distinguish these seventeen-gilled crayfishes, as a whole, from the eighteen-gilled species; and this is effected by changing the generic name. They are no longer called *Astacus*, but *Cambarus* (fig. 63).

All the individual crayfish referred to thus far, therefore, have been sorted out, first into the groups termed *species;* and then these species have been further sorted into two divisions, termed *genera.* Each genus is an abstraction, formed by summing up the common characters of the species which it includes, just as each species is an abstraction, composed of the common characters of the individuals which belong to it; and the one has no more existence in nature than the other. The definition of the genus is simply a statement of the plan of structure which is common to all the species included under that genus; just as the definition of the species is a statement of the common plan of structure which runs throughout the individuals which compose the species.

Again, crayfishes are found in the fresh waters of the Southern hemisphere; and almost the whole of what has been said respecting the structure of the English crayfish applies to these; in other words, their general plan is the same. But, in these southern crayfishes, the podobranchiæ have no distinct lamina, and the first somite of the abdomen is devoid of appendages in both sexes. The southern crayfishes, like those of the Northern hemisphere, are divisible into many species; and these species

are susceptible of being grouped into six genera—*Astacoides* (fig. 65), *Astacopsis*, *Chæraps*, *Parastacus* (fig. 64),

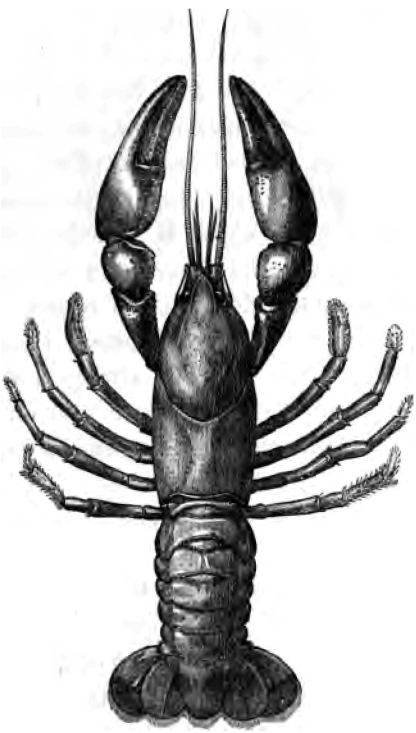

FIG. 64.—*Parastacus brasiliensis* (½ nat. size). From southern Brazil.

Engæus, and *Paranephrops*—on the same principle as that which has led to the grouping of the Northern forms into two genera. But the same convenience which has

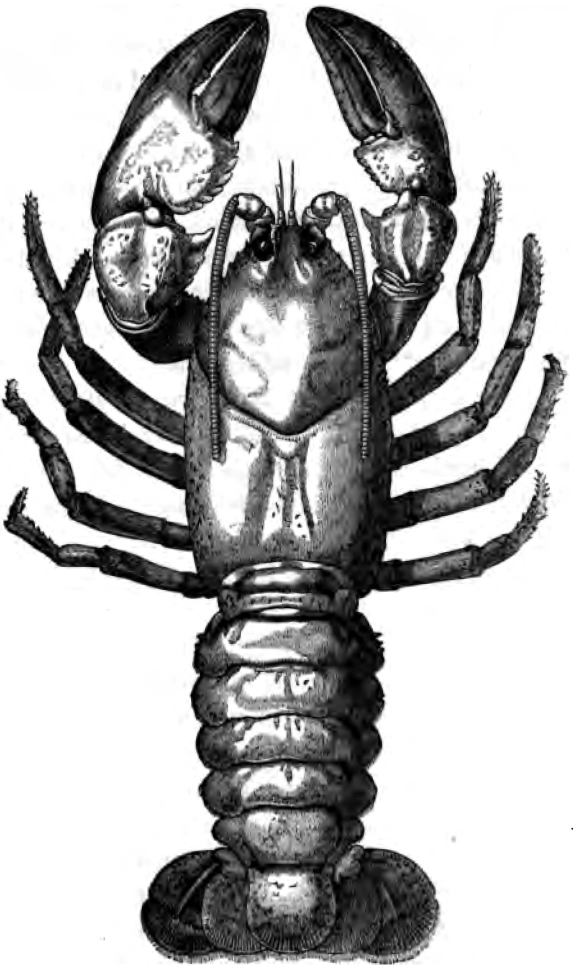

FIG. 65.—*Astacoides madagascarensis* (⅓ nat. size). From Madagascar.

led to the association of groups of similar species into genera, has given rise to the combination of allied genera into higher groups, which are termed *Families*. It is obvious that the definition of a family, as a statement of the characters in which a certain number of genera agree, is another morphological abstraction, which stands in the same relation to generic, as generic do to specific abstractions. Moreover, the definition of the family is a statement of the plan of all the genera comprised in that family.

The family of the Northern crayfishes is termed *Potamobiidæ;* that of the Southern crayfishes, *Parastacidæ*. But these two families have in common all those structural characters which are special to neither; and, carrying out the metaphorical nomenclature of the zoologist a stage further, we may say that the two form a *Tribe*—the definition of which describes the plan which is common to both families.

It may conduce to intelligibility if these results are put into a graphic form. In fig. 66, A. is a diagram representing the plan of an animal in which all the externally visible parts which are found, more or less modified, in the natural objects which we call individual crayfishes are roughly sketched. It represents the plan of the tribe. B. is a diagram exhibiting such a modification of A. as converts it into the plan common to the whole family of the *Parastacidæ*. C. stands in the same relation to the *Potamobiidæ*. If the scheme were thoroughly worked out, diagrams representing the peculiarities of

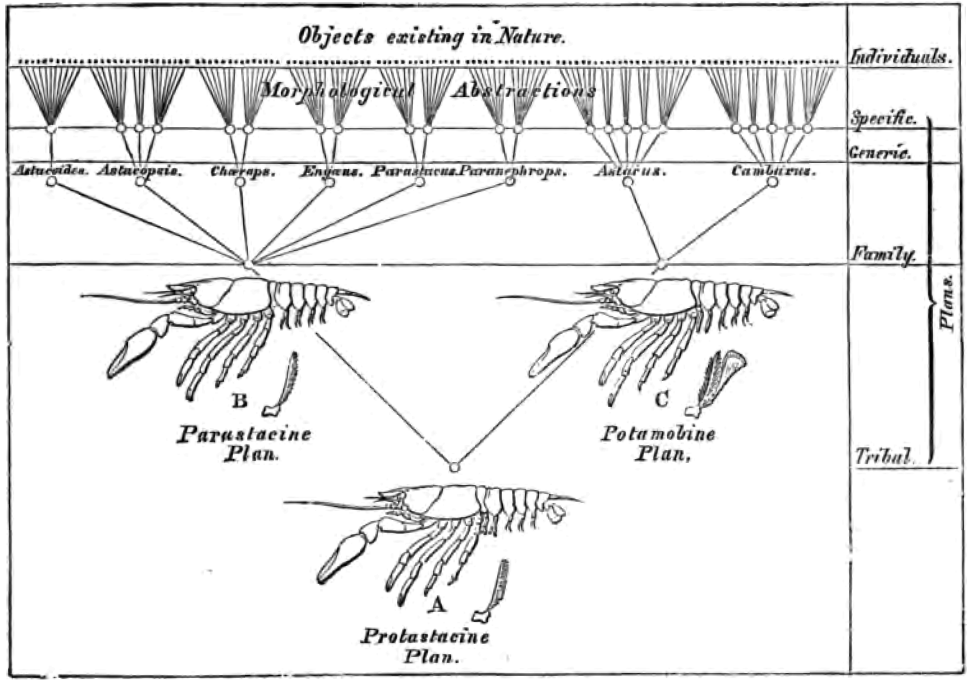

FIG. 66.—Diagram of the morphological relations of the Astacina.

form which characterize each of the genera and species, would appear in the place of the names of the former, or of the circles which represent the latter. All these figures would represent abstractions — mental images which have no existence outside the mind. Actual facts would begin with drawings of individual animals, which we may suppose to occupy the place of the dots above the upper line in the diagram.

That all crayfishes may be regarded as modifications of the common plan A, is not an hypothesis, but a generalization obtained by comparing together the observations made upon the structure of individual crayfishes. It is simply a graphic method of representing the facts which are commonly stated in the form of a definition of the tribe of crayfishes, or *Astacina*.

This definition runs as follows:—

Multicellular animals provided with an alimentary canal and with a chitinous cuticular exoskeleton; with a ganglionated central nervous system traversed by the œsophagus; possessing a heart and branchial respiratory organs.

The body is bilaterally symmetrical, and consists of twenty metameres (or somites and their appendages), of which six are associated into a head, eight into a thorax, and six into an abdomen. A telson is attached to the last abdominal somite.

The somites of the abdominal region are all free, those of the head and thorax, except the hindermost, which is

partially free, are united into a cephalothorax, the tergal wall of which has the form of a continuous carapace. The carapace is produced in front into a rostrum, at the sides into branchiostegites.

The eyes are placed at the ends of movable stalks. The antennules are terminated by two filaments. The exopodite of the antenna has the form of a mobile scale. The mandible has a palp. The first and second maxillæ are foliaceous; the second being provided with a large scaphognathite. There are three pairs of maxillipedes, and the endopodites of the third pair are narrow and elongated. The next pair of thoracic appendages is much larger than the rest, and is chelate, as are the two following pairs, which are slender ambulatory limbs. The hindmost two pairs of thoracic appendages are ambulatory limbs, like the foregoing, but not chelate. The abdominal appendages are small swimmerets, except the sixth pair, which are very large, and have the exopodite divided by a transverse joint.

All the crayfishes have a complex gastric armature. The seven anterior thoracic limbs are provided with podobranchiæ, but the first of these is always more or less completely reduced to an epipodite. More or fewer arthrobranchiæ always exist. Pleurobranchiæ may be present or absent.

In this tribe of *Astacina* there are two families, the *Potamobiidæ* and the *Parastacidæ;* and the definition of each of these families is formed by superadding to the

definition of the tribe the statement of the special peculiarities of the family.

