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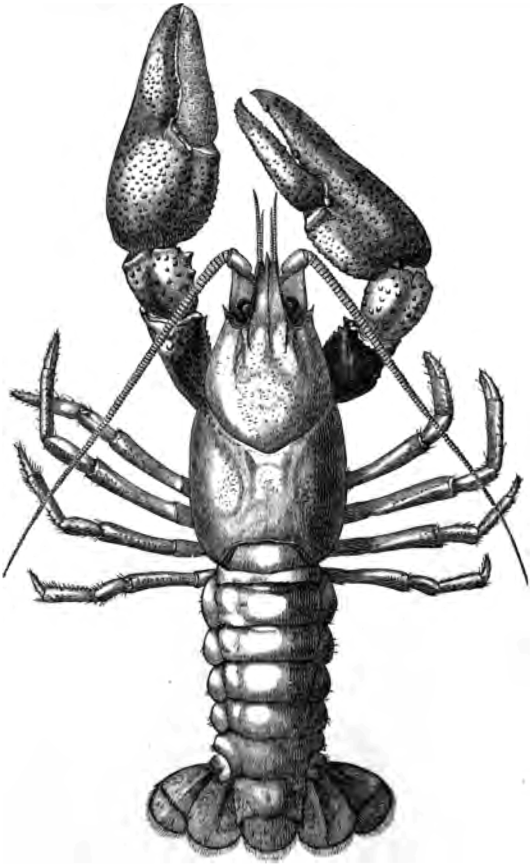

THE COMMON CRAYFISH.

(*Astacus fluviatilis*, Male.)

Frontispiece.]

THE CRAYFISH

AN INTRODUCTION TO
THE STUDY OF ZOOLOGY

BY

T. H. HUXLEY, F.R.S.

WITH EIGHTY-TWO ILLUSTRATIONS

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"Διὸ δεῖ μὴ δυσχεραίνειν παιδικῶς τὴν περὶ τῶν ἀτιμοτέρων ζώων ἐπίσκεψιν· ἐν πᾶσι γάρ τοῖς φυσικοῖς ἔνεστί τι θαυμαστόν."—ARISTOTLE, *De Partibus*, I. 5.

"Qui enim Autorum verba legentes, rerum ipsarum imagines (eorum verbis comprehensa) sensibus propriis non abstrahunt, hi non veras Ideas, sed falsa Idola et phantasmata inania mente concipiunt . . . .

"Insusurro itaque in aurem tibi (amice Lector !) ut quæcunque à nobis in hisce . . . . exercitationibus tractabuntur, ad exactam experientiæ trutinam pensites: fidemque iis non aliter adhibeas, nisi quatenus eadem indubitato sensuum testimonio firmissime stab liri deprehenderis."—HARVEY. *Exercitationes de Generatione. Præfatio.*

"La seule et vraie Science est la connaissance des faits: l'esprit ne peut pas y suppléer et les faits sont dans les sciences ce qu'est l'expérience dans la vie civile."

"Le seul et le vrai moyen d'avancer la science est de travailler à la description et à l'histoire des differentes choses qui en font l'objet." — BUFFON. *Discours de la manière d'étudier et de traiter l'Histoire Naturelle.*

"Ebenso hat mich auch die genäuere Untersuchung unsers Krebses gelehret, dass, so gemein und geringschätzig solcher auch den meisten zu seyn scheinet, sich an selbigem doch so viel Wunderbares findet, dass es auch den grossten Naturforscher schwer fallen sollte solches alles deutlich zu beschreiben."—ROESEL V. ROSENHOF. *Insecten Belustigungen.—"Der Flusskrebs hiesiges Landes mit seinen merkwurdigen Eigenschaften."*

PREFACE.

In writing this book about Crayfishes it has not been my intention to compose a zoological monograph on that group of animals. Such a work, to be worthy of the name, would require the devotion of years of patient study to a mass of materials collected from many parts of the world. Nor has it been my ambition to write a treatise upon our English crayfish, which should in any way provoke comparison with the memorable labours of Lyonet, Bojanus, or Strauss Durckheim, upon the willow caterpillar, the tortoise, and the cockchafer. What I have had in view is a much humbler, though perhaps, in the present state of science, not less useful object. I have desired, in fact, to show how the careful study of one of the commonest and most insignificant of animals, leads us, step by step, from every-day knowledge to the widest generalizations and the most difficult problems of zoology; and, indeed, of biological science in general.

It is for this reason that I have termed the book an "Introduction to Zoology." For, whoever will follow its pages, crayfish in hand, and will try to verify for himself the statements which it contains, will find himself brought face to face with all the great zoological questions which excite so lively an interest at the present day; he will understand the method by which alone we can hope to attain to satisfactory answers of these questions; and, finally, he will appreciate the justice of Diderot's remark, "Il faut être profond dans l'art ou dans la science pour en bien posséder les éléments."

And these benefits will accrue to the student whatever shortcomings and errors in the work itself may be made apparent by the process of verification. "Common and lowly as most may think the crayfish," well says Roesel von Rosenhof, "it is yet so full of wonders that the greatest naturalist may be puzzled to give a clear account of it." But only the broad facts of the case are of fundamental importance; and, so far as these are concerned, I venture to hope that no error has slipped into my statement of them. As for the details, it must be remembered, not only that some omission or mistake is almost unavoidable, but that new lights come with new methods of investigation; and that better modes of statement follow upon the improvement of our general views introduced by the gradual widening of our knowledge.

I sincerely hope that such amplifications and rectifications may speedily abound; and that this sketch may be the means of directing the attention of observers in all parts of the world to the crayfishes. Combined efforts will soon furnish the answers to many questions which a single worker can merely state; and, by completing the history of one group of animals, secure the foundation of the whole of biological science.

In the Appendix, I have added a few notes respecting points of detail with which I thought it unnecessary to burden the text; and, under the head of Bibliography, I have given some references to the literature of the subject which may be useful to those who wish to follow it out more fully.

I am indebted to Mr. T. J. Parker, demonstrator of my biological class, for several anatomical drawings; and for valuable aid in supervising the execution of the woodcuts, and in seeing the work through the press.

Mr. Cooper has had charge of the illustrations, and I am indebted to him and to Mr. Coombs, the accurate and skilful draughtsman to whom the more difficult subjects were entrusted, for such excellent specimens of xylographic art as the figures of the Crab, Lobster, Rock Lobster, and Norway Lobster.

T. H. H.

LONDON,
November, 1879.

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THE CRAYFISH:

AN INTRODUCTION TO THE STUDY OF ZOOLOGY.

CHAPTER I.

