to side nearly at right angles with one another. A longitudinal section shows that both the horizontal and the vertical contours of the cornea are very nearly semicircular, and that the lines which mark off the facets merely arise from a slight modification of its substance between the facets. The outer contour of each facet forms part of the general curvature of the outer face of the cornea; the inner contour sometimes exhibits a slight deviation

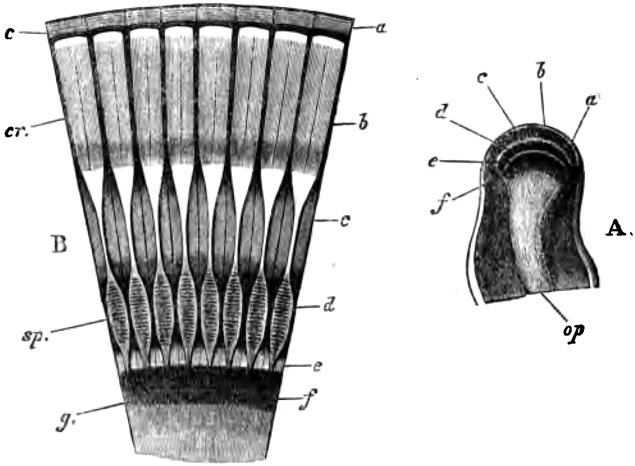

FIG. 28.—*Astacus fluviatilis.*—A, a vertical section of the eye-stalk (× 6); B, a small portion of the same, showing the visual apparatus more highly magnified; *a*, cornea; *b*, outer dark zone; *c*, outer white zone; *d*, middle dark zone; *e*, inner white zone; *f*, inner dark zone; *cr*, crystalline cones; *g*, optic ganglion; *op*, optic nerve; *sp*, striated spindles.

from the general curvature of the inner face, but usually nearly coincides with it.

When a longitudinal or a transverse section is taken through the whole eyestalk, the optic nerve (fig. 28, A, *op*) is seen to traverse its centre. At first narrow and cylindrical, it expands towards its extremity into a sort of bulb (B, *g*), the outer surface of which is curved in correspondence with the inner surface of the cornea. The terminal half of the bulb contains a great quantity of dark colouring matter or pigment, and, in section, appears as what may be termed the *inner dark zone* (*f*). Outside this, and in connection with it, follows a white line, the *inner white zone* (*e*), then comes a *middle dark zone* (*d*); outside this an outer pale band, which may be called the *outer white zone* (*c*), and between this and the cornea (*a*) is another broad band of dark pigment, the *outer dark zone* (*b*).

When viewed under a low power, by reflected light, this outer dark zone is seen to be traversed by nearly parallel straight lines, each of which starts from the boundary between two facets, and can be followed inwards through the outer white zone to the middle dark zone. Thus the whole substance of the eye between the outer surface of the bulb of the optic nerve and the inner surface of the cornea is marked out into as many segments as the cornea has facets; and each segment has the form of a wedge or slender pyramid, the base of which is four-sided, and is applied against the inner surface of one of the facets of the cornea, while its summit lies in the middle dark zone. Each of these *visual pyramids* consists of an axial structure, the *visual rod,* invested by a sheath. The latter extends inwards from the margin of each facet of the cornea, and contains pigment in two regions of its length, the intermediate space being devoid of pigment. As the position of the pigmented regions in relation to the length of the pyramid is always the same, the pigmented regions necessarily take the form of two consecutive zones when the pyramids are in their natural position.

The visual rod consists of two parts, an external *crystalline cone* (fig. 28, B, *cr*), and an internal *striated spindle* (*sp*). The *crystalline cone* consists of a transparent glassy-looking substance, which may be made to split up longitudinally into four segments. Its inner end narrows into a filament which traverses the outer white zone, and, in the middle dark zone, thickens into a four-sided spindle-shaped transparent body, which appears transversely striated. The inner end of this *striated spindle* narrows again, and becomes continuous with nerve fibres which proceed from the surface of the optic bulb.

The exact mode of connection of the nerve-fibres with the visual rods is not certainly made out, but it is probable that there is direct continuity of substance, and that each rod is really the termination of a nerve fibre.

Eyes having essentially the same structure as that of the crayfish are very widely met with among *Crustacea* and *Insecta*, and are commonly known as *compound eyes*. In many of these animals, in fact, when the cornea is removed, each facet is found to act as a separate lens; and when proper arrangements are made, as many distinct pictures of external objects are found behind it as there are facets. Hence the notion suggested itself that each visual pyramid is a separate eye, similar in principle of construction to the human eye, and forming a picture of so much of the external world as comes within the range of its lens, upon a retina supposed to be spread out on the surface of the crystalline cone, as the human retina is spread over the surface of the vitreous humour.

But, in the first place, there is no evidence, nor any probability, that there is anything corresponding to a retina on the outer face of the crystalline cone; and secondly, if there were, it is incredible that, with such an arrangement of the refractive media as exists in the cornea and crystalline cones, rays proceeding from points in the external world should be brought to a focus in correspondingly related points of the surface of the supposed retina. But without this no picture could be formed, and no distinct vision could take place. It is very probable, therefore, that the visual pyramids do not play the part of the simple eyes of the *Vertebrata*, and the only alternative appears to be the adoption of a modification of the theory of *mosaic vision*, propounded many years by Johannes Müller.

Each visual pyramid, isolated from its fellows by its coat of pigment, may be supposed, in fact, to play the part of a very narrow straight tube, with blackened walls, one end of which is turned towards the external world, while the other incloses the extremity of one of the nerve fibres. The only light which can reach the latter, under these circumstances, is such as proceeds from points which lie in the direction of a straight line represented by the produced axis of the tubes.

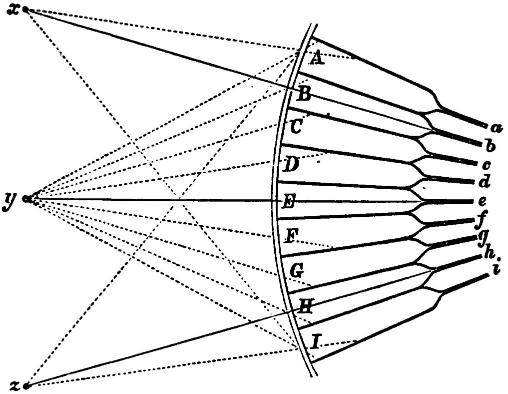

FIG. 29.—Diagram showing the course of rays of light from three points *x*, *y*, *z*, through the nine visual rods (supposed to be empty tubes) A—I of a compound eye ; *a*—*i*, the nerve fibres connected with the visual rods.

Suppose A—I to be nine such tubes, *a*—*i* the corresponding nerve fibres, and *x y z* three points from which light proceeds. Then it will be obvious that the only light from *x* which will excite sensation, will be the ray which traverses B and reaches the nerve-fibre *b*, while that from *y* will affect only *e*, and that from *x* only *h*. The result, translated into sensation, will be three points of light on a dark ground, each of which answers to one of the luminous points, and indicates its direction in reference to the eye and its angular distance from the other two.*

The only modification needed in the original form of the theory of mosaic vision, is the supposition that part, or the whole, of the visual rod, is not merely a passive transmitter of light to the nerve-fibre, but is, itself, in someway concerned in transmuting the mode of motion, light, into that other mode of motion which we call nervous energy. The visual rod is, in fact, to be regarded as the physiological end of the nerve, and the instrument by which the conversion of the one form of motion into the other takes place; just as the auditory hairs are instruments by which the sonorous waves are converted into molecular movements of the substance of the auditory nerves.

It is wonderfully interesting to observe that, when the so-called compound eye is interpreted in this manner,

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* Since the visual rods are strongly refracting solids, and not empty tubes, the diagram given in fig. 29 does not represent the true course of the rays, indicated by dotted lines, which fall obliquely on any cornea of a crayfish's eye. Such rays will be more or less bent towards the axis of the visual rod of that cornea; but whether they reach its apex and so affect the nerve or not will depend on the curvature of the cornea; its refractive index and that of the crystalline cone; and the relation between the length and the thickness of the latter.

the apparent wide difference between it and the vertebrate eye gives place to a fundamental resemblance. The rods and cones of the retina of the vertebrate eye are extraordinarily similar in their form and their relations to the fibres of the optic nerve, to the visual rods of the arthropod eye. And the morphological discrepancy, which is at first so striking, and which arises from the fact that the free ends of the visual rods are turned towards the light, while those of the rods and cones of the vertebrate eye are turned from it, becomes a confirmation of the parallel between the two when the development of the vertebrate eye is taken into account. For it is demonstrable that the deep surface of the retina in which the rods and cones lie, is really a part of the outer surface of the body turned inwards, in the course of the singular developmental changes which give rise to the brain and the eye of vertebrate animals.

Thus the crayfish has, at any rate, two of the higher sense organs, the ear and the eye, which we possess ourselves; and it may seem a superfluous, not to say a frivolous, question, if any one should ask whether it can hear and see.

But, in truth, the inquiry, if properly limited, is a very pertinent one. That the crayfish is led by the use of its eyes and ears to approach some objects and avoid others, is beyond all doubt; and, in this sense, most indubitably it can both hear and see. But if the question means, do luminous vibrations give it the sensations of light and darkness, of colour and form and distance, which they give to us? and do sonorous vibrations produce the feelings of noise and tone, of melody and of harmony, as in us?—it is by no means to be answered hastily, perhaps cannot be answered at all, except in a tentative, probable way.

The phenomena to which we give the names of sound and colour are not physical things, but are states of consciousness, dependent, there is every reason to believe, on the functional activity of certain parts of our brains. Melody and harmony are names for states of consciousness which arise when at least two sensations of sound have been produced. All these are manufactured articles, products of the human brain; and it would be exceedingly hazardous to affirm that organs capable of giving rise to the same products exist in the vastly simpler nervous system of the crustacean. It would be the height of absurdity to expect from a meat-jack the sort of work which is performed by a Jacquard loom; and it appears to me to be little less preposterous to look for the production of anything analogous to the more subtle phenomena of the human mind in something so minute and rude in comparison to the human brain, as the insignificant cerebral ganglia of the crayfish.