Thus, the *Potamobiidæ* are those *Astacina* in which the podobranchiæ of the second, fourth, fifth, and sixth thoracic appendages are always provided with a plaited lamina, and that of the first is an epipodite devoid of branchial filaments. The first abdominal somite invariably bears appendages in the males, and usually in both sexes. In the males these appendages are styliform, and those of the second somite are always peculiarly modified. The appendages of the four following somites are relatively small. The telson is very generally divided by a transverse incomplete hinge. None of the branchial filaments are terminated by hooks; nor are any of the coxopoditic setæ, or the longer setæ of the podobranchiæ hooked, though hooked tubercles occur on the stem and on the laminæ of the latter. The coxopoditic setæ are always long and tortuous.

In the *Parastacidæ*, on the other hand, the podobranchiæ are devoid of more than a rudiment of a lamina, though the stem may be alate. The podobranchia of the first maxillipede has the form of an epipodite; but, in almost all cases, it bears a certain number of well developed branchial filaments. The first abdominal somite possesses no appendages in either sex: and the appendages of the four following somites are large. The telson is never divided by a transverse hinge. More or fewer of the branchial filaments of the podo-

branchiæ are terminated by short hooked spines; and the coxopoditic setæ, as well as those which beset the stems of the podobranchiæ, have hooked apices.

The definitions of the genera would in like manner be given by adding the distinctive characters of each genus to the definitions of the family; and those of the species by adding its character to those of the genus. But at present it is unnecessary to pursue this topic further.

There are no other inhabitants of the fresh waters, or of the land, which could be mistaken for crayfishes; but certain marine animals, familiar to every one, are so strikingly similar to them, that one of these was formerly included in the same genus, *Astacus;* while another is very often known as the "Sea-crayfish." These are the "Common Lobster," the "Norway Lobster," and the "Rock Lobster" or "Spiny Lobster."

The common lobster (*Homarus vulgaris*, fig. 67) presents the following distinctive characters. The last thoracic somite is firmly adherent to the rest; the exopodite of the antenna is so small as to appear like a mere movable scale; all the abdominal appendages are well developed in both sexes; and, in the males, the two anterior pairs are somewhat like those of the male *Astacus*, but less modified.

The principal difference from the *Astacina* is exhibited by the gills, of which there are twenty on each side; namely, six podobranchiæ, ten arthrobranchiæ, and four

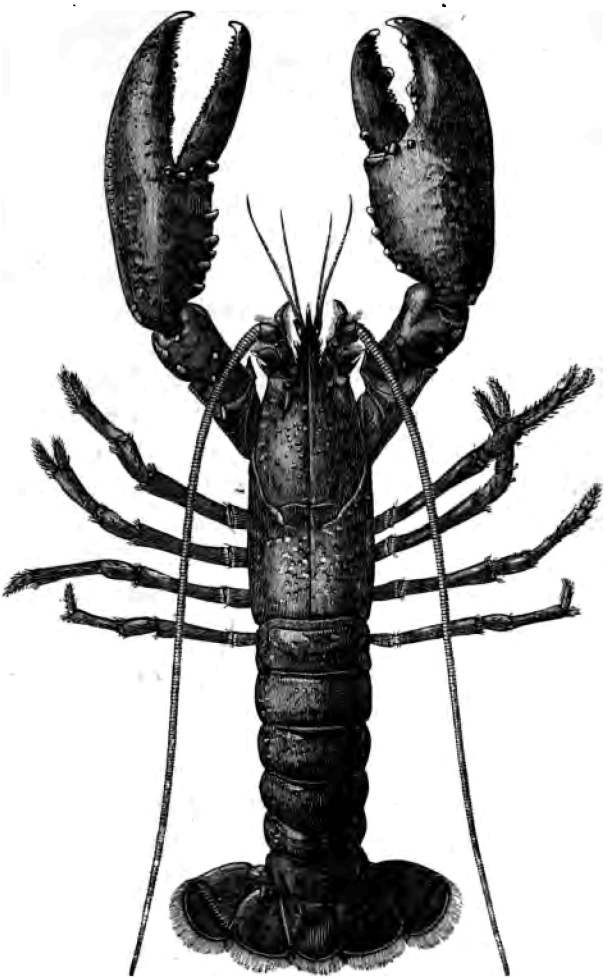

FIG. 67. *Homarus vulgaris* (⅛ nat. size).

fully developed pleurobranchiæ. Moreover, the branchial filaments of these gills are much stiffer and more closely set than in most crayfishes. But the most important distinction is presented by the podobranchiæ, in which the stem is, as it were, completely split into two parts longitudinally (as in fig. 68, B); one half (*ep*)

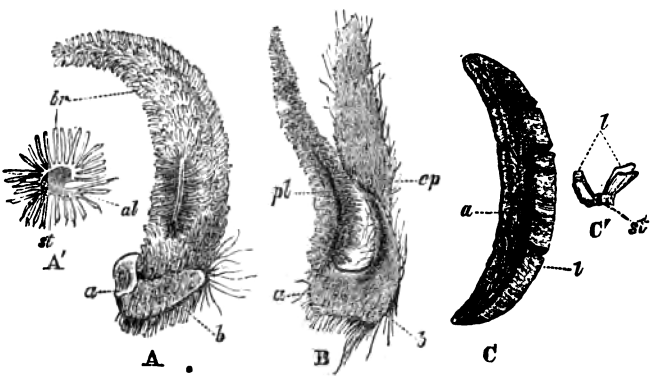

FIG. 68. Podobranchiæ of A, *Paraxtacus*; B, *Nephrops*; C, *Palæmon*. A', C', transverse sections of A and C respectively. *a*, point of attachment; *al*, wing-like expansion of the stem; *b*, base; *br*, branchial filaments; *ep*, epipodite; *l*, branchial laminæ; *pl*, plume; *st*, stem.

corresponding with the lamina of the crayfish gill, and the other (*pl*) with its plume. Hence the base (*b*) of the podobranchia bears the gill in front; while, behind, it is continued into a broad epipoditic plate (*ep*) slightly folded upon itself longitudinally but not plaited, as in the crayfish.

The Norway Lobster (*Nephrops norvegicus*, fig. 69)

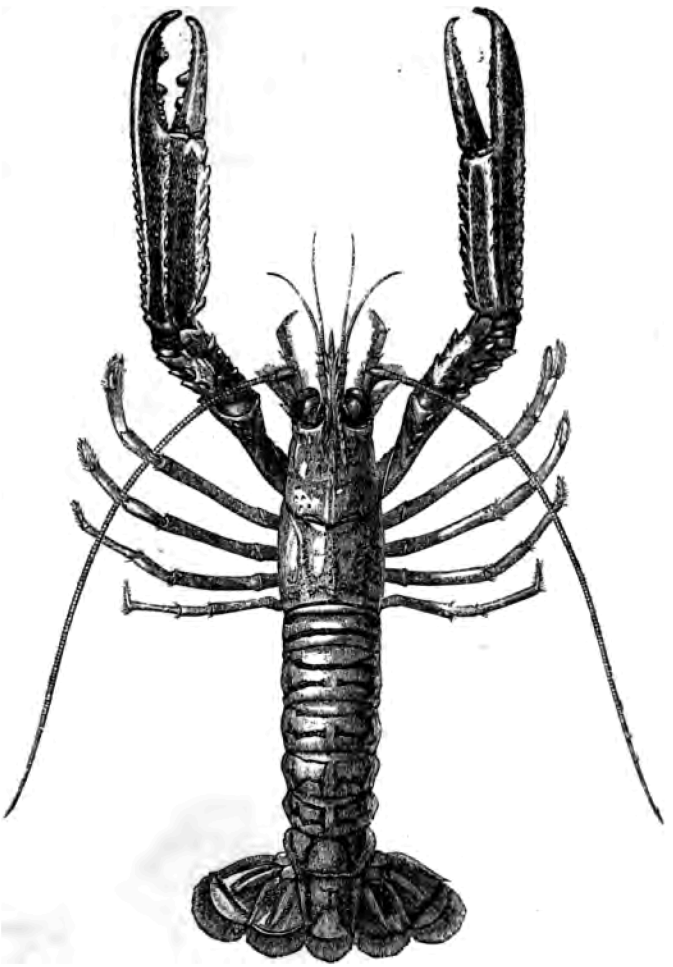

Fig. 69. *Nephrops norvegicus* (½ nat. size).

resembles the lobster in those respects in which the latter differs from the crayfishes: but the antennary squame is large; and, in addition, the branchial plume of the podobranchia of the second maxillipede is very small or absent, so that the total number of functional branchiæ is reduced to nineteen on each side.

These two genera, *Homarus* and *Nephrops*, therefore, represent a family, *Homarina*, constructed upon the same common plan as the crayfishes, but differing so far from the *Astacina* in the structure of the branchiæ and in some other points, that the distinction must be expressed by putting them into a different tribe. It is obvious that the special characteristics of the plan of the *Homarina* give it much more likeness to that of the *Potamobiidæ* than to that of the *Parastacidæ*.

The Rock Lobster (*Palinurus*, fig. 70) differs much more from the crayfishes than either the common lobster or the Norway lobster does. Thus, to refer only to the more important distinctions, the antennæ are enormous; none of the five posterior pairs of thoracic limbs are chelate, and the first pair are not so large in proportion to the rest as in the crayfishes and lobsters. The posterior thoracic sterna are very broad, not comparatively narrow, as in the foregoing genera. There are no appendages to the first somite of the abdomen in either sex. In this respect, it is curious to observe that, in contradistinction from the *Homarina*, the Rock Lobsters are more closely allied to the *Parastacidæ* than to the *Potamobiidæ*.