THE NATURAL HISTORY OF THE COMMON CRAYFISH

(*Astacus fluviatilis.*)

MANY persons seem to believe that what is termed Science is of a widely different nature from ordinary knowledge, and that the methods by which scientific truths are ascertained involve mental operations of a recondite and mysterious nature, comprehensible only by the initiated, and as distinct in their character as in their subject matter, from the processes by which we discriminate between fact and fancy in ordinary life.

But any one who looks into the matter attentively will soon perceive that there is no solid foundation for the belief that the realm of science is thus shut off from that of common sense; or that the mode of investigation which yields such wonderful results to the scientific investigator, is different in kind from that which is employed for the commonest purposes of everyday existence. Common sense is science exactly in so far as it fulfils the ideal of common sense; that is, sees facts as they are, or, at any rate, without the distortion of prejudice, and reasons from them in accordance with the dictates of sound judgment. And science is simply common sense at its best; that is, rigidly accurate in observation, and merciless to fallacy in logic.

Whoso will question the validity of the conclusions of sound science, must be prepared to carry his scepticism a long way; for it may be safely affirmed, that there is hardly any of those decisions of common sense on which men stake their all in practical life, which can justify itself so thoroughly on common sense principles, as the broad truths of science can be justified.

The conclusion drawn from due consideration of the nature of the case is verified by historical inquiry; and the historian of every science traces back its roots to the primary stock of common information possessed by all mankind.

In its earliest development knowledge is self-sown. Impressions force themselves upon men's senses whether they will or not, and often against their will. The amount of interest which these impressions awaken is determined by the coarser pains and pleasures which they carry in their train, or by mere curiosity; and reason deals with the materials supplied to it as far as that interest carries it, and no farther. Such common knowledge is rather brought than sought; and such ratiocination is little more than the working of a blind intellectual instinct.

It is only when the mind passes beyond this condition that it begins to evolve science. When simple curiosity passes into the love of knowledge as such, and the gratification of the æsthetic sense of the beauty of completeness and accuracy seems more desirable than the easy indolence of ignorance; when the finding out of the causes of things becomes a source of joy, and he is counted happy who is successful in the search; common knowledge of nature passes into what our forefathers called Natural History, from whence there is but a step to that which used to be termed Natural Philosophy, and now passes by the name of Physical Science.

In this final stage of knowledge, the phenomena of nature are regarded as one continuous series of causes and effects; and the ultimate object of science is to trace out that series, from the term which is nearest to us, to that which is at the furthest limit accessible to our means of investigation.

The course of nature as it is, as it has been, and as it will be, is the object of scientific inquiry; whatever lies beyond, above, or below this, is outside science. But the philosopher need not despair at the limitation of his field of labour: in relation to the human mind Nature is boundless; and, though nowhere inaccessible, she is everywhere unfathomable.

The Biological Sciences embody the great multitude of truths which have been ascertained respecting living beings; and as there are two chief kinds of living things, animals and plants, so Biology is, for convenience sake, divided into two main branches, Zoology and Botany.

Each of these branches of Biology has passed through the three stages of development, which are common to all the sciences; and, at the present time, each is in these different stages in different minds. Every country boy possesses more or less information respecting the plants and animals which come under his notice, in the stage of common knowledge; a good many persons have acquired more or less of that accurate, but necessarily incomplete and unmethodised knowledge, which is understood by Natural History; while a few have reached the purely scientific stage, and, as Zoologists and Botanists, strive towards the perfection of Biology as a branch of Physical Science.

Historically, common knowledge is represented by the allusions to animals and plants in ancient literature; while Natural History, more or less grading into Biology, meets us in the works of Aristotle, and his continuators in the Middle Ages, Rondoletius, Aldrovandus, and their contemporaries and successors. But the conscious attempt to construct a complete science of Biology hardly dates further back than Treviranus and Lamarck, at the beginning of this century, while it has received its strongest impulse, in our own day, from Darwin.

My purpose, in the present work, is to exemplify the general truths respecting the development of zoological science which have just been stated by the study of a special case; and, to this end, I have selected an animal, the Common Crayfish, which, taking it altogether, is better fitted for my purpose than any other.

It is readily obtained,* and all the most important points of its construction are easily deciphered; hence, those who read what follows will have no difficulty in ascertaining whether the statements correspond with facts or not. And unless my readers are prepared to take this much trouble, they may almost as well shut the book; for nothing is truer than Harvey's dictum, that those who read without acquiring distinct images of the things about which they read, by the help of their own senses, gather no real knowledge, but conceive mere phantoms and idola.

It is a matter of common information that a number of our streams and rivulets harbour small animals, rarely more than three or four inches long, which are very similar to little lobsters, except that they are usually of a dull, greenish or brownish colour, generally diversified with pale yellow on the under side of the body, and sometimes with red on the limbs. In rare cases, their

* If crayfish are not to be had, a lobster will be found to answer to the description of the former, in almost all points; but the gills and the abdominal appendages present differences; and the last thoracic somite is united with the rest in the lobster. (*See* Chap. V.)

general hue may be red or blue. These are "crayfishes," and they cannot possibly be mistaken for any other inhabitants of our fresh waters.

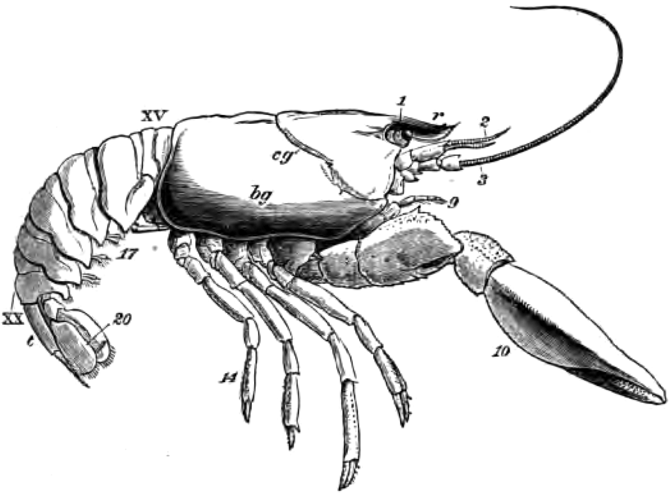

FIG. 1.—*Astacus fluviatilis.*—Side view of a male specimen (nat. size):—*bg*, branchiostegite; *cg*, cervical groove; *r*, rostrum; *t*, telson.—1, eye-stalk; 2, antennule; 3, antenna; 9, external maxillipede; 10, forceps; 14, last ambulatory leg; 17, third abdominal appendage; 20, lateral lobe of the tail-fin, or sixth abdominal appendage; XV, the first; and XX, the last abdominal somite. In this and in succeeding figures the numbers of the somites are given in Roman, those of the appendages in ordinary numerals.

