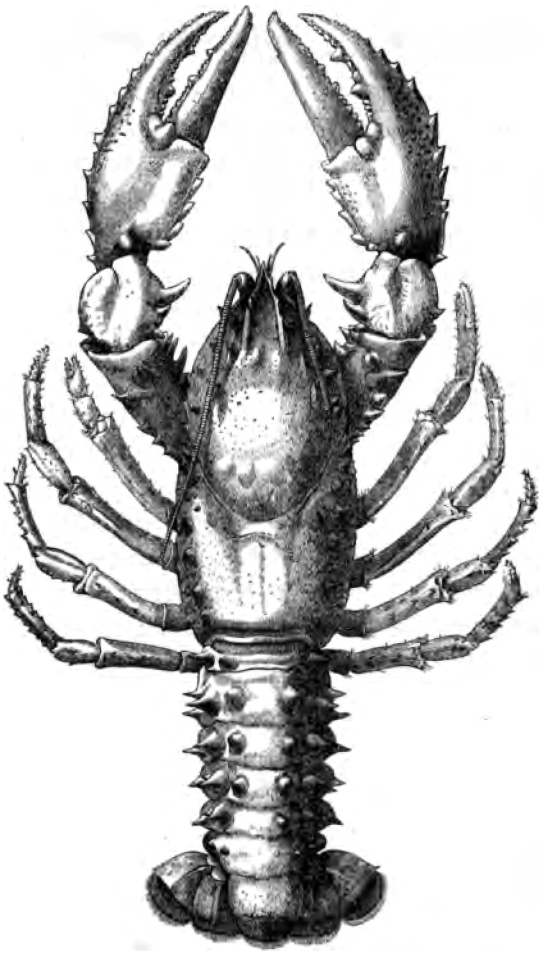


FIG. 76.—Australian Crayfish (⅓ nat. size).*

* The nomenclature of the Australian crayfishes requires thorough revision. I therefore, for the present, assign no name to this cray-

cates by a narrow passage with the sea; and also at Sta. Cruz in the upper basin of the Rio Pardo, an affluent of the Jacuhy, "by digging it out of holes in the ground." The latter (*P. brasiliensis*, fig. 64) was obtained at Porto Alegre, and further inland, in the region of the primitive forest at Rodersburg, in shallow streams.

In addition to these, no crayfish have as yet been found in any of the great rivers, such as the Orinoko; the Amazon, in which they were specially sought for by Agassiz; or in the La Plata, on the eastern side of the Andes. But, on the west, an "*Astacus*" *chilensis* is described in the "Histoire Naturelle des Crustacées," (vol. ii. p. 333). It is here stated that this crayfish "habite les côtes du Chili," but the freshwaters of the Chilian coast are doubtless to be understood.

Finally, Madagascar has a genus and species of crayfish (*Astacoides madagascariensis*, fig. 65) peculiar to itself.

On comparing the results obtained by the study of the geographical distribution of the crayfishes with those brought to light by the examination of their morphological characters, the important fact that there is a broad and general correspondence between the two becomes apparent. The wide equatorial belt of the earth's surface which separates the crayfishes of the northern from those of the southern hemisphere, is a sort of geographical

fish. It is probably identical with the *A. nobilis* of Dana and the *A. armatus* of Von Martens.

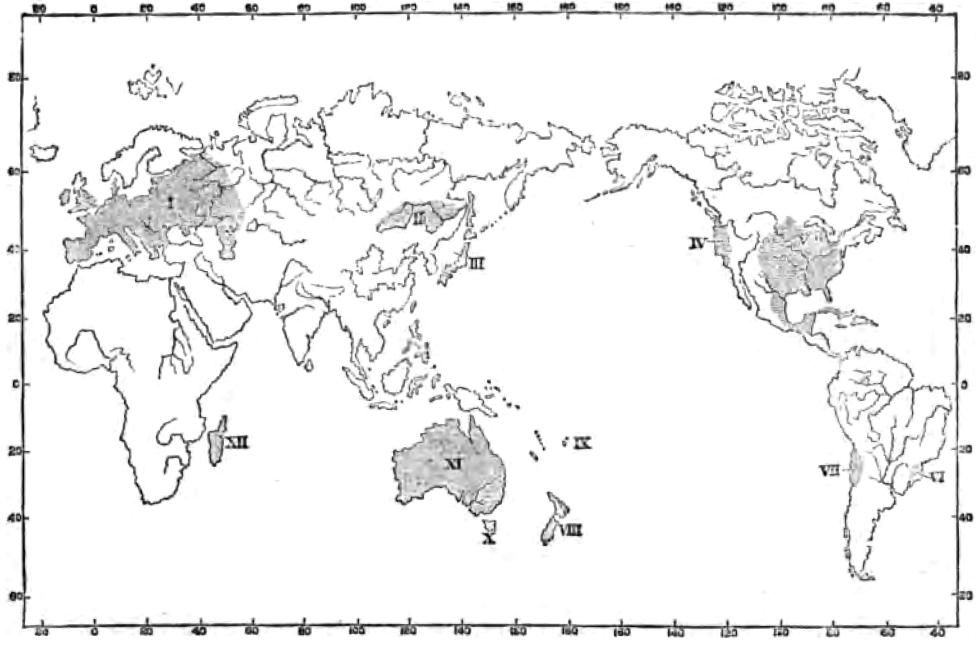


FIG 77.—MAP OF THE WORLD, showing the geographical distribution of the Crayfishes. I. Eur-asiatic Crayfishes; II. Amurland Crayfishes; III. Japanese Crayfishes; IV. Western North American Crayfishes; V. Eastern North American Crayfishes; VI. Brazilian Crayfishes; VII. Chilian Crayfishes; VIII. Novozelanian Crayfishes; IX. Fijian Crayfishes; X. Tasmanian Crayfishes; XI. Australian Crayfishes; XII. Mascarene Crayfishes.

representation of the broad morphological differences which mark off the *Potamobiidæ* from the *Parastacidæ*. Each group occupies a definite area of the earth's surface, and the two are separated by an extensive border-land untenanted by crayfishes.

A similar correspondence is exhibited, though less distinctly, when we consider the distribution of the genera and species of each group. Thus, among the *Potamobiidæ*, *Astacus torrentium* and *nobilis* belong essentially to the northern, western, and southern watersheds of the central European highlands, the streams of which flow respectively into the Baltic and the North Seas, the Atlantic and the Mediterranean (fig. 77, I.); *A. leptodactylus*, *pachypus*, *angulosus*, and *colchicus*, appertain to the Pontocaspian watershed, the rivers of which drain into the Black Sea and the Caspian (I.); while *Astacus dauricus* and *A. Schrenckii* are restricted to the widely separated basin of the Amur, which sheds its waters into the Pacific (II.). The *Astaci* of the rivers of western North America, which flow into the Pacific (IV.), and the *Cambari* of the Eastern or Atlantic water-shed (V.) are separated by the great physical barrier of the Rocky Mountain ranges. Finally, with regard to the *Parastacidæ*, the widely separated geographical regions of New Zealand (VIII.), Australia (IX.), Madagascar (XII.), and South America (VI. and VII.), are inhabited by generically distinct groups.

But when we look more closely into the matter, it will

be found that the parallel between the geographical and the morphological facts cannot be quite strictly carried out.

Astacus torrentium, as we have seen, inhabits both the British Islands and the continent of Europe; nevertheless, there is every reason to believe that twenty miles of sea water is an insuperable barrier to the passage of crayfishes from one land to the other. For though some crayfishes live in brackish water, there is no evidence that any existing species can maintain themselves in the sea. A fact of the same character meets us at the other side of the Eurasiatic continent, the Japanese and the Amurland crayfishes being closely allied; although it is not clear that there are any identical species on the two sides of the Sea of Japan.

Another circumstance is still more remarkable. The West American crayfishes are but little more different from the Pontocaspian crayfishes, than these are from *Astacus torrentium*. On the face of the matter, one might therefore expect the Amurland and Japanese crayfishes, which are intermediate in geographical position, to be also intermediate, morphologically, between the Pontocaspian and the West American forms. But this is not the case. The branchial system of the Amurland *Astaci* appears to be the same as that of the rest of the genus; but, in the males, the third joint (ischiopodite) of the second and third pair of ambulatory limbs is provided with a conical, recurved, hook-like process; while, in the females, the hinder edge of the penultimate thoracic

sternum is elevated into a transverse prominence, on the posterior face of which there is a pit or depression.*

In both these characters, but more especially in the former, the Amurland and Japanese *Astaci* depart from both the Pontocaspian and the West American *Astaci*, and approach the *Cambari* of Eastern North America.