At the most, one may be justified in supposing the existence of something approaching dull feeling in ourselves; and, to return to the problem stated in the beginning of this chapter, so far as such obscure consciousness accompanies the molecular changes of its nervous substance, it will be right to speak of the mind of a crayfish. But it will be obvious that it is merely putting the cart before the horse, to speak of such a mind as a factor in the work done by the organism, when it is merely a dim symbol of a part of such work in the doing.

Whether the crayfish possesses consciousness or not, however, does not affect the question of its being an engine, the actions of which at any moment depend, on the one hand, upon the series of molecular changes excited, either by internal or by external causes, in its neuro-muscular machinery; and, on the other, upon the disposition and the properties of the parts of that machinery. And such a self-adjusting machine, containing the immediate conditions of its action within itself, is what is properly understood by an automaton.

Crayfishes, as we have seen, may attain a considerable age; and there is no means of knowing how long they might live, if protected from the innumerable destructive influences to which they are at all ages liable.

It is a widely received notion that the energies of living matter have a natural tendency to decline, and finally disappear; and that the death of the body, as a whole, is the necessary correlate of its life. That all living things sooner or later perish needs no demonstration, but it would be difficult to find satisfactory grounds for the belief that they must needs do so. The analogy of a machine that, sooner or later, must be brought to a standstill by the wear and tear of its parts, does not hold, inasmuch as the animal mechanism is continually renewed and repaired; and, though it is true that individual components of the body are constantly dying, yet their places are taken by vigorous successors. A city remains, notwithstanding the constant death-rate of its inhabitants; and such an organism as a crayfish is only a corporate unity, made up of innumerable partially independent individualities.

Whatever might be the longevity of crayfishes under imaginable perfect conditions, the fact that, notwithstanding the great number of eggs they produce, their number remains pretty much the same in a given district, if we take the average of a period of years, shows that about as many die as are born; and that, without the process of reproduction, the species would soon come to an end.

There are many examples among members of the group of *Crustacea* to which the crayfish belongs, of animals which produce young from internally developed germs, as some plants throw off bulbs which are capable of reproducing the parent stock; such is the case, for example, with the common water flea (*Daphnia*). But nothing of this kind has been observed in the crayfish; in which, as in the higher animals, the reproduction of the species is dependent upon the combination of two kinds of living matter, which are developed in different individuals, termed *males* and *females*.

These two kinds of living matter are *ova* and *spermatozoa*, and they are developed in special organs, the *ovary* and the *testis*. The ovary is lodged in the female; the testis, in the male.

The *ovary* (fig. 30, *ov*) is a body of a trefoil form, which is situated immediately beneath, or in front of, the heart, between the floor of the pericardial sinus and the alimentary canal. From the ventral face of this organ two short and wide canals, the *oviducts* (*od*), lead down to the bases of the second pair of walking limbs, and terminate in the apertures (*od'*) already noticed there.

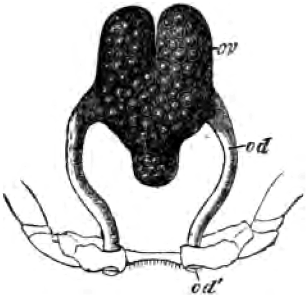

FIG. 30.—*Astacus fluviatilis.*—The female reproductive organs (× 2); *ov*, ovary; *od*, oviduct; *od'*, aperture of oviduct.

The *testis* (fig. 31, *t*) is somewhat similar in form to the ovary, but, the three divisions are much narrower and more elongated: the hinder median division lies under the heart; the anterior divisions are situated between the heart behind, and the stomach and the liver in front (figs. 5 and 12, *t*). From the point at which the three divisions join, proceed two ducts, which are termed the *vasa deferentia* (fig. 31, *vd*). These are very narrow, long, and make many coils before they reach the apertures upon the bases of the hindermost pair of walking limbs, by which they open externally (fig. 31, *vd'*, and fig. 35, *vd*). Both the ovary and the testis are very much larger

FIG. 31.—*Astacus fluviatilis.*—The male reproductive organs (× 2); *t*, testis; *vd*, vas deferens; *vd'*, aperture of vas deferens.

during the breeding season than at other times; tne large brownish-yellow eggs become conspicuous in the ovary,

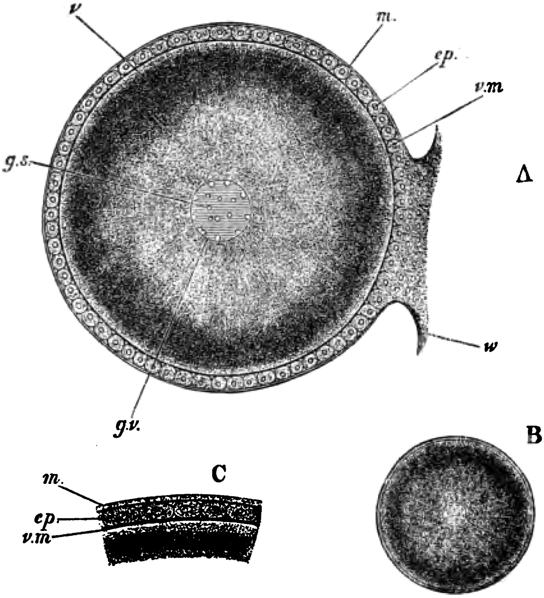

FIG. 32.—*Astacus fluviatilis.*—A, a two-thirds grown egg contained in its ovisac (× 50); B, an egg removed from the ovisac (× 10); C, a portion of the wall of an ovisac with the adjacent portion of the contained egg, highly magnified; *ep*, epithelium of ovisac; *gs*, germinal spots; *gv*, germinal vesicle; *m*, membrana propria; *v*, vitellus; *vm*, vitelline membrane; *w*, stalk of ovisac.

and the testis assumes a milk-white colour, at this period.

The walls of the ovary are lined internally by a layer of nucleated cells, separated from the cavity of the organ by a delicate structureless membrane. The growth of these cells gives rise to papillary elevations which project into the cavity of the ovary, and eventually become globular bodies attached by short stalks, and invested by the structureless membrane as a *membrana propria* (fig. 32, *m*). These are the *ovisacs*. In the mass of cells which becomes the ovisac, one rapidly increases in size and occupies the centre of the ovisac, while the others

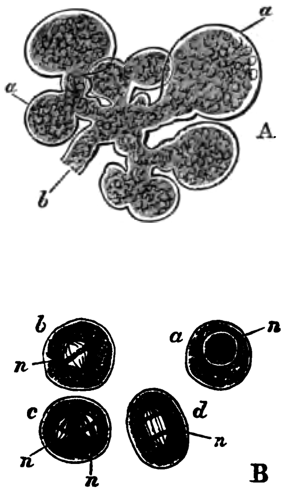

FIG. 33.—*Astacus fluviatilis.*—A, a lobule of the testis, showing *a*, acini, springing from *b*, the ultimate termination of a duct (× 50). B, spermatic cells ; *a*, with an ordinary globular nucleus *n ; b*, with a spindle-shaped nucleus ; *c*, with two similar nuclei ; and *d*, with a nucleus undergoing division (× 600).

surround it as a peripheral coat (*ep.*). This central cell is the *ovum.* Its nucleus enlarges, and becomes what is called the *germinal vesicle* (*g.v.*). At the same time numerous small corpuscles, flattened externally and convex internally, appear in it and are the *germinal spots* (*g.s.*). The protoplasm of the cell, as it enlarges, becomes granular and opaque, assumes a deep brownish-yellow colour, and is thus converted into the *yelk* or *vitellus* (*v.*). As the egg grows, a structureless *vitelline membrane* is formed between the vitellus and the cells which line the ovisac, and incloses the egg, as in a bag. Finally, the ovisac bursts, and the egg, falling into the cavity of the ovary, makes its way down the oviduct, and sooner or later passes out by its aperture. When they leave the oviduct, the ova are invested by a viscous, transparent substance, which attaches them to the swimmerets of the female, and then sets; thus each egg, inclosed in a tough case, is firmly suspended by a stalk, which, on the one side, is continued into the substance of the case, while, on the other, it is fixed to the swimmeret. The swimmerets are kept constantly in motion, so that the eggs are well supplied with aërated water.

The testis consists of an immense number of minute spheroidal vesicles (fig. 33, A, *a*), attached like grapes to the ends of short stalks (*b*), formed by the ultimate ramifications of the vasa deferentia. The vesicles may, in fact, be regarded as dilatations of the ends and sides

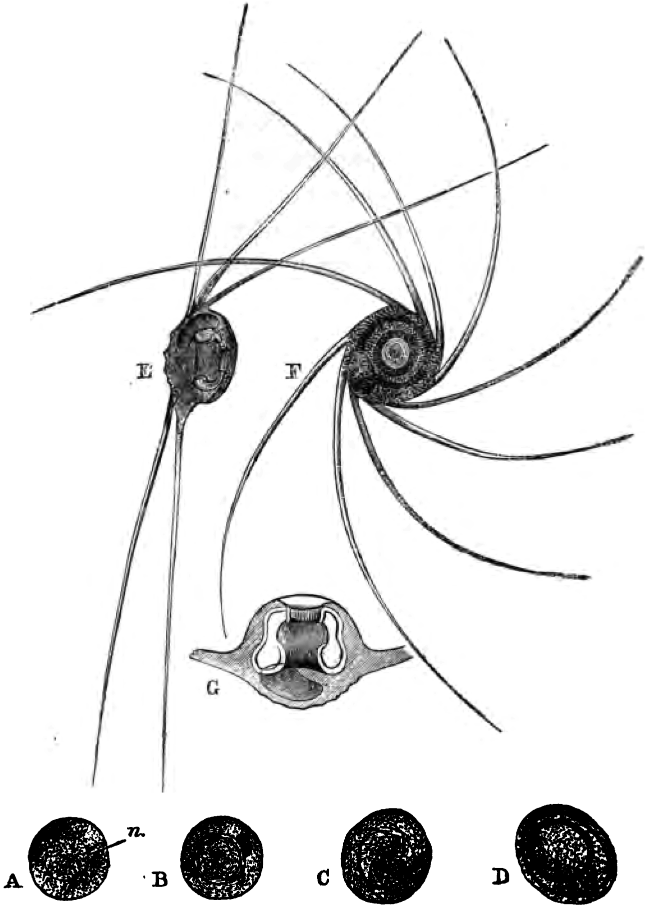

Fig. 34.—*Astacus fluviatilis.*—A—D, different stages in the development of a spermatozoon from a seminal cell; E, a mature spermatozoon seen from the side; F, the same viewed *en face* (all × 850); G, a diagrammatic vertical section of the same.

of the finest branches of the ducts of the testis. The cavity of each vesicle is filled by the large nucleated cells which line its walls (fig. 33, B), and, as the breeding season approaches, these cells multiply by division. Finally, they undergo some very singular changes of form and internal structure (fig. 34, A—D), each becoming converted into a flattened spheroidal body, about $\frac{1}{1700}$th of an inch in diameter, provided with a number of slender curved rays, which stand out from its sides (fig. 34, E—G). These are the *spermatozoa.*

The spermatozoa accumulate in the testicular vesicles, and give rise to a milky-looking substance, which traverses the smaller ducts, and eventually fills the vasa deferentia. This substance, however, consists, in addition to the spermatozoa, of a viscid material, secreted by the walls of the vasa deferentia, which envelopes the spermatozoa, and gives the secretion of the testis the form and the consistency of threads of vermicelli.

