increase or diminution of one results in the increase or diminution of all. If the agencies of the first order — i.e., secular cooling, heating of the sun, and astronomic stresses — be neglected, the other agencies are interdependent in such a manner that there is a tendency secularly to establish an equilibrium; and doubtless such an equilibrium would be established in a period not of great length considered geologically. But the agencies of the first order continuously destroy the static equilibrium, and, conjoined with the others, they produce the sequence of changes discovered in geologic history.

The rate of internal cooling is manifestly diminishing, and physicists incline to the opinion that the heating due to the sun is diminishing. From this stand-point, then, the rate of change in geologic history is secularly diminishing. On the other hand, the secondary agencies of change increase in efficiency by reason of increased heterogeneity in the structure of the crust. From the irregularities of the upper surface, and those probably existing at the lower, as suggested by many facts, the crust is heterogeneous in thickness, and doubtless is becoming more so. It also becomes more and more heterogeneous in constitution by the progressing differentiation of its parts, exhibited in the diversification of geologic formations, density, temperature, conductivity, hydration, and chemical and lithical constitution. This internal heterogeneity renders the crust more sensitive to external agencies of change, so that a smaller amount of primary change serves to unlock a given amount of secondary change. At the present stage of geologic research the facts are not sufficient to establish the quantitative relation between the diminished rate of change from the primary agencies and the increased rate of change from the secondary agencies. It is therefore impossible to predicate any variation in the rate of change from the close of archaean time to the present.

J. W. POWELL.

EVOLUTION OF THE DECAPOD ZOEA.

PRINCIPLES applicable to adults are often equally applicable to larvae. In the discussion of natural selection most writers have confined themselves to adult animals and their reaction upon environment. There is no reason, however, why the principle should not be extended to include larval forms; and, indeed, to a slight extent this has already been done. Weismann's 'Theory of descent' proceeds upon this line, and indicates some of the important results which may arise from such research. Crustacean larvae offer particularly good opportunity for work in this direction. They are abundant, are easily obtained, and readily studied. They present great varieties of form, which are frequently not in any degree related to the adult characteristics. Indeed, crustacean larvae seem almost like a distinct group of animals, and may be studied as such, with the extra advantage that they are highly variable, and undergo rapid metamorphosis. Some of the possibilities of such research may be seen by a short consideration of the different forms of decapod zoea.

To make the subject clear, it will be necessary to give a brief description of three types of decapod larvae, confining ourselves, however, only to such points as particularly concern us here. The first is the type, which is undoubtedly the oldest, known as the protozoea. It is a comparatively rare form, being found in a few macruran species (Peneus, Lucifer, Euphausia). Fig. 1 represents such a larva. As far as concerns us, the peculiarities are these: the long body consists of a large cephalothorax, a more or less complete thorax, and an abdomen. The important point is, that all of the regions of the body are represented. When viewed from above, the part of the body composed of thorax and abdomen is seen to be very slender and weak, and to extend for a long distance backwards. A second important point is the method of locomotion: unlike all other forms, the antennae, instead of being sensory organs, are used in locomotion. They are large, and covered with swimming-hairs, which convert them into paddles; and, by moving them to and fro, the protozoea slowly propels itself by a series of jerks through the water. The telson is a third important feature: it is small, being in our figure no broader than the abdomen; it is usually forked, and carries a number of long spines (typically seven, though the number varies); it is not a swimming-organ, — a point of particular interest. One other feature must be mentioned, — the usual though not universal absence of protective spines.

A second type is that of the ordinary macruran zoea; e.g., the larva of the common shrimp. Such a zoea is represented in fig. 2. Here we find a number of changes. First we see that only two regions of the body are present, the cephalothorax and the abdomen, the thorax being unrepresented. The cephalothorax is not very different from that of the protozoea. The abdomen is, however, very different: it is distinctly divided into segments, all of which are well developed; it is tolerably thick, and is a much more powerful structure than the corresponding part of the protozoea. The muscular and usually the nervous system is well developed. In short, the abdomen is much more perfect than that of fig. 1. The locomotion of this zoea is entirely different from that of the protozoea. It does not use its antennae for moving, but propels itself vigorously with powerful strokes of its abdomen, after the manner of the lobster: at least, this is its motion when trying to escape danger; and that is all that concerns us. In correlation with this changed locomotion, the antennae have altered their form, and are now true sense-organs. On the other hand, the telson has become broadened into a flat swimming-organ. It is much broader than the rest of the abdomen, and is used as a paddle to augment the effects of the powerful strokes of the abdomen.