In these crayfishes, in fact, one or both of the same pairs of legs in the male are provided with similar

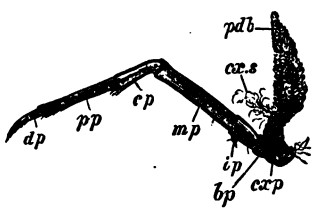


FIG. 78.—*Cambarus* (Guatemala) penultimate leg. *cxp*, coxopodite; *cx.s*, coxopoditic setæ; *pdb*, podobranchia; *bp*, basipodite; *ip*, ischiopodite; *mp*, meropodite; *cp* carpopodite; *pp*, propodite; *dp*, dactylopodite.

hook-like processes; while, in the females, the modification of the penultimate thoracic sternum is carried still further and gives rise to the curious structure described by Dr. Hagen as the "annulus ventralis."

In all the *Cambari*, the pleurobranchiæ appear to be entirely suppressed, and the hindermost podobranchia has no lamina; while the areola is usually extremely narrow. The proportional size of the areola in the Amurland

* Kessler, l. c.

crayfishes is not recorded; in the Japanese crayfish, judging by the figure given by De Haan, it is about the same as in the western *Astaci*. On the other hand, in the West American crayfishes it is distinctly smaller; so that, in this respect, they perhaps more nearly approach the *Cambari*. Unfortunately, nothing is known as to the branchiæ of the Amurland crayfishes. According to De Haan, those of the Japanese species resemble those of the western *Astaci:* as those of the West American *Astaci* certainly do.

With respect to the *Parastacidæ;* in the remarkable length and flatness of the epistoma, the crayfishes of Australia, Madagascar, and South America, resemble one another. But in its peculiar truncated rostrum (see fig. 65) and in the extreme modification of its branchial system, which I have described elsewhere, the Madagascar genus stands alone.

The *Paranephrops* of New Zealand and the Fijis, with its wide and short epistoma, long rostrum, and large antennary squames, is much more unlike the Australian forms than might be expected from its geographical position. On the other hand, considering their wide separation by sea, the amount of resemblance between the New Zealand and the Fiji species is very remarkable.

If the distribution of the crayfishes is compared with that of terrestrial animals in general, the points of

difference are at least as remarkable as the resemblances.

With respect to the latter, the area oocupied by the *Potamobiidæ*, corresponds roughly with the Palæarctic and Nearctic divisions of the great Arctogæal provinces of distribution indicated by mammals and birds; while distinct groups of crayfishes occupy a larger or smaller part of the other, namely, the Austro-Columbian, Australian, and Novozelanian primary distributional provinces of mammals and birds. Again, the peculiar crayfishes of Madagascar answer to the special features of the rest of the fauna of that island.

But the North American crayfishes extend much further South than the limits of the Nearctic fauna in general; while the absence of any group of crayfishes in Africa, or in the rest of the old world, south of the great Asiatic table-land, forms a strong contrast to the general resemblance of the North African and Indian fauna to that of the rest of Arctogæa. Again, there is no such vast difference between the crayfishes of New Zealand, Australia, and South America, as there is between the mammals and the birds of those regions.

It may be concluded, therefore, that the conditions which have determined the distribution of crayfishes have been very different from those which have governed the distribution of mammals and birds. But if we compare with the distribution of the crayfishes, not that of terrestrial animals in general, but only that of freshwater

fishes, some very curious points of approximation become manifest. The *Salmonidæ*, or fishes of the salmon and trout kind, a few of which are exclusively marine, many both marine and freshwater, while others are confined to fresh water, are distributed over the northern hemisphere, in a manner which recalls the distribution of the Potamobine crayfishes,* though they do not extend so far to the South in the new world, while they go a little further, namely, as far as Algeria, Northern Asia Minor, and Armenia, in the old world. With the exception of the single genus *Retropinna*, which inhabits New Zealand, no true salmonoid fish occurs south of the equator; but, as Dr. Günther has pointed out, two groups of freshwater fishes, the *Haplochitonidæ* and the *Galaxidæ*, which stand in somewhat the same relation to the *Salmonidæ* as the *Parastacidæ* do to the *Potamobiidæ*, take the place of the *Salmonidæ* in the fresh waters of New Zealand, Australia, and South America. There are two species of *Haplochiton* in Tierra del Fuego; and of the closely allied genus *Prototroctes*, one species is found in South Australia, and one in New Zealand; of the *Galaxidæ*, the same species, *Galaxias attennuatus*, occurs in the streams of New Zealand, Tasmania, the Falkland Islands, and Peru.

Thus, these fish avoid South Africa, as the crayfishes

* According to Dr. Günther their southern range is similarly limited by the Asiatic Highlands. But they abound in the rivers both of the old and new worlds which flow into the Arctic sea; and though those on

do; but I am not aware that any member of the group is found in Madagascar, and thus completes the analogy.

The preservation of the soft parts of animals in the fossil state depends upon favourable conditions of rare occurrence; and, in the case of the *Crustacea*, it is not often that one can hope to meet with such small hard parts as the abdominal members, in a good state of preservation. But without recourse to the branchial apparatus, and to the abdominal appendages, it might be very difficult to say whether a given crustacean belonged to the Astacine, or to the closely allied Homarine group. Of course, if the accompanying fossils indicated that the deposit in which the remains occur, was of freshwater origin, the presumption in favour of their Astacine nature would be very strong; but if they were inhabitants of the sea, the problem whether the crustacean in question was a marine Astacine, or a true Homarine, might be very hard to solve.

Undoubted remains of crayfishes have hitherto been discovered only in freshwater strata of late tertiary age. In Idaho, North America, Professor Cope * found, in association with *Mastodon mirificus*, and *Equus excelsus*, several species, which he considers to be distinct from

the western side of the Rocky Mountains are different from the Eastern American forms, yet there are species common to both the Asiatic and the American coasts of the North Pacific.

* On three extinct *Astaci* from the freshwater Tertiary of Idaho. Proceedings of the American Philosophical Society, 1869–70.

the existing American crayfishes; whether they are *Cambari* or *Astaci* does not appear. But, in the lower chalk of Ochtrup, in Westphalia, and therefore in a marine deposit, Von der Marck and Schlüter* have obtained a single, somewhat imperfect, specimen of a crustacean, which they term *Astacus politus*, and which, singularly enough, has the divided telson found only in the genus *Astacus*. It would be very desirable to know more about this interesting fossil. For the present it affords a strong presumption that a marine Potamobine existed as far back as the earlier part of the cretaceous epoch.

Such are the more important facts of Morphology, Physiology, and Distribution, which make up the sum of our present knowledge of the Biology of Crayfishes. The imperfection of that knowledge, especially as regards the relations between Morphology and Distribution, becomes a serious drawback when we attack the final problem of Biology, which is to find out why animals of such structure and active powers, and so localized, exist?

It would appear difficult to frame more than two fundamental hypotheses in attempting to solve this problem. Either we must seek the origin of crayfishes in conditions extraneous to the ordinary course of natural

* Neue Fische und Krebse aus der Kreide von Westphalen. Palæontographica, Bd. XV., p. 302; tab. XLIV., figs. 4 and 5.

operations, by what is commonly termed Creation; or we must seek for it in conditions afforded by the usual course of nature, when the hypothesis assumes some shape of the doctrine of Evolution. And there are two forms of the latter hypothesis; for, it may be assumed, on the one hand, that crayfishes have come into existence, independently of any other form of living matter, which is the hypothesis of spontaneous or equivocal generation, or abiogenesis; or, on the other hand, we may suppose that crayfishes have resulted from the modification of some other form of living matter; and this is what, to borrow a useful word from the French language, is known as *transformism*.

I do not think that any hypothesis respecting the origin of crayfishes can be suggested, which is not referable to one or other of these, or to a combination of them.

As regards the hypothesis of creation, little need be said. From a scientific point of view, the adoption of this speculation is the same thing as an admission that the problem is not susceptible of solution. Moreover, the proposition that a given thing has been created, whether true or false, is not capable of proof. By the nature of the case direct evidence of the fact is not obtainable. The only indirect evidence is such as amounts to proof that natural agencies are incompetent to cause the existence of the thing in question. But such evidence is out of our reach. The most that

can be proved, in any case, is that no known natural cause is competent to produce a given effect; and it is an obvious blunder to confound the demonstration of our own ignorance with a proof of the impotence of natural causes. However, apart from the philosophical worthlessness of the hypothesis of creation, it would be a waste of time to discuss a view which no one upholds. And, unless I am greatly mistaken, at the present day, no one possessed of knowledge sufficient to give his opinion importance is prepared to maintain that the ancestors of the various species of crayfish were fabricated out of inorganic matter, or brought from nothingness into being, by a creative fiat.

Our only refuge, therefore, appears to be the hypothesis of evolution. And, with respect to the doctrine of abiogenesis, we may also, in view of a proper economy of labour, postpone its discussion until such time as the smallest fragment of evidence that a crayfish can be evolved by natural agencies from not living matter, is brought forward.

In the meanwhile, the hypothesis of transformism remains in possession of the field; and the only profitable inquiry is, how far are the facts susceptible of interpretation, on the hypothesis that all the existing kinds of crayfish are the product of the metamorphosis of other forms of living beings; and that the biological phenomena which they exhibit are the results of the interaction, through past time, of two series of

factors: the one, a process of morphological and concomitant physiological modification; the other, a process of change in the condition of the earth's surface.