The ripening and detachment of both the ova and the spermatozoa take place immediately after the completion of ecdysis in the early autumn; and at this time, which is the breeding season, the males seek the females with great avidity, in order to deposit the fertilizing matter contained in the vasa deferentia on the sterna of their hinder thoracic and anterior abdominal somites. There it adheres as a whitish, chalky-looking mass ; but the manner in which the contained spermatozoa reach and enter the ova is unknown. The analogy of what occurs in other animals, however, leaves no doubt that an actual mixture of the male and female elements takes place and constitutes the essential part of the process of impregnation.

Ova to which spermatozoa have had no access, give rise to no progeny; but, in the impregnated ovum, the young crayfish takes its origin in a manner to be described below, when the question of development is dealt with.

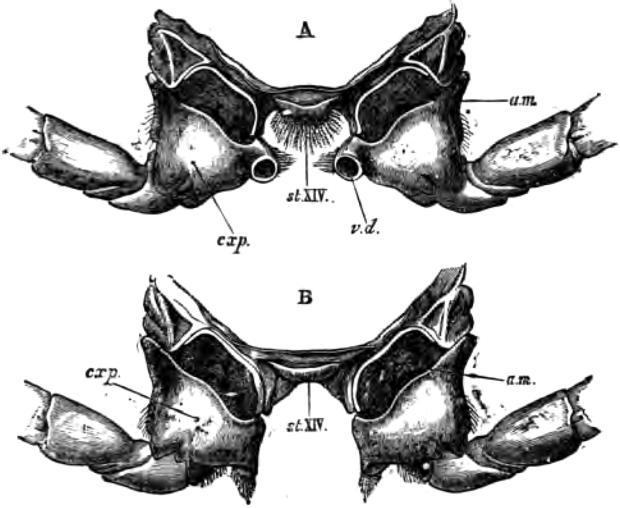

FIG. 35.—*Astacus fluviatilis.*—The last thoracic sternum, seen from behind, with the proximal ends of the appendages, A, in the male, B, in the female, (× 3). *am*, articular membrane; *cxp*, coxopodite; *st XIV*, last thoracic sternum; *vd*, aperture of vas deferens.

CHAPTER IV.

THE MORPHOLOGY OF THE COMMON CRAYFISH: THE STRUCTURE AND THE DEVELOPMENT OF THE INDIVIDUAL.

In the two preceding chapters the crayfish has been studied from the point of view of the physiologist, who, regarding an animal as a mechanism, endeavours to discover how it does that which it does. And, practically, this way of looking at the matter is the same as that of the teleologist. For, if all that we know concerning the purpose of a mechanism is derived from observation of the manner in which it acts, it is all one, whether we say that the properties and the connexions of its parts account for its actions, or that its structure is adapted to the performance of those actions.

Hence it necessarily follows that physiological phenomena can be expressed in the language of teleology. On the assumption that the preservation of the individual, and the continuance of the species, are the final causes of the organization of an animal, the existence of that organization is, in a certain sense, explained, when it is shown that it is fitted for the attainment of those ends; although, perhaps, the importance of demonstrating the proposition that a thing is fitted to do that which it does, is not very great.

But whatever may be the value of teleological explanations, there is a large series of facts, which have as yet been passed over, or touched only incidentally, of which they take no account. These constitute the subject matter of *Morphology*, which is related to physiology much as, in the not-living world, crystallography is related to the study of the chemical and physical properties of minerals.

Carbonate of lime, for example, is a definite compound of calcium, carbon, and oxygen, and it has a great variety of physical and chemical properties. But it may be studied under another aspect, as a substance capable of assuming crystalline forms, which, though extraordinarily various, may all be reduced to certain geometrical types. It is the business of the crystallographer to work out the relations of these forms; and, in so doing, he takes no note of the other properties of carbonate of lime.

In like manner, the morphologist directs his attention to the relations of form between different parts of the same animal, and between different animals; and these relations would be unchanged if animals were mere dead matter, devoid of all physiological properties—a kind of mineral capable of a peculiar mode of growth.

A familiar exemplification of the difference between teleology and morphology may be found in such works of human art as houses.

A house is certainly, to a great extent, an illustration of adaptation to purpose, and its structure is, to that extent, explicable by teleological reasonings. The roof and the walls are intended to keep out the weather; the foundation is meant to afford support and to exclude damp; one room is contrived for the purpose of a kitchen; another for that of a coal-cellar; a third for that of a dining-room; others are constructed to serve as sleeping rooms, and so on; doors, chimneys, windows, drains, are all more or less elaborate contrivances directed towards one end, the comfort and health of the dwellers in the house. What is sometimes called sanitary architecture, now-a-days, is based upon considerations of house teleology. But though all houses are, to begin with and essentially, means adapted to the ends of shelter and comfort, they may be, and too often are, dealt with from a point of view, in which adaptation to purpose is largely disregarded, and the chief attention of the architect is given to the form of the house. A house may be built in the Gothic, the Italian, or the Queen Anne style; and a house in any one of these styles of architecture may be just as convenient or inconvenient, just as well or as ill adapted to the wants of the resident therein, as any of the others. Yet the three are exceedingly different.

To apply all this to the crayfish. It is, in a sense, a house with a great variety of rooms and offices, in which the work of the indwelling life in feeding, breathing, moving, and reproducing itself, is done. But the same may be said of the crayfish's neighbours, the perch and the water-snail; and they do all these things neither better nor worse, in relation to the conditions of their existence, than the crayfish does. Yet the most cursory inspection is sufficient to show that the "styles of architecture" of the three are even more widely different than are those of the Gothic, Italian, and Queen Anne houses.

That which Architecture, as an art conversant with pure form, is to buildings, Morphology, as a science conversant with pure form, is to animals and plants. And we may now proceed to occupy ourselves exclusively with the morphological aspect of the crayfish.

As I have already mentioned, when dealing with the physiology of the crayfish, the entire body of the animal, when reduced to its simplest morphological expression, may be represented as a cylinder, closed at each end, except so far as it is perforated by the alimentary apertures (fig. 6); or we may say that it is a tube, inclosing another tube, the edges of the two being continuous at their extremities. The outer tube has a chitinous outer coat or cuticle, which is continued on to the inner face of the inner tube. Neglecting this for the present, the outermost part of the wall of the outer tube, which answers to the *epidermis* of the higher animals, and the innermost part of the wall of the inner tube, which is an *epithelium*, are formed by a layer of nucleated cells. A continuous layer of cells, therefore, is everywhere to be found on both the external and the internal free surfaces of the body. So far as these cells belong to the proper external wall of the body, they constitute the *ectoderm*, and so far as they belong to its proper internal wall, they compose the *endoderm*. Between these two layers of nucleated cells lie all the other parts of the body, composed of connective tissue, muscles, vessels, and nerves; and all these (with the exception of the ganglionic chain, which we shall see properly belongs to the ectoderm) may be regarded as a single thick stratum, which, as it lies between the ectoderm and the endoderm, is called the *mesoderm*.

If the intestine were closed posteriorly instead of opening by the vent, the crayfish would virtually be an elongated sac, with one opening, the mouth, affording an entrance into the alimentary cavity: and, round this cavity, the three layers just referred to—endoderm, mesoderm, and ectoderm—would be disposed concentrically.

We have seen that the body of the crayfish thus composed is obviously separable into three regions—the *cephalon* or head, the *thorax*, and the *abdomen*. The latter is at once distinguished by the size and the mobility of its segments: while the thoracic region is marked off from that of the head, outwardly, only by the cervical groove. But, when the carapace is removed, the lateral depression already mentioned, in which the scaphognathite lies, clearly indicates the natural boundary between the head and the thorax. It has further been observed that there are, in all, twenty pairs of appendages, the six hindermost of which are attached to the abdomen. If the other fourteen pairs are carefully removed, it will be found that the six anterior belong to the head, and the eight posterior to the thorax.

The abdominal region may now be studied in further detail. Each of its seven movable segments, except the telson, represents a sort of morphological unit, the repetition of which makes up the whole fabric of the body.

If the abdomen is divided transversely between the

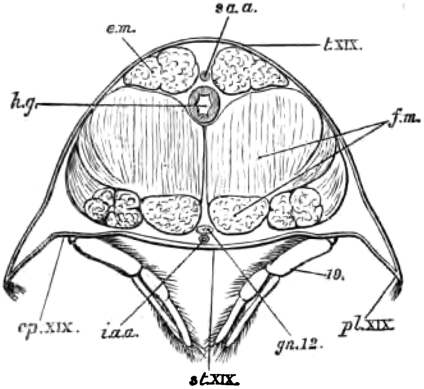

FIG. 36.—*Astacus fluviatilis.*—A transverse section through the nineteenth (fifth abdominal) somite (× 2). *e.m.*, extensor muscles; *f.m.*, flexor muscles; *gn. 12*, the fifth abdominal ganglion; *h.g.*, hind-gut; *i.a.a.*, inferior abdominal artery; *s.a.a*, superior abdominal artery; *pl. XIX*, pleura of the somite; *st. XIX*, its sternum; *t. XIX*, its tergum; *ep. XIX*, its epimera; *19*, its appendages.

fourth and fifth, and the fifth and sixth segments, the fifth will be isolated, and can be studied apart. It constitutes what is called a *metamere;* in which are distinguishable a central part termed the *somite,* and two *appendages* (fig. 36).