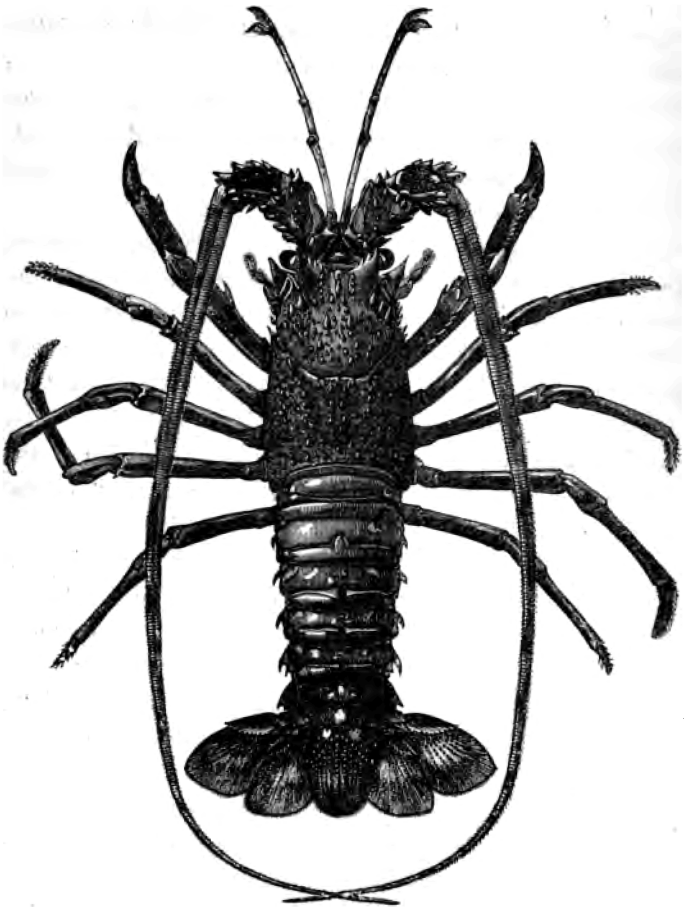

FIG. 70. *Palinurus vulgaris* (about ¼ nat. size).

The gills are similar to those of the lobsters, but reach the number of twenty-one on each side.

. In their fundamental structure the rock lobsters agree with the crayfishes; hence the plans of the two may be regarded as modifications of a plan common to both. To this end, the only considerable changes needful in the tribal plan of the crayfishes, are the substitution of simple for chelate terminations to the middle thoracic limbs and the suppression of the appendages of the first somite of the abdomen.

Thus not only all the crayfishes, but all the lobsters and rock lobsters, different as they are in appearance, size, and habits of life, reveal to the morphologist unmistakable signs of a fundamental unity of organization; each is a comparatively simple variation of the general theme—the common plan.

Even the branchiæ, which vary so much in number in different members of these groups, are constructed upon a uniform principle, and the differences which they present are readily intelligible as the result of various modifications of one and the same primitive arrangement.

In all, the gills are *trichobranchiæ;* that is, each gill is somewhat like a bottle-brush, and presents a stem beset, more or less closely, with many series of branchial filaments. The largest number of complete branchiæ possessed by any of the *Potamobiidæ*, *Parastacidæ*, *Homaridæ*, or *Palinuridæ*, is twenty-one on each side;

and when this number is present, the total is made up of the same numbers of podobranchiæ, arthrobranchiæ, and pleurobranchiæ attached to corresponding somites. In *Palinurus* and in the genus *Astacopsis* (which is one of the *Parastacidæ*), for example, there are six podobranchiæ attached to the thoracic limbs from the second to the seventh inclusively; five pairs of arthrobranchiæ are attached to the interarticular membranes of the thoracic limbs from the third to the seventh inclusively, and one to that of the second, making eleven in all; while four pleurobranchiæ are fixed to the epimera of the four hindmost thoracic somites. Moreover, in *Astacopsis*, the epipodite of the first thoracic appendage (the first maxillipede) bears branchial filaments, and is a sort of reduced gill.

These facts may be stated in a tabular form as follows:—

The branchial formula of Astacopsis.

Somites and their Appendages.	Podobranchiæ.	Arthrobranchiæ. Anterior.	Arthrobranchiæ. Posterior.	Pleurobranchiæ.	
VII. ...	0 (ep. r.)	0	0	0	= 0 (cp. r.)
VIII. ...	1	1	0	0	= 2
IX. ...	1	1	1	0	= 3
X. ...	1	1	1	0	= 3
XI. ...	1	1	1	1	= 4
XII. ...	1	1	1	1	= 4
XIII. ...	1	1	1	1	= 4
XIV. ...	0	0	0	1	= 1
	6 + cp. r.	+ 6	+ 5	+ 4	= 21 + cp. r.

This tabular "branchial formula" exhibits at a glance not only the total number of branchiæ, but that of each kind of branchia; and that of all kinds connected with each somite; and it further indicates that the podobranchia of the first thoracic somite has become so far modified, that it is represented only by an epipodite, with branchial filaments scattered upon its surface.

In *Palinurus*, these branchial filaments are absent and the branchial formula therefore becomes—

Somites and their Appendages.	Podobranchiæ.	Arthrobranchiæ. Anterior.	Arthrobranchiæ. Posterior.	Pleurobranchiæ.	
VII. ...	0 (ep.)	0	0	0	= 0 (ep.)
VIII. ...	1	1	0	0	= 2
IX. ...	1	1	1	0	= 3
X. ...	1	1	1	0	= 3
XI. ...	1	1	1	1	= 4
XII. ...	1	1	1	1	= 4
XIII. ...	1	1	1	1	= 4
XIV. ...	0	0	0	1	= 1
	6 + ep. +	6 +	5 +	4	= 21 + ep.

In the lobster, the solitary arthrobranchia of the eighth somite disappears, and the branchiæ are reduced to twenty on each side.

In *Astacus*, this branchia remains; but, in the English crayfish, the most anterior of the pleurobranchiæ has vanished, and mere rudiments of the two next remain. It has been mentioned that other *Astaci* present a rudiment of the first pleurobranchia.

The branchial formula of Astacus.

Somites and their Appendages.	Podo-branchiæ.	Arthrobranchiæ. Anterior.	Arthrobranchiæ. Posterior.	Pleuro-branchiæ.	
VII. ...	0 (ep.) ...	0 ...	0 ...	0	= 0 (ep.)
VIII. ...	1 ...	1 ...	0 ...	0	= 2
IX. ...	1 ...	1 ...	1 ...	0	= 3
X. ...	1 ...	1 ...	1 ...	0	= 3
XI. ...	1 ...	1 ...	1 ...	0 or *r*	= 3 or 3 + *r*
XII. ...	1 ...	1 ...	1 ...	*r*	= 3 + *r*
XIII. ...	1 ...	1 ...	1 ...	*r*	= 3 + *r*
XIV. ...	0 ...	0 ...	0 ...	1	= 1
	6 + ep. + 6	+ 5	+	1 + 2 or 3*r*	= 18 + ep. + 2 or 3 *r*.

In *Cambarus*, the number of the branchiæ is reduced to seventeen by the disappearance of the last pleurobranchia; while, in *Astacoides*, the process of reduction is carried so far, that only twelve complete branchiæ are left, the rest being either represented by mere rudiments, or disappearing altogether.

The branchial formula of Astacoides.

Somites and their Appendages.	Podo-branchiæ.	Arthrobranchiæ. Anterior.	Arthrobranchiæ. Posterior.	Pleuro-branchiæ.	
VII. ...	0 (ep. r.)	0 ...	0 ...	0	= 0 (ep. r.)
VIII. ...	1 ...	*r* ...	0 ...	0	= 1 + *r*
IX. ...	1 ...	1 ...	0 ...	0	= 2
X. ...	1 ...	1 ...	*r* ...	0	= 2 + *r*
XI. ...	1 ...	1 ...	*r* ...	0	= 2 + *r*
XII. ...	1 ...	1 ...	*r* ...	0	= 2 + *r*
XIII. ...	1 ...	1 ...	*r* ...	0	= 2 + *r*
XIV. ...	0 ...	0 ...	0 ...	1	= 1
	6 + *ep.r*	5 + *r* +	0 + 4*r* +	1	= 12 + ep. r. + 5 *r*.

As these formulæ show, those trichobranchiate crustacea, which possess fewer than twenty-one complete branchiæ on each side, commonly present traces of the missing ones, either in the shape of epipodites, as in the case of the podobranchiæ, or of minute rudiments, in the case of the arthrobranchiæ and the pleurobranchiæ.

In the marine, prawn-like, genus *Penæus* (fig. 73, Chap. VI.), the gills are curiously modified trichobranchiæ. The number of functional branchiæ is, as in the lobster, twenty; but the study of their disposition shows that the total is made up in a very different way.

The branchial formula of Penæus.

Somites and their Appendages.	Podo-branchiæ.	Arthrobranchiæ. Anterior.	Arthrobranchiæ. Posterior.	Pleuro-branchiæ.	
VII. ...	0 (ep.) ...	1 ...	0 ...	0 =	1 + ep.
VIII. ...	0 (ep.) ...	1 ...	1 ...	1 =	3 + ep.
IX. ...	0 (ep.) ...	1 ...	1 ...	1 =	3 + ep.
X. ...	0 (ep.) ...	1 ...	1 ...	1 =	3 + ep.
XI. ...	0 (ep.) ...	1 ...	1 ...	1 =	3 + ep.
XII. ...	0 (ep.) ...	1 ...	1 ...	1 =	3 + ep.
XIII. ...	0 ...	1 ...	1 ...	1 =	3
XIV. ...	0 ...	0 ...	0 ...	1 =	1
	0 + 6 ep. +	7 +	6 +	7 =	20 + 6 ep.

This case is very interesting; for it shows that the whole of the podobranchiæ may lose their branchial character, and be reduced to epipodites, as is the case with the first in the crayfish and lobster, and indeed in most of the forms under consideration. And since all but one of the somites bear both arthrobranchiæ and pleurobranchiæ,

the suggestion arises that each hypothetically complete thoracic somite should possess four gills on each side, giving the following

Hypothetically complete branchial formula.