The animals may be seen walking along the bottom of the shallow waters which they prefer, by means of four pairs of jointed legs (fig. 1); but, if alarmed, they swim backwards with rapid jerks, propelled by the strokes of a broad, fan-shaped flipper, which terminates the hinder end of the body (fig. 1, *t*, *20*). In front of the four pairs of legs, which are used in walking, there is a pair of limbs of a much more massive character, each of which ends in two claws disposed in such a manner as to constitute a powerful pincer (fig. 1; *10*). These claws are the chief weapons of offence and defence of the crayfish, and those who handle them incautiously will discover that their grip is by no means to be despised, and indicates a good deal of disposable energy. A sort of shield covers the front part of the body, and ends in a sharp projecting spine in the middle line (*r*). On each side of this is an eye, mounted on a movable stalk (*1*), which can be turned in any direction: behind the eyes follow two pairs of feelers; in one of these, the feeler ends in two, short, jointed filaments (*2*); while, in the other, it terminates in a single, many-jointed filament, like a whip-lash, which is more than half the length of the body (*3*). Sometimes turned backwards, sometimes sweeping forwards, these long feelers continually explore a considerable area around the body of the crayfish.

If a number of crayfishes, of about the same size, are compared together, it will easily be seen that they fall into two sets; the jointed tail being much broader, especially in the middle, in the one set than in the other (fig. 2). The broad-tailed crayfishes are the females, the others the males. And the latter may be still more easily known by the possession of four curved styles, attached to the under face of the first two rings of the tail, which are turned forwards between the hinder legs, on the under side of the body (fig. 3, A; *15, 16*). In the female, there are mere soft filaments in the place of the first pair of styles (fig. 3, B; *15*).

Crayfishes do not inhabit every British river, and even where they are known to abound, it is not easy to find them at all times of the year. In granite districts and others, in which the soil yields little or no calcareous matter to the waters which flow over it, crayfishes do not occur. They are intolerant of great heat and of much sunshine; they are therefore most active towards the evening, while they shelter themselves under the shade of stones and banks during the day. It has been observed that they frequent those parts of a river which run north and south, less than those which have an easterly and westerly direction, inasmuch as the latter yield more shade from the mid-day sun.

During the depth of winter, crayfishes are rarely to be seen about in a stream; but they may be found in abundance in its banks, in natural crevices and in burrows which they dig for themselves. The burrows may be from a few inches to more than a yard deep, and it has been noticed that, if the waters are liable to freeze, the burrows are deeper and further from the surface than otherwise. Where the soil, through which a stream haunted by crayfishes runs, is soft and peaty, the crayfishes work their way into it in all directions, and thousands of them, of all sizes, may be dug out, even at a considerable distance from the banks.

It does not appear that crayfishes fall into a state of torpor in the winter, and thus "hybernate" in the strict sense of the word. At any rate, so long as the weather is open, the crayfish lies at the mouth of his burrow, barring the entrance with his great claws, and with protruded feelers keeps careful watch on the passers-by. Larvæ of insects, water-snails, tadpoles, or frogs, which come within reach, are suddenly seized and devoured, and it is averred that the water-rat is liable to the same fate. Passing too near the fatal den, possibly in search of a stray crayfish, whose flavour he highly appreciates, the vole is himself seized and held till he is suffocated, when his captor easily reverses the conditions of the anticipated meal.

In fact, few things in the way of food are amiss to the crayfish; living or dead, fresh or carrion, animal or vegetable, it is all one. Calcareous plants, such as the stoneworts (*Chara*), are highly acceptable; so are any kinds of succulent roots, such as carrots; and it is said that crayfish sometimes make short excursions inland, in search of vegetable food. Snails are devoured, shells and all; the cast coats of other crayfish are turned to account as supplies of needful calcareous matter; and the unprotected or weakly member of the family is not spared. Crayfishes, in fact, are guilty of cannibalism in its worst form; and a French observer pathetically remarks, that, under certain circumstances, the males "*méconnaissent les plus saints devoirs;*" and, not content with mutilating or killing their spouses, after the fashion of animals of higher moral pretensions, they descend to the lowest depths of utilitarian turpitude, and finish by eating them.

In the depth of winter, however, the most alert of crayfish can find little enough food; and hence, when they emerge from their hiding-places in the first warm days of spring, usually about March, the crayfishes are in poor condition.

At this time, the females are found to be laden with eggs, of which from one to two hundred are attached beneath the tail, and look like a mass of minute berries (fig. 3, B). In May or June, these eggs are hatched, and give rise to minute young, which are sometimes to be found attached beneath the tail of the mother, under whose protection they spend the first few days of their existence.

In this country, we do not set much store upon crayfishes as an article of food, but on the Continent, and especially in France, they are in great request. Paris alone, with its two millions of inhabitants, consumes annually from five to six millions of crayfishes, and pays about £16,000 for them. The natural productivity of the rivers of France has long been inadequate to supply the demand for these delicacies; and hence, not only are large quantities imported from Germany, and elsewhere, but the artificial cultivation of crayfish has been successfully attempted on a considerable scale.

Crayfishes are caught in various ways; sometimes the fisherman simply wades in the water and drags them out of their burrows; more commonly, hoop-nets baited with frogs are let down into the water and rapidly drawn up, when there is reason to think that crayfish have been attracted to the bait; or fires are lighted on the banks at night, and the crayfish, which are attracted, like moths, to the unwonted illumination, are scooped out with the hand or with nets.

Thus far, our information respecting the crayfish is such as would be forced upon anyone who dealt in crayfishes, or lived in a district in which they were commonly used for food. It is common knowledge. Let us now try to push our acquaintance with what is to be learned about the animal a little further, so as to be able to give an account of its Natural History, such as might have been furnished by Buffon if he had dealt with the subject.

There is an inquiry which does not strictly lie within the province of physical science, and yet suggests itself naturally enough at the outset of a natural history. The animal we are considering has two names, one common, *Crayfish*, the other technical, *Astacus fluviatilis*. How has it come by these two names, and why, having a common English name for it already, should naturalists call it by another appellation derived from a foreign tongue?

The origin of the common name, "crayfish," involves some curious questions of etymology, and indeed, of history. It might readily be supposed that the word "cray" had a meaning of its own, and qualified the substantive "fish"—as "jelly" and "cod" in "jellyfish" and "codfish." But this certainly is not the case. The old English method of writing the word was "crevis" or "crevice," and the "cray" is simply a phonetic spelling of the syllable "cre," in which the "e" was formerly pronounced as all the world, except ourselves, now pronounce that vowel. While "fish" is the "vis" insensibly modified to suit our knowledge of the thing as an aquatic animal.

