25th March, 1874.

A Paper was read by JOSEPH JOHN MURPHY, F.G.S., President of the Society,

On the Origin and Metamorphoses of Insects.

The present paper is meant as little more than a review of Sir John Lubbock's work on the same subject. I agree with him in beginning by taking as proved the doctrine of evolution :—that is to say the doctrine of the derivation of every species by descent from some lower and simpler form ;—and I agree on the whole with his conclusions, though I think he is inclined to underrate the difficulties of the subject. I regard the metamorphoses of insects as one of the greatest difficulties of the evolution theory, though this is not true of all metamorphoses.

Metamorphosis is defined as development with change of plan. All winged insects acquire their wings by metamorphosis—no insect has wings when it leaves the egg. It ought however to be mentioned that the transformations of the Echinodermata (star-fish, sea-urchins, &c.) are phenomena of quite a different order from the metamorphoses of insects. In true metamorphoses, as those of insects and frogs, the parts of the mature form are developed out of the corresponding parts of the larva. In the transformations of the Echinodermata this is not the case; the earliest form, which Dr. Wyville Thomson calls the pseudembryo, but which I should prefer to call the pre-embryo, is not a larva, but is its function more analogous to a placenta. In the star-fish it is cast off like a placenta when the mature form has been produced; in the sea-urchin its substance is absorbed; but in no case are its parts transformed into the parts of the mature animal.*

* See Dr. Wyville Thomson on the Embryology of the Echinodermata, *Natural History Review*, July, 1863.

These transformations appear to me a great difficulty in the way of Darwin's theory, or any other modification of the theory of evolution. So far as I am aware, no suggestion has yet been made towards accounting for the origin of this extraordinary mode of development. The subject of true metamorphosis will on the contrary be found fertile in such suggestions.

Among true metamorphoses, none appear to throw so much light on the process whereby one class of organisms has been derived from another, as the transformations of the Batrachia (frogs, newts, &c.) from aquatic and water-breathing into terrestrial and air-breathing animals. Both the respiratory and the motor systems are altogether changed; the branchiæ, or gills, of the tadpole wither and disappear; lungs are developed; legs bud forth; and in the frog, though not in the newt, the tail is absorbed and disappears. Some light is thrown on these transformations by the facts that among the water-breathing classes of animals generally the respiratory organs are remarkably variable in form and position, and among Invertebrates they are so even as to their presence or absence—that in many cases they do not appear till a late stage of the animal's development*—and that in all the lowest organisms, and in many which are not among the lowest, there are no distinct respiratory organs, and the entire surface is a respiratory surface.

The Batrachian class also contains good instances of the loss of metamorphoses through suppression of stages of development. Thus the land newt, which lives in dry mountainous regions where there are no pools of fresh water, is an exception to the general law that Bartrachians leave the egg in a tadpole form. It passes through the tadpole state before leaving the egg. And it has been lately stated, apparently on good authority, that the same is true of a variety of the frog found in the volcanic island of Guadaloupe, where also there are no pools of fresh water.†

If the theory of evolution is true, the larval forms in such cases

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* For this fact among the Crustacea, see Fritz Müller's "Facts for Darwin." Dr. Rolleston mentions (Forms of Animal Life, introduction, p. cxvi.) that the tracheæ or breathing-tubes of the insect *Chlœon dimidiatum* are absent in the early developmental stages.

