes of skin take place without any material alteration of form, and the change, instead of being spread over many, is confined to the last two moults.

The explanation of this difference is, I believe, to be found in the structure of the mouth. That of the caterpillar is provided with a pair of strong jaws, fitted to eat leaves; and the digestive organs are adapted for this kind of food. On the contrary, the mouth of the butterfly is suctorial; it has a long proboscis, beautifully adapted to suck the nectar from flowers, but which would be quite useless, and indeed only an embarrassment to the larva.

* For differences in larvæ consequent on variation in the external conditions, see *ante*, p. 31.

The digestive organs also are adapted for the assimilation, not of leaves, but of honey. Now it is evident that if the mouth-parts of the larva were slowly metamorphosed into those of the perfect insect, through a number of small changes, the insect would in the meantime be unable to feed, and liable to perish of starvation in the midst of plenty. On the contrary, in the Orthoptera, and as a general rule, among those insects in which the changes are gradual, the mouth of the so-called larva resembles that of the perfect insect, and the principal difference is in the presence of wings.

Similar considerations throw much light on the nature of the chrysalis or pupa state—that remarkable period of death-like quiescence which is one of the most striking characteristics of insect metamorphosis. The comparative quiescence of the pupa is mainly owing to the rapidity of the changes going on in it. In the chrysalis of a butterfly, for instance, not only (as has been already mentioned) are the mouth and digestive organs undergoing change, but the same is the case with the muscles. The powerful ones which move the wings are in process of formation; and even if they were in a condition favourable to motion, still the nervous system, by which the movements are set on foot and regulated, is also in a state of such rapid change that it could scarcely act.

It must not be forgotten that all insects, indeed all articulate animals, are inactive for a longer or shorter space of time after each moult.

The slighter the change the shorter the period of inaction. Thus, after the ordinary moult of a caterpillar, the insect only requires rest until the new skin is hardened. When, however, the change is great and gradual, the period of inaction is correspondingly prolonged. The inactivity of the pupa is therefore not a new condition peculiar to this stage, but a prolongation of the inaction which accompanies every change of skin. Most pupæ indeed have some slight powers of motion; those which assume the chrysalis state in wood or under ground usually come to the surface when about to assume the perfect state, and the aquatic pupæ of certain Diptera, swim about with much activity. Among the Neuroptera certain families have pupæ as quiescent as those of the Lepidoptera; others, as, for instance, Raphidia, are quiescent at first, but at length acquire sufficient strength to walk, though enclosed within the pupa skin, a power dependent partly on the fact that this skin is very thin. Others again, as, for instance, dragon-flies, are quiescent on assuming the pupa state, only in the same manner and for a similar time as at other changes of skin.

JOHN LUBBOCK

(To be continued.)

NOTES FROM THE “CHALLENGER”

III.

THE MILLER-CASELLA THERMOMETER

AT 8 A.M., on March 26, we sounded, lat. $19^{\circ} 41' N.$ long. $65^{\circ} 7' W.$, in 3,875 fathoms. The sounding was perfectly satisfactory, and left no doubt that the depth was estimated within a very small error. The “Hydra” sounding instrument was used weighted to 3 cwt. A slip water-bottle, and two Miller-Casella thermometers (Nos. 39 and 42) were sent down along with it as usual. The tube of the “Hydra” came up filled with a reddish clay containing a considerable quantity of carbonate of lime. The two thermometers were broken, and as the mode in which the fracture occurred is in itself curious, and has an important bearing upon the use of these instruments at extreme depths, I will briefly describe the condition of the thermometers when they came to the surface.

No. 39, a valuable instrument, with a small and constant error, which we had used for some time whenever