Now "crevis" is clearly one of two things. Either it is a modification of the French name "écrevisse," or of the Low Dutch name "crevik," by which the crayfish is known in these languages. The former derivation is that usually given, and, if it be correct, we must refer "crayfish" to the same category as "mutton," "beef," and "pork," all of which are French equivalents, introduced by the Normans, for the "sheep's flesh," "ox flesh," and "swine's flesh," of their English subjects. In this case, we should not have called a crayfish, a crayfish, except for the Norman conquest.

On the other hand, if "crevik" is the source of our word, it may have come to us straight from the Angle and Saxon contingent of our mixed ancestry.

As to the origin of the technical name; ἀστακός, *astakos*, was the name by which the Greeks knew the lobster; and it has been handed down to us in the works of Aristotle, who does not seem to have taken any special notice of the crayfish. At the revival of learning, the early naturalists noted the close general similarity between the lobster and the crayfish; but, as the latter lives in fresh water, while the former is a marine animal, they called the crayfish, in their Latin, *Astacus fluviatilis*, or the "river-lobster," by way of distinction; and this nomenclature was retained until, about forty-five years ago, an eminent French Naturalist, M. Milne-Edwards, pointed out that there are far more extensive differences between lobsters and crayfish than had been supposed; and that it would be advisable to mark the distinctness of the things by a corresponding difference in their names. Leaving *Astacus* for the crayfishes, he proposed to change the technical name of the lobster into *Homarus*, by latinising the old French name "*Omar*," or "*Homar*" (now *Homard*), for that animal.

At the present time, therefore, while the recognised technical name of the crayfish is *Astacus fluviatilis*, that of the lobster is *Homarus vulgaris*. And as this nomenclature is generally received, it is desirable that it should not be altered; though it is attended by the inconvenience, that *Astacus*, as we now employ the name, does not denote that which the Greeks, ancient and modern, signify, by its original, *astakos;* and does signify something quite different.

Finally, as to why it is needful to have two names for the same thing, one vernacular, and one technical. Many people imagine that scientific terminology is a needless burden imposed upon the novice, and ask us why we cannot be content with plain English. In reply, I would suggest to such an objector to open a conversation about his own business with a carpenter, or an engineer, or, still better, with a sailor, and try how far plain English will go. The interview will not have lasted long before he will find himself lost in a maze of unintelligible technicalities. Every calling has its technical terminology; and every artisan uses terms of art, which sound like gibberish to those who know nothing of the art, but are exceedingly convenient to those who practise it.

In fact, every art is full of conceptions which are special to itself; and, as the use of language is to convey our conceptions to one another, language must supply signs for those conceptions. There are two ways of doing this: either existing signs may be combined in loose and cumbrous periphrases; or new signs, having a well-understood and definite signification, may be invented. The practice of sensible people shows the advantage of the latter course; and here, as elsewhere, science has simply followed and improved upon common sense.

Moreover, while English, French, German, and Italian artisans are under no particular necessity to discuss the processes and results of their business with one another, science is cosmopolitan, and the difficulties of the study of Zoology would be prodigiously increased, if Zoologists of different nationalities used different technical terms for the same thing. They need a universal language; and it has been found convenient that the language shall be the Latin in form, and Latin or Greek in origin. What in English is Crayfish, is *Écrevisse* in French; *Flusskrebs*, in German; *Cammaro*, or *Gambaro*, or *Gammarello*, in Italian: but the Zoologist of each nationality knows that, in the scientific works of all the rest, he shall find what he wants to read under the head of *Astacus fluviatilis*.

But granting the expediency of a technical name for the Crayfish, why should that name be double? The reply is still, practical convenience. If there are ten children of one family, we do not call them all Smith, because such a procedure would not help us to distinguish one from the other; nor do we call them simply John, James, Peter, William, and so on, for that would not help us to identify them as of one family. So we give them all two names, one indicating their close relation, and the other their separate individuality—as John Smith, James Smith, Peter Smith, William Smith, &c. The same thing is done in Zoology; only, in accordance with the genius of the Latin language, we put the Christian name, so to speak, after the surname.

There are a number of kinds of Crayfish, so similar to one another that they bear the common surname of *Astacus*. One kind, by way of distinction, is called *fluviatile*, another *slender-handed*, another *Dauric*, from the region in which it lives; and these double names are rendered by—*Astacus fluviatilis*, *Astacus leptodactylus*, and *Astacus dauricus;* and thus we have a nomenclature which is exceedingly simple in principle, and free from confusion in practice. And I may add that, the less attention is paid to the original meaning of the substantive and adjective terms of this binomial nomenclature, and the sooner they are used as proper names, the better. Very good reasons for using a term may exist when it is first invented, which lose their validity with the progress of knowledge. Thus *Astacus fluviatilis* was a significant name so long as we knew of only one kind of crayfish; but now that we are acquainted with a number of kinds, all of which inhabit rivers, it is meaningless. Nevertheless, as changing it would involve endless confusion, and the object of nomenclature is simply to have a definite name for a definite thing, nobody dreams of proposing to alter it.

Having learned this much about the origin of the names of the crayfish, we may next proceed to consider those points which an observant Naturalist, who did not care to go far beyond the surface of things, would find to notice in the animal itself.

Probably the most conspicuous peculiarity of the crayfish, to any one who is familiar only with the higher animals, is the fact that the hard parts of the body are outside and the soft parts inside; whereas in ourselves, and in the ordinary domestic animals, the hard parts, or bones, which constitute the skeleton, are inside, and the soft parts clothe them. Hence, while our hard framework is said to be an *endoskeleton*, or internal skeleton; that of the crayfish is termed an *exoskeleton*, or external skeleton. It is from the circumstance that the body of the crayfishes is enveloped in this hard crust, that the name of *Crustacea* is applied to them, along with the crabs, shrimps, and other such animals. Insects, spiders, and centipedes have also a hard exoskeleton, but it is usually not so hard and thick as in the *Crustacea*.

If a piece of the crayfish's skeleton is placed in strong vinegar, abundant bubbles of carbonic acid gas are given off from it, and it rapidly becomes converted into a soft laminated membrane, while the solution will be found to contain lime. In fact the exoskeleton is composed of a peculiar animal matter, so much impregnated with carbonate and phosphate of lime that it becomes dense and hard.