In the exoskeleton of the somites of the abdomen several regions have already been distinguished; and although they constitute one continuous whole, it will be convenient to speak of the *sternum* (fig. 36, *st. XIX*), the *tergum* (*t. XIX*), and, the *pleura* (*pl. XIX*), as if they were separate parts, and to distinguish that portion of the sternal region, which lies between the articulation of the appendage and the pleuron, on each side, as the *epimeron* (*ep. XIX*). Adopting this nomenclature, it may be said of the fifth somite of the abdomen, that it consists of a segment of the exoskeleton, divisible into tergum, pleura, epimera, and sternum, with which two appendages are articulated; that it contains a double ganglion (*gn. 12*), a section of the flexor (*fm*) and extensor (*em*) muscles, and of the alimentary (*hg*) and vascular (*s.a.a, i.a.a*) systems.

The appendage (fig. 36, *19*), which is attached to an articular cavity situated between the sternum and the epimeron, is seen to consist of a stalk or stem, which is made up of a very short basal joint, the *coxopodite* (fig. 37, D and E, *cx.p*), followed by a long cylindrical second joint, the *basipodite* (*b.p*), and receives the name of *protopodite.* At its free end, it bears two flattened narrow

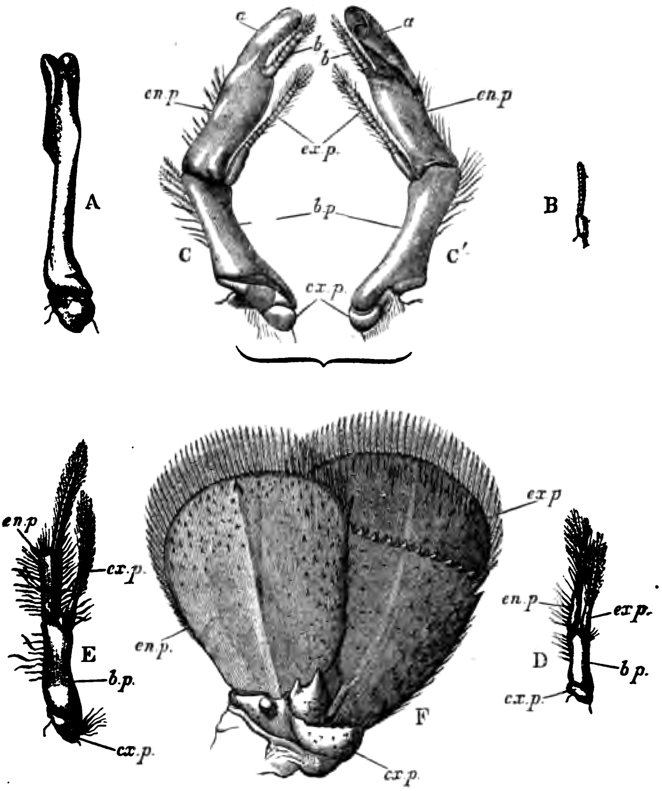

Fig. 37.—*Astacus fluviatilis.*—Appendages of the left side of the abdomen (× 3). A, the posterior face of the first appendage of the male; B, the same of the female; C, posterior, and C′, anterior faces of the second appendage of the male; D, the third appendage of the male; E, the same of the female; F, the sixth appendage. *a*, the rolled plate of the endopodite; *b*, the jointed extremity of the same; *bp.*, basipodite; *cx.p.*, coxopodite; *en.p.*, endopodite; *ex.p.*, exopodite.

plates, of which one is attached to the inner side of the extremity of the protopodite, and is called the *endopodite* (*en.p*), while the other is fixed a little higher up to the outer side of that extremity, and is the *exopodite* (*ex.p*). The exopodite is shorter than the endopodite. The endopodite is broad and is undivided for about half its length, from the attached end; the other half is narrower and is divided into a number of small segments, which, however, are not united by definite articulations, but are merely marked off from one another by slight constrictions of the exoskeleton. The exopodite has a similar structure, but its undivided portion is shorter and narrower. The edges of both the exopodite and the endopodite are fringed with long setæ.

In the female crayfish, the appendages of this and of the fourth and third somites are larger than in the male (compare *D* and *E*, fig. 37).

The fourth and fifth somites, with their appendages, may be described in the same terms as the third, and in the sixth there is no difficulty in recognising the corresponding parts of the somite; but the appendages (fig. 37, *F*), which constitute the lateral portions of the caudal fin, at first sight appear very different. In their size, no less than in their appearance, they depart widely from the appendages of the preceding somites. Nevertheless, each will be found to consist of a basal stalk, answering to the protopodite (*cx.p*), which however is very broad and thick, and is not divided into two joints; and of two terminal oval plates, which represent the endopodite (*en.p*) and the exopodite (*ex.p*). The latter is divided by a transverse suture into two pieces; and the edge of the larger or basal moiety is beset with short spines, of which two, at the outer end of the series, are larger than the rest.

The second somite is longer than the first (fig. 1); it has very broad pleura, while those of the first somite are small and hidden by the overlapping front margins of the pleura of the second somite.

In the female, the appendages of the second somite of the abdomen are similar to those of the third, fourth, and fifth somites; but in those of the first somite (fig. 37, *B*), there is a considerable variation. Sometimes, in fact, the appendages of this somite are altogether wanting; sometimes one is present, and not the other; and sometimes both are found. But, when they exist, these appendages are always small; and the protopodite is followed by only one imperfectly jointed filament, which appears to represent the endopodite of the other appendages.

In the male, the appendages of the first and second somites of the abdomen are not only of relatively large size, but they are widely different from the rest, those of the first somite departing from the general type further than those of the second. In the latter (*C*, *C′*) there is a protopodite (*cx.p*, *bp*) with the ordinary structure, and it is followed by an endopodite (*en.p*) and an exopodite (*ex.p*); but the former is singularly modified. The undivided basal part is large, and is produced on the inner side into a lamella (*a*), which extends slightly beyond the end of the terminal jointed portion (*b*). The inner half of this lamella is rolled upon itself, in such a manner as to give rise to a hollow cone, something like an extinguisher (*C′*, *a*).

The appendage of the first somite (*A*) is an unjointed styliform body, which appears to represent the protopodite, together with the basal part and the inner prolongation of the endopodite of the preceding appendage. The terminal half of the appendage is really a broad plate, slightly bifid at the summit, but the sides of the plate are rolled in, in such a manner that the anterior half bends round and partially incloses the posterior half. They thus give rise to a canal, which is open at each end, and only partially closed behind.

These two pairs of curiously modified appendages are ordinarily turned forwards and applied against the sterna of the posterior part of the thorax, in the interval between the bases of the hinder thoracic limbs (see fig. 3, *A*). They serve as conduits by which the spermatic matter of the male is conveyed from the openings of the ducts of the testes to its destination.

If we confine our attention to the third, fourth, and fifth metameres of the abdomen of the crayfish, it is obvious that the several somites and their appendages, and the various regions or parts into which they are divisible, correspond with one another, not only in form, but in their relations to the general plan of the whole abdomen. Or, in other words, a diagrammatic plan of one somite will serve for all the three somites, with insignificant variations in detail. The assertion that these somites are constructed upon the same plan, involves no more hypothesis than the statement of an architect, that three houses are built upon the same plan, though the façades and the internal decorations may differ more or less.

In the language of morphology, such conformity in the plan of organisation is termed *homology*. Hence, the several metameres in question and their appendages, are *homologous* with one another; while the regions of the somites, and the parts of their appendages, are also *homologues*.

When the comparison is extended to the sixth metamere, the homology of the different parts with those of the other metameres, is undeniable, notwithstanding the great differences which they present. To recur to a previous comparison, the ground plan of the building is the same, though the proportions are varied. So with regard to the first and second metameres. In the second pair of appendages of the male, the difference from the ordinary type of appendage is comparable to that produced by adding a portico or a turret to the building; while, in the first pair of appendages of the female, it is as if one wing of the edifice were left unbuilt;

and, in those of the male, as if all the rooms were run into one.

It is further to be remarked, that, just as of a row of houses built upon the same plan, one may be arranged so as to serve as a dwelling-house, another as a warehouse, and another as a lecture hall, so the homologous appendages of the crayfish are made to subserve various functions. And as the fitness of the dwelling-house, the warehouse, and the lecture-hall for their several purposes would not in the least help us to understand why they should all be built upon the same general plan; so, the adaptation of the appendages of the abdomen of the crayfish to the discharge of their several functions does not explain why those parts are homologous. On the contrary, it would seem simpler that each part should have been constructed in such a manner as to perform its allotted function in the best possible manner, without reference to the rest. The proceedings of an architect, who insisted on constructing every building in a town on the plan of a Gothic cathedral, would not be explicable by considerations of fitness or convenience.

In the cephalothorax, the division into somites is not at first obvious, for, as we have seen, the dorsal or tergal surface is covered over by a continuous shield, distinguished into thoracic and cephalic regions only by the cervical groove. Even here, however, when a transverse section of the thorax is compared with that of the abdomen (figs. 15 and 36), it will be obvious that the tergal and the sternal regions of the two answer to one another; while the branchiostegites correspond with greatly developed pleura; and the inner wall of the branchial chamber, which extends from the bases of the appendages to the attachment of the branchiostegite, represents an immensely enlarged epimeral region.

On examination of the sternal aspect of the cephalothorax the signs of division into somites become plain (figs. 3 and 39, *A*). Between the last two ambulatory limbs there is an easily recognisable sternum (*XIV.*), though it is considerably narrower than any of the sterna of the abdominal somites, and differs from them in shape.

The deep transverse fold which separates this hindermost thoracic sternum from the rest of the sternal wall of the cephalothorax, is continued upwards on the inner or epimeral wall of the branchial cavity; and thus the sternal and the epimeral portions of the posterior thoracic somite are naturally marked off from those of the more anterior somites.