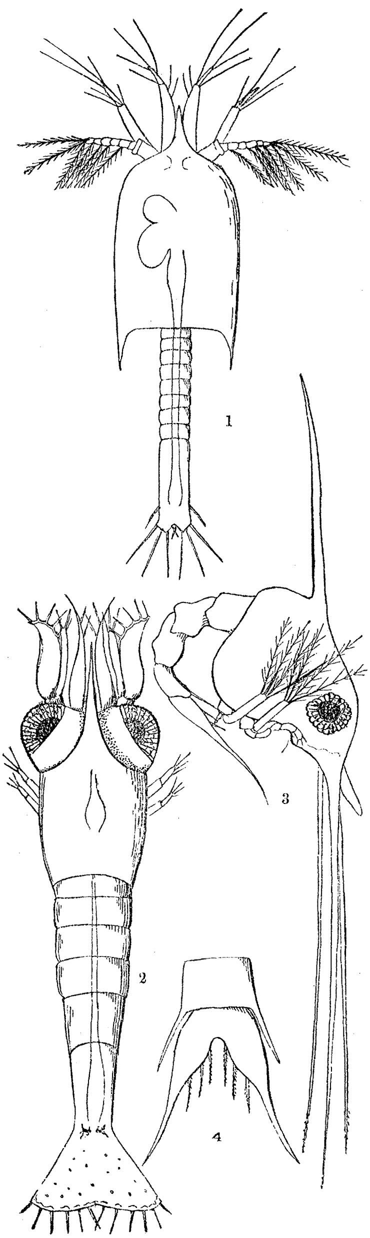

FIG. 1.— Protozoea of Lucifer (after Brooks). FIG. 2.— Zoea of Gebixi. FIG. 3.— Zoea of Panopeus. FIG. 4.— Telson of Panopeus zoea.

It still retains a number of spines, but they are usually quite small.

A third type is the zoea of the ordinary crab. Fig. 3 is such a zoea. Here we see a number of striking peculiarities. As in the shrimp zoea, we find no middle body; i.e., the thorax is absent. The abdomen is quite small, and always occupies a characteristic position. Instead of being stretched out behind the body, as in the shrimp zoea, it is bent under the cephalothorax, as in the figure. Still another mode of locomotion is here found. It is true that occasionally it uses its tail; but its ordinary locomotion is neither with antennae nor abdomen, but by means of its first two pairs of maxillipeds. These are very long, and carry large numbers of swimming-hairs, and serve as oars, with which the zoea paddles itself along. Its motion, while swifter than that of the protozoea, is not so vigorous as that of the shrimp. The tail has become modified into a form halfway between the tails of the other two larvae described. It is somewhat broadened, and probably has a slight motor function; but its chief use is protection (fig. 4). The most noticeable feature is the very remarkable cephalothorax. This is of enormous comparative size, entirely covering the body when the abdomen is flexed. It is further armed with a number (usually four) of long spines, which project in different directions, and are strong and sharp. No one can be in doubt as to the use of this arrangement. The large cephalothorax, with its resisting spines, serves as a protective case for the more delicate organs within; and, further, when the abdomen is flexed, the spines of the peculiar telson are placed in such a position as to give additional protection, being then directed forwards.

Now, is there any connection between these three forms, and is it possible to discover any explanation for their peculiarities? In the first place, comparative embryology shows good reasons for believing that the first type, protozoea, is the oldest, and that the others are derived from this form. The evidence cannot be here deduced, but may be found by referring to Claus, Brooks, or Balfour. Assuming, then, this to be the case, the question resolves itself into the simpler one, what caused the protozoea to undergo changes which converted it into the remarkable zoea form?

A simple experiment, easily performed by any one at the seashore, suggests an answer. The experiment is simply to endeavor to catch a specimen of each of these types of larvae with a moderately small dipping-tube. It will be noticed that all of the larvae seem to have a dread of the suction which is produced by the tube; and all will swim away from it, unless it be too strong. It will be further seen that it is next to impossible to catch the shrimp zoea. He darts away with the vigorous strokes of his tail, and, unless the fisherman is very quick, he is gone. Some of the crab zoeas will be easily caught; but they will be seen, upon examination, to have doubled themselves up into as compact a mass as possible, with all their spines projecting, and consequently in position to offer the greatest defence against enemies. Other crab zoeas will be found not so easily caught. If the zoea fished for be of the species figured, or, still better, be the larva of Porcellana, and the dipping-tube be small, it will be found impossible to catch it. The long spines project so far in different directions, that the larva cannot enter the tube. Finally the protozoea will be easily caught: it swims slowly, and cannot escape the tube; nor does it present projecting spines which prevent its entrance into a small orifice.