† See *Nature*, 27th March, 1873.

as that of the Batrachians represent ancestral forms; frogs are descended from tadpoles or tadpole-like fishes. What makes such a change possible is, that variations sometimes occur at a not very early age;—in this case, at the age when the metamorphosis of the tadpole begins;—and when this occurs, the variations are, according to Darwin, generally inherited by the offspring at the same age. What makes possible the loss of metamorphoses, as in the case of the land newt and the Guadaloupe frog, is the fact that variations are sometimes inherited at an earlier age than that at which they occurred in the parent: thus, if, as every believer in evolution will admit, the species now mentioned are descended from species which went through the usual Batrachian metamorphoses, the metamorphoses have in these cases disappeared by occurring at an earlier period—namely, in embryonic life. The embryo of the land newt before it leaves the egg is a tadpole. But it is probable there are cases where all trace of the ancestral form is lost, even in the larva and the embryo; and if this has taken place throughout any entire class, its true ancestry and affinities will have thereby become almost, if not quite, impossible to discover. Had the entire Batrachian class lost all trace of the tadpole state, its close affinities with fishes would probably be scarcely suspected.

The metamorphoses of the Batrachia are adaptive metamorphoses: that is to say, their purpose is to adapt the animal to a new kind of life—to raise it from an aquatic to a terrestrial existence. It seems probable that the first impulse to the transformation of a tadpole-like fish into an air-breathing animal was given by the drying up of the pools of water in which it lived. This conjecture is supported by experiments on the axolotl, a member of this class, which does not always undergo metamorphosis, but frequently remains a permanent tadpole, and propagates in that state. As in all members of the class, its metamorphosis, when this occurs, partly consists in the withering of the branchiæ or gills; and it has been found that the change of the animal's colour, which normally accompanies the withering of the branchiæ, is promoted by their removal: an operation which does not appear to be injurious.

One of the most important discoveries in zoology since Cuvier's time is that of the development of the Cirrhipedes or Barnacles from

Crustacean larvæ. Cuvier, and Linnæus before him, knowing this remarkable class only in the mature state, regarded them as Mollusca; but no naturalist has hesitated to place them among or near the Crustacea, since it has become known that their larvæ are scarcely to be distinguished from other Crustacean larvæ. The same is true of the Lerneæ, which in the mature state are parasitic on fishes, and were formerly supposed to be worms. And the Linguatulina, which in their mature state are internal parasites of air-breathing animals, and resemble worms, are shown by their larval state to belong to the Arachnida, of which class the spider and scorpion are the highest types. All these three are adaptive metamorphoses, being accompanied by a total change in the mode of the animal's life : the larva is free, but the mature animal is absolutely or at least comparatively fixed. They are also retrograde metamorphoses, being changes from a higher to a lower existence. All retrograde metamorphoses are probably adaptive, but the converse is not true; the adaptive metamorphoses of the frog and other Batrachians are not retrograde but progressive.

There are, however, metamorphoses which do not appear to be adaptive. When the animal, at its various stages of transformation, lives in the same locality and leads the same kind of life, its metamorphoses cannot be regarded as adaptive; and, so far as I see, can be ascribed only to an innate impulse to development. This applies to the metamorphoses of the higher Crustacea (crabs, lobsters, &c.). The earlier transformations here are from one free swimming form to another.

The Crustacea are one of the four classes that constitute the Arthropoda, a great division of the animal kingdom, which precisely coincides with the Linnæan class of insects. The other three classes are the Arachnida, to which the spider and scorpion belong; the Myriopoda, or centipedes and millepedes; and the true or Hexapod Insects, in which class alone wings are developed. Arthropods may be generally defined as segmented animals with jointed appendages. The segmentation is well seen in the centipede; in the spider it appears to be obliterated. The jointed appendages are almost, if not quite, universal among the Arthropoda; they assume various forms—antennæ, jaws, chelate or claw-bearing arms, legs, and swimming feet—all of which are homologous with each other, in the same sense that the arms and legs of man are homologous. It must be observed that, unlike the jaws of Vertebrates, those of Arthropods open horizontally. All the variously modified appendages now mentioned are found in the lobster and prawn. Segmentation is a character which Arthropods share with worms, but the jointed appendages or limbs, from which they derive their name, are, so far as is known at present, altogether peculiar to this division. Both the body and the limbs are constructed on a plan opposite to that of Vertebrates, the hard parts being outside and the soft parts within.