The epimeral region of this somite presents a very curious structure (fig. 38). Immediately above the articular cavities for the appendages there is a shield-shaped plate, the posterior, convex edge of which is sharp, prominent, and setose. Close to its upper boundary the plate exhibits a round perforation (*plb.*), to the margins of which the stem of the hindermost pleurobranchia (fig. 4, *plb. 14*) is attached; and in front of this, it is connected, by a narrow neck, with an elongated triangular piece, which takes a vertical direction, and lies in the fold which separates the posterior thoracic somite from the next in front. The base of this piece unites with the epimeron of the penultimate somite. Its apex is connected with the anterior end of the horizontal arm of an L-shaped calcified bar (fig. 38, *a*), the upper end of the vertical arm of which is firmly, but moveably, connected with the anterior and lateral edge of the tergum of the first abdominal somite (*t. XV.*). The tendon of one

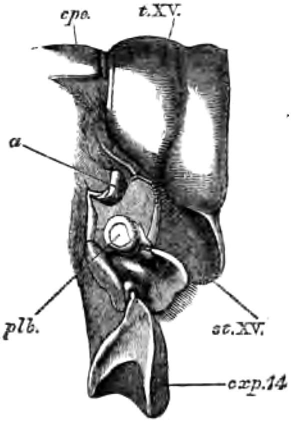

FIG. 38.—*Astacus fluviatilis*.—The mode of connexion between the last thoracic and the first abdominal somites (× 3). *a*, L-shaped bar; *cpe*, carapace; *cxp. 14*, coxopodite of the last ambulatory leg; *plb.*, place of attachment of the pleurobranchia; *st. XV*, sternum, and *t. XV*, tergum of the first abdominal somite.

of the large extensor muscles of the abdomen is attached close to it.

The sternum and the shield-shaped epimeral plates constitute a solid, continuously calcified, ventral element of the skeleton, to which the posterior pair of legs is attached; and as this structure is united with the somites in front of and behind it only by soft cuticle, except where the shield-shaped plate is connected, by the intermediation of the triangular piece, with the epimeron which lies in front of it, it is freely movable backwards and forwards on the imperfect hinge thus constituted.

In the same way, the first somite of the abdomen, and, consequently, the abdomen as a whole, moves upon the hinges formed by the union of the L-shaped pieces with the triangular pieces.

In the rest of the thorax, the sternal and the epimeral regions of the several somites are all firmly united together. Nevertheless, shallow grooves answering to folds of the cuticle, which run from the intervals between the articular cavities for the limbs towards the tergal end of the inner wall of the branchial chamber, mark off the epimeral portions of as many somites as there are sterna, from one another.

A short distance above the articular cavities a transverse groove separates a nearly square area of the lower part of the epimeron from the rest. Towards the anterior and upper angle of this area, in the two somites which lie immediately in front of the hindermost, there is a small round aperture for the attachment of the

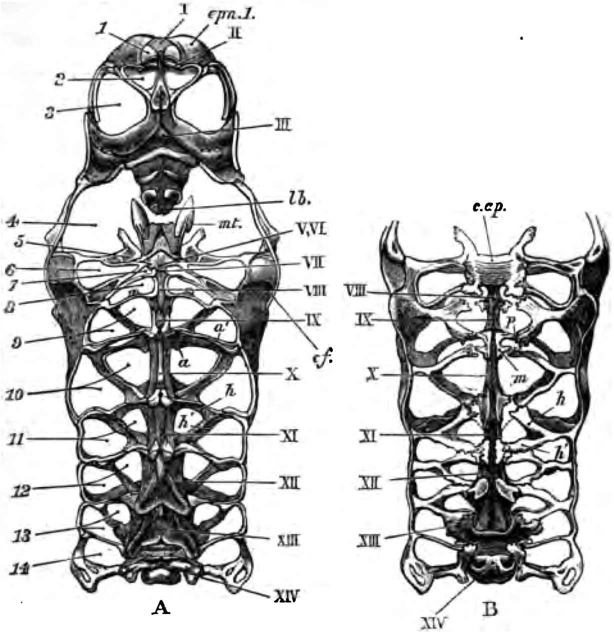

FIG. 39.—*Astacus fluviatilis*.—The cephalothoracic sterna and the endophragmal system (× 2). *A*, from beneath; *B*, from above. *a*, *a'*, arthrophragms or partitions between the articular cavities for the limbs; *c.ap*, cephalic apodeme; *cf*, cervical fold; *epn. 1*, epimeron of the antennulary somite; *h*, anterior, and *h'*, posterior horizontal process of endopleurite; *lb*, labrum; *m*, mesophragm; *mt*, metastoma; *p*, paraphragm ; *I—XIV*, cephalothoracic sterna; *1—14*, articular cavities of the cephalothoracic appendages. (The anterior cephalic sterna are bent downwards in A so as to bring them into the same plane with the remaining cephalothoracic sterna; in B these sterna are not shown.)

rudimentary branchia. These areæ of the epimera, in fact, correspond with the shield-shaped plate of the hindermost somite. In the next most anterior somite (that which bears the first pair of ambulatory legs) there is only a small elevation in the place of the rudimentary branchia; and in the anterior four thoracic somites nothing of the kind is visible.

On the sternal aspect of the thorax (figs. 3 and 39, A) a triangular space is interposed between the basal joints or coxopodites of the penultimate and the ante-penultimate pairs of ambulatory legs, while the coxopodites of the more anterior limbs are closely approximated. The triangular area in question is occupied by two sterna (fig. 39, A, *XII*, *XIII*), the lateral margins of which are raised into flange-like ridges. The next two sterna (*X*, *XI*) are longer, especially that which lies between the forceps (*X*), but they are very narrow; while the lateral processes are reduced to mere tubercles at the posterior ends of the sterna. Between the three pairs of maxillipedes, the sterna (*VII*, *VIII*, *IX*) are yet narrower, and become gradually shorter; but traces of the tubercles at their posterior ends are still discernible. The most anterior of these sternal rods passes into a transversely elongated plate, shaped like a broad arrow (*V*, *VI*), which is constituted by the conjoined sterna of the two posterior somites of the head.

Anteriorly to this, and between it and the posterior end of the elongated oral aperture, the sternal region is occupied only by soft or imperfectly calcified cuticle, which, on each side of the hinder part of the mouth, passes into one of the lobes of the metastoma (*mt*). At the base of each of these lobes there is a calcified plate, united by an oblique suture with another, which occupies the whole length of the lobe and gives it firmness. The soft narrow lip which constitutes the lateral boundary of the oral aperture, and lies between it and the mandible, passes, in front, into the posterior face of the labrum (*lb*).

In front of the mouth, the sternal region which appertains, in part, to the antennæ, and, in part, to the mandibles, is obvious as a broad plate (*III*), termed the *epistoma*. The middle third of the posterior edge of the epistoma gives rise to a thickened transverse ridge, with rounded ends, slightly excavated behind, and is then continued into the labrum (*lb*), which is strengthened by three pairs of calcifications, arranged in a longitudinal series. The sides of the front edge of the epistoma are excavated, and bound the articular cavities for the basal joints of the antennæ (*3*); but, in the middle line, the epistoma is continued forwards into a spear-head shaped process (figs. 39 and 40, *II*), to which the posterior end of the antennulary sternum contributes. The antennulary sternum is very narrow, and its anterior or upper end runs into a small but distinct conical median spine (fig. 40, *t.*). Upon this follows an uncalcified plate, bent into the form of a half cylinder (*I*), which lies between the inner ends of the eye-stalks and is united with adjacent parts only by flexible cuticle, so that it is freely movable. This represents the whole of the sternal region, and probably more, of the ophthalmic somite.

The sterna of fourteen somites are thus identifiable in the cephalothorax. The corresponding epimera are represented, in the thorax, by the thin inner walls of the branchial chamber; the pleura, by the branchiostegites; and the terga, by so much of the median region of the carapace as lies behind the cervical groove. That part of the carapace which is situated in front of this groove occupies the place of the terga of the head; while the low ridge, skirting the oral and præ-oral region, in which it terminates laterally, represents the pleura of the cephalic somites.

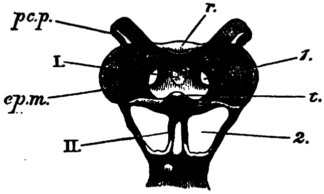

FIG. 40.—*Astacus fluviatilis.*—The ophthalmic and antennulary somites (× 3). *I*, ophthalmic, and *II*, antennulary sternum; *1*, articular surface for eyestalk; *2*, for antennule; *epm*, epimeral plate; *pcp*, procephalic process; *r*, base of rostrum; *t*, tubercle.

The epimera of the head are, for the most part, very narrow; but those of the antennulary somite are broad plates (fig. 40, *epm.*), which constitute the posterior wall of the orbits. I am inclined to think that a transverse ridge, which unites these under the base of the rostrum, represents the tergum of the antennulary somite, and that the rostrum itself belongs to the next or antennary somite.*

The sharp convex ventral edge of the rostrum (fig. 41) is produced into a single, or sometimes two divergent spines, which descend, in front of the ophthalmic somite, towards the conical tubercle mentioned above: it thus gives rise to an imperfect partition between the orbits.

FIG. 41.—*Astacus fluviatilis.*—The rostrum, seen from the left side.

The internal face of the sternal wall of the whole of the thorax and of the post-oral part of the head, presents a complicated arrangement of hard parts, which is known as the *endophragmal system* (figs. 39, *B*, 42, and 43), and which performs the office of an internal skeleton by affording attachment to muscles, and serving to protect important viscera, while at the same time it ties the somites together, and unites them into a solid whole. In reality, however, the curious pillars and bulkheads which enter into the composition of the endophragmal system are all

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* There are some singular marine crustacea, the *Squillidæ*, in which both the ophthalmic and the antennary somites are free and movable, while the rostrum is articulated with the tergum of the antennary somite.

mere infoldings of the cuticle, or *apodemes;* and, as such, they are shed along with the other cuticular structures during the process of ecdysis.

Without entering into unnecessary details, the general principle of the construction of the endophragmal skeleton may be stated as follows. Four apodemes are developed between every two somites, and as every apodeme is a fold of the cuticle, it follows that the anterior wall of each belongs to the somite in front, and the posterior wall to the somite behind. All four apodemes lie in the ventral half of the somite and form a single transverse series; consequently there are two nearer the middle line, which are termed the *endosternites,* and two further off, which are the *endopleurites.* The former lie at the inner, and the latter at the outer ends of the partitions or *arthrophragms* (fig. 39, A, *a, a′*, fig. 42, *aph*), between the articular cavities for the basal joints of the limbs, and they spring partly from the latter and partly from the sternum and the epimera respectively.