This simple experiment teaches us four things: 1°. The dread of suction exhibited by all forms indicates that their chief enemies are small animals, largely, perhaps, fishes which swallow them in their widely-opened mouth; 2°. The behavior of the macruran zoea shows evidently, that, in its struggle for existence, it relies for its protection upon its power of flight, and this gives us immediately a hint as to the meaning of the broad tail; 3°. The crab zoeas rely for their protection, not upon flight, but upon the efficacy of their defensive armor, either as an actual defence, whose resistance baffles the jaws of the fish, or as an apparatus which prevents their entering the mouth of a small enemy (this consideration immediately explains the use of the excessively long spines in Panopeus and Porcellana, which seem to be such encumbrances to the freedom of the larva); 4°. The protozoea seems to possess none of these means for protection; and, indeed, in every respect the protozoea seems ill protected. Its slow, hesitating motion, its long weak abdomen, its long antennae with their numerous swimming-hairs, — all render it easily entangled by rubbish, and easily caught by any enemy.

Taking all of these points into consideration, we get suggestions as to a possible explanation of the remarkable differences between the crab and the shrimp zoea, — differences which seem difficult to understand, since the Brachyura and Macrura are evidently so nearly related. All decapod larvae are freely swimming animals, gaining their own living by an active search for food: they are therefore subjected to a struggle for existence precisely similar to that of adult animals. The principle of natural selection will be as potent to select and modify them as it is in selecting and modifying adults. If, therefore, we assume the protozoea as an original form, we must expect to find it in many cases highly modified, and must expect in most larvae to find, not a protozoea, but a greatly different form, and one better adapted for the struggle for existence. Nor must we be surprised if the embryologist comes to the conclusion that the modified larval stages do not represent stages of ancestral history.

That the protozoea larva is not well adapted for a struggle with numerous enemies is evident to any one who observes how easily it is captured. Assuming that this is the early larval form, we should not expect, from what we know of the workings of nature, that such an evidently weak form would be preserved, except in isolated cases. To adapt such a larva to a more effective struggle, there are three methods: the larvae may be largely increased in numbers, which would, of course, increase the chance of the species for survival; or they may develop powers of flight, which will enable them to escape their enemies; or the larvae may develop some sort of defensive armor, which will enable them passively to resist all ordinary attacks. Abundant examples of each of these methods may be found in almost any group of the animal kingdom, but probably no better instances than the larvae in question; and this is all the more interesting, since it shows that some of the principles affecting adults also in a similar way have their influence on larvae. With these points in mind, it is possible to explain all of the important differences between the protozoea and the two zoea types.

What explanation can we find for the shortened body? Two explanations for this can be found, both of which probably had their influence. The possession of such a long, weak, almost functionless hind-body as is found in the protozoea is certainly calculated to render its possessor a more easy prey to enemies than it would be were the body more compact. The shortening may therefore be simply a protective measure. Or a second principle has probably had even more influence. There is good reason for believing that the amount of energy of a developing animal is limited, and, if expended in one direction, cannot be employed in a second. If, for example, a child over-develops its brain, its body is sure to suffer. Now, this principle has had a similar effect in our larvae. In the protozoea the energy of development is evenly distributed to all parts of the body. The result is, that we find here a larva with almost all of the body present, but in a low state of development: the larva is consequently comparatively weak. If, however, the development of a part of the body should be postponed, the parts which did develop could reach a greater state of perfection, since the whole energy of development could be directly turned toward their perfection. In all existing zoeas the development of the thorax has been thus postponed. The zoeas are found, therefore, to be much more vigorous than the protozoeas, their muscular and nervous system is better developed, and they are in all respects more fitted for an active struggle for existence; and this applies equally well to the macruran or the crab zoea, and will assist in accounting for the absence of a thorax in the two forms, — a point which seemed a great difficulty to Balfour.

In other respects the crab and the shrimp zoea have taken two different lines. The macruran type has become modified for its struggle by acquiring great powers of flight: we find its body, therefore, long and slim; but, unlike the protozoea, it is very powerful, has well-developed muscles, and a broad, paddle-like tail, which, with the assistance of the powerful abdomen, forms an effective organ of flight. Every thing which might impede its motion has disappeared. The antennae are small, and the other appendages are such as to present no hinderances. The whole body has become adapted to its swift motion.

On the other hand, the crab zoea has taken a different line, and has developed, instead of a power of flight, a defensive armor. Its cephalothorax has enlarged, has become strong, and has developed a number of defensive spines, whose use has already been noticed. Its tail, not particularly needed for swimming, has not developed into a broad plate, but has become an augmentation of the defensive armor by the form and position of its spines. Some species have carried this line of development still farther, and are provided with enormously long spines, many times the length of the body, which effectually prevent their being swallowed by small animals. The development of the spinous protection would seem to be correlated with the absence of a swimming-tail. Some species (Pinnotheres, Tatuira) which do not possess any of these spines show a tendency toward a modification of the telson, which has in these cases become quite broad and flat.