It will be observed that the body of the crayfish is naturally marked out into several distinct regions. There

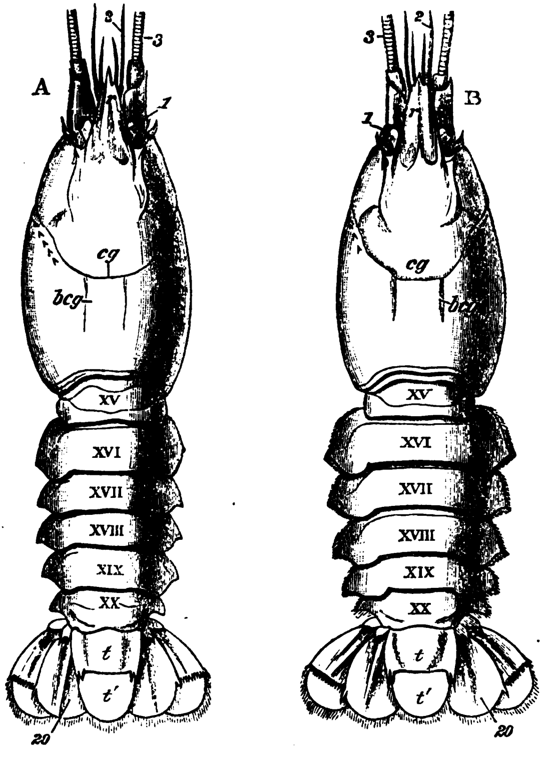

FIG. 2.—*Astacus fluviatilis.*—Dorsal or tergal views (nat. size). A, male; B, female:—*bcg*, branchio-cardiac groove, which marks the boundary between the pericardial and the branchial cavities; *cg*, cervical groove; these letters are placed on the carapace; *r*, rostrum; *t*, *t′*, the two divisions of the telson; *1*, eye-stalks; *2*, antennules; *3*, antennæ; *20*, lateral lobes of tail-fin; XV–XX, somites of the abdomen.

is a firm and solid front part, covered by a large continuous shield, which is called the *carapace;* and a jointed hind part, commonly termed the tail (fig. 2). From the perception of a partially real, and partially fanciful, analogy with the regions into which the body is divided in the higher animals, the fore part is termed the *cephalo-thorax,* or head (*cephalon*) and chest (*thorax*) combined, while the hinder part receives the name of *abdomen.*

Now the exoskeleton is not of the same constitution throughout these regions. The abdomen, for example, is composed of six complete hard rings (fig. 2, xv–xx), and a terminal flap, on the under side of which the vent (fig. 3, *a*) is situated, and which is called the *telson* (fig. 2, *t*, *t'*). All these are freely moveable upon one another, inasmuch as the exoskeleton which connects them is not calcified, but is, for the most part, soft and flexible, like the hard exoskeleton when the lime salts have been removed by acid. The mechanism of the joints will have to be attentively considered by-and-by; it is sufficient, at present, to remark that, wherever a joint exists, it is produced in the same fashion, by the exoskeleton remaining soft in certain regions of the jointed part.

The carapace is not jointed; but a transverse groove is observed about the middle of it, the ends of which run down on the sides and then turn forwards (figs. 1 and 2, *cg*). This is called the *cervical groove,* and it marks off the region of the head, in front, from that of the thorax behind.

The thorax seems at first not to be jointed at all; but if its under, or what is better called its *sternal*, surface is examined carefully, it will be found to be divided into as many transverse bands, or segments, as there are pairs of legs (fig. 3); and, moreover, the hindermost of these segments is not firmly united with the rest, but can be moved backwards and forwards through a small space (fig. 3, B; xiv).

Attached to the sternal side of every ring of the abdomen of the female there is a pair of limbs, called *swimmerets*. In the five anterior rings, these are small and slender (fig. 3, B; *15*, *19*); but those of the sixth ring are very large, and each ends in two broad plates (*20*). These two plates on each side, with the telson in the middle, constitute the flapper of the crayfish, by the aid of which it executes its retrograde swimming movements. The small swimmerets move together with a regular swing, like paddles, and probably aid in propelling the animal forwards. In the breeding female (B), the eggs are attached to them; while, in the male, the two anterior pairs (A; *15*, *16*) are converted into the peculiar styles which distinguish that sex.

The four pairs of legs which are employed for walking purposes, are divided into a number of joints, and the foremost two pairs are terminated by double claws, arranged so as to form a pincer, whence they are said to

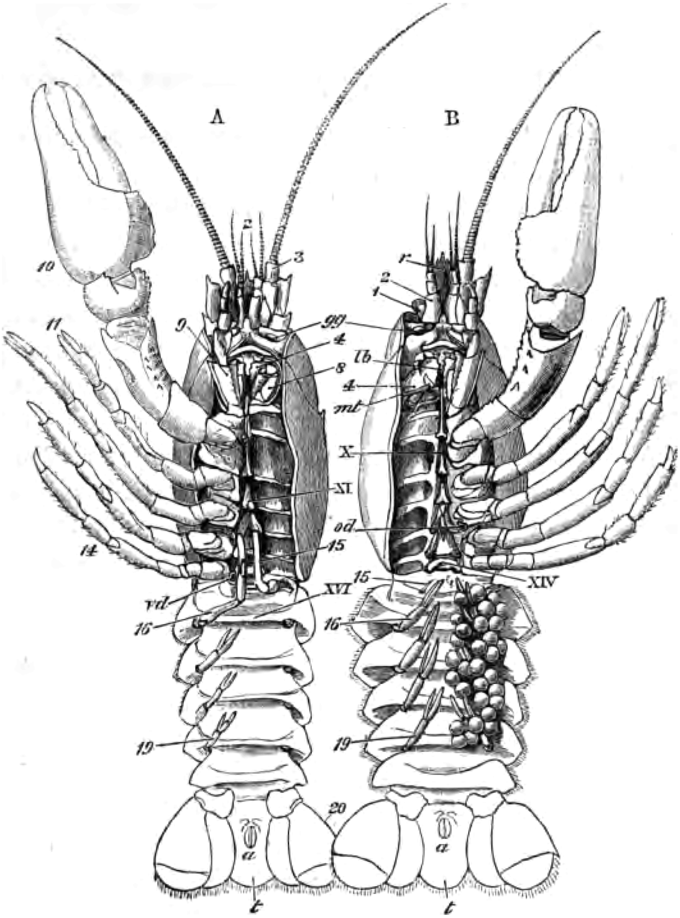

Fig. 3.—*Astacus fluviatilis.*—Ventral or sternal views (nat. size). A, male; B, female:—*a*, vent; *gg*, opening of the green gland; *lb*, labrum; *mt*, metastoma or lower lip; *od*, opening of the oviduct; *vd*, that of the vas deferens. *1*, eye-stalk; *2*, antennule; *3*, antenna; *4*, mandible; *8*, second maxillipede; *9*, third or external maxillipede; *10*, forceps; *11*, first leg; *14*, fourth leg; *15, 16, 19, 20*, first, second, fifth, and sixth abdominal appendages; x., xi., xiv., sterna of the fourth, fifth, and eighth thoracic somite; xvi., sternum of the second abdominal somite. In the male, the 9th to the 14th and the 16th to the 19th appendages are removed on the animal's left side: in the female, the antenna (with the exception of its basal joint) and the 5th to the 14th appendages on the animal's right are removed; the eggs also are shown attached to the swimmerets of the left side of the body.

be *chelate.* The two hindermost pairs, on the other hand, end in simple claws.