Somites and their Appendages.		Podo-branchiæ.		Arthrobranchiæ. Anterior.		Arthrobranchiæ. Posterior.		Pleuro-branchiæ.		
VII.	...	1	...	1	...	1	...	1	=	4
VIII.	...	1	...	1	...	1	...	1	=	4
IX.	...	1	...	1	...	1	...	1	=	4
X.	...	1	...	1	...	1	...	1	=	4
XI.	...	1	...	1	...	1	...	1	=	4
XII.	...	1	...	1	...	1	...	1	=	4
XIII.	...	1	...	1	...	1	...	1	=	4
XIV.	...	1	...	1	...	1	...	1	=	4
		8	+	8	+	8	+	8	=	32

Starting from this hypothetically complete branchial formula, we may regard all the actual formulæ as produced from it by the more or less complete suppression of the most anterior, or of the most posterior branchiæ, or of both, in each series. In the case of the podobranchiæ, the branchiæ are converted into epipodites; in that of the other branchiæ, they become rudimentary, or disappear.

In general appearance a common prawn (*Palæmon*, fig. 71) is very similar to a miniature lobster or crayfish. Nor does a closer examination fail to reveal a complete fundamental likeness. The number of the somites, and of the appendages, and their general character and dispo-

sition, are in fact the same. But, in the prawn, the abdomen is much larger in proportion to the cephalothorax; the

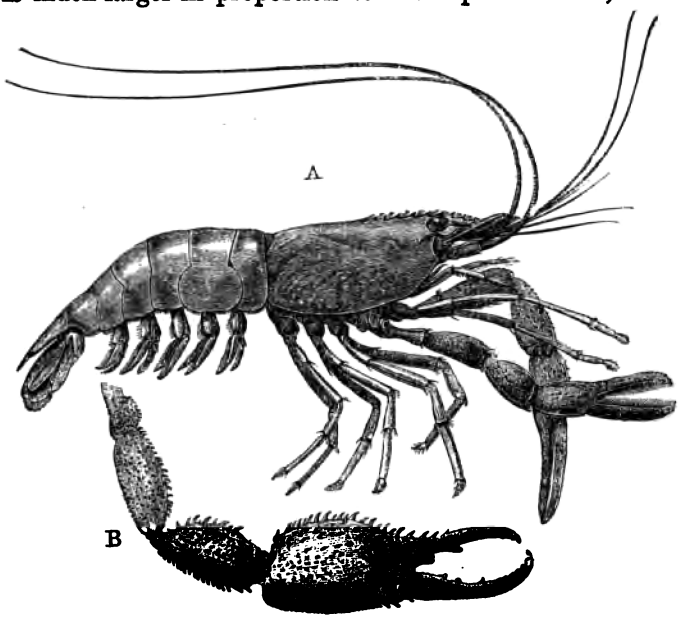

FIG. 71. *Palæmon jamaicensis* (about ½ nat. size). A, female; B, fifth thoracic appendage of male.

basal scale, or expodite of the antenna, is much larger; the external maxillipedes are longer, and differ less from the succeeding thoracic appendages. The first pair of these, which answers to the forceps of the crayfish, is chelate, but it is very slender; the second pair, also chelate, is always larger than the first, and is sometimes exceedingly

long and strong (fig. 71, B); the remaining thoracic limbs are terminated by simple claws. The five anterior abdominal somites are all provided with large swimmerets, which are used like paddles, when the animal swims quietly; and, in the males, the first pair is only slightly different from the rest. The rostrum is very large, and strongly serrated.

None of these differences from the crayfish, however, is so great, as to prepare us for the remarkable change observable in the respiratory organs. The total number of the gills is only eight. Of these, five are large pleurobranchiæ, attached to the epimera of the five hinder thoracic somites; two are arthrobranchiæ, fixed to the interarticular membrane of the external maxillipede; and one, which is the only complete podobranchia, belongs to the second maxillipede. The podobranchiæ of the first and third maxillipedes are represented only by small epipodites. The branchial formula therefore is:—

Somites and their Appendages.	Podobranchiæ.	Arthrobranchiæ. Anterior.	Arthrobranchiæ. Posterior.	Pleurobranchiæ.	
VII. ...	0 (ep.)	0 ...	0 ...	0	= 0 (ep.)
VIII. ...	1 ...	0 ...	0 ...	0	= 1
IX. ...	0 (ep.)	1 ...	1 ...	0	= 2 (ep.)
X. ...	0 ...	0 ...	0 ...	1	= 1
XI. ...	0 ...	0 ...	0 ...	1	= 1
XII. ...	0 ...	0 ...	0 ...	1	= 1
XIII. ...	0 ...	0 ...	0 ...	1	= 1
XIV. ...	0 ...	0 ...	0 ...	1	= 1
	1 + 2 cp.	+ 1	+ 1	+ 5	= 8 + 2 ep.

The prawn, in fact, presents us with an extreme case of that kind of modification of the branchial system, of which *Penæus* has furnished a less complete example. The series of the podobranchiæ is reduced almost to nothing, while the large pleurobranchiæ are the chief organs of respiration.

But this is not the only difference. The prawn's gills are not brush-like, but are foliaceous. They are not *trichobranchiæ*, but *phyllobranchiæ;* that is to say, the central stem of the branchia, instead of being beset with numerous series of slender filaments, bears only two rows of broad flat lamellæ (fig. 68, C, C′, *l*), which are attached to opposite sides of the stem (C′, *s*), and gradually diminish in size from the region of the stem by which it is fixed, upwards and downwards. These lamellæ are superimposed closely upon one another, like the leaves of a book; and the blood traversing the numerous passages by which their substance is excavated, comes into close relation with the currents of aerated water, which are driven between the branchial leaflets by a respiratory mechanism of the same nature as that of the crayfish.

Different as these phyllobranchiæ of the prawns are in appearance from the trichobranchiæ of the preceding *Crustacea*, they are easily reduced to the same type. For in the genus *Axius*, which is closely allied to the lobsters, each branchial stem bears a single series of filaments on its opposite sides; and if these biserial filaments are supposed to widen out into broad leaflets, the transition from

the trichobranchia to the phyllobranchia will be very easily effected.

The shrimp (*Crangon*) also possesses phyllobranchiæ, and differs from the prawn chiefly in the character of its locomotive and prehensile thoracic limbs.

There are yet other very well-known marine animals, which, in common appreciation, are always associated with the lobsters and crayfishes, although the difference of general appearance is vastly greater than in any of the cases which have yet been considered. These are the Crabs.

In all the forms we have hitherto been considering, the abdomen is as long as, or longer than, the cephalothorax, while its width is the same, or but little less. The sixth somite has very large appendages, which, together with the telson, make up a powerful tail-fin; and the large abdomen is thus fitted for playing an important part in locomotion.

Again, the length of the cephalothorax is much greater than its width, and it is produced in front into a long rostrum. The bases of the antennæ are freely movable, and they are provided with a movable exopodite. Moreover, the eye-stalks are not inclosed in a cavity or orbit, and the eyes themselves appear above and in front of the antennules. The external maxillipedes are narrow, and their endopodites are more or less leg-like.

None of these statements apply to the crabs. In these

animals the abdomen is short, flattened, and apt to escape immediate notice, as it is habitually kept closely applied against the under surface of the cephalothorax. It is

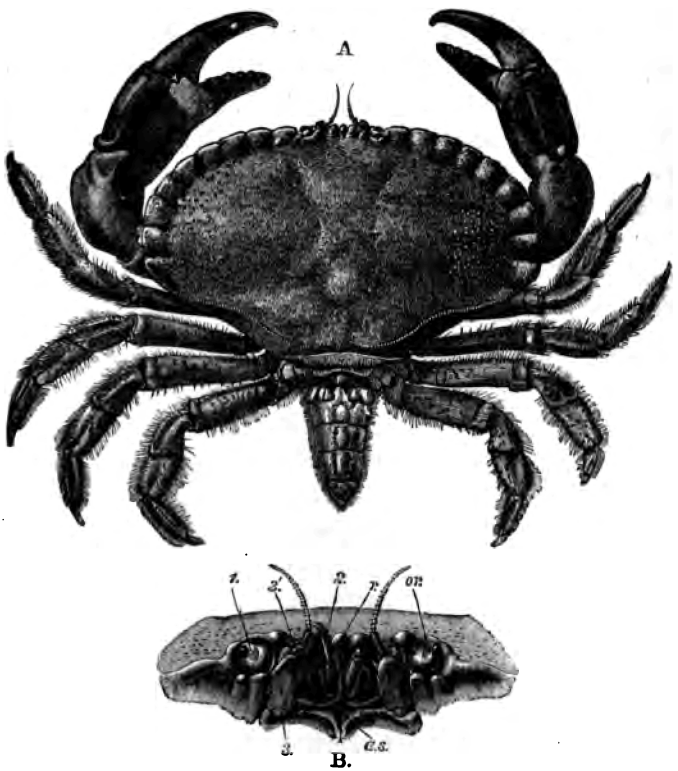

FIG. 72. *Cancer pagurus*, male (⅓ nat. size). A, dorsal view, with the abdomen extended; B, front view of "face." *as*, antennary sternum; *or*, orbit; *r*, rostrum; 1. eyestalk; 2. antennule; 3. base of antenna; 3′, free portion of antenna.

not used as a swimming organ; and the sixth somite possesses no appendages whatever. The breadth of the cephalothorax is often greater than its length, and there is no prominent rostrum. In its place there is a truncated process (fig. 72, B, *r*), which sends down a vertical partition, and divides from one another two cavities, in which the swollen basal joints of the small antennules (*2*) are lodged. The outer boundary of each of these cavities is formed by the basal part of the antenna (*3*), which is firmly fixed to the edge of the carapace. There is no exopoditic scale; and the free part of the antenna (*3'*) is very small. The convex corneal surface of the eye appears outside the base of the antenna, lodged in a sort of orbit (*or*), the inner margin of which is formed by the base of the antenna, while the upper and outer boundaries are constituted by the carapace. Thus, while in all the preceding forms, the eye is situated nearest the middle line, and is most forward, while the antennule lies outside and behind it, and the antenna comes next; in the crab, the antennule occupies the innermost place, the antenna comes next, and the eye appears to be external to and behind the other two. But there is no real change in the attachments of the eye-stalks. For if the antennule and the basal joint of the antenna are removed, it will be seen that the base of the eye-stalk is attached, as in the crayfish, close to the middle line, on the inner side, and in front of the antennule. But it is very long and extends outwards, behind the antennule and the antenna;

its corneal surface alone being visible, as it projects into the orbit.