The endosternite (fig. 42, *ens.*) ascends vertically, with a slight inclination forwards, and its summit narrows and assumes the form of a pillar, with a flat, transversely elongated capital. The inner prolongation of the capital is called the *mesophragm* (*mph.*), the outer the *paraphragm* (*pph.*). The mesophragms of the two endosternites of a somite usually unite by a median suture, and thus form a complete arch over the sternal canal (*s.c.*), which lies between the endosternites.

The endopleurites (*en.pl.*) are also vertical plates, but they are relatively shorter, and their inner angles give off two nearly horizontal processes, one of which passes obliquely forwards (fig. 39, B, *h*, fig. 42, *h.p.*) and unites with the paraphragm of the endosternite of the somite in front, while the other, passing obliquely backwards (fig. 39, *h'*), becomes similarly connected with the endosternite of the somite behind.

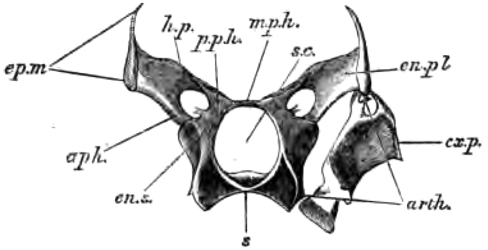

FIG. 42.—*Astacus fluviatilis.*—A segment of the endophragmal system (× 3). *aph*, arthrophragm; *arth*, arthrodial or articular cavity; *cxp*, coxopodite of the ambulatory leg; *enpl*, endopleurite; *ens*, endosternite; *epm*, epimeron; *hp*, horizontal process of endopleurite; *mph*, mesophragm; *pph*, paraphragm; *s*, sternum of somite; *sc*, sternal canal.

The endopleurites of the last thoracic somite are rudimentary, and its endosternites are small. On the other hand, the mesophragmal processes of the endosternites of the two posterior somites of the head (fig. 39, B, *c.ap*), by which the endophragmal system terminates in front, are particularly strong and closely united together. They thus, with their endopleurites, form a solid partition between the stomach, which lies upon them, and the mass of coalesced anterior thoracic and posterior cephalic ganglia situated beneath them. Strong processes are given off from their anterior and outer angles, which curve round the tendons of the adductor muscles of the mandibles, and give attachment to the abductors.

In front of the mouth there is no such endophragmal system as that which lies behind it. But the anterior gastric muscles are attached to two flat calcified plates, which appear to lie in the interior of the head (though they are really situated in its upper and front wall) on each side of the base of the rostrum, and are called the *procephalic processes* (figs. 40, 43, *p.cp*). Each of these plates constitutes the posterior wall of a narrow cavity which opens externally into the roof of the orbit, and has been regarded (though, as it appears to me, without sufficient reason) as an olfactory organ. I am disposed to think, though I have not been able to obtain complete evidence of the fact, that the procephalic processes are the representatives of the "procephalic lobes" which terminate the anterior end of the body in the embryo crayfish. At any rate, they occupy the same position relatively to the eyes and to the carapace; and the hidden position of these processes, in the adult, appears to arise from the extension of the carapace at the base of the rostrum over the fore part of the originally free sternal surface of the head. It has thus covered over the procephalic processes, in which the sternal wall of the body terminated; and the cavities which lie in front of them are simply the interspaces left between the inferior or posterior wall of the prolongation of the carapace and the originally exposed external faces of these regions of the cephalic integument.

Fourteen somites having thus been distinguished in the cephalothorax, and six being obvious in the abdomen, it is clear that there is a somite for every pair of appendages. And, if we suppose the carapace divided into segments answering to these sterna, the whole body will be made up of twenty somites, each having a pair of appendages. As the carapace, however, is not actually divided into terga in correspondence with the sterna which it covers, all we can safely conclude from the anatomical facts is that it represents the tergal region of the somites, not that it is formed by the coalescence of primarily distinct terga. In the head, and in the greater part of the thorax, the somites are, as it were, run together, but the last thoracic somite is partly free and to a slight extent moveable, while the abdominal somites are all free, and moveably articulated together. At the anterior end of the body, and, apparently, from the antennary somite, the tergal region gives rise to the rostrum, which projects between and beyond the eyes. At the opposite extremity, the telson is a corresponding median outgrowth of the last somite, which has become moveably articulated therewith. The narrowing of the sternal moieties of the anterior thoracic somites, together with the sudden widening of the same parts in the posterior cephalic somites, gives rise to the lateral depression (fig. 39, *cf*) in which the scaphognathite lies. The limit thus indicated corresponds with that marked by the cervical groove upon the surface of the carapace, and separates the head from the thorax. The three pair of maxillipedes (*7, 8, 9*), the forceps (*10*), the ambulatory

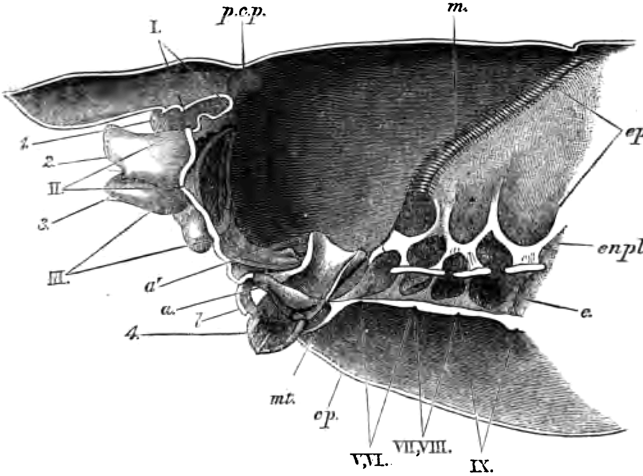

FIG. 43.—*Astacus fluviatilis.*—Longitudinal section of the anterior part of the cephalothorax (× 3). *I—IX*, sterna of first nine cephalothoracic somites; *1*, eyestalk ; *2*, basal joint of antennule ; *3*, basal joint of antenna ; *4*, mandible; *a*, inner division of the masticatory surface of the mandible ; *a'*, apophysis of the mandible for muscular attachment; *cp*, free edge of carapace ; *e*, endosternite ; *enpl*, endopleurite ; *epm*, epimeral plate; *l*, labrum ; *m*, muscular fibres connecting epimera with interior of carapace; *mt*, metastoma ; *pcp.* procephalic process.

limbs (*11—14*), and the eight somites of which they are the appendages (*VII—XIV*), lie behind this boundary and belong to the thorax. The two pairs of maxillæ (*5*, *6*) the mandibles (*4*), the antennæ (*3*), the antennules (*2*), the eyestalks (*1*), and the six somites to which they are attached (*I—VI*), lie in front of the boundary and compose the head.

Another important point to be noticed is that, in front of the mouth, the sternum of the antennary somite (fig. 43, *III*) is inclined at an angle of 60° or 70° to the direction of the sterna behind the mouth. The sternum of the antennulary somite (*II*) is at right angles to the latter; and that of the eyes (*I*) looks upwards as well as forwards. Hence, the front of the head beneath the rostrum, though it looks forwards, or even upwards, is homologous with the sternal aspect of the other somites. It is for this reason that the feelers and the eyestalks take a direction so different from that of the other appendages. The change of aspect of the sternal surface in front of the mouth, thus effected, is what is termed the *cephalic flexure.*

Since the skeleton which invests the trunk of the crayfish is made up of a twenty-fold repetition of somites, homologous with those of the abdomen, we may expect to find that the appendages of the thorax and of the head, however unlike they may seem to be to those of the abdomen, are nevertheless reducible to the same fundamental plan.

The third maxillipede is one of the most complete of these appendages, and may be advantageously made the starting point of the study of the whole series.

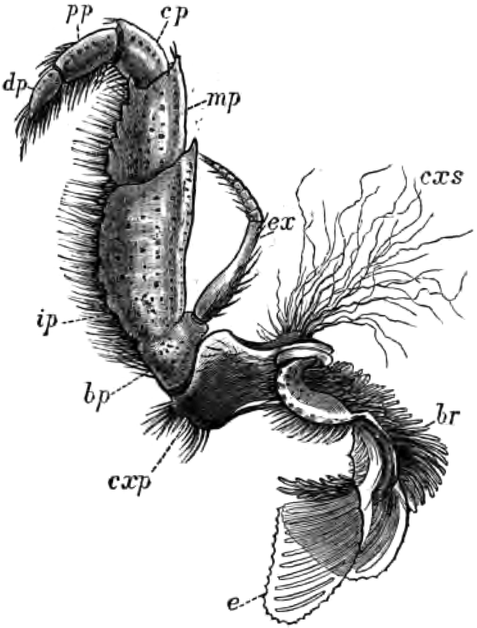

FIG. 44.—*Astacus fluviatilis.*—The third or external maxillipede of the left side (× 3). *e*, lamina, and *br*, branchial filaments of the podobranchia ; *cxp*, coxopodite ; *cxs*, coxopoditic setæ ; *bp*, basipodite ; *ex*, exopodite ; *ip*, ischiopodite ; *mp*, meropodite ; *cp*, carpopodite ; *pp*, propodite ; *dp*, dactylopodite.

Neglecting details for the moment, it may be said that the appendage consists of a basal portion (fig. 44, *cxp, bp*), with two terminal divisions (*ip* to *dp*, and *ex*), which are directed forwards, below the mouth, and a third, lateral appendage (*e*, *br*), which runs up, beneath the carapace, into the branchial chamber. The latter is the gill, or podobranchia, attached to this limb, and it is something not represented in the abdominal limbs. But, with regard to the rest of the maxillipede, it is obvious that the basal portion (*cxp*, *bp*) represents the protopodite, and the two terminal divisions the endopodite and the exopodite respectively. It has been observed that, in the abdominal appendages, the extent to which segmentation occurs in homologous parts varies indefinitely; an endopodite, for example, may be a continuous plate, or may be subdivided into many joints. In the maxillipede, the basal portion is divided into two joints; and, as in the abdominal limb, the first, or that which articulates with the thorax, is termed the *coxopodite* (*cxp*), while the second is the *basipodite* (*bp*). The stout, leg-like endopodite appears to be the direct continuation of the basipodite; while the much more narrow and slender exopodite articulates with its outer side. The exopodite (*ex*) is by no means unlike one of the exopodites of the abdominal limbs, consisting as it does of an undivided base and a many-jointed terminal filament. The endopodite, on the contrary, is strong and massive, and is divided into five joints, named, from that nearest to the base onwards, *ischiopodite* (*ip*), *meropodite* (*mp*), *carpopodite* (*cp*), *propodite* (*pp*), and *dactylopodite* (*dp*).