In front of these legs, come the great prehensile limbs (*10*), which are chelate, like those which immediately follow them, but vastly larger. They often receive the special name of *chelæ;* and the large terminal joints are called the "hand." We shall escape confusion if we call these limbs the *forceps,* and restrict the name of *chela* to the two terminal joints.

All the limbs hitherto mentioned subserve locomotion and prehension in various degrees. The crayfish swims by the help of its abdomen, and the hinder pairs of abdominal limbs; walks by means of the four hinder pairs of thoracic limbs; lays hold of anything to fix itself, or to assist in climbing, by the two chelate anterior pairs of these limbs, which are also employed in tearing the food seized by the forceps and conveying it to the mouth; while it seizes its prey and defends itself with the forceps. The part which each of these limbs plays is termed its *function,* and it is said to be the *organ* of that function; so that all these limbs may be said to be organs of the functions of locomotion, of offence and defence.

In front of the forceps, there is a pair of limbs which have a different character, and take a different direction from any of the foregoing (*9*). These limbs, in fact, are turned directly forwards, parallel with one another, and with the middle line of the body. They are divided into a number of joints, of which one of those near the base is longer than the rest, and strongly toothed along the inner edge, or that which is turned towards its fellow. It is obvious that these two limbs are well adapted to crush and tear whatever comes between them, and they are, in fact, *jaws* or organs of manducation. At the same time, it will be noticed that they retain a curiously close general resemblance to the hinder thoracic legs; and hence, for distinction's sake, they are called outer *foot-jaws*, or external *maxillipedes*.

If the head of a stout pin is pushed between these external maxillipedes, it will be found that it passes without any difficulty into the interior of the body, through the mouth. In fact, the mouth is relatively rather a large aperture; but it cannot be seen without forcing aside, not only these external foot-jaws, but a number of other limbs, which subserve the same function of manducation, or chewing and crushing the food. We may pass by the organs of manducation, for the present, with the remark that there are altogether three pairs of maxillipedes, followed by two pairs of somewhat differently formed *maxillæ*, and one pair of very stout and strong jaws, which are termed the *mandibles* (*4*). All these jaws work from side to side, in contradistinction to the jaws of vertebrated animals, which move up and down. In front of, and above the mouth, with the jaws which cover it, are seen the long feelers, which are called the *antennæ* (*3*); above, and in front of them, follow the small feelers, or *antennules* (*2*); and over them, again, lie the *eye stalks* (*1*). The antennæ are organs of touch; the antennules, in addition, contain the organs of hearing; while, at the ends of the eyestalks, are the organs of vision.

Thus we see that the crayfish has a jointed and segmented body, the rings of which it is composed being very obvious in the abdomen, but more obscurely traceable elsewhere; that it has no fewer than twenty pairs of what may be called by the general name of *appendages;* and that these appendages are turned to different uses, or are organs of different functions, in different parts of the body. The crayfish is obviously a very complicated piece of living machinery. But we have not yet come to the end of all the organs that may be discovered even by cursory inspection. Every one who has eaten a boiled crayfish, or a lobster, knows that the great shield, or carapace, is very easily separated from the thorax and abdomen, the head and the limbs which belong to that region coming away with the carapace. The reason of this is not far to seek. The lower edges of that part of the carapace which belongs to the thorax approach the bases of the legs pretty closely, but a cleft-like space is left; and this cleft extends forwards to the sides of the region of the mouth, and backwards and upwards, between the hinder margin of the carapace and the sides of the first ring of the abdomen, which are partly overlapped by, and partly overlap, that margin. If the blade of a pair of scissors is carefully introduced into the cleft from behind, as high up as it will go without tearing anything, and a cut is then made, parallel with the middle line, as far as the cervical groove, and thence following the cervical groove to the base of the outer foot-jaws, a large flap will be removed. This flap of the carapace is called the *branchiostegite* (fig. 1, *bg*), because it covers the gills or *branchiæ* (fig. 4), which are now exposed. They have the appearance of a number of delicate plumes, which take a direction from the bases of the legs upwards and forwards behind, upwards and backwards in front, their summits converging towards the upper end of the cavity in which they are placed, and which is called the *branchial chamber*. These branchiæ are the respiratory organs; and they perform the same functions as the gills of a fish, to which they present some similarity.

If the gills are cleared away, it is seen that the branchial cavity is bounded, on the inner side, by a sloping wall, formed by a delicate, but more or less calcified layer of the exoskeleton, which constitutes the proper outer wall of the thorax. At the upper limit of the branchial cavity, the layer of exoskeleton is very thin, and turning outwards, is continued into the inner wall or lining of the branchiostegite, which is also very thin (*see* fig. 15, p. 70).

Thus the branchial chamber is altogether outside the body, to which it stands in somewhat the same relation as the space between the flaps of a man's coat and his waistcoat would do to the part of the body enclosed by the