We return to the subject of the metamorphoses of the higher Crustacea.

Fritz Müller, in his "Facts for Darwin," has described the development of a species of Prawn, belonging, or allied to, the genus *Peneus*. Its form, when first hatched, is that called a Nauplius, and bears no more resemblance to its mature form than does a caterpillar to a butterfly. A Nauplius is a minute animal of an oval form, without any trace of segmentation; it has six swimming legs, but no jaws, and has a single eye placed medially. This form is common as a larval form among the lower Crustacea, but Müller's *Peneus* is the only instance yet known of its occurrence among the higher members of the class. To believers in evolution it will appear certain that orders must be closely akin when their larval forms are almost exactly alike.

So long as the *Peneus* remains in the Nauplius state, there is nothing about it to suggest that it is to develop into an animal of the same order with the lobster. The fact that it has six legs might suggest some affinity with the true or hexapod Insects. This, however, would be an altogether erroneous conjecture, for its legs are not homologous with those of Insects. If their homologues in the Insects can be identified at all, they are not the legs, but the appendages of the head, the antennæ and jaws. In the subsequent metamorphoses of the Nauplius, the first two pairs of its legs are transformed into antennæ, of which the Crustacea have two pairs; the third pair is transformed into the mandibles or anterior pair of jaws. The part of the body of the Nauplius which bears these appendages becomes the head of the mature prawn; the tail end remains the tail end, and development proceeds by the growth of segments between these, forming a long tail-like abdomen, which is the corresponding part to that usually, but inaccurately, called the tail of the lobster. New limbs appear, a carapace or shell is developed from the head, and the two eyes of the mature form make their appearance. In this state the animal is called a Zoea. This form is very common among the higher Crustacea; most crabs appear to leave the egg as Zoeas.

The next stage is what Müller calls the Mysis-form. It differs from the Zoea chiefly in having acquired feet on the newly-formed segments. This changes into the mature form by some of the swimming feet acquiring chelæ or claws, while others posterior to these are changed into walking feet; and at the same time the respiratory function, which in the Nauplius took place probably through the entire surface, and in the Zoea through the lateral parts of the carapace, is assumed by branchiæ, which are developed on the thorax.*

These changes are perfectly continuous. There is no abrupt change similar to the unfolding of the Insect's wings, nor is there any stage like the pupa or chrysalis stage of many Insects. If the theory of evolution is true, it can scarcely be doubted that as the tadpole represents the fish from which the frog is descended, so the developmental stages of Müller's prawn represents the ancestry of the entire order of Macrurous Crustacea, to which the prawn and the lobster belong. A Nauplius, or some form nearly resembling it, was probably the ancestor of the entire Crustacean class: a Zoea was descended from this, and became the ancestor of all the higher or Malacostracan Crustacea; a Mysis form was descended from the Zoea, and gave origin to the macrurous or long-tailed order, though not to the crabs, which do not pass through the Mysis stage. The Nauplius stage, it is true, appears to be exceptional among the higher Crustacea, which mostly leave the egg in the Zoea form; but the fact that the Nauplius form occurs among the higher Crustacea at all is sufficient to prove the affinity of the entire order; and its absence in most cases only shows that it has dropped out of the chain of successive developmental forms, just as the tadpole stage has been lost

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* See Mr. Dallas's translation of Müller's "Facts for Darwin" (Murray, 1869), pages 58, 59, 60, and 61, whereon are figured the nauplius, two Zoea-stages, and the Mysis-stage of this prawn.

in the case of the land-newt and the Guadaloupe frog. In the case of the lobster the Zoea stage also has dropped out, and the animal leaves the egg in a form resembling the Mysis. Finally, the fresh-water crayfish undergoes no metamorphosis at all.*