Again, the ischiopodites of the external maxillipedes are expanded into broad quadrate plates, which meet in the middle line, and close over the other manducatory organs, like two folding-doors set in a square doorway. Behind these there are great chelate forceps, as in the crayfish; but the succeeding four pairs of ambulatory limbs are terminated by simple claws.

When the abdomen is forcibly turned back, its sternal surface is seen to be soft and membranous. There are no swimmerets; but, in the female, the four anterior pairs of abdominal limbs are represented by singular appendages, which give attachment to the eggs; while in the males there are two pairs of styliform organs attached to the first and second somites of the abdomen, which correspond with those of the male crayfishes.

The ventral portions of the branchiostegites are sharply bent inwards, and their edges are so closely applied throughout the greater part of their length to the bases of the ambulatory limbs, that no branchial cleft is left. In front of the bases of the forceps, however, there is an elongated aperture, which can be shut or opened by a sort of valve, connected with the external maxillipede, which serves for the entrance of water into the branchial cavity. The water employed in respiration, and kept in constant motion by the action of the scaphognathite, is baled out through two apertures, which

are separated from the foregoing by the external maxillipedes, and lie at the sides of the quadrate space in which these organs are set.

There are only nine gills on each side, and these, as in the prawn and shrimp, are phyllobranchiæ. Seven of the branchiæ are pyramidal in shape, and for the most part of large size. When the branchiostegite is removed, they are seen lying close against its inner walls, their apices converging towards its summit. The two hindermost of these gills are pleurobranchiæ, the other five are arthrobranchiæ. The two remaining gills are podobranchiæ, and belong to the second and the third maxillipedes respectively. Each is divided into a branchial and an epipoditic portion, the latter having the form of a long curved blade. The branchial portion of the podobranchia of the second maxillipede is long, and lies horizontally under the bases of the four anterior arthrobranchiæ; while the gill of the podobranchia of the third maxillipede is short and triangular, and fits in between the bases of the second and the third arthrobranchiæ. The epipodite of the third maxillipede is very long, and its base furnishes the valve of the afferent aperture of the branchial cavity, which has been mentioned above. The podobranchia of the first maxillipede is represented only by a long curved epipoditic blade, which can sweep over the outer surface of the gills, and doubtless serves to keep them clear of foreign bodies.

The branchial formula of Cancer pagurus.

Somites and their Appendages.	Podo-branchiæ.	Arthrobranchiæ. Anterior.	Arthrobranchiæ. Posterior.	Pleuro-branchiæ.	
VII. ...	0 (ep.)	0 ...	0 ...	0 =	0
VIII. ...	1 ...	1 ...	0 ...	0 =	2
IX. ...	1 ...	1 ...	1 ...	0 =	3
X. ...	0 ...	1 ...	1 ...	0 =	2
XI. ...	0 ...	0 ...	0 ...	1 =	1
XII. ...	0 ...	0 ...	0 ...	1 =	1
XIII. ...	0 ...	0 ...	0 ...	0 =	0
XIV. ...	0 ...	0 ...	0 ...	0 =	0
	2 + ep.	+ 3 +	2 +	2 =	9 + ep.

It will be observed that the suppression of branchiæ has here taken place in all the series, and at both the anterior and the posterior ends of each. But the defect in total number is made up by the increase of size, not of the pleurobranchiæ alone, as in the case of the prawns, but of the arthrobranchiæ as well. At the same time the whole apparatus has become more specialized and perfected as a breathing organ. The close fitting of the edges of the carapace, and the possibility of closing the inhalent and exhalent apertures, render the crabs much more independent of actual immersion in water than most of their congeners; and some of them habitually live on dry land and breathe by means of the atmospheric air which they take into and expel from their branchial cavities.

Notwithstanding all these wide departures from the structure and habits of the crayfishes, however, attentive examination shows that the plan of construction of the

crab is, in all fundamental respects, the same as that of the crayfish. The body is made up of the same number of somites. The appendages of the head and of the thorax are identical in number, in function, and even in the general pattern of their structure. But two pairs of abdominal appendages in the female, and four pairs in the male, have disappeared. The exopodites of the antennæ have vanished, and not even epipodites remain to represent the podobranchiæ of the posterior five pairs of thoracic limbs. The exceedingly elongated eye-stalks are turned backwards and outwards, above the bases of the antennules and the antennæ, and the bases of the latter have become united with the edges of the carapace in front of them. In this manner the extraordinary face, or *metope* (fig. 72, B) of the crab results from a simple modification of the arrangement of parts, every one of which exists in the crayfish. The same common plan serves for both.

The foregoing illustrations are taken from a few of our commonest and most easily obtainable *Crustacea;* but they amply suffice to exemplify the manner in which the conception of a plan of organization, common to a multitude of animals of extremely diverse outward forms and habits, is forced upon us by mere comparative anatomy.

Nothing would be easier, were the occasion fitting, than to extend this method of comparison to the whole of the several thousand species of crab-like, crayfish-like, or

prawn-like animals, which, from the fact that they all have their eyes set upon movable stalks, are termed the *Podophthalmia*, or stalk-eyed *Crustacea*; and by arguments of similar force to prove that they are all modifications of the same common plan. Not only so, but the sand-hoppers of the sea-shore, the wood-lice of the land, and the water-fleas or the monoculi of the ponds, nay, even such remote forms as the barnacles which adhere to floating wood, and the acorn shells which crowd every inch of rock on many of our coasts, reveal the same fundamental organization. Further than this, the spiders and the scorpions, the millipedes and the centipedes, and the multitudinous legions of the insect world, show us, amid infinite diversity of detail, nothing which is new in principle to any one who has mastered the morphology of the crayfish.

Given a body divided into somites, each with a pair of appendages; and given the power to modify those somites and their appendages in strict accordance with the principles by which the common plan of the *Podophthalmia* is modified in the actually existing members of that order; and the whole of the *Arthropoda*, which probably make up two-thirds of the animal world, might readily be educed from one primitive form.

And this conclusion is not merely speculative. As a matter of observation, though the *Arthropoda* are not all evolved from one primitive form, in one sense of the words, yet they are in another. For each can be traced

back in the course of its development to an ovum, and that ovum gives rise to a blastoderm, from which the parts of the embryo arise in a manner essentially similar to that in which the young crayfish is developed.

Moreover, in a large proportion of the *Crustacea*, the embryo leaves the egg under the form of a small oval body, termed a *Nauplius* (fig. 73, D), provided with (usually) three pairs of appendages, which play the part of swimming limbs, and with a median eye. Changes of form accompanied by sheddings of the cuticle take place, in virtue of which the larva passes into a new stage, when it is termed a *Zoœa* (C). In this, the three pairs of locomotive appendages of the *Nauplius* are metamorphosed into rudimentary antennules, antennæ, and mandibles, while two or more pairs of anterior thoracic appendages provided with exopodites and hence appearing bifurcated, subserve locomotion. The abdomen has grown out and become a notable feature of the Zoœa, but it has no appendages.

In some *Podophthalmia*, as in *Penæus* (fig. 73), the young leaves the egg as a Nauplius, and the Nauplius becomes a Zoœa. The hinder thoracic appendages, each provided with an epipodite, appear; the stalked eyes and the abdominal members are developed, and the larva passes into what is sometimes called the *Mysis* or *Schizopod* stage. The adult state differs from this chiefly in the presence of branchiæ and the rudimentary character of the exopodites of the five posterior thoracic limbs.

In the Opossum-shrimps (*Mysis*) the young does not leave the pouch of the mother until it is fully

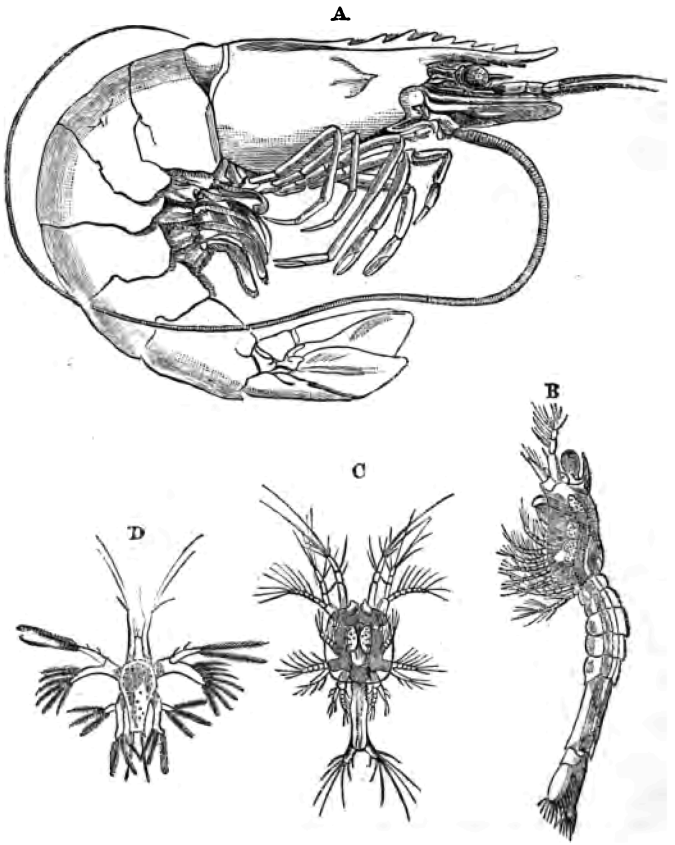

FIG. 73. *Penæus semisulcatus.* A, adult (after de Haan, ½ nat. size); B, Zoæa, and C, less advanced Zoæa of a species of *Penæus.* D, Nauplius. (B, C, and D, after Fritz Müller.)

developed; and, in this case, the *Nauplius* state is passed through so rapidly and in so early and imperfect a condition of the embryo, that it would not be recognized