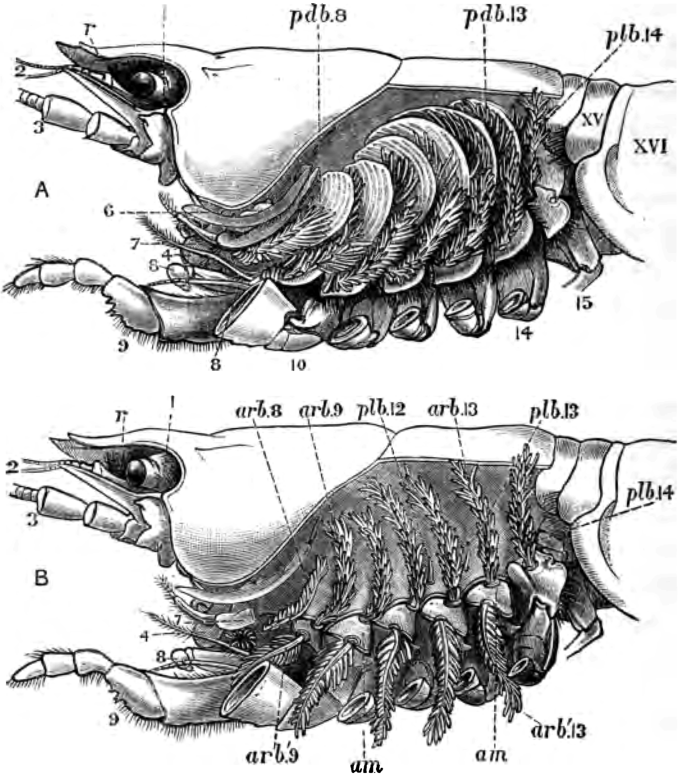

FIG. 4.—*Astacus fluviatilis.*—In A, the gills, exposed by the removal of the branchiostegite, are seen in their natural position ; in B, the podobranchiæ (*see* p. 75) are removed, and the anterior set of arthrobranchiæ turned downwards (× 2) : *1*, eye-stalk ; *2*, antennule ; *3*, antenna ; *4*, mandible ; *6*, scaphognathite ; *7*, first maxillipede, in B the epipodite, to which the line points, is partly removed ; *8*, second maxillipede ; *9*, third maxillipede ; *10*, forceps ; *14*, fourth ambulatory leg ; *15*, first abdominal appendage ; XV., first, and XVI., second abdominal somite ; *arb. 8*, *arb. 9*, *arb. 13*, the posterior arthrobranchiæ of the second and third maxillipedes and of the third ambulatory leg ; *arb'. 9*, *arb'. 13*, the anterior arthrobranchiæ of the third maxillipede and of the third ambulatory leg ; *pbd. 8*, podobranchiæ of the second maxillipede ; *pbd. 13*, that of the third ambulatory leg ; *plb. 12*, *plb. 13*, the two rudimentary pleurobranchiæ ; *plb. 14*, the functional pleurobranchia ; *r*, rostrum.

waistcoat, if we suppose the lining of the flaps to be made in one piece with the sides of the waistcoat. Or a closer parallel still would be brought about, if the skin of a man's back were loose enough to be pulled out, on each side, into two broad flaps covering the flanks.

It will be observed that the branchial chamber is open behind, below, and in front; and, therefore, that the water in which the crayfish habitually lives has free ingress and egress. Thus the air dissolved in the water enables breathing to go on, just as it does in fishes. As is the case with many fishes, the crayfish breathes very well out of the water, if kept in a situation sufficiently cool and moist to prevent the gills from drying up; and thus there is no reason why, in cool and damp weather, the crayfish should not be able to live very well on land, at any rate among moist herbage, though whether our common crayfishes do make such terrestrial excursions is perhaps doubtful. We shall see, by-and-by, that there are some exotic crayfish which habitually live on land, and perish if they are long submerged in water.

With respect to the internal structure of the crayfish, there are some points which cannot escape notice, however rough the process of examination may be.

Thus, when the carapace is removed in a crayfish which has been just killed, the heart is seen still pulsating. It is an organ of considerable relative size (fig. 5, *h*), which is situated immediately beneath the

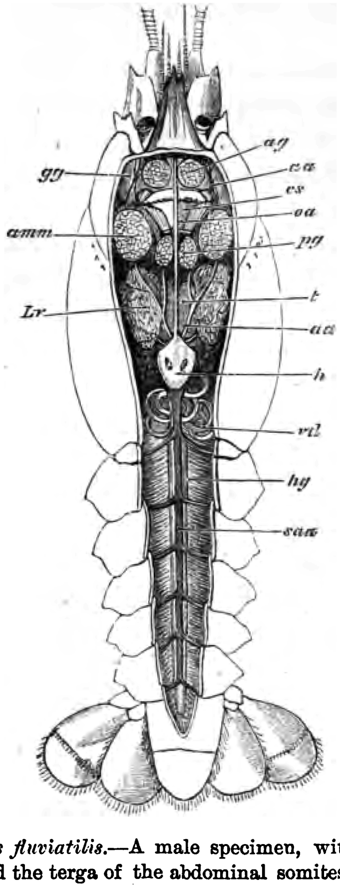

FIG. 5.—*Astacus fluviatilis.*—A male specimen, with the roof of the carapace and the terga of the abdominal somites removed to show the viscera (nat. size) :—*aa*, antennary artery ; *ag*, anterior gastric muscles ; *amm*, adductor muscles of the mandibles; *cs*, cardiac portion of the stomach ; *gg*, green glands ; *h*, heart ; *hg*, hind gut, or large intestine ; *Lr*, liver ; *oa*, ophthalmic artery ; *pg* posterior gastric muscles ; *saa*, superior abdominal artery ; *t*, testis ; *vd*, vas deferens.

middle region of that part of the carapace which lies behind the cervical groove; or, in other words, in the dorsal region of the thorax. In front of it, and therefore in the head, is a large rounded sac, the stomach (fig. 5, *cs;* fig. 6, *cs*, *ps*), from which a very delicate intestine (figs. 5 and 6, *hg*) passes straight back through the thorax and abdomen to the vent (fig. 6, *a*).

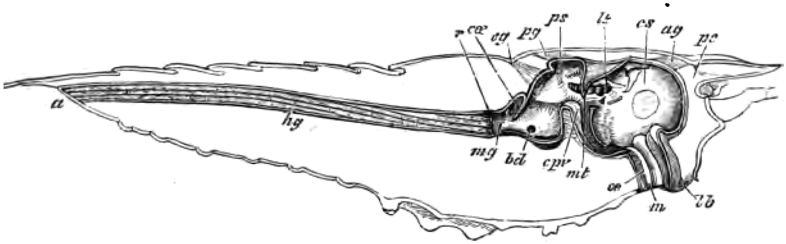

FIG. 6.—*Astacus fluviatilis.*—A longitudinal vertical section of the alimentary canal, with the outline of the body (nat. size) :—*a*, vent; *ag*, anterior gastric muscle; *bd*, entrance of left bile duct; *cg*, cervical groove; *cæ*, cæcum; *cpv*, cardio-pyloric valve; *cs*, cardiac portion of stomach; the circular area immediately below the end of the line from *cs* marks the position of the gastrolith of the left side; *hg*, hind-gut; *lb*, labrum; *lt*, lateral tooth of stomach; *m*, mouth; *mg*, mid-gut; *mt*, median tooth; *œ*, œsophagus; *pc*, procephalic process; *pg*, posterior gastric muscle; *ps*, pyloric portion of stomach; *r*, annular ridge, marking the commencement of the hind-gut.

In summer, there are commonly to be found at the sides of the stomach two lenticular calcareous masses, which are known as "crabs'-eyes," or *gastroliths*, and were, in old times, valued in medicine as sovereign remedies for all sorts of disorders. These bodies (fig. 7) are smooth and flattened, or concave, on the side which is turned towards the cavity of the stomach; while the opposite side, being convex and rough with irregular prominences, is something like a "brain-stone" coral.