The facts of Crustacean metamorphosis, which I have now described in extreme outline, appear to tell very strongly in favour of the general theory of evolution. But I cannot agree with Müller that they at all favour the specially Darwinian form of that theory. Natural selection among spontaneous accidental variations may, at least, help to account for very great changes in the organism to correspond with changed conditions of life. It may, no doubt, account in part for the change in the respiratory and motor systems of the first race of tadpoles that were transformed into air-breathing animals, when the waters in which they lived began to dry up. But it does not follow that the same process is likely to be sufficient while the conditions of life remain unchanged; and this appears to have been the case throughout the greater part of the evolution of the higher Crustacea, because the Nauplius, the Zoea, and the Mysis forms are all freely swimming animals, living under conditions which do not sensibly differ. The minute and random variations which alone Darwin's theory recognises are unlikely to work great changes under unchanging conditions of life; and this for two reasons. In the first place, such spontaneous variations are then less likely to occur, because permanence of circumstances promotes constancy of form, while on the other hand changes of circumstances promote variation; and in the second place, if under such conditions they do occur, they will be less likely to give any sensible advantage to the individuals possessing them than changes of similar magnitude occurring along with changing conditions. I cannot think that the evolution and the metamorphoses now described can be referred to any other cause than a formative impulse impressed at the beginning on living matter by Creative Power.

Besides this general argument, a remarkable special argument on the subject is yielded by Müller's very interesting researches on the development of his prawn. He says† of its Mysis that "the long

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* Stated by Müller (page 47), on the authority of Rathke.

† Page 61.

abdomen, which just before was laboriously dragged along as a useless burden, now, with its powerful muscles, jerks the animal through the water in a series of lively jumps." The Nauplius has no abdomen; this part is acquired when the Nauplius develops into a Zoea, and consists of segments which appear in front of the tail of the Nauplius. Darwin's theory will account only for changes which are immediately beneficial; and Müller's account appears to show that its abdomen is not immediately useful to this Zoea, but is developed for the purpose of subsequently becoming useful as a swimming organ, and developing feet upon its surface. It may be suggested that the abdomen has some physiological function which makes it useful to the Zoea, but this seems scarcely probable.

The metamorphoses of the true Insects present much greater difficulties than those of the Crustacea. Among the Crustacea we have seen that each temporary form worn by the animal during its development probably represents the mature form of one of its remote ancestors. But this does not appear to be true of the Insects, as will appear from a study of their metamorphoses. Insects are the only invertebrate animals that have wings, and their wings resemble nothing else in the animal kingdom. But, though characteristic of the insect class, wings are not universal in it. Some insect orders are wingless, and there are wingless genera in most, if not all, the orders. In many cases the wings are a sexual character, being possessed by the males alone; and in all cases they are acquired by metamorphosis: no insect leaves the egg with wings. These three facts are all mutually connected; characters which are late in development tend to be variable as between species of the same order, and the same is true of characters which belong to one sex only without appertaining to the reproductive system.* It is obvious that any account of the origin of the class of insects must be unsatisfactory, unless it can explain the origin of the wings; for it would be contrary to all analogy to suppose that organs so very peculiar as these, or, indeed, any organs whatever, could at their first origin be suddenly produced; and the wings are developed in a comparatively

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* Such characters are called by Darwin secondary sexual characters.

short time during the last period of larva life, and unfolded, not gradually but all at once, at the final metamorphosis.