If we set aside, as not worth serious consideration, the assumption that the *Astacus torrentium* of Britain was originally created apart from the *Astacus torrentium* of the Continent; it follows, either that this crayfish has passed across the sea by voluntary or involuntary migration; or that the *Astacus torrentium* existed before the English Channel, and spread into England while these islands were still continuous with the European mainland; and that the present isolation of the English crayfishes from the members of the same species on the Continent is to be accounted for by those changes in the physical geography of western Europe which, as there is abundant evidence to prove, have separated the British Islands from the mainland.

There is no evidence that our crayfish has been purposely introduced by human agency into Great Britain; and from the mode of life of crayfish and the manner in which the eggs are carried about by the parent during their development, transport by birds or floating timber would seem to be out of the question. Again, although *Astacus nobilis* is said to venture into the brackish waters of the Gulf of Finland, and *A. leptodactylus*, as we have seen, makes itself at home in the more or less salt Caspian, there is no reason to believe that *Astacus torrentium* is capable of existing in sea-

water, still less of crossing the many miles of sea which separate England from even the nearest point of the Continent. In fact, the existence of the same kind of crayfish on both sides of the Channel appears to be only a case of the general truth, that the Fauna of the British Islands is identical with a part of that of the Continent; and as our foxes, badgers, and moles certainly have neither swum across, nor been transported by man, but existed in Britain while it was still continuous with western Europe, and have been isolated by the subsequent intervention of the sea, so we may confidently explain the presence of *Astacus torrentium* by reference to the same operation.

If we take into account the occurrence of *Astacus nobilis* over so large a part of the area occupied by *Astacus torrentium;* its absence in the British Islands, and in Greece; and the closer affinity which exists between *A. nobilis* and *A. leptodactylus,* than between *A. nobilis* and *A. torrentium;* it seems not improbable that *Astacus torrentium* was the original tenant of the whole western European area outside the Ponto-Caspian watershed; and that *A. nobilis* is an invading offshoot of the Ponto-Caspian or *leptodactylus* form which has made its way into the western rivers in the course of the many changes of level which central Europe has undergone; in the same way as *A. leptodactylus* is now passing into the rivers of the Baltic provinces of Russia.

The study of the glacial phenomena of central Europe

has led Sartorius von Waltershausen* to the conclusion that at the time when the glaciers of the Alps had a much greater extension than at present, a vast mass of freshwater extended from the valley of the Danube to that of the Rhone, around the northern escarpment of the Alpine chain, and connected the head-waters of the Danube with those of the Rhine, the Rhone, and the northern Italian rivers. As the Danube debouches into the Black Sea, and this was formerly connected with the Aralo-Caspian Sea, an easy passage would thus be opened up by which crayfishes might pass from the Aralo-Caspian area to western Europe. If they spread by this road, the *Astacus torrentium* may represent the first wave of migration westward, while *A. nobilis* answers to a second, and *A. leptodactylus*, with its varieties, remains as the representative of the old Aralo-Caspian crayfishes. And thus the crayfishes would present a curious parallel with the Iberian, Aryan, and Mongoloid streams of westward movement among mankind.

If we thus suppose the western Eurasiatic crayfishes to be simply varieties of a primitive Aralo-Caspian stock, their limitation to the south by the Mediterranean and by the great Asiatic highlands becomes easily intelligible.

The extremely severe climatal conditions which obtain in northern Siberia may sufficiently account for the

*"Untersuchungen ueber die Klimate der Gegenwart und der Vorwelt." Natuurkundige Verhandelingen van de Hollandsche Maatschappij der Wetenschappen te Haarlem, 1865.

absence of crayfishes (if they are really absent) in the rivers Obi, Yenisei, and Lena, and in the great lake Baikal, which lies more than 1,300 feet above the sea, and is frozen over from November to May. Moreover, there can be no doubt that, at a comparatively recent period, the whole of this region, from the Baltic to the mouth of the Lena, was submerged beneath a southward extension of the waters of the Arctic ocean to the Aralo-Caspian Sea and Lake Baikal, and a westward extension to the Gulf of Finland.

The great lakes and inland seas which stretch, at intervals, from Baikal, on the east, to Wenner in Sweden, on the west, are simply pools, isolated partly by the rising of the ancient sea-bottom and partly by evaporation; and often completely converted into fresh water by the inflow of the surrounding land-drainage. But the population of these pools was originally the same as that of the Northern Ocean, and a few species of marine crustaceans, mollusks, and fish, besides seals, remain in them as living evidences of the great change which has taken place. The same process which, as we shall see, has isolated the *Mysis* of the Arctic seas in the lakes of Sweden and Finland, has shut up with it other arctic marine crustacea, such as species of *Gammarus* and *Idothea*. And the very same species of *Gammarus* is imprisoned, along with arctic seals, in the waters of Lake Baikal.

The distribution of the American crayfishes agrees equally well with the hypothesis of the northern origin of

the stock from which they have been evolved. Even under existing geographical conditions, an affluent of the Mississippi, the St. Peter's river, communicates directly, in rainy weather, with the Red river, which flows into Lake Winnipeg, the southernmost of the long series of intercommunicating lakes and streams, which occupy the low and flat water-parting between the southern and the northern watersheds of the North American Continent. But the northernmost of these, the Great Slave Lake, empties itself by the Mackenzie river into the Arctic Ocean, and thus provides a route by which crayfishes might spread from the north over all parts of North America east of the Rocky Mountains.

The so-called Rocky Mountain range is, in reality, an immense table-land, the edges of which are fringed by two principal lines of mountainous elevations. The table-land itself occupies the place of a great north and south depression which, in the cretaceous epoch, was occupied by the sea and probably communicated with the ocean at its northern, as well as at its southern end. During and since this epoch it became gradually filled up, and it now contains an immense thickness of deposits of all ages from the cretaceous to the pliocene—the earlier marine, the later more and more completely freshwater. During the tertiary epoch, various portions of this area have been occupied by vast lakes, the more northern of which doubtless had outlets into the Northern sea. That crayfish existed in the vicinity of the Rocky Mountains

in the latter part of the tertiary epoch is testified by the Idaho fossils. And there is thus no difficulty in understanding their presence in the rivers which have now cut their way to the Pacific coast.

The similarity of the crayfish of the Amurland and of Japan is a fact of the same order as the identity of the English crayfish with the *Astacus torrentium* of the European Continent, and is to be explained in an analogous fashion. For there can be no doubt that the Asiatic continent formerly extended much further to the eastward than it does at present, and included what are now the islands of Japan. Even with this alteration of the geographical conditions, however, it is not easy to see how crayfishes can have got into the Amur-Japanese fresh waters. For a north-eastern prolongation of the Asiatic highlands, which ends to the north in the Stanovoi range, shuts in the Amur basin on the west; while the Amur debouches into the sea of Okhotsk, and the Pacific ocean washes the shores of the Japanese islands.

But there are many grounds for the conclusion that, in the latter half of the tertiary epoch, eastern Asia and North America were connected, and that the chain of the Kurile and Aleutian islands may indicate the position of a great extent of submerged land. In that case, the sea of Okhotsk and Behring's sea may occupy the site of inland waters which formerly placed the mouth of the Amur in direct communication with the Northern Ocean, just as the Black Sea, at present, brings the basin of the

Danube into connection, first with the Mediterranean and then with the western Atlantic; and, as in former times, it gave access from the south to the vast area now drained by the Volga. When the Black Sea communicated with the Aralo-Caspian sea, and this opened to the north into the Arctic sea, a chain of great inland waters must have skirted the eastern frontier of Europe, just such as would now lie on the eastern frontier of Asia if the present coast underwent elevation.

Supposing, however, that the ancestral forms of the *Potamobiidæ* obtained access to the river basins in which they are now found, from the north, the hypothesis that a mass of fresh water once occupied a great part of the region which is now Siberia and the Arctic Ocean, would be hardly tenable, and it is, in fact, wholly unnecessary for our present purpose.

The vast majority of the stalk-eyed crustaceans are, and always have been, exclusively marine animals; the crayfishes, the *Atyidæ*, and the fluviatile crabs (*Thelphusidæ*), being the only considerable groups among them which habitually confine themselves to fresh waters. But even in such a genus as *Penæus*, most of the species of which are exclusively marine, some, such as *Penæus brasiliensis*, ascend rivers for long distances. Moreover, there are cases in which it cannot be doubted that the descendants of marine *Crustacea* have gradually accustomed themselves to fresh water conditions, and have, at the same time, become more or less modified,

so that they are no longer absolutely identical with those descendants of their ancestors which have continued to live in the sea.*

In several of the lakes of Norway, Sweden and Finland, and in Lake Ladoga, in Northern Europe; in Lake Superior and Lake Michigan, in North America; a small crustacean, *Mysis relicta*, occurs in such abundance as to furnish a great part of the supply of food to the fresh water fishes which inhabit these lakes. Now, this *Mysis relicta* is hardly distinguishable from the *Mysis oculata* which inhabits the Arctic seas, and is certainly nothing but a slight variety of that species.