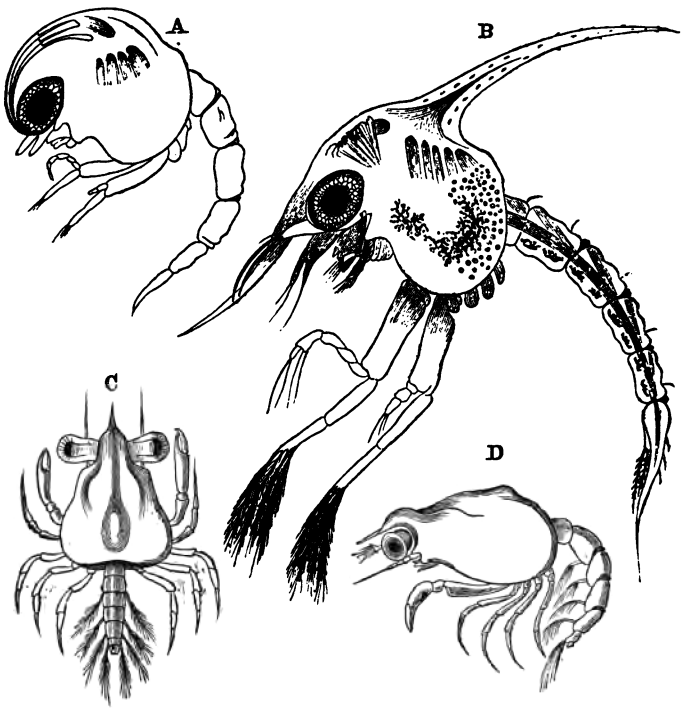

FIG. 74. *Cancer pagurus.* A, newly hatched Zoœa; B, more advanced Zoœa; C, dorsal, and D, side view of Megalopa (after Spence Bate). The figures A and B are more magnified than C and D.)

except for the cuticle which is developed and is subsequently shed.

In the great majority of the *Podophthalmia*, the Nauplius stage seems to be passed over without any such clear evidence of its occurrence, and the young is set free as a Zoœa. In the lobsters, which have, throughout life, a large abdomen provided with swimmerets, the Zoœa, after going through a Mysis or Schizopod stage, passes into the adult form.

In the crab, the young leaves the egg as a Zoœa (fig. 74, A and B). But this is not followed by a Schizopod stage, inasmuch as the five hinder pair of thoracic limbs are apparently, from the first, devoid of exopodites. But the Zoœa, after it has acquired stalked eyes and a complete set of thoracic and abdominal members, and has passed into what is called the *Megalopa* stage (fig. 74, C and D), suffers a more complete metamorphosis. The carapace widens, the fore part of the head is modified so as to bring about the formation of the characteristic metope: and the abdomen, losing more or fewer of its posterior appendages, takes up its final position under the thorax.

In the Zoœa state, those thoracic limbs which give rise to the maxillipedes are provided with well-developed exopodites, and in the free Mysis state all these limbs have exopodites. In the Opossum-shrimps these persist throughout life; in *Penæus*, the rudiments of them only remain; in the lobster, they disappear altogether.

Thus, in these animals, there is no difficulty in demonstrating that embryological uniformity of type of all the

limbs, complete evidence of which was not furnished by the development of the crayfish. In this crustacean, in fact, it would appear that the process of development has undergone its maximum of abbreviation. The embryo presents no distinct and independent Nauplius or Zoœa stages, and, as in the crab, there is no Schizopod or Mysis stage. The abdominal appendages are developed very early, and the new born young, which resembles the Megalopa stage of the crab, differs only in a few points from the adult animal.

Guided by comparative morphology, we are thus led to admit that the whole of the *Arthropoda* are connected by closer or more remote degrees of affinity with the crayfish. If we were to study the perch and the pond-snail with similar care, we should be led to analogous conclusions. For the perch is related by similar gradations, in the first place, with other fishes; then more remotely, with frogs and newts, reptiles, birds, and mammals; or, in other words, with the whole of the great division of the *Vertebrata*. The pond-snail, by like reasoning upon analogous data, is connected with the *Mollusca*, in all their innumerable kinds of slugs, shellfish, squids, and cuttlefish. And, in each case, the study of development takes us back to an egg as the primary condition of the animal, and to the process of yelk division, the formation of a blastoderm, and the conversion of that blastoderm into a more or less modified

gastrula, as the early stages of development. The like is true of all the worms, sea-urchins, starfishes, jellyfishes, polypes, and sponges; and it is only in the minutest and simplest forms of animal life that the germ, or representative of the ovum becomes metamorphosed into the adult form without the preliminary process of division.

In the majority even of these *Protozoa*, the typical structure of the nucleated cell is retained, and the whole animal is the equivalent of a histological unit of one of the higher organisms. An *Amœba* is strictly comparable, morphologically, to one of the corpuscles of the blood of the crayfish.

Thus, to exactly the same extent as it is legitimate to represent all the crayfishes as modifications of the common astacine plan, it is legitimate to represent all the multicellular animals as modifications of the gastrula, and the gastrula itself as a peculiarly disposed aggregate of cells; while the *Protozoa* are such cells either isolated, or otherwise aggregated.

It is easy to demonstrate that all plants are either cell aggregates, or simple cells; and as it is impossible to draw any precise line of demarcation, either physiological or morphological, between the simplest plants, and the simplest of the *Protozoa*, it follows that all forms of life are morphologically related to one another; and that in whatever sense we say that the English and the Californian crayfish are allied, in the same sense, though not to the same degree, must we admit that all living things

are allied. Given one of those protoplasmic bodies, of which we are unable to say certainly whether it is animal or plant, and endow it with such inherent capacities of self-modification as are manifested daily under our eyes by developing ova, and we have a sufficient reason for the existence of any plant, or of any animal.

This is the great result of comparative morphology; and it is carefully to be noted that this result is not a speculation, but a generalisation. The truths of anatomy and of embryology are generalised statements of facts of experience; the question whether an animal is more or less like another in its structure and in its development, or not, is capable of being tested by observation; the doctrine of the unity of organisation of plants and animals is simply a mode of stating the conclusions drawn from experience. But, if it is a just mode of stating these conclusions, then it is undoubtedly conceivable that all plants and all animals may have been evolved from a common physical basis of life, by processes similar to those which we every day see at work in the evolution of individual animals and plants from that foundation.

That which is conceivable, however, is by no means necessarily true; and no amount of purely morphological evidence can suffice to prove that the forms of life have come into existence in one way rather than another.

There is a common plan among churches, no less than

among crayfishes; nevertheless the churches have certainly not been developed from a common ancestor, but have been built separately. Whether the different kinds of crayfishes have been built separately, is a problem we shall not be in a position to grapple with, until we have considered a series of facts connected with them, which have not yet been touched upon.

CHAPTER VI.

THE DISTRIBUTION AND THE ÆTIOLOGY OF THE CRAYFISHES.

So far as I have been able to discover, all the crayfishes which inhabit the British islands agree in every point with the full description given above, at p. 230. They are abundant in some of our rivers, such as the Isis, and other affluents of the Thames; and they have been observed in those of Devon;* but they appear to be absent from many others. I cannot hear of any, for example, in the Cam or the Ouse, on the east, or in the rivers of Lancashire and Cheshire, on the west. It is still more remarkable that, according to the best information I can obtain, they are absent in the Severn, though they are plentiful in the Thames and Severn canal. Dr. M'Intosh, who has paid particular attention to the fauna of Scotland, assures me that crayfish are unknown north of the Tweed. In Ireland, on the other hand, they occur in many localities;† but the question whether their diffusion, and even their introduction into this

* Moore. Magazine of Natural History. New Series, III., 1839.

† Thompson. Annals and Magazine of Natural History, XI., 1843.

island, has or has not been effected by artificial means, is involved in some obscurity.

English zoologists have always termed our crayfish *Astacus fluviatilis;* and, up to a recent period, the majority of Continental naturalists have included a corresponding form of *Astacus* under that specific name.

Thus M. Milne Edwards, in his classical work on the *Crustacea,** published in 1837, observes under the head of "Écrevisse commune. *Astacus fluviatilis:*" "There are two varieties of this crayfish; in the one, the rostrum gradually becomes narrower from its base onwards, and the lateral spines are situated close to its extremity; in the other, the lateral edges of the rostrum are parallel in their posterior half and the lateral spines are stronger and more remote from the end."

The "first variety," here mentioned, is known under the name of "Écrevisse à pieds blancs"† in France, by way of distinction from the "second variety," which is termed "Écrevisse à pieds rouges," on account of the more or less extensive red coloration of the forceps and ambulatory limbs. This second variety is the larger, commonly attaining five inches in length, and sometimes reaching much larger dimensions; and it is more highly esteemed for the market, on account of its better flavour.

In Germany, the two forms have long been popularly distinguished, the former by the name of "Steinkrebs,"

* "Histoire Naturelle des Crustacés."

† Carbonnier. "L'Écrevisse," p. 8.

or "stone crayfish," and the latter by that of "Edelkrebs," or "noble crayfish."

Milne Edwards, it will be observed, speaks of these two forms of crayfish as "varieties" of the species *Astacus fluviatilis;* but, even as far back as the year 1803 some zoologists began to regard the "stone crayfish" as a distinct species, to which Schrank applied the name of *Astacus torrentium*, while the "noble crayfish" remained in possession of the old denomination, *Astacus fluviatilis;* and, subsequently, various forms of "stone-crayfishes" have been further distinguished as the species *Astacus saxatilis, A. tristis, A. pallipes, A. fontinalis,* &c. On the other hand, Dr. Gerstfeldt,* who has devoted especial attention to the question, denies that these are anything more than varieties of one species; but he holds this and Milne Edwards's "second variety" to be specifically distinct from one another.

We thus find ourselves in the presence of three views respecting the English and French crayfishes.

1. They are all varieties of one species—*A. fluviatilis.*

2. There are two species—*A. fluviatilis,* and *A. torrentium,* of which last there are several varieties.

3. There are, at fewest, five or six distinct species.

Before adopting the one or the other of these views, it is necessary to form a definite conception of the meaning of the terms "species" and "variety."