All naturalists are now agreed that the wings are morphologically part of the respiratory system. Insects breathe by means of tracheæ or air-tubes, which open on the animal's side and ramify through the body. The wings are formed on the outer termination of the tracheæ; and during the development of the wings and before they come into activity, their veins appear to be tubes which are continuous with the tracheæ. Dr. Duncan says* of the final metamorphosis of the small tortoise-shell butterfly :—"The wings, then scarcely as large as hemp-seeds, are gradually distended at their base, and are perceptibly enlarged at each respiration." The wings appear to be homologous with the external branchiæ of some aquatic larvæ, as the *Cloe bioculata*, the *Ephemera vulgata*, and the *Phryganea clavicornis*.† "The adult insect," says Dr. Duncan, "becomes an air-breather, and spiracles (or mouths of the tracheæ) are developed in its sides exactly in the places where the gills were attached during its fish-like life. In the larvæ of the May-flies (Ephemera) the branchiæ are formed of expansions of the skin, which are very delicate, thin, and variously folded and fringed, and they are attached in pairs to the first seven segments of the abdomen. The tracheæ are included in the folds, and are continued into the body of the larvæ, and they transmit the purified air to it; but the gills disappear during metamorphosis."‡ In *Pteromarcys regalis*, an insect inhabiting damp places, these branchiæ remain through life.§ This is consequently a perennibranchiate insect, and its case is analogous to the perennibranchiate batrachians, which I have described as being permanent tadpoles. In the existing species, as we have seen, these branchiæ are developed on the abdomen, and such a position, for mechanical reasons, would be an impossible one for wings. But, considering the remarkable variability of the respiratory

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* Duncan's Transformation of Insects, page 51.

† See the magnified figures of the larvæ of these species in Dr. Duncan's work, pages 47, 48. *Cloe* is also called *Chloeon*, and is mentioned under that name in a note on p. 77 of this volume.

‡ Same, page 48.

§ Rolleston's *Forms of Animal Life*, introduction, page cx.

organs of aquatic invertebrates generally, there is nothing improbable in the supposition that such branchiæ in one species were developed on the thorax, and came into use as swimming organs, and ultimately as wings. It is mentioned by Sir John Lubbock that the muscles which are attached to the branchiæ of the larvæ of *Cloe* (which he calls *Chloeon*) "in several remarkable points resemble those of the true wings."*

It has been mentioned in support of this hypothesis, that an insect has been lately discovered by Sir John Lubbock, and named *Polynema Natans*, which uses its wings in swimming. But, interesting as is this fact, I do not think it is relevant to the present question: for the *Polynema* belongs to the order *Hymenoptera*, the same order that contains the bee and the ant, which is perhaps the highest of all the insect orders, and does not appear in any way to point to the origin of the class.

If the conclusion is accepted which is here stated as to the probable origin of the Insect's wing, it may appear a necessary inference that the first Insects were water-breathing animals. This, however, does not appear to have been the case; it seems more probable that insects were an air-breathing class from the first; that aquatic respiration was always as exceptional among the Insects as aërial respiration among the Crustacea, and that wings were first formed in one of those exceptional families which took to an aquatic life, and developed branchiæ upon their tracheæ. The reasons for this apparently strange conclusion are as follow:—

As we have seen, the branchiæ, or water-breathing organs, of some larvæ, which appear to be homologous with the wings of mature insects, are developed on the external terminations of the tracheæ or breathing-tubes; and, though in the larvæ in question the tracheæ serve for aquatic respiration, yet tracheæ appear to be essentially and originally air-breathing organs; for air-breathing organs are in general internal, so as to bring the air into the body: while water-breathing organs are in general external, so as to bring the blood out into the water. Consequently, when a water-breathing insect has its branchiæ

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* Monograph of the *Collembola and Thysanura*, published by the Ray Society, page 53.

formed in connexion with tracheæ, it appears most probable that the tracheæ are inherited from an air-breathing ancestry; for internal breathing organs like tracheæ could not be formed in a water-breathing race.*

Further, not only is aquatic respiration exceptional among insects, but when it does occur there is no uniformity in the respiratory organs. Sir John Lubbock remarks:—"From the various modes by which respiration is effected among different groups of aquatic insects, we are justified in concluding that the original insect stock was a land animal."† Were the water-breathing insects representatives in that respect of the original stock of the class, then their respiratory organs would resemble their origin and resemble each other; but when we find them unlike in the different water-breathing groups, we conclude them to have been separately developed. In the same way aërial respiration is exceptional among the Crustacea, and the respiratory organs of the various air breathing groups are quite unlike each other, showing that they also have been developed separately.‡

The hypothesis that the branchiæ which have been developed into wings were of later origin than the tracheæ, and of later origin than any other important organ, agrees also with the facts that their presence is very inconstant in the class, and that when they exist they are never developed until the final metamorphosis.