In the case of the lakes of Norway and Sweden, there is independent evidence that they formerly communicated with the Baltic, and were, in fact, fiords or arms of the sea. The communication of these fiords with the sea having been gradually cut off, the marine animals they contained have been imprisoned; and as the water has been slowly changed from salt to fresh by the drainage of the surrounding land, only those which were able to withstand the altered conditions have survived. Among these is the *Mysis oculata*, which has in the meanwhile undergone the slight variation which has converted it into *Mysis relicta*. Whether the same explanation ap-

* See on this interesting subject: Martens, "On the occurrence of marine animal forms in fresh water." Annals of Natural History, 1858: Lovèn. "Ueber einige im Wetter und Wener See gefundene Crustaceen." Halle Zeitschrift für die Gesammten Wissenschaften, xix., 1862: G. O. Sars, "Histoire Naturelle des Crustacés d'eau douce de Norvège," 1867.

plies to Lakes Superior and Michigan, or whether the *Mysis oculata* has not passed into these masses of fresh water by channels of communication with the Arctic Ocean which no longer exist, is a secondary question. The fact remains that *Mysis relicta* is a primitively marine animal which has become completely adapted to fresh-water life.

Several species of prawns (*Palæmon*) abound in our own seas. Other marine prawns are found on the coasts of North America, in the Mediterranean, in the South Atlantic and Indian Oceans, and in the Pacific as far south as New Zealand. But species of the same genus (*Palæmon*) are met with, living altogether in fresh water, in Lake Erie, in the rivers of Florida, in the Ohio, in the rivers of the Gulf of Mexico, of the West India Islands and of eastern South America, as far as southern Brazil, if not further; in those of Chili and those of Costa Rica in western South America; in the Upper Nile, in West Africa, in Natal, in the Islands of Johanna, Mauritius, and Bourbon, in the Ganges, in the Molucca and Philippine Islands, and probably elsewhere.

Many of these fluviatile prawns differ from the marine species not only in their great size (some attaining a foot or more in length), but still more remarkably in the vast development of the fifth pair of thoracic appendages. These are always larger than the slender fourth pair (which answer to the forceps of the crayfishes); and, in the males especially, they are very long and strong, and

are terminated by great chelæ, not unlike those of the crayfishes. Hence these fluviatile prawns (known in many places by the name of "Cammarons") are not unfrequently confounded with true crayfishes; though

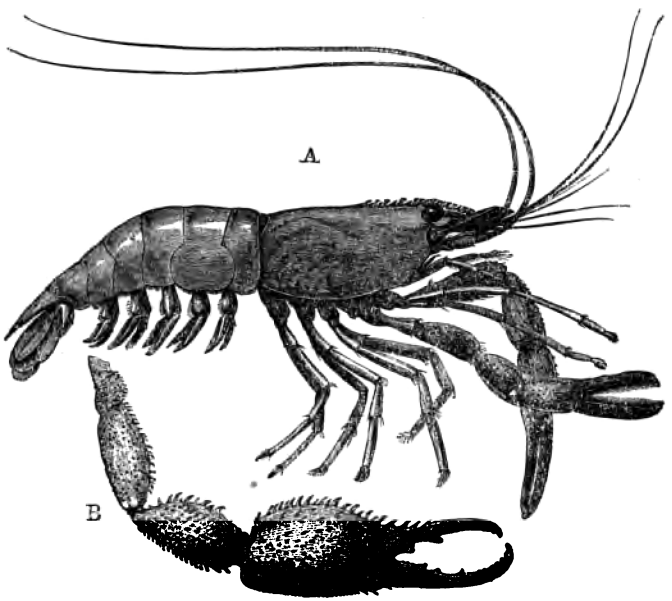


FIG. 79. *Palæmon jamaicensis* (about ⅔ nat. size). A, female; B, fifth thoracic appendage of male.

the fact that there are only three pair of ordinary legs behind the largest, forceps-like pair, is sufficient at once to distinguish them from any of the *Astacidæ*.

Species of these large-clawed prawns live in the

brackish water lagoons of the Gulf of Mexico, but I am not aware that any of them have yet been met with in the sea itself. The *Palæmon lacustris* (*Anchistia migratoria*, Heller) abounds in fresh-water ditches and canals between Padua and Venice, and in the Lago di Garda, as well as in the brooks of Dalmatia; but its occurrence in the Adriatic or the Mediterranean, which has been asserted, appears to be doubtful. So the Nile prawn, though very similar to some Mediterranean prawns, does not seem to be identical with any at present known.*

In all these cases, it appears reasonable to apply the analogy of the *Mysis relicta*, and to suppose that the fluviatile prawns are simply the result of the adaptive modification of species which, like their congeners, were primitively marine.

But if the existing sea prawns were to die out, or to be beaten in the struggle for existence, we should have, scattered over the world in isolated river basins, more or less distinct species of freshwater prawns,† the areas inhabited by which might hereafter be indefinitely enlarged or diminished, by alteration in the elevation of the

* Heller, "Die Crustaceen des südlichen Europas," p. 259. Klunzinger, "Ueber eine Süsswasser-crustacee im Nil," with the notes by von Martens and von Siebold: Zeitschrift für Wissenschaftliche Zoologie, 1866.

† This seems actually to have happened in the case of the widely-spread allies and companions of the fluviatile prawns, *Atya* and *Caridina*. I am not aware that truly marine species of these genera are known.

land and by other changes in physical geography. And, indeed, under these circumstances, the freshwater prawns themselves might become so much modified, that, even if the descendants of their ancestors remained unchanged in structure and habits in the sea, the relationship of the two might no longer be obvious.

These considerations appear to me to indicate the direction in which we must look for a rational explanation of the origin of crayfishes and their present distribution.

I have no doubt that they are derived from ancestors which lived altogether in the sea, as the great majority of the *Mysidæ* and many of the prawns do now; and that, of these ancestral crayfishes, there were some which, like *Mysis oculata* or *Penæus brasiliensis*, readily adapted themselves to fresh water conditions, ascended rivers, and took possession of lakes. These, more or less modified, have given rise to the existing crayfishes, while the primitive stock would seem to have vanished. At any rate, at the present time, no marine crustacean with the characters of the *Astacidæ* is known.

As crayfishes have been found in the later tertiaries of North America, we shall hardly err in dating the existence of these marine crayfishes at least as far back as the miocene epoch; and I am disposed to think that, during the earlier tertiary and later mesozoic periods, these *Crustacea* not only had as wide a distribution as the Prawns and *Penæi* have now, but were differentiated into two groups, one with the general characters of the

Potamobiidæ in the northern hemisphere, and another, with those of the *Parastacidæ*, in the southern hemisphere.

The ancestral Potamobine form probably presented the peculiarities of the *Potamobiidæ* in a less marked degree than any existing species does. Probably the four pleurobranchiæ were all equally well developed; the laminæ of the podobranchiæ smaller and less distinct from the stem; the first and second abdominal appendages less specialised; and the telson less distinctly divided. So far as the type was less specially Potamobine, it must have approached the common form in which *Homarus* and *Nephrops* originated. And it is to be remarked that these also are exclusively confined to the northern hemisphere.

The wide range and close affinity of the genera *Astacus* and *Cambarus* appear to me to necessitate the supposition that they are derived from some one already specialised Potamobine form; and I have already mentioned the grounds upon which I am disposed to believe that this ancestral Potamobine existed in the sea which lay north of the miocene continent in the northern hemisphere.

In the marine primitive crayfishes south of the equator, the branchial apparatus appears to have suffered less modification, while the suppression of the first abdominal appendages, in both sexes, has its analogue among the *Palinuridæ*, the headquarters of which are in the southern hemisphere. That they should have ascended

the rivers of New Zealand, Australia, Madagascar, and South America, and become fresh water *Parastacidæ*, is an assumption which is justified by the analogy of the fresh-water prawns. It remains to be seen whether marine *Parastacidæ* still remain in the South Pacific and Atlantic Oceans, or whether they have become extinct.

In speculating upon the causes of an effect which is the product of several co-operating factors, the nature of each of which has to be divined by reasoning backwards from its effects, the probability of falling into error is very great. And this probability is enhanced when, as in the present case, the effect in question consists of a multitude of phenomena of structure and distribution about which much is yet imperfectly known. Hence the preceding discussion must rather be regarded as an illustration of the sort of argumentation by which a completely satisfactory theory of the ætiology of the crayfish will some day be established, than as sufficing to construct such a theory. It must be admitted that it does not account for the whole of the positive facts which have been ascertained; and that it requires supplementing, in order to furnish even a plausible explanation of various negative facts.