* "Ueber die Flusskrebse Europas." Mém. de l'Acad. de St. Petersburg, 1859.

The word "species" in Biology has two significations; the one based upon morphological, the other upon physiological considerations.

A species, in the strictly morphological sense, is simply an assemblage of individuals which agree with one another, and differ from the rest of the living world in the sum of their morphological characters; that is to say, in the structure and in the development of both sexes. If the sum of these characters in one group is represented by A, and that in another by A + n; the two are morphological species, whether n represents an important or an unimportant difference.

The great majority of species described in works on Systematic Zoology are merely morphological species. That is to say, one or more specimens of a kind of animal having been obtained, these specimens have been found to differ from any previously known by the character or characters n; and this difference constitutes the definition of the new species, and is all we really know about its distinctness.

But, in practice, the formation of specific groups is more or less qualified by considerations based upon what is known respecting variation. It is a matter of observation that progeny are never exactly like their parents, but present small and inconstant differences from them. Hence, when specific identity is predicated of a group of individuals, the meaning conveyed is not that they are all exactly alike, but only that their differences are so

small, and so inconstant, that they lie within the probable limits of individual variation.

Observation further acquaints us with the fact, that, sometimes, an individual member of a species may exhibit a more or less marked variation, which is propagated through all the offspring of that individual, and may even become intensified in them. And, in this manner, a *variety*, or *race*, is generated within the species; which variety, or race, if nothing were known respecting its origin, might have every claim to be regarded as a separate morphological species. The distinctive characters, of a race, however, are rarely equally well marked in all the members of the race. Thus suppose the species A to develope the race A + x; then the difference x is apt to be much less in some individuals than in others; so that, in a large suite of specimens, the interval between A + x and A will be filled up by a series of forms in which x gradually diminishes.

Finally, it is a matter of observation that modification of the physical conditions under which a species lives favours the development of varieties and races.

Hence, in the case of two specimens having respectively the characters A and A + n, although, *primâ facie*, they are of distinct species; yet if a large collection shows us that the interval between A and A + n is filled up by forms of A having traces of n, and forms of A + n in which n becomes less and less, then it will be con-

cluded that A and A + *n* are races of one species and not separate species. And this conclusion will be fortified if A and A + *n* occupy different stations in the same geographical area.

Even when no transitional forms between A and A + *n* are discoverable, if *n* is a small and unimportant difference, such as of average size, colour, or ornamentation, it may be fairly held that A and A + *n* are mere varieties; inasmuch as experience proves that such variations may take place comparatively suddenly; or the intermediate forms may have died out and thus the evidence of variation may have been effaced.

From what has been said it follows that the groups termed morphological species are provisional arrangements, expressive simply of the present state of our knowledge.

We call two groups species, if we know of no transitional forms between them, and if there is no reason to believe that the differences which they present are such as may arise in the ordinary course of variation. But it is impossible to say whether the progress of inquiry into the characters of any group of individuals may prove that what have hitherto been taken for mere varieties are distinct morphological species; or whether, on the contrary, it may prove that what have hitherto been regarded as distinct morphological species are mere varieties.

What has happened in the case of the crayfish is this:

the older observers lumped all the Western European forms which came under their notice under one species, *Astacus fluviatilis;* noting, more or less distinctly, the stone crayfish and the noble crayfish as races or varieties of that species. Later zoologists, comparing crayfishes together more critically, and finding that the stone crayfish is ordinarily markedly different from the noble crayfish, concluded that there were no transitional forms, and made the former into a distinct species, tacitly assuming that the differential characters are not such as could be produced by variation.

It is at present an open question whether further investigation will or will not bear out either of these assumptions. If large series of specimens of both stone crayfishes and noble crayfishes from different localities are carefully examined, they will be found to present great variations in size and colour, in the tuberculation of the carapace and limbs, and in the absolute and relative sizes of the forceps.

The most constant characters of the stone crayfish are :—

1. The tapering form of the rostrum and the approximation of the lateral spines to its point; the distance between these spines being about equal to their distance from the apex of the rostrum (fig. 61, A).

2. The development of one or two spines from the ventral margin of the rostrum.

3. The gradual subsidence of the posterior part of

the post-orbital ridge, and the absence of spines on its surface.

4. The large relative size of the posterior division of the telson (G).

On the contrary, in the noble crayfish :—

1. The sides of the posterior two-thirds of the rostrum are nearly parallel, and the lateral spines are fully a third of the length of the rostrum from its point; the distance between them being much less than their distance from the apex of the rostrum (B).

2. No spine is developed from the ventral margin of the rostrum.

3. The posterior part of the post-orbital ridge is a more or less distinct, sometimes spinous elevation.

4. The posterior division of the telson is smaller relatively to the anterior division (H).

I may add that I have found three rudimentary pleurobranchiæ in the noble crayfish, and never more than two in the stone crayfish.

In order to ascertain whether no crayfish exist in which the characters of the parts here referred to are intermediate between those defined, it would be necessary to examine numerous examples of each kind of crayfish from all parts of the areas which they respectively inhabit. This has been done to some extent, but by no means thoroughly; and I think that all that can be safely said, at present, is that the existence of intermediate forms is not proven. But, whatever the constancy of the

differences between the two kinds of crayfishes, there can surely be no doubt as to their insignificance; and no question that they are no more than such as, judging by analogy, might be produced by variation.

From a morphological point of view, then, it is really impossible to decide the question whether the stone crayfish and the noble crayfish should be regarded as species or as varieties. But, since it will, hereafter, be convenient to have distinct names for the two kinds, I shall speak of them as *Astacus torrentium* and *Astacus nobilis*.*

In the physiological sense, a species means, firstly, a group of animals the members of which are capable of completely fertile union with one another, but not with the members of any other group; and, secondly, it means all the descendants of a primitive ancestor or ancestors, supposed to have originated otherwise than by ordinary generation.

It is clear that, even if crayfishes had an unbegotten ancestor, there is no means of knowing whether the stone crayfish and the noble crayfish are descendants of the same, or of different ancestors, so that the second sense of species hardly concerns us. As to the first sense, there is no evidence to show whether the two

* According to strict zoological usage the names should be written *A. fluviatilis* (var. *torrentium*) and *A. fluviatilis* (var. *nobilis*) on the hypothesis that the stone crayfish and the noble crayfish are varieties; and *A. torrentium* and *A. fluviatilis* on the hypothesis that they are species; but as I neither wish to prejudge the species question, nor to employ cumbrously long names, I take a third course

kinds of crayfish under consideration are capable of fertile union or whether they are sterile. It is said, however, that hybrids or mongrels are not met with in the waters which are inhabited by both kinds, and that the breeding season of the stone crayfish begins earlier than that of the noble crayfish.

M. Carbonnier, who practises crayfish culture on a large scale, gives some interesting facts bearing on this question in the work already cited. He says that, in the streams of France, there are two very distinct kinds of crayfishes—the red-clawed crayfish (L'Écrevisse à pieds rouges), and the white-clawed crayfish (L'Écrevisse à pieds blancs), and that the latter inhabit the swifter streams. In a piece of land converted into a crayfish farm, in which the white-clawed crayfish existed naturally in great abundance, 300,000 red-clawed crayfish were introduced in the course of five years; nevertheless, at the end of this time, no intermediate forms were to be seen, and the "pieds rouges" exhibited a marked superiority in size over the "pieds blancs." M. Carbonnier, in fact, says that they were nearly twice as big.

On the whole, the facts as at present known, seem to incline rather in favour of the conclusion that *A. torrentium* and *A. nobilis* are distinct species; in the sense that transitional forms have not been clearly made out, and that, possibly, they do not interbreed.

As I have already remarked, the very numerous

specimens of English and Irish crayfishes which have passed through my hands, have all presented the character of *Astacus torrentium*, with which also the description given in works of recognised authority coincides as far as it goes.* The same form is found in many parts of France, as far south as the Pyrenees, and it is met with as far east as Alsace and Switzerland. I have recently† been enabled, by the kindess of Dr. Bolivar, of Madrid, who sent me a number of crayfishes from the neighbourhood of that city, to satisfy myself that the Spanish peninsula contains crayfishes altogether similar to those of Britain, except that the subrostral spine is less developed. Further, I have no doubt that Dr. Heller‡ is right in his identification of the English crayfish with a form which he describes under the name of *A. saxatilis*. He says that it is especially abundant in Southern Europe, and that it occurs in Greece, in Dalmatia, in the islands of Cherso and Veglia, at Trieste, in the Lago di Garda, and at Genoa. Further, *Astacus torrentium* appears to be widely distributed in North Germany. The eastern limit of this crayfish is uncertain; but, according to Kessler,§ it does not occur within the limits of the Russian empire.

* See Bell. "British Stalk-eyed Crustacea," p. 237.

† Since the statement respecting the occurrence of crayfishes in Spain on p. 44 was printed.

‡ "Die Crustaceen des Südlichen Europas," 1863.

§ "Die Russischen Flusskrebse." Bulletin de la Société Impériale des Naturalistes de Moscow, 1874.

Astacus torrentium appears to be particularly addicted to rapid highland streams and the turbid pools which they feed.

Astacus nobilis is indigenous to France, Germany, and the Italian peninsula. It is said to be found at Nice and at Barcelona, though I cannot hear of it elsewhere in Spain. Its south-eastern limit appears to be the Lake of Zirknitz, in Carniola, not far from the famous caves of Adelsberg. It is not known in Dalmatia, in Turkey, nor in Greece. In the Russian empire, according to Kessler, this crayfish chiefly inhabits the watershed of the Baltic. The northern limit of its distribution lies between Christianstad, in the Gulf of Bothnia (62° 16′ N), and Serdobol, at the northern end of Lake Ladoga. "Eastward of Lake Ladoga it is found in the Uslanka, a tributary of the Swir. It appears to be the only crayfish which exists in the waters which flow from the south into the Gulf of Finland and into the Baltic; except in those streams and lakes which have been artificially connected with the Volga, and in which it is partially replaced by *A. leptodactylus*." It still inhabits the Lakes of Beresai and Bologoe, as well as the affluents of the Msta and the Wolchow; and it is met with in affluents of the Dnieper, as far as Mohilew. *Astacus nobilis* is also found in Denmark and Southern Sweden; but, in the latter country, its introduction appears to have been artificial. This crayfish is said occasionally to be met with on the Livonian coast in the waters of the Baltic, which, however, it must

be remembered, are much less salt than ordinary sea water.