Finally, Sir John Lubbock has given what appears to be strong reasons for thinking that the first insects resembled the *Thysanura*, an order which are all air-breathers and all wingless, and undergo no metamorphosis. He has gone so far as to indicate the genus *Campodea* as that which has probably remained nearest the original form. *Campodea staphylinus*, as figured by him,§ is an insect about a quarter of an inch in length, with strongly-marked segmentation of

* These reasons are scarcely conclusive, because it may be argued that the tracheæ of the Insects and the Myriopoda (centipèdes) are homologous with the "water-vascular system" of the lower worms or the "segmental organs" of the higher worms or Annelids. But this appears improbable, because the Crustacea, which are the characteristically water-breathing class of Arthropods, have no water-vascular system, and nothing resembling either the tracheæ of Insects or the so-called lungs of spiders.

† *Collembola and Thysanura*, already quoted, page 53.

‡ See Müller's "Facts for Darwin," already quoted.

§ See his work above referred to. See plate 50 of the same work.

the body, no wings, six legs, a pair of jointed antenuæ about one-fourth of the length of the body, and a pair of jointed tail-bristles a little longer than the antenuæ. (In some Thysanura these tail-bristles are used for leaping, whence the name of spring-tails.) *Campodea* has a strong resemblance to the larva of *Cloe* or *Chloeon*, already mentioned; and Sir John Lubbock, in another memoir, states that the metamorphosis of the latter is remarkably continuous and free from abrupt changes, from which he draws what appears to be the reasonable conclusion that it comes tolerably near to representing the original type of insect metamorphosis.

Difficult as is the question of the origin of the insect's wings, the metamorphoses of the parts of the mouth present greater difficulties still. Among some insect orders, as, for instance, the Lepidoptera (moths and butterflies), the mouth of the larva is mandibulate and adapted for biting, while that of the mature form is suctorial. According to Sir John Lubbock, the mouth in the Thysanura is intermediate in structure between the mandibulate and the suctorial types; and he thinks it probable that the first insects had such a mouth, from which the various and more specialised forms of mouth now found in both the larval and the mature forms have been descended. He endeavours to account for the very surprising fact of the larva and the mature insect in many cases having different types of mouth structure, by the suggestion that the larva and the mature insect were placed in circumstances where different forms of mouth were needed by different kinds of food, and that natural selection produced in both cases the forms of mouth that were needed. This, however, seems to be putting on the theory of natural selection a strain that it will not bear. It is, perhaps, possible that natural selection might adopt a mouth to the habitual food; but to suppose that it could afterwards transform and redevelop the same animal's mouth to suit another kind of food, appears not more admissible than to ascribe to natural selection the periodical change of colour in the fur of the ermine.* The transformation of the mouth takes place at the final metamorphosis, together with the development of the wings. While the development of the wings and the development of the

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* See page 7 of this volume.

mouth organs is going on, the insect remains in the pupa or chrysalis state, during which it is quite inactive and does not feed. The necessity for the insect to enter into this state, which may almost be called re-entering into the egg, does not depend on the development of the wings, but on the transformation of the mouth. Many insects, as for instance the Orthoptera (grasshoppers, &c.), acquire wings without the mouth being redeveloped, and they do not enter into the chrysalis state, but develop their wings without any cessation of activity; and others, among which I believe are the wingless working ants, pass through the chrysalis state without ever acquiring wings. It is obvious that such a state is necessary, because a mouth in the act of undergoing transformation from a mandibulate to a suctorial type would be incapable of work, like a machine while under repair. It is remarkable that those insects which pass through this state have the widest distribution, in consequence probably of its being, like the egg state, favourable to dispersion by driftwood and similar means.*