The positive fact which presents a difficulty is the closer resemblance between the Amur-Japanese crayfish and the East American *Cambari*, than between the

latter and the West American *Astaci;* and the closer resemblance between the latter and the Pontocaspian crayfish, than either bear to the Amur-Japanese form. If the facts had been the other way, and the West American and Amur-Japanese crayfish had changed places, the case would have been intelligible enough. The primitive Potamobine stock might then have been supposed to have differentiated itself into a western astacoid, and an eastern cambaroid form;* the latter would have ascended the American, and the former the Asiatic rivers. As the matter stands, I do not see that any plausible explanation can be offered without recourse to suppositions respecting a former more direct communication between the mouth of the Amur, and that of the North American rivers, in favour of which no definite evidence can be offered at present.

The most important negative fact which remains to be accounted for is the absence of crayfishes in the rivers of a large moiety of the continental lands, and in numerous islands. Differences of climatal conditions are obviously inadequate to account for the absence of crayfishes in Jamaica, when they are present in Cuba; for their absence in Mozambique, and the islands of Johanna and Mauritius, when they are present in Madagascar; and for their absence in the Nile, when they exist in Guatemala.

* Just as there is an American form of *Idothea* and an Asiatic form in the Arctic ocean at the present day.

At present, I confess that I do not see my way to a perfectly satisfactory explanation of the absence of crayfishes in so many parts of the world in which they might, *d priori*, be expected to exist; and I can only suggest the directions in which an explanation may be sought.

The first of these is the existence of physical obstacles to the spread of crayfishes, at the time at which the Potamobine and the Parastacine stocks respectively began to take possession of the rivers, some of which have now ceased to exist; and the second is the probability that, in many rivers which have been accessible to crayfishes, the ground was already held by more powerful competitors.

If the ancestors of the Potamobine crayfishes originated only among those primitive crayfishes which inhabited the seas north of the miocene continent, their present limitation to the south, in the old world, is as easily intelligible as is their extension southward, in the course of the river basins of Northern America as far as Guatemala, but no further. For the elevation of the Eurasiatic highlands had commenced in the miocene epoch, while the isthmus of Panama was interrupted by the sea.

With respect to the Southern hemisphere, the absence of crayfishes in Mauritius and in the islands of the Indian Ocean, though they occur in Madagascar, may be due to the fact that the former islands are of comparatively late volcanic origin; while Madagascar is the remnant of

a very ancient continental area, the oldest indigenous population of which, in all probability, is directly descended from that which occupied it at the beginning of the tertiary epoch. If Parastacine *Crustacea* inhabited the southern hemisphere at this period, and subsequently became extinct as marine animals, their preservation in the freshwaters of Australia, New Zealand, and the older portions of South America may be understood. The difficulty of the absence of crayfishes in South Africa * remains; and all that can be said is, that it is a difficulty of the same nature as that which confronts us when we compare the fauna of South Africa in general with that of Madagascar. The population of the latter region has a more ancient aspect than that of the former; and it may be that South Africa, in its present shape, is of very much later date than Madagascar.

With respect to the second point for consideration, it is to be remarked that, in the temperate regions of the world, the crayfishes are by far the largest and strongest of any of the inhabitants of freshwater, except the *Vertebrata;* and that while frogs and the like fall an easy prey to them, they must be formidable enemies and competitors even to fishes, aquatic reptiles, and the smaller aquatic mammals. In warm climates, however, not only the large prawns which have been mentioned, but *Atyæ*

* But it must be remembered that we have as yet everything to learn respecting the fauna of the great inland lakes and river systems of South Africa.

and fluviatile crabs (*Thelphusa*) compete for the possession of the freshwaters; and it is not improbable that under some circumstances, they may be more than a match for crayfishes; so that the latter might either be driven out of territory they already occupied, as *Astacus leptodactylus* is driving out *A. nobilis* in the Russian rivers; or might be prevented from entering rivers already tenanted by their rivals.

In connection with this speculation, it is worthy of remark that the area occupied by the fluviatile crabs is very nearly the same as that zone of the earth's surface from which crayfish are excluded, or in which they are scanty. That is to say, they are found in the hotter parts of the eastern side of the two Americas, the West Indies, Africa, Madagascar, Southern Italy, Turkey and Greece, Hindostan, Burmah, China, Japan, and the Sandwich Islands. The large-clawed fluviatile prawns are found in the same regions of America, on both east and west coasts, in Africa, Southern Asia, the Moluccas, and the Philippine Islands; while the *Atyidæ* not only cover the same area, but reach Japan, extend over Polynesia, to the Sandwich Islands, on the north, and New Zealand, on the south, and are found on both shores of the Mediterranean; a blind form (*Troglocaris Schmidtii*), in the Adelsberg caves, representing the blind *Cambarus* of the caves of Kentucky.

The hypothesis respecting the origin of crayfishes

which has been tentatively put forward in the preceding pages, involves the assumption that marine Crustacea of the astacine type were in existence during the deposition of the middle tertiary formations, when the great continents began to assume their present shape. That such was the case there can be no doubt, inasmuch as abundant remains of Crustacea of that type occur still earlier in the mesozoic rocks. They prove the existence of ancient crustaceans, from which the crayfishes may have been derived, at that period of the earth's history when the conformation of the land and sea were such as to admit of their entering the regions in which we now find them.

The materials which have, up to the present, time been collected are too scanty to permit of the tracing out of all the details of the genealogy of the crayfish. Nevertheless, the evidence which exists is perfectly clear, as far as it goes, and is in complete accordance with the requirements of the doctrine of evolution.

Mention has been made of the close affinity between the crayfishes and the lobsters—the *Astacina* and the *Homarina;* and it fortunately happens that these two groups, which may be included under the common name of the *Astacomorpha*, are readily distinguishable from all the other *Podophthalmia* by peculiarities of their exoskeleton which are readily seen in all well-preserved fossils. In all, as in the crayfish, there are large forceps, followed by two pairs of chelate ambulatory limbs, while

the succeeding two pairs of legs are terminated by simple claws. The exopodite of the last abdominal appendage is divided into two parts by a transverse suture. The pleura of the second abdominal somite are larger than the others, and overlap those of the first somite, which are very small. Any fossil crustacean which presents all these characters, is certainly one of the *Astacomorpha*.

The *Astacina*, again, are distinguished from the *Homarina* by the mobility of the last thoracic somite, and the characters of the first and second abdominal appendages, when they are present; or by their entire absence. But it is so difficult to make out anything about either of these characters in fossils, that, so far as I am aware, we know nothing about them in any fossil Astacomorph. And hence, it may be impossible to say to which division any given form belongs, unless its resemblances to known types are so minute and so close as to remove doubt.

For the present purpose, the series of the fossiliferous rocks may be grouped as follows:—1. Recent and Quaternary. 2. Newer Tertiary (Pliocene and Miocene). 3. Older Tertiary (Eocene). 4. Cretaceous (Chalk, Greensand and Gault). 5. Wealden. 6. Jurassic (Purbeck to Inferior Oolite). 7. Liassic. 8. Triassic. 9. Permian. 10. Carboniferous. 11. Devonian. 12. Silurian. 13. Cambrian.

Now the oldest known member of the group of the

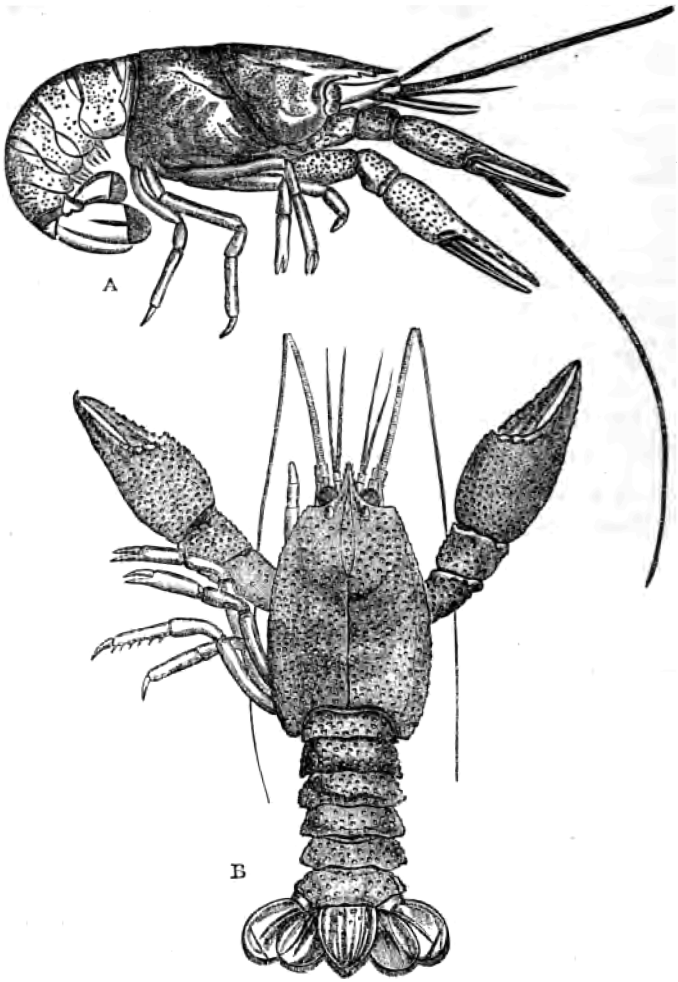


FIG. 80.—A, *Pseudastacus pustulosus* (nat. size). B, *Eryma modestiformis* (×2). Both figures after Oppel.

decapod *Podophthalmia* to which the *Astacomorpha* belong occurs in the Carboniferous formation. It is the genus *Anthrapalæmon*—a small and very curious crustacean, about which nothing more need be said at present, as it does not appear to have special affinities with the *Astacomorpha*. In the later formations, up to the top of the Trias, podophthalmatous *Crustacea* are very rare; and, unless the Triassic genus *Pemphix* is an exception, no Astacomorphs are known to occur in them. The specimens of *Pemphix* which I have examined are not sufficiently complete to enable me to express any opinion about them.