We may assume, then, that at one time the decapods, or the stem from which they arose, universally possessed a larval stage somewhat similar to the form known as a protozoea. As the struggle for existence became more and more severe among the Crustacea, modifications arose which took two directions. The adults became changed; and there arose in this way the different types which we know as Anomura, Brachyura, and Macrura. But at the same time natural selection had its influence upon the free larvae quite independent of its influence upon the adult. The larvae, therefore, also became slowly modified for their own protection; and from the protozoea arose the zoea types, with their infinite variety. It is quite evident that these changes may take place in the larvae without materially affecting the adult, for the circumstances bringing them about influence the larvae alone. Still it is probable that habits and form of the adult may have some influence upon the general shape of the larvae. The larva must eventually transform itself into the adult; and the more nearly it approaches the adult form, the less radical will be the change. We can therefore understand why the zoea of the walking animal, such as the crab, would develop protective apparatus, while the zoea of the rapidly-swimming Macrura would acquire organs of flight. We have therefore an explanation of the two facts, that the larvae of the greater groups exhibit a certain unity, while within a given genus the different species may widely vary. H. W. CONN.

THE EXPLOSIONS ON THE UNDERGROUND RAILWAYS OF LONDON.

THE explosion of Feb. 25, at the Victoria station, London, lends interest to the official report of Col. Majendie, on the results of an investigation of the circumstances attending the explosion near the Praed Street station, on the 30th of October last, and the one between Charing Cross and Westminster stations. The first explosion occurred in a tunnel about a hundred and thirty-eight feet distant from the station, as the 7.52 P.M. train was passing. The damage in the tunnel consisted of a vertical crater in the wall about twelve by thirteen inches, and four to six inches deep. Immediately below this crater, and extending about fifteen inches along the wall, was a horizontal crater about six inches deep, partly in the ballast, and partly in the brick footing of the tunnel. The flinty ballast in this crater was considerably splintered, and the brick footing pulverized. A two-inch iron gas-pipe ran along the wall at a height of ten inches. A length of this, measuring fourteen feet, was blown away, one end being much torn and twisted, and the whole piece bent into the form of a bow. At a distance of fifteen inches from the wall, and parallel with it, was an iron switch-rod, consisting of an inch and a quarter gas-pipe, supported on iron rollers at the level of the rails, from which it was distant two feet nine inches, the rollers being fixed on a wooden plank laid on the ballast. This board had about four feet of its length blown to splinters, and a large piece thrown upon the rail, and some of the wheels of the train passed over it. A length of the switch-rod measuring about two feet, and corresponding exactly with the portion of the gas-pipe which sustained the maximum injury, was blown out, the central part of this detached portion being split up and torn. This piece of switch-rod also bore marks of the wheels upon it. A telegraph cable, running along the wall at the height of eight feet and a half, was cut by the explosion. The walls of the tunnel were scored somewhat by the sharp *débris* blown against them, and the end of a sleeper opposite the crater, but partially protected by the ballast in which it was embedded, had a number of pieces of splintered stone driven deeply into it. The rails were entirely uninjured.

The injury to the passing train was confined principally to the last two carriages of the six composing the train. In these the greater part of the glass was broken into small fragments. Panels and partitions were shattered, the roofs and floors disturbed, the foot-boards broken, and the carriages seemed to be completely wrecked, yet no part of the framing or running-gear was injured. The gas throughout the train was extinguished, yet the apparatus was found to be uninjured. It is interesting to note, that the injury to the train was not confined to the side upon which the explosion took place, but extended also to the opposite side; and in the case of one carriage the damage was most marked on that side. Sixty-two persons were injured by cuts and contusions from the pieces of glass and *débris*, and, in one or two cases, by fracture of the drum of the ear and by severe shocks. Five of the injured were confined in the hospital for a considerable time. The breaking of the glass and putting out of the gas occurred on the surface, at the openings of the tunnel, for a distance of three hundred and fifty feet.

The second explosion, which occurred almost simultaneously with the first, took place at a point two hundred and forty-one yards from Charing Cross, and four hundred and eighty-eight yards from Westminster. As it occurred opposite a bay, the only damage done was the breaking of glass, and the extinction of the gas in both stations; the injuring of the telegraph and telephone wires for about sixty yards; the formation of a crater in the ballast, measuring about three by four inches, and one inch deep; and the 'pitting' of the walls of the tunnel, on the side of the explosion for some little distance to the right and left of the crater, and on the opposite side for a somewhat greater distance. The rails were entirely uninjured; but the ends of two sleepers, close to the point where the explosion occurred, sustained some injury.