It will be observed that while the two forms, *A. torrentium* and *A. nobilis*, are intermixed over a large part of Central Europe, *A. torrentium* has a wider north-westward, south-westward, and south-eastward extension, being the sole occupant of Britain, and apparently of the greater part of Spain and of Greece. On the other hand, in the northern and eastern parts of Central Europe, *A. nobilis* appears to exist alone.

Further to the east, a new form, *Astacus leptodactylus* (fig. 75), makes its appearance. Whether *A. leptodactylus* exists in the upper waters of the Danube, does not appear, but in the lower Danube and in the Theiss it is the dominant, if not the exclusive, crayfish. From hence it extends through all the rivers which flow into the Black, Azov, and Caspian Seas, from Bessarabia and Podolia on the west, to the Ural mountains on the east. In fact, the natural habitat of this crayfish appears to be the watershed of the Pontocaspian area, excluding that part of the Black Sea which lies southward of the Caucasus on the one hand, and of the mouths of the Danube on the other.*

It is a remarkable circumstance that this crayfish not only thrives in the brackish waters of the estuaries of the rivers which debouche into the Black Sea and the Sea of Azov, but that it is found even in the salter

* These statements rest on the authority of Kessler and Gerstfeldt, in their memoirs already cited.

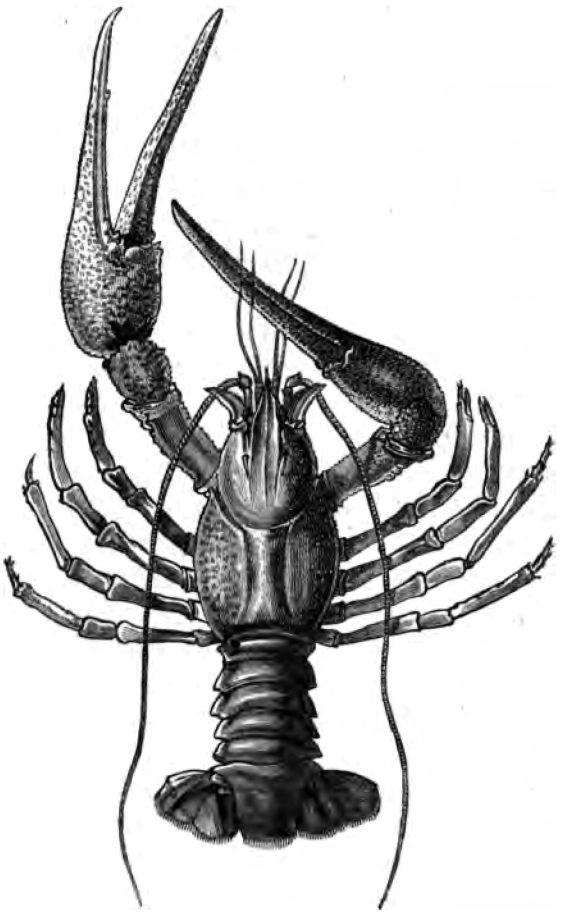

FIG. 75.—*Astacus leptodactylus* (after Rathke, ½ nat. size).

southern parts of the Caspian, in which it lives at considerable depths.

In the north, *Astacus leptodactylus* is met with in the rivers which flow into the White Sea, as well as in many streams and lakes about the Gulf of Finland. But it has probably been introduced into these streams by the canals which have been constructed to connect the basin of the Volga with the rivers which flow into the Baltic and into the White Sea. In the latter, the invading *A. leptodactylus* is everywhere overcoming and driving out *A. nobilis* in the struggle for existence, apparently in virtue of its more rapid multiplication.*

In the Caspian and in the brackish waters of the estuaries of the Dniester and the Bug, a somewhat different crayfish, which has been called *Astacus pachypus*, occurs; another closely allied form (*A. angulosus*) is met with in the mountain streams of the Crimea and of the northern face of the Caucasus; and a third, *A. colchicus*, has recently been discovered in the Rion, or Phasis of the ancients, which flows into the eastern extremity of the Black Sea.

With respect to the question whether these Ponto-caspian crayfishes are specifically distinct from one another, and whether the most widely distributed kind, *A. leptodactylus*, is distinct from *A. nobilis*, exactly the same difficulties arise as in the case of the west European

* Kessler (Die Russischen Flusskrebse, l. c. p. 369-70), has an interesting discussion of this question.

crayfishes. Gerstfeldt, who has had the opportunity of examining large series of specimens, concludes that the Pontocaspian crayfishes and *A. nobilis* are all varieties of one species. Kessler, on the contrary, while he admits that *A. angulosus* is, and *A. pachypus* may be, a variety of *A. leptodactylus*, affirms that the latter is specifically distinct from *A. nobilis*.

Undoubtedly, well marked examples of *A. leptodactylus* are very different from *A. nobilis*.

1. The edges of the rostrum are produced into five or six sharp spines, instead of being smooth or slightly serrated as in *A. nobilis*.

2. The fore part of the rostrum has no serrated spinous median keel, such as commonly, though not universally, exists in *A. nobilis*.

3. The posterior end of the post-orbital ridge is still more distinct and spiniform than in *A. nobilis*.

4. The abdominal pleura of *A. leptodactylus* are narrower, more equal sided, and triangular in shape.

5. The chelæ of the forceps, especially in the males, are more elongated; and the moveable and fixed claws are slenderer and have their opposed edges straighter and less tuberculated.

But, in all these respects, individual specimens of *A. nobilis* vary in the direction of *A. leptodactylus* and *vice versâ;* and if *A. angulosus* and *A. pachypus* are varieties of *A. leptodactylus*, I cannot see why Gerstfeldt's conclusion that *A. nobilis* is another variety of

the same form need be questioned on morphological grounds. However, Kessler asserts that, in those localities in which *A. leptodactylus* and *A. nobilis* live together, no intermediate forms occur, which is presumptive evidence that they do not intermix by breeding.

No crayfishes are known to inhabit the rivers of the northern Asiatic watershed, such as the Obi, Yenisei, and Lena. None are known * in the sea of Aral, or the great rivers Oxus and Jaxartes, which feed that vast lake; nor any in the lakes of Balkash and Baikal. If further exploration verifies this negative fact, it will be not a little remarkable; inasmuch as two †, if not more, kinds of crayfishes are found in the basin of the great river Amur, which drains a large area of north-eastern Asia, and debouches into the Gulf of Tartary, in about the latitude of York.

Japan has one species (*A. japonicus*), perhaps more; but no crayfish has as yet been made known in any part of eastern Asia, south of Amurland. There are certainly none in Hindostan; none are known in Persia, Arabia, or Syria. In Asia Minor the only recorded locality is the Rion. No crayfish has yet been discovered in the whole continent of Africa.‡

* It would be hazardous, however, to assume that none exist, especially in the Oxus, which formerly flowed into the Caspian.

† *A. dauricus* and *A. Schrenckii*.

‡ Whatever the so-called *Astacus capensis* of the Cape Colony may be, it is certainly not a crayfish.

Thus, on the continent of the old world, the crayfishes are restricted to a zone, the southern limit of which coincides with certain great geographical features; on the west, the Mediterranean, with its continuation, the Black Sea; then the range of the Caucasus, followed by the great Asiatic highlands, as far as the Corea on the east. On the north, though there is no such physical boundary, the crayfishes appear to be entirely excluded from the Siberian river basins; while east and west, though a sea-barrier exists, the crayfishes extend beyond it, to reach the British islands and those of Japan.

Crossing the Pacific, we meet with some half-a-dozen kinds of crayfishes,* different from those of the old world, but still belonging to the genus *Astacus*, in British Columbia, Oregon, and California. Beyond the Rocky Mountains, from the Great Lakes to Guatemala, crayfishes abound, as many as thirty-two different species having been described, but they all belong to the genus *Cambarus* (fig. 63, p. 248). Species of this genus also occur in Cuba,† but, so far as is at present known, not in any of the other West Indian islands. The occurrence of a curious dimorphism among the male *Cambari* has been described by Dr. Hagen; and a blind *Cambarus*

* Dr. Hagen in his "Monograph of the North American Astacidæ," enumerates six species; *A. Gambelii*, *A. klamathensis*, *A. leeniusculus*, *A. nigrescens*, *A. oreganus*, *and A. Trowbridgii*.

† Von Martens. *Cambarus cubensis*. Archiv. für Naturgeschichte, xxxviii.

is found, along with other blind animals, in the subterranean caves of Kentucky.

All the crayfishes of the northern hemisphere belong to the *Potamobiidæ*, and no members of this family are known to exist south of the equator. The crayfishes of the southern hemisphere, in fact, all belong to the division of the *Parastacidæ*, and in respect of the number and variety of forms and the size which they reach, the head-quarters of the *Parastacidæ* is the continent of Australia. Some of the Australian crayfishes (fig. 76) attain a foot or more in length, and are as large as full-sized lobsters. The genus *Engæus* of Tasmania comprises small crayfish which, like some of the *Cambari*, live habitually on land, in burrows which they excavate in the soil.

New Zealand has a peculiar genus of crayfishes, *Paranephrops*, a species of which is found in the Fiji Islands, but none are known to occur elsewhere in Polynesia.

Two kinds of crayfish have been obtained in southern Brazil, and have been described by Dr. v. Martens,* as *A. pilimanus* and *A. brasiliensis*. I have shown that they belong to a peculiar genus, *Parastacus*. The former was procured at Porto Alegre, which is situated in 30° S. Latitude, close to the mouth of the Jacuhy, at the north end of the great Laguna do Patos, which communi-

* Südbrasilische Süss- und Brackwasser Crustaceen, nach den Sammlungen des Dr. Reinh. Hensel. Archiv. für Naturgeschichte, xxxv. 1869.