The second maxillipede (fig. 45, B) has essentially the same composition as the first, but the exopodite (*ex*) is relatively larger, the endopodite (*ip—dp*) smaller and softer; and, while the ischiopodite (*ip*) is the longest joint in the third maxillipede, it is the meropodite (*mp*) which is longest in the second. In the first maxillipede (fig. 45, A) a great modification has taken place. The coxopodite (*cxp*) and the basipodite (*bp*) are broad thin plates with setose cutting edges, while the endopodite (*en*) is short and only two-jointed, and the undivided portion of the exopodite (*ex*) is very long. The place of

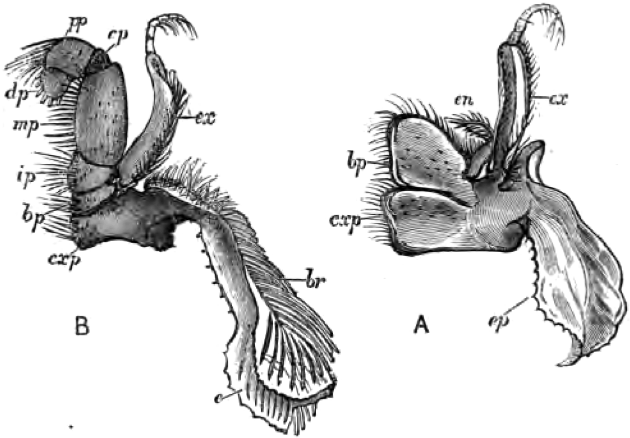

Fig. 45.—*Astacus fluviatilis.*—A, the first; B, the second maxillipede of the left side (× 3). *cxp*, coxopodite; *bp*, basipodite; *e*, *br*, podobranchia; *ep*, epipodite; *en*, endopodite; *ex*, exopodite; *ip*, ischiopodite; *mp*, meropodite; *cp*, carpopodite; *pp*, propodite; *dp*, dactylopodite.

the podobranchia is taken by a broad soft membranous plate entirely devoid of branchial filaments (*ep*). Thus, in the series of the thoracic limbs, on passing forwards from the third maxillipede, we find that though the plan of the appendages remains the same; (1) the protopodite increases in relative size; (2) the endopodite diminishes; (3) the exopodite increases; (4) the podobranchia finally takes the form of a broad membranous plate and loses its branchial filaments.

Writers on descriptive Zoology usually refer to the parts of the maxillipedes under different names from those which are employed here. The protopodite and the endopodite taken together are commonly called the *stem* of the maxillipede, while the exopodite is the *palp*, and the metamorphosed podobranchia, the real nature of which is not recognised, is termed the *flagellum*.

When the comparison of the maxillipedes with the abdominal members, however, had shown the fundamental uniformity of composition of the two, it became desirable to invent a nomenclature of the homologous parts which should be capable of a general application. The names of protopodite, endopodite, exopodite, which I have adopted as the equivalents of the "stem" and the "palp," were proposed by Milne-Edwards, who at the same time suggested *epipodite* for the "flagellum." And the lamellar process of the first maxillipede is now very generally termed an epipodite; while the podobranchiæ, which have exactly the same relations to the following limbs, are spoken of as if they were totally different structures, under the name of branchiæ or gills.

The flagellum or epipodite of the first maxillipede, however, is nothing but the slightly modified stem of a podobranchia, which has lost its branchial filaments; but the term "epipodite" may be conveniently used for podobranchiæ thus modified. Unfortunately, the same term is applied to certain lamelliform portions of the branchiæ of other crustacea, which answer to the laminæ of the crayfishes' branchiæ; and this ambiguity must be borne in mind, though it is of no great moment.

On examining an appendage from that part of the thorax which lies behind the third maxillipede, say, for example, the sixth thoracic limb (the second walking leg) (fig. 46), the two joints of the protopodite and the five joints of the endopodite are at once identifiable, and so is the podobranchia; but the exopodite has vanished altogether. In the eighth, or last, thoracic limb, the podobranchia has also disappeared. The fifth and sixth limbs also differ from the seventh and eighth, in being chelate; that is to say, one angle of the distal end of the propodite is prolonged and forms the fixed leg of the pincer. The produced angle is that which is turned downwards when the limb is fully extended (fig. 46). In the forceps, the great chela is formed in just the same way; the only important difference lies in the fact that, as in the external maxillipede, the basipodite and the ischiopodite are immoveably united. Thus,

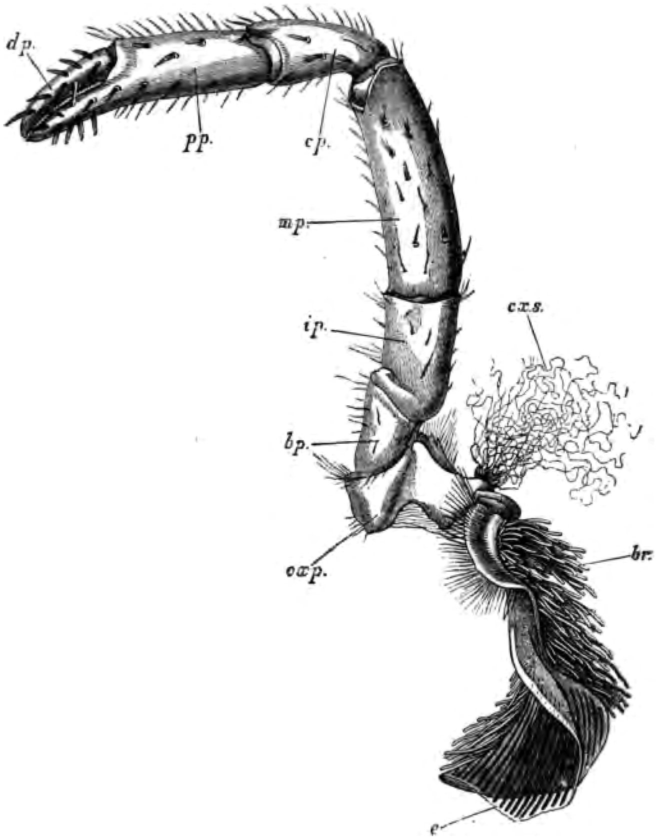

FIG. 46.—*Astacus fluviatilis.*—The second ambulatory leg of the left side (× 3). *cxp*, coxopodite; *bp*, basipodite; *br*, gill; *cxs*, coxopoditic setæ; *e*, lamina of gill or epipodite; *ip*, ischiopodite; *mp*, meropodite; *cp*, carpopodite; *pp*, propodite; *dp*, dactylopodite.

the limbs of the thorax are all reducible to the same type as those of the abdomen, if we suppose that, in the posterior five pair, the exopodites are suppressed; and that, in all but the last, podobranchiæ are superadded.

Turning to the appendages of the head, the second maxilla (fig. 47, C) presents a further modification of the disposition of the parts seen in the first maxillipede. The coxopodite (*cxp*) and the basipodite (*bp*) are still thinner and more lamellar, and are subdivided by deep fissures which extend from their inner edges. The endopodite (*en*) is very small and undivided. In the place of the exopodite and the epipodite there is only one great plate, the scaphognathite (*sg*) which either is such an epipodite as that of the first maxillipede with its anterior basal process much enlarged, or represents both the exopodite and the epipodite. In the first maxilla (B), the exopodite and the epipodite have disappeared, and the endopodite (*en*) is insignificant and unjointed. In the mandibles (A), the representative of the protopodite is strong and transversely elongated. Its broad inner or oral end presents a semicircular masticatory surface divided by a deep longitudinal groove into two toothed ridges. The one of these follows the convex anterior or inferior contour of the masticatory surface, projects far beyond the other, and is provided with a sharp serrated edge; the other (fig. 43, *a*) gives rise to the straight posterior or superior contour of the masticatory surface, and is more obtusely tuberculated. In front, the inner ridge is continued into a process by which the mandible articulates with the epistoma (fig. 47, A, *ar*). The endopodite is represented by the three-jointed *palp* (*p*), the terminal joint of which is oval and beset with numerous strong setæ, which are especially abundant along its anterior edge.

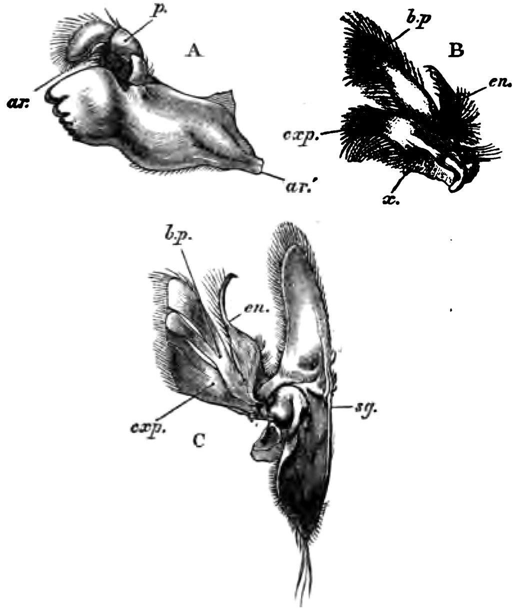

FIG. 47.—*Astacus fluviatilis*—A, mandible ; B, first maxilla ; C, second maxilla of the left side (× 3). *ar*, internal, and *ar′*, external articular process of the mandible ; *bp*, basipodite ; *cxp*, coxopodite ; *en*, endopodite ; *p*, palp of the mandible ; *sg*, scaphognathite ; *x*, internal process of the first maxilla.

In the antenna (fig. 48, C) the protopodite is two-jointed. The basal segment is small, and its ventral face presents the conical prominence on the posterior aspect of which is the aperture of the duct of the renal gland (*gg*). The terminal segment is larger and is subdivided by deep longitudinal folds, one upon the dorsal and one upon the ventral face, into two moieties which are more or less moveable upon one another. In front and externally it bears the broad flat *squame* (*exp*) of the antenna, as an exopodite. Internally, the long annulated " feeler " which represents the endopodite, is connected with it by two stout basal segments.