The case is altered when we reach the Middle Lias. In fact this yields several forms of a genus, *Eryma* (fig. 80, B), which also occurs in the overlying strata almost up to the top of the Jurassic series, and presents so many variations that nearly forty different species have been recognised. *Eryma* is, in all respects, an Astacomorph, and so far as can be seen, it differs from the existing genera only in such respects as those in which they differ from one another. Thus it is quite certain that Astacomorphous *Crustacea* have existed since a period so remote as the older part of the Mesozoic period; and any hesitation in admitting this singular persistency of type on the part of the crayfishes, is at once removed by the consideration of the fact that, along with *Eryma*, in the Middle Lias, prawn-like *Crustacea*, generically identical with the existing *Penæus*, flourished in the sea

and left their remains in the mud of the ancient sea bottom.

Eryma is the only crustacean, which can be certainly ascribed to the *Astacomorpha*, that has hitherto been found in the strata from the Middle Lias to the lithographic slates; which last lie in the upper part of the Jurassic series. In the freshwater beds of the Wealden, no *Astacomorpha* are known, and although no very great

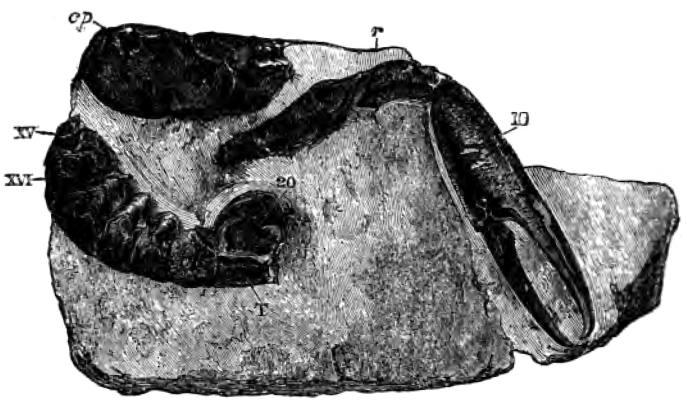


FIG. 81. — *Hoploparia longimana* (⅔ nat. size). — *cp*, carapace; *r*, rostrum, T, telson; XV., XVI., first and second abdominal somites; 10, forceps; 20, last abdominal appendage.

weight is to be attached to a negative fact of this kind, it is, so far, evidence that the *Astacomorpha* had not yet taken to freshwater life. In the marine deposits of the Cretaceous epoch, however, astacomorphous forms, which

are known by the generic names of *Hoploparia* and *Enoploclytia*, are abundant.

The differences between these two genera, and between both and *Eryma*, are altogether insignificant from a broad morphological point of view. They appear to me to be of less importance than those which obtain between the different existing genera of crayfishes.

Hoploparia is found in the London clay. It therefore extends beyond the bounds of the Mesozoic epoch into the older Tertiary. But when this genus is compared with the existing *Homarus* and *Nephrops*, it is found partly to resemble the one and partly the other. Thus, on one line, the actual series of forms which have succeeded one another from the Liassic epoch to the present day, is such as must have existed if the common lobster and the Norway lobster are the descendants of *Erymoid* crustaceans which inhabited the seas of the Liassic epoch.

Side by side with *Eryma*, in the lithographic slates, there is a genus, *Pseudastacus* (fig. 80, A), which, as its name implies, has an extraordinarily close resemblance to the crayfishes of the present day. Indeed there is no point of any importance in which (in the absence of any knowledge of the abdominal appendages in the males) it differs from them. On the other hand, in some features, as in the structure of the carapace, it differs from *Eryma*, much as the existing crayfishes differ from *Nephrops*. Thus, in the latter part of the Jurassic epoch, the Astacine type

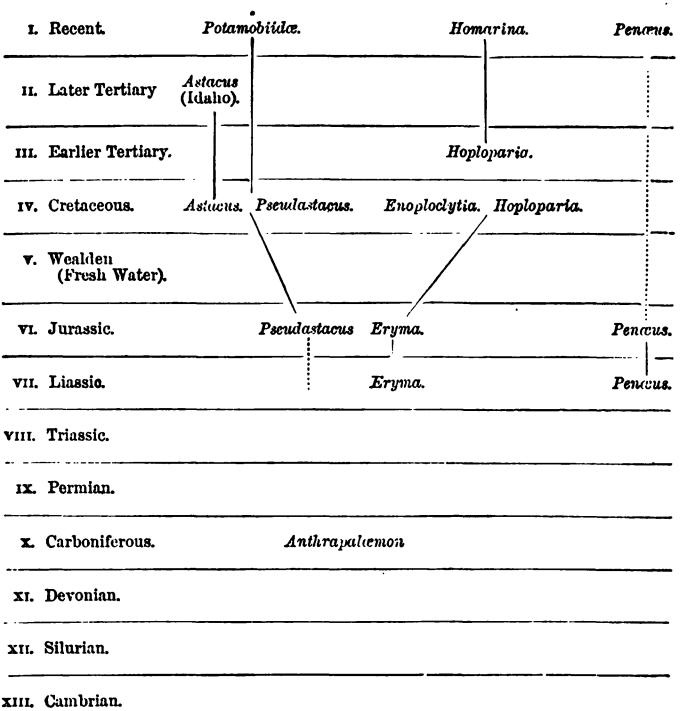
was already distinct from the Homarine type, though both were marine; and, since *Eryma* begins at least as early as the Middle Lias, it is possible that *Pseudastacus* goes back as far, and that the common protastacine form is to be sought in the Trias. *Pseudastacus* is found in the marine cretaceous rocks of the Lebanon, but has not yet been traced into the Tertiary formations.

I am disposed to think that *Pseudastacus* is comparable to such a form as *Astacus nigrescens* rather than to any of the *Parastacidæ*, as I doubt the existence of the latter group at any time in northern latitudes.

In the chalk of Westphalia (also a marine deposit) a single specimen of another Astacomorph has been discovered, which possesses an especial interest as it is a true *Astacus* (*A. politus*, Von der Marck and Schlüter), provided with the characteristic transversely divided telson which is found in the majority of the *Potamobiidæ*.

If we arrange the results of palæontological inquiry which have now been stated in the form of a table such as that which is given on the following page, the significance of the succession of astacomorphous forms, in time, becomes apparent.

SUCCESSIVE FORMS OF THE ASTACOMORPHOUS TYPE.



If an Astacomorphous crustacean, having characters intermediate between those of *Eryma* and those of *Pseudastacus*, existed in the Triassic epoch or earlier; if it gradually diverged into Pseudastacine and Erymoid forms; if these again took on Astacine and Homarine

characters, and finally ended in the existing *Potamobiidæ* and *Homarina*, the fossil forms left in the track of this process of evolution would be very much what they actually are. Up to the end of the Mesozoic epoch the only known *Potamobiidæ* are marine animals. And we have already seen that the facts of distribution suggest the hypothesis that they must have been so, at least up to this time.

Thus, with respect to the Ætiology of the crayfishes, all the known facts are in harmony with the requirements of the hypothesis that they have been gradually evolved in the course of the Mesozoic and subsequent epochs of the world's history from a primitive Astacomorphous form.

And it is well to reflect that the only alternative supposition is, that these numerous successive and coexistent forms of insignificant animals, the differences of which require careful study for their discrimination, have been separately and independently fabricated, and put into the localities in which we find them. By whatever verbal fog the question at issue may be hidden, this is the real nature of the dilemma presented to us not only by the crayfish, but by every animal and by every plant; from man to the humblest animalcule; from the spreading beech and towering pine to the *Micrococci* which lie at the limit of microscopic visibility.

NOTES.

NOTE 1., CHAPTER I., p. 17.

THE CHEMICAL COMPOSITION OF THE EXOSKELETON.

THE harder parts of the exoskeleton of the crayfish contain rather more than half their weight of calcareous salts. Of these nearly seven-eighths consist of carbonate of lime, the rest being phosphate of lime.

The animal matter consists for the most part of a peculiar substance termed *Chitin*, which enters into the composition of the hard parts not only of the *Arthropoda* in general but of many other invertebrated animals. Chitin is not dissolved even by hot caustic alkalies, whence the use of solutions of caustic potash and soda in cleaning the skeletons of crayfishes. It is soluble in cold concentrated hydrochloric acid without change, and may be precipitated from its solution by the addition of water.