These remarks, however, go no way at all to explain the origin of the chrysalis state, which certainly is among the greatest difficulties of the theory of evolution. The total change from the tadpole to the frog, or from the nauplius to the prawn, is almost, if not quite, as great as the total change from the worm-like larvæ of Hymenoptera or Diptera to the mature winged forms, but the metamorphoses of the Batrachia and the Crustacea are gradual and continuous: they present nothing comparable to the almost sudden development of the insect's wings, and nothing resembling the chrysalis state. Indeed, I believe there is nothing in the entire animal kingdom at all like the latter, except the "encysted" state, which is common among the Protozoa. Sir John Lubbock suggests that the chrysalis state has been produced by the crowding together into a short time of a series of changes, which at first were gradual; and this is probably true, because gradual change is the rule in the animal kingdom, and rapid, almost sudden, change, like that of the chrysalis into the winged insect, is the exception.

Some of the Diptera (two-winged flies) while in the chrysalis state undergo a very remarkable process of almost total redevelop-

* Rolleston's "Forms of Animal Life." Introduction, page cxiii.

ment. Instead of the tissues of the larva being transformed into those of the perfect insect, they are as it were melted down, except at certain spots, into an almost liquid substance, out of which the tissues of the winged insect are developed. Were it not for the spots which remain undissolved, this process would remind us of some dimorphic substance being dissolved from the crystalline state and crystallised again in a totally different form. Mr. Mivart, in his reply to Darwin, entitled "The Genesis of Species," has based on this fact an argument against Darwin's theory; but I think we know too little of the more obscure laws of life to base on it any argument either one way or the other.

We have seen that among Batrachia and among Crustacea the larval forms probably represent ancestral forms. But this cannot be true in the same sense among insects. We have seen that the frog is probably descended from a tadpole, and the prawn from a nauplius; but the butterfly is not descended from a caterpillar, or the fly from a maggot. In the case of Müller's prawn, the perfect form is descended from a Mysis-like animal, the Mysis form from a Zoea, and the Zoea from a Nauplius. But the winged insect cannot be descended from a chrysalis, because the motionless chrysalis can never have been the mature reproductive state of any species whatever; and it appears impossible that the suctorial butterfly can be descended from the mandibulate caterpillar, because the intermediate stages of mouth structure would be inefficient. It thus appears certain that the "complete metamorphosis" of those insects which pass through the chrysalis state and undergo redevelopment of the mouth parts, unlike the metamorphoses of the Crustacea and the Batrachia, is not original or primitive, but has been acquired.

The resemblance of a caterpillar to a centipede, though obvious enough, is no proof of kindred. The nature of the connection between Insects and Myriopods is a debateable question; but, whatever it may be, insects are certainly not descended from Myriopods. But the resemblance of the grubs, which are the larval forms of Hymenoptera and Diptera, to worms, is of a different nature, and appears to be due to reversion to a worm-like ancestor, from which not insects only, but all the Arthropod classes, are descended. This reversion appears to be due to abundance of food and inactivity of life. Sir John Lubbock says :*—"The larvæ of Lepidoptera live on plants; activity to them would be useless, and they do not possess it. The larvæ of most Hymenoptera (for instance, of the bee, wasp, Cynips, &c.), of Diptera, and of some Coleoptera (beetles), live in circumstances which call for even less locomotion, and have relapsed almost into the condition of their far-distant vermiform ancestor."