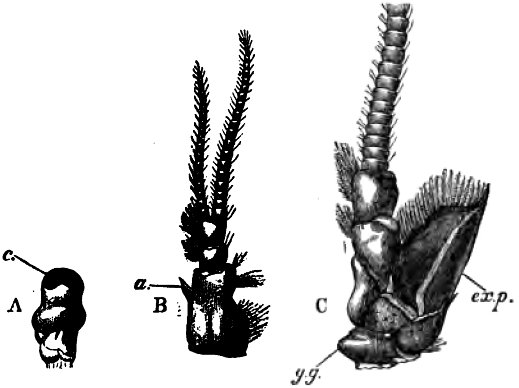

FIG. 48.—*Astacus fluviatilis.*—A, eye-stalk ; B, antennule ; C, antenna of the left side (× 3). *a*, spine of the basal joint of the antennule ; *c*, corneal surface of the eye ; *exp*, exopodite or squame of the antenna ; *gg*, aperture of the duct of the green gland.

The antennule (fig. 48, B) has a three-jointed stem and two terminal annulated filaments, the outer of which is thicker and longer than the inner, and lies rather above as well as external to the latter. The peculiar form of the basal segment of the stem of the antennule has already been adverted to (p. 116). It is longer than the other two segments put together, and near the anterior end its sternal edge is produced into a single strong spine (*a*). The stem of the antennule answers to the protopodite of the other limbs, though its division into three joints is unusual; the two terminal annulated filaments represent the endopodite and the exopodite.

Finally, the eyestalk (A) has just the same structure as the protopodite of an abdominal limb, having a short basal and a long cylindrical terminal joint.

From this brief statement of the characters of the appendages, it is clear that, in whatever sense it is allowable to say that the appendages of the abdomen are constructed upon one plan, which is modified in execution by the excess of development of one part over another, or by the suppression of parts, or by the coalescence of one part with another, it is allowable to say that all the appendages are constructed on the same plan, and are modified on similar principles. Given a general type of appendage consisting of a protopodite, bearing a podobranchia, an endopodite and an exopodite, all the actual appendages are readily derivable from that type.

In addition, therefore, to their adaptation to the purposes which they subserve, the parts of the skeleton of the crayfish show a unity in diversity, such as, if the animal were a piece of human workmanship, would lead us to suppose that the artificer was under an obligation not merely to make a machine capable of doing certain kinds of work, but to subordinate the nature and arrangement of the mechanism to certain fixed architectural conditions.

The lesson thus taught by the skeletal organs is reiterated and enforced by the study of the nervous and the muscular systems. As the skeleton of the whole body is capable of resolution into the skeletons of twenty separate metameres, variously modified and combined; so is the entire ganglionic chain resolvable into twenty pairs of ganglia various in size, distant in this region and approximated in that; and so is the muscular system of the trunk conceivable as the sum of twenty *myotomes* or segments of the muscular system appropriate to a metamere, variously modified according to the degree of mobility of the different regions of the organism.

The building up of the body by the repetition and the modification of a few similar parts, which is so obvious from the study of the general form of the somites and of their appendages, is still more remarkably illustrated, if we pursue our investigations further, and trace out the more intimate structure of these parts. The tough, outer coat, which has been termed the *cuticula*, except so far as it presents different degrees of hardness, from the presence or absence of calcareous salts, is obviously everywhere of the same nature; and, by macerating a crayfish in caustic alkali, which destroys all its other components of the body, it will be readily enough seen that a continuation of the cuticular layer passes in at the mouth and the vent, and lines the alimentary canal; furthermore, that processes of the cuticle covering various parts of the trunk and limbs extend inwards, and afford surfaces of attachment to the muscles, as the *apodemata* and *tendons*. In technical language, the cuticular substance which thus enters so largely into the composition of the bodily fabric of the crayfish is called a *tissue*.

The flesh, or *muscle*, is another kind of tissue, which is readily enough distinguished from cuticular tissue by the naked eye; but, for a complete discrimination of all the different tissues, recourse must be had to the microscope, the application of which to the study of the ultimate optical characters of the morphological constituents of the body has given rise to that branch of morphology which is known as *Histology*.

If we count every formed element of the body, which is separable from the rest by definite characters, as a tissue, there are no more than eight kinds of such tissues in the crayfish; that is to say, every solid constituent of the body consists of one or more of the following eight histological groups:—

1. Blood corpuscles; 2. Epithelium; 3. Connective tissue; 4. Muscle; 5. Nerve; 6. Ova; 7. Spermatozoa; 8. Cuticle.

1. A drop of freshly-drawn blood of the crayfish contains multitudes of small particles, the *blood corpuscles*,

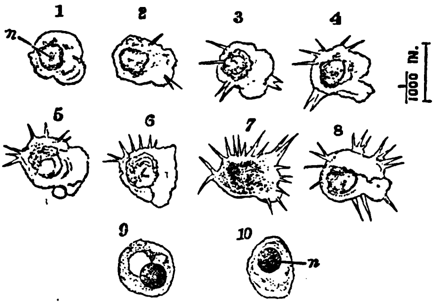

FIG. 49.—*Astacus fluviatilis.*—The corpuscles of the blood, highly magnified. *1*—*8*, show the changes undergone by a single corpuscle during a quarter of an hour; *n*, the nucleus; *9* and *10* are corpuscles killed by magenta, and having the nucleus deeply stained by the colouring matter.

which rarely exceed 1-700th, and usually are about 1-1000th, of an inch in diameter (fig. 49). They are sometimes pale and delicate, but generally more or less dark, from containing a number of minute strongly refracting granules, and they are ordinarily exceedingly irregular in form. If one of them is watched continuously for two or three minutes, its shape will be seen to undergo the constant but slow changes to which passing reference has already been made (p. 69). One or other of the irregular prolongations will be drawn in, and another thrown out elsewhere. The corpuscle, in fact, has an inherent contractility, like one of those low organisms, known as an *Amœba,* whence its motions are frequently called *amœbiform.* In its interior, an ill-marked oval contour may be seen, indicating the presence of a spheroidal body, about 1-2000th of an inch in diameter, which is the nucleus of the corpuscle (*n*). The addition of some re-agents, such as dilute acetic acid, causes the corpuscles at once to assume a spherical shape, and renders the nucleus very conspicuous (fig. 49, *9* and *10*). The blood corpuscle is, in fact, a simple nucleated cell, composed of a contractile protoplasmic mass, investing a nucleus ; it is suspended freely in the blood; and, though as much a part of the crayfish organism as any other of its histological elements, leads a quasi-independent existence in that fluid.

2. Under the general name of *epithelium,* may be included a form of tissue, which everywhere underlies the exoskeleton (where it corresponds with the epidermis of the higher animals), and the cuticular lining of the alimentary canal, extending thence into the hepatic cæca. It is further met with in the generative organs, and in the green gland. Where it forms the subcuticular layer of the integument and of the alimentary canal, it is found to

consist of a protoplasmic substance (fig. 50), in which close set nuclei (*n*) are imbedded. If a number of blood corpuscles could be supposed to be closely aggregated together into a continuous sheet, they would give rise to such a structure as this; and there can be no doubt that it really is an aggregate of nucleated cells, though the limits between the individual cells are rarely visible in the fresh state. In the liver, however, the cells grow, and become detached from one another in the wider and lower parts of the cæca, and their essential nature is thus obvious.

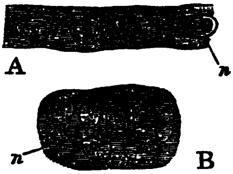

FIG. 50.—*Astacus fluviatilis.*—Epithelium, from the epidermic layer subjacent to the cuticle, highly magnified. *A*, in vertical section; *B*, from the surface. *n*, nuclei.

3. Immediately beneath the epithelial layer follows a tissue, disposed in bands or sheets, which extend to the subjacent parts, invest them, and connect one with another. Hence this is called *connective tissue.*

The connective tissue presents itself under three forms. In the first there is a transparent homogeneous-looking matrix, or ground substance, through which are scattered many nuclei. In fact, this form of connective tissue very closely resembles the epithelial tissue, except that the intervals between the nuclei are wider, and that the substance in which they are imbedded cannot be broken up into a separate cell-body for each nucleus. In the second form (fig. 51, *A*) the matrix exhibits fine wavy parallel lines, as if it were marked out into imperfect fibres. In this form, as in the next to be described, more or less spherical cavities, which contain a clear fluid, are excavated in the matrix; and the number of

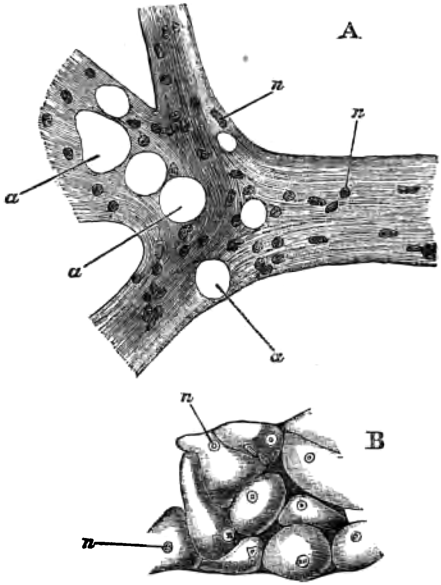

FIG. 51.—*Astacus fluviatilis.*—Connective tissue; *A*, second form; *B*, third form. *a*, cavities; *n*, nuclei. Highly magnified.

these is sometimes so great, that the matrix is proportionally very much reduced, and the structure acquires a close superficial similarity to that of the parenchyma of plants. This is still more the case with a third form, in which the matrix itself is marked off into elongated or rounded masses, each of which has a nucleus in its interior (fig. 51, *B*). Under one form or another, the connective tissue extends throughout the body, ensheathing the various organs, and forming the walls of the blood sinuses.

The third form is particularly abundant in the outer investment of the heart, the arteries, the alimentary canal, and the nervous centres. About the cerebral and anterior thoracic ganglia, and on the exterior of the heart, it usually contains more or less fatty matter. In these regions, many of the nuclei, in fact, are hidden by the accumulation round them of granules of various sizes, some of which are composed of fat, while others consist of a proteinaceous material. These aggregates of granules are usually spheroidal; and, with the matrix in which they are imbedded and the nucleus which they surround, they are often readily detached when a portion of the connective tissue is teased out, and are then known as *fat cells.* From what has been said respecting the distribution of the connective tissue, it is obvious that if all the other tissues could be removed, this tissue would form a continuous whole, and represent a sort of model, or cast, of the whole body of the crayfish.