Chitin contains nitrogen, and according to the latest investigations (Ledderhose, "Ueber Chitin und seine Spaltungs-produkte:" Zeitschrift für Physiologische Chemie, II. 1879) its composition is represented by the formula $C_{15}\ H_{26}\ N_2\ O_{10}$.

NOTE II., CHAPTER I., p. 29.

THE CRAB'S EYES, OR GASTROLITHS.

The "Gastroliths," as the "crab's eyes" may be termed, are found fully developed only in the latter part of the summer season, just before ecdysis sets in. They then give rise to rounded prominences, one on

each side of the anterior part of the cardiac division of the stomach. The proper wall of the stomach is continued over the outer surface of the prominence ; and, in fact, forms the outer wall of the chamber in which the gastrolith is contained, the inner wall being formed by the cuticular lining of the stomach. When the outer wall is cut through, it is readily detached from the convex outer surface of the gastrolith, with which it is in close contact. The inner surface of the gastrolith is usually flat or slightly concave. Sometimes it is strongly adherent to the chitonous cuticula ; but when fully formed it is readily detached from the latter. Thus the proper wall of the stomach invests only the outer face of the gastrolith, the inner face of which is adherent to, or at any rate in close contact with, the cuticula. The gastrolith is by no means a mere concretion, but is a cuticular growth, having a definite structure. Its inner surface is smooth, but the outer surface is rough, from the projection of irregular ridges which form a kind of meshwork. A vertical section shows that it is composed of thin superimposed layers, of which the inner are parallel with the flat inner surface, while the outer becomes gradually concentric with the outer surface. Moreover, the inner layers are less calcified than the outer, the projections of the outer surface being particularly dense and hard. In fact, the gastroliths are very similar to other hard parts of the exoskeleton in structure, except that the densest layers are nearest the epithelial substratum, instead of furthest away from it.

When ecdysis occurs, the gastroliths are cast off along with the gastric armature in general, into the cavity of the stomach, and are there dissolved, a new cuticle being formed external to them from the proper wall of the stomach. The dissolved calcareous matter is probably used up in the formation of the new exoskeleton.

According to the observations of M. Chantran (Comptes Rendus, LXXVIII. 1874) the gastroliths begin to be formed about forty days before ecdysis takes place in crayfish of four years' old ; but the interval is less in younger crayfish, and is not more than ten days during the first year after birth. When shed into the stomach during ecdysis they are ground down, not merely dissolved. The process of destruction and absorption takes twenty-four to thirty hours in very young crayfish, seventy to eighty hours in adults. Unless the gastroliths are normally developed and re-absorbed, ecdysis is not healthily effected, and the crayfish dies in the course of the process.

According to Dulk ("Chemische Untersuchung der Krebsteine:" Müller's Archiv. 1835), the gastroliths have the following composition :—

Animal matter soluble in water	11·43
Animal matter insoluble in water (probably chitin)	4·33
Phosphate of lime	18·60
Carbonate of lime	63·16
Soda reckoned as carbonate	1·41
	98·93

The proportion of mineral to animal matter and of phosphate to carbonate of lime is therefore greater in the gastroliths than in the exoskeleton in general.

NOTE III., CHAPTER I., p. 31.

GROWTH OF CRAYFISH.

The statements in the text, after the words "By the end of the year," regarding the sizes of the crayfish at different ages, are given on the authority of M. Carbonnier (L'Écrevisse. Paris, 1869); but they obviously apply only to the large "Écrevisse à pieds rouges" of France, and not to the English crayfish, which appears to be identical with the "Écrevisse à pieds blancs," and is of much smaller size. According to M. Carbonnier (l. c. p. 51), the young crayfish just born is "un centimètre et demi environ," that is to say, three-fifths of an inch long. The young of the English crayfish still attached to the mother, which I have seen, rarely exceeds half this length.

M. Soubeiran ("Sur l'histoire naturelle et l'education des Écrevisses:" Comptes Rendus, LX. 1865) gives the result of his study of the growth of the crayfishes reared at Clairefontaine, near Rambouillet, in the following table :

	Mean length. Metres.	Mean weight. Grammes.
Crayfish of the year	0·025	0·50
„ 1 year old	0·050	1·50
„ 2 years old	0·070	3·50
„ 3 years „	0·090	6·50
„ 4 years „	0·110	17·50
„ 5 years „	0·125	18·50
„ indeterminate	0·160	30·00
„ very old	0·190	125·00

These observations must also apply to the "Écrevisse à pieds rouges."

Note IV., Chapter I, p. 37.

THE ECDYSES OF CRAYFISHES.

There is a good deal of discrepancy between different observers as to the frequency of the process of ecdysis in crayfishes. In the text I have followed M. Carbonnier, but M. Chantran ("Observations sur l'histoire naturelle des Écrevisses:" Comptes Rendus, LXXI. 1870, and LXXIII. 1871), who appears to have studied the question (on the "écrevisse à pieds rouges" apparently) very carefully, declares that the young crayfish moults no fewer than eight times in the course of the first twelve months. The first moult takes place ten days after it is hatched; the second, third, fourth, and fifth, at intervals of from twenty to twenty-five days, so that the young animal moults five times in the course of the ninety to one hundred days of July, August, and September. From the latter month to the end of April in the following year, no ecdysis takes place. The sixth takes place in May, the seventh in June, and the eighth in July. In the second year of its age, the crayfish moults five times, that is to say, in August and in September, and in May, June, and July following. In the third year, the crayfish commonly moults only twice, namely in July and in September. At a greater age than this, the females moult only once a year, from August to September; while the males moult twice, first in June and July; afterwards in August and September.

The details of the process of ecdysis are discussed by Braun, "Ueber die histologischen Vorgänge bei der Häutung von *Astacus fluviatilis*." Würzburg Arbeiten, Bd. II.

Note V., Chapter I., p. 39.

REPRODUCTION IN CRAYFISHES.

The males are said to approach the females in November, December, and January, in the case of the French crayfishes. In England they certainly begin as early as the beginning of October, if not earlier. According to M. Chantran (Comptes Rendus, 1870), and M. Gerbe (Comptes Rendus, 1858), the male seizes the female with his pincers, throws her on her back, and deposits the spermatic matter, firstly, on the external plates of the caudal fin; secondly, on the thoracic sterna around the external openings of the oviducts. During this operation, the appendages of the two first abdominal somites are carried backwards,

the extremities of the posterior pair are inclosed in the groove of the anterior pair; and the end of the vas deferens becoming everted and prominent, the seminal matter is poured out, and runs slowly along the groove of the anterior appendage to its destination, where it hardens and assumes a vermicular aspect. The filaments of which it is composed are, in fact, tubular spermatophores, and consist of a tough case or sheath filled with seminal matter. The spoon-shaped extremity of the second abdominal appendage, working backwards and forwards in the groove of the anterior appendage, clears the seminal matter out of it, and prevents it from becoming choked.

After an interval which varies from ten to forty-five days, oviposition takes place. The female, resting on her back, bends the end of the abdomen forward over the hinder thoracic sterna, so that a chamber is formed into which the oviducts open. The eggs are passed into the chamber by one operation, usually during the night, and are plunged into a viscous greyish mucus with which it is filled. The spermatozoa pass out of the vermicular spermatophores, and mix with this fluid, in which the peculiarity of their form renders them readily recognisable. The spermatozoa are thus brought into close relation with the ova, but what actually becomes of them is unknown.

The origin of the viscous matter which fills the abdominal chamber when the eggs are deposited in it, and the manner in which these become fixed to the abdominal limbs is discussed by Lereboullet ("Recherches sur le mode de fixation des œufs aux faux pattes abdominaux dans les Écrevisses." Annales des Sciences Naturelles, 4e Ee. T. XIV. 1860), and by Braun (Arbeiten aus dem Zoologisch-Zootomischen Institut in Würzburg, II.).

NOTE VI., CHAPTER I., p. 42.

ATTACHMENT OF THE YOUNG CRAYFISH TO THE MOTHER.

I observe that I had overlooked a passage in the Report on the award of the Prix Montyon for 1872, Comptes Rendus, LXXV. p. 1341, in which M. Chantran is stated to have ascertained that the young crayfishes fix themselves "en saisissant avec un de leurs pinces le filament qui suspend l'œuf à une fausse patte de la mère."

In the paper already cited from the Comptes Rendus for 1870, M. Chantran states that the young remain attached to the mother during ten days after hatching, that is to say, up to the first moult. Detached before this period, they die; but after the first moult, they sometimes leave the

mother and return to her again, up to twenty-eight days, when they become independent.

In a note appended to M. Chantran's paper, M. Robin states, that "the young are suspended to the abdomen of the mother by the intermediation of a chitinous hyaline filament, which extends from a point of the internal surface of the shell of the egg as far as the four most internal filaments of each of the lobes of the median membranous plate of the caudal appendage. The filaments exist when the embryos have not yet attained three-fourths of their development." Is this a larval coat? Rathke does not mention it and I have seen nothing of it in those recently hatched young which I have had the opportunity of examining.