Moreover, when the stomach is laid open, three large

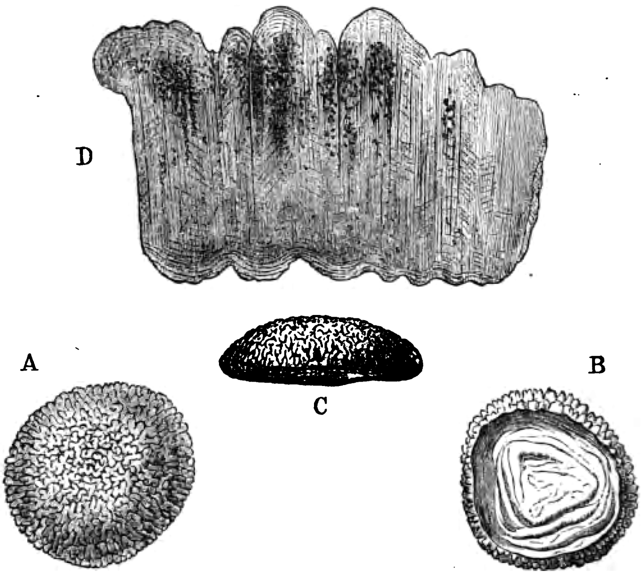

FIG. 7.—*Astacus fluviatilis.*—A gastrolith; A, from above; B, from below; C, from one side (all × 5); D, in vertical section (× 20).

reddish teeth are seen to project conspicuously into its interior (fig. 6, *lt*, *mt*); so that, in addition to its six pairs of jaws, the crayfish has a supplementary crushing mill in its stomach. On each side of the stomach, there is a soft yellow or brown mass, commonly known as the liver (fig. 5, *Lr*); and, in the breeding season, the ovaries of the females, or organs in which the eggs are formed, are very conspicuous from the dark-coloured eggs which they contain, and which, like the exoskeleton, turn red when they are boiled. The corresponding part in a cooked lobster goes by the name of the "coral."

Beside these internal structures, the most noticeable are the large masses of flesh, or muscle, in the thorax and abdomen, and in the pincers; which, instead of being red, as in most of the higher animals, is white. It will further be observed that the blood, which flows readily when a crayfish is wounded, is a clear fluid, and is either almost colourless, or of a very pale reddish or neutral tint. Hence the older Naturalists thought that the crayfish was devoid of blood, and had merely a sort of ichor in place of it. But the fluid in question is true blood; and if it is received into a vessel, it soon forms a soft, but firm, gelatinous clot.

The crayfish grows rapidly in youth, but enlarges more and more slowly as age advances. The young animal which has just left the egg is of a greyish colour, and about one quarter of an inch long. By the end of the year, it may have reached nearly an inch and a half in length. Crayfishes of a year old are, on an average, two inches long; at two years, two inches and four-fifths; at three years, three inches and a half; at four years, four inches and a half nearly; and at five years, five inches. They go on growing till, in exceptional cases, they may attain between seven inches and eight inches in length; but at what degree of longevity this unusual dimension is reached is uncertain. It seems probable, however, that the life of these animals may be prolonged to as much as fifteen or twenty years. They appear to reach maturity, so far as the power of reproduction is concerned, in their fifth or, more usually, their sixth year. However, I have seen a female, with eggs attached under the abdomen, only two inches long, and therefore, probably, in her second year. The males are commonly larger than females of the same age.

The hard skeleton of a crayfish, once formed, is incapable of being stretched, nor can it increase by interstitial addition to its substance, as the bone of one of the higher animals grows. Hence it follows, that the enlargement of the body, which actually takes place, involves the shedding and reproduction of its investment. This might be effected by insensible degrees, and in different parts of the body at different times, as we shed our hair; but, as a matter of fact, it occurs periodically and universally, somewhat as the feathers of birds are moulted. The whole of the old coat of the body is thrown off at once, and suddenly; and the new coat, which has, in the meanwhile, been formed beneath the old one, remains soft for a time, and allows of a rapid increase in the dimensions of the body before it hardens. This sort of moulting is what is technically termed *ecdysis*, or *exuviation*. It is commonly spoken of as the "shedding of the skin," and there is no harm in using this phrase, if we recollect that the shed coat is not the skin, in the proper sense of the word, but only what is termed a *cuticular layer*, which is secreted upon the outer surface of the true integument. The cuticular skeleton of the crayfish, in fact, is not even so much a part of the skin as the cast of a snake, or as our own nails. For these are composed of coherent, formed parts of the epidermis; while the hard investment of the crayfish contains no such formed parts, and is developed on the outside of those structures which answer to the constituents of the epidermis in the higher animals. Thus the crayfish grows, as it were, by starts; its dimensions remaining stationary in the intervals of its moults, and then rapidly increasing for a few days, while the new exoskeleton is in the course of formation.

The ecdysis of the crayfish was first thoroughly studied a century and a half ago, by one of the most accurate observers who ever lived, the famous Réaumur, and the following account of this very curious process is given nearly in his words.*

A few hours before the process of exuviation com-

* See Réaumur's two Memoirs, "Sur les diverses reproductions qui se font dans les écrevisses, les omars, les crabes, etc.," "Histoire de l'Académie royale des Sciences," année 1712; and "Additions aux observations sur la mue des écrevisses données dans les Mémoires de 1712." Ibid. 1718.

mences, the crayfish rubs its limbs one against the other, and, without changing its place, moves each separately, throws itself on its back, bends its tail, and then stretches it out again, at the same time vibrating its antennæ. By these movements, it gives the various parts a little play in their loosened sheaths. After these preparatory steps, the crayfish appears to become distended; in all probability, in consequence of the commencing retraction of the limbs into the interior of the exoskeleton of the body. In fact, it has been remarked, that if, at this period, the extremity of one of the great claws is broken off, it will be found empty, the contained soft parts being retracted as far as the second joint. The soft membranous part of the exoskeleton, which connects the hinder end of the carapace with the first ring of the abdomen, gives way, and the body, covered with the new soft integument, protrudes; its dark brown colour rendering it easily distinguishable from the greenish-brown old integument.

Having got thus far, the crayfish rests for a while, and then the agitation of the limbs and body recommences. The carapace is forced upwards and forwards by the protrusion of the body, and remains attached only in the region of the mouth. The head is next drawn backwards, while the eyes and its other appendages are extracted from their old investment. Next the legs are pulled out, either one at a time, or those of one, or both, sides together. Sometimes a limb gives way and is left behind in its sheath.

The operation is facilitated by the splitting of the old integument of the limb along one side longitudinally.

When the legs are disengaged, the animal draws its head and limbs completely out of their former covering; and, with a sudden spring forward, while it extends its abdomen, it extracts the latter, and leaves its old skeleton behind. The carapace falls back into its ordinary position, and the longitudinal fissures of the sheaths of the limbs close up so accurately, that the shed integument has just the appearance the animal had when