This may in some degree explain the metamorphoses of the Sitaris, which are the most anomalous in the whole of the wonderful class of which we are treating. The larval form of a certain beetle, the Sitaris, as described by M. Fabre, is a minute, active insect, furnished with six legs, two long antennæ, and four eyes. These larvæ are hatched in the nest of a bee; and when the male bees emerge in the spring from the burrows, which they do before the females, the larvæ spring on them, and afterwards take an early opportunity of crawling on to the female bees. When the latter lay their eggs, one in each cell, on the surface of the contained honey,† the larva leaps on the egg and devours it. It then undergoes a complete change; its eyes disappear, its legs and antenuæ become rudimentary, and it feeds on honey; so that it now more closely resembles the ordinary larvæ of insects. Ultimately it undergoes further transformations, and finally emerges as a perfect beetle."‡

In conclusion, permit me to make a few remarks on the relation of the Insects to the other Arthropod classes.

All who believe in evolution are probably agreed that the origin of the entire Arthropod division is to be sought among the lower Crustacea, in some form resembling the Nauplius. But beyond this there appears to be no agreement. The best suggestion yet made is, perhaps, that at the conclusion of Müller's "Facts for Darwin":—"For the Insecta alone, the development of the Malacostraca (or higher Crustacea) may, perhaps, present a point of union. Like many Zoeas, the Insecta possess three pairs of limbs serving for the reception of nourishment,§ and three pairs serving for locomotion. Like the

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* *Collembola and Thysanura*, p. 53.

† It will be perceived that this a different species from the hive-bee.

‡ Darwin's *Origin of Species*, fourth edition, page 530.

§ These three pairs of modified limbs are "a pair of mandibles and two pairs of maxillæ, the hinder pair of which are coalescent, and form the labium."—*Huxley.*

Zoeas, they have an abdomen without appendages: as in all Zoeas, the mandibles are destitute of palpi. Certainly but little in common, compared with the much which separates these two animal forms. Nevertheless, the supposition that the Insecta had for their common ancestor a Zoea which raised itself to a life on land, may be recommended for further examination." To this I would add that a connexion is shown to exist between the Malacostraca and the Insecta, and also between these two and the Arachinda (spiders, scorpions, mites, &c.), by the remarkable fact that in these three groups, when the segmentation can be made out, the segments of which the animal is composed generally number twenty-one, counting the tail end as a segment. The only assignable reason for this is a common ancestry.

But what is the relation of the Myriopoda to the other Arthropod classes? Among the Myriopoda, as among the lower Crustacea or Entomostraca, the number of segments varies greatly. Does not this separate them from those groups in which the number of segments is uniform? We must not answer this question too hastily. The presence of such a common character proves true affinity between groups; but its absence does not necessarily prove the absence of affinity, for it may have been lost by reversion. Nevertheless, when we see such a character as that of having neither more nor less than 21 segments, tolerably constant throughout the three vast groups of the Malacostraca, the Arachnida, and the Insecta, and totally absent in the Myriopoda, it seems difficult to doubt that it points to a true affinity between those groups possessing it, which they do not share with the group that does not possess it. On the other hand, the Myriopoda resemble the Insects in having one pair of antennæ (the Crustacea having two pairs, and the Arachnida none), in the absence of palpi on the mandibles, which the Crustacea and the Arachnida possess, and in the respiration, which is tracheal. Huxley,* than whom there are few if any higher authorities, thinks there is a specially near kindred between the Myriopoda and the Insecta. But against this, besides the argument from the number of the segments, it is to be mentioned that the Myriopoda resemble the Crustacea, and differ from insects and Arachnids, in growing by the intercalation of new segments between

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* See the review of Häckel's work in Huxley's *Essays and Critiques.*

those first formed, while Insects and Arachnids do not increase the number of their segments during growth. The resemblance between the tracheal systems of the Myriopoda and the Insecta is no doubt very remarkable; but when we consider the variability of respiratory organs generally, it is perhaps not impossible that these systems may have been separately evolved in the two classes. It appears to be certain that instances do exist of the separate evolution of very similar organs.*

In conclusion, I have only to express a hope that I have done something to make intelligible some of the most wonderful phenomena of the animal kingdom.

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* See page 18 of this volume.