NOTE VII., CHAPTER II., p. 64.

THE "SALIVARY" GLANDS AND THE SO-CALLED "LIVER" OF THE CRAYFISH.

Braun (Arbeiten aus dem Zoologisch-Zootomischen Institut in Würzburg, Bd. II. and III.) has described "salivary" glands in the walls of the œsophagus, in the metastoma, and in the first pair of maxillæ of the crayfish.

Hoppe-Seyler (Pflügers Archiv, Bd. XIV. 1877) finds that the yellow fluid ordinarily found in the stomachs of crayfishes always contains peptone. It dissolves fibrin readily, without swelling it up, at ordinary temperatures; more quickly at 40° Centigrade. The action is delayed by even a trace of hydrochloric acid, and is stopped by the addition of a few drops of water containing 0.2 per cent. of that acid. By adding alcohol to the yellow fluid, a precipitate is obtained, which is soluble in water and in glycerine. The aqueous solution of the precipitate has a strong digestive action on fibrin, which is arrested by acidulation with hydrochloric acid. These reactions show that the fluid is very similar to, if not identical with, the pancreatic fluid of vertebrates.

The secretion of the "liver" taken directly from that gland, has a more strongly acid reaction than the fluid in the stomach, but has similar digestive properties. So has an aqueous extract of the gland, and a watery solution of the alcoholic precipitate. The aqueous extract also possesses a strong diastatic action on starch, and breaks up olive oil. There is no more glycogen in the "liver" than is to be found in other organs, and no constituents of true bile are to be met with.

NOTE VIII., CHAPTER II., p. 81.

ANAL RESPIRATION IN CRAYFISH.

Lereboullet ("Note sur une respiration anale observée chez plusieurs Crustacés;" Mémoires de la Société d'Histoire Naturelle de Strasbourg, IV. 1850) has drawn attention to what he terms "anal respiration" in young crayfish, in which he observed water to be alternately taken into and expelled from the rectum fifteen to seventeen times in a minute. I have never been able to observe anything of this kind in the uninjured adult animal, but if the thoracic ganglia are destroyed, a regular rhythmical dilatation and closing of the anal end of the rectum at once sets in, and goes on as long as the hindermost ganglia of the abdomen retain their integrity. I am much disposed to imagine that the rhythmical movement is inhibited, when the uninjured crayfish is held in such a position that the vent can be examined.

NOTE IX. CHAPTER II., p. 82.

THE GREEN GLAND.

The existence of guanin in the green gland rests on the authority of Will and Gorup-Besanez (Gelehrte Anzeigen, d. k. Baienzschen Akademie, No. 233, 1848), who say that in this organ and in the organ of Bojanus of the freshwater mussel, they found "a substance the reactions of which with the greatest probability indicate guanin," but that they had been unable to obtain sufficient material to give decisive results.

Leydig (Lehrbuch der Histologie, p. 467) long ago stated that the green gland consists of a much convoluted tube containing granular cells disposed around a central cavity. Wassiliew ("Ueber die Niere des Flusskrebses:" Zoologischer Anzeiger, I. 1878) supports the same view, giving a full account of the minute structure of the organ, and comparing it with its homologues in the *Copepoda* and *Phyllopoda*.

NOTE X., CHAPTER III., p. 105.

THE ANATOMY OF THE NERVOUS SYSTEM OF THE CRAYFISH.

The details respecting the origin and the distribution of the nerves are intentionally omitted. See the memoir by Lemoine of which the title is given in the "Bibliography."

NOTE XI., CHAPTER III., p. 110.

THE FUNCTIONS OF THE NERVOUS SYSTEM OF THE CRAYFISH.

Mr. J. Ward, in his "Observations on the Physiology of the Nervous System of the Crayfish," (Proceedings of the Royal Society, 1879) has given an account of a number of interesting and important experiments on this subject.

NOTE XII., CHAPTER III. p. 124.

THE THEORY OF MOSAIC VISION.

Oscar Schmidt ("Die Form der Krystalkegel im Arthropoden Auge:" Zeitschrift für Wissenschaftliche Zoologie, XXX. 1878) has pointed out certain difficulties in the way of the universal application of the theory of mosaic vision in its present form, which are well worthy of consideration. I do not think, however, that the substance of the theory is affected by Schmidt's objections.

NOTE XIII., CHAPTER III., p. 135.

THE SPERMATOZOA.

Since the discovery of the spermatozoa of the crayfish in 1835-36 by Henle and von Siebold, the structure and development of these bodies have been repeatedly studied. The latest discussion of the subject is contained in a memoir of Dr. C. Grobben ("Beiträge zur Kenntniss der männlichen Geschlechtsorgane der Dekapoden:" Wien, 1878). There is no doubt that the spermatozoon consists of a flattened or hemispherical body, produced at its circumference into a greater or less number of long tapering curved processes (fig. 34 F). In the interior of this are two structures, one of which occupies the greater part of the body, and, when the latter lies flat, looks like a double ring. This may be called, for distinctness' sake, the *annulate corpuscle*. The other is a much smaller *oval corpuscle*, which lies on one side of the first. The annulate corpuscle is dense, and strongly refracting; the oval corpuscle is soft, and less sharply defined. Dr. Grobben describes the annulate corpuscle as "napfartig," or cup-shaped; closed below, open above, and with the upper edge turned inwards, and applied to the inner side of the wall of the cup. It appeared to me, on the other hand, that the annulate corpuscle is really a hollow ring, somewhat

like one of the ring-shaped air-cushions one sees, on a very small scale. Dr. Grobben describes the spermatoblastic cells of the testis and their nuclear spindles; but his account of the development of the spermatozoa does not agree with my own observations, which, so far as they have gone, lead me to infer that the annulate corpuscle of the spermatozoon is the metamorphosed nucleus of the cell from which the spermatozoon is developed. For want of material, however, I was unable to bring my investigations to a satisfactory termination, and I speak with reserve.

NOTE XIV., CHAPTER IV., p. 174.

THE MORPHOLOGY OF THE CRAYFISH.

The founder of the morphology of the *Crustacea*, M. Milne Edwards, counts the telson as a somite, and consequently considers that twenty-one somites enter into the composition of the body in the *Podophthalmia*. Moreover, he assigns the anterior seven somites to the head, the middle seven to the thorax, and the hinder seven to the abdomen. There is a tempting aspect of symmetry about this arrangement; but as to the limits of the head, the natural line of demarcation between it and the thorax seems to me to be so clearly indicated between the somite which bears the second maxillæ and that which carries the first maxillipedes in the *Crustacea*, and between the homologous somites in Insects, that I have no hesitation in retaining the grouping which I have for many years adopted. The exact nature of the telson needs to be elucidated, but I can find no ground for regarding it as the homologue of a single somite.

It will be observed that these differences of opinion turn upon questions of grouping and nomenclature. It would make no difference to the general argument if it were admitted that the whole body consists of twenty-one somites and the head of seven.

NOTE XV., CHAPTER IV., p. 199.

THE HISTOLOGY OF THE CRAYFISH.

In dealing with the histology of the crayfish I have been obliged to content myself with stating the facts as they appear to me. The discussion of the interpretations put upon these facts by other observers, especially in the case of those tissues, such as muscle, on which there is as yet no complete agreement even as to matters of observation, would require a whole treatise to itself.

NOTE XVI., CHAPTER IV., p. 221.

THE DEVELOPMENT OF THE CRAYFISH.

The remark made in the last note applies still more strongly to the history of the development of the crayfish. Notwithstanding the masterly memoir of Rathke, which constitutes the foundation of all our knowledge on this subject; the subsequent investigations of Lereboullet; and the still more recent careful and exhaustive works of Reichenbach and Bobretsky, a great many points require further investigation. In all its most important features I have reason to believe that the account of the process of development given in the text, is correct.

NOTE XVII., CHAPTER VI., p. 297.

PARASITES OF CRAYFISHES.

In France and Germany crayfishes (apparently, however, only *A. nobilis*) are infested by parasites, belonging to the genus *Branchiobdella*. These are minute, flattened, vermiform animals, somewhat like small leeches, from one-half to one-third of an inch in length, which attach themselves to the under side of the abdomen (*B. parasitica*), or to the gills (*B. astaci*), and live on the blood and on the eggs of the crayfish. A full account of this parasite, with reference to the literature of the subject, is given by Dormer ("Ueber die Gattung Branchiobdella:" Zeitschrift für Wiss. Zoologie, XV. 1865). According to Gay, a similar parasite is found on the Chilian crayfish. I have never met with it on the English crayfish. The Lobster has a somewhat similar parasite, *Histriobdella*. Girard, in the paper cited in the Bibliography, gives a curious account of the manner in which the little lamellibranchiate mollusk, *Cyclas fontinalis*, shuts the ends of the ambulatory limbs of crayfishes which inhabit the same waters, between its valves, so that the crayfish resembles a cat in walnut shells, and the pinched ends of the limbs become eroded and mutilated.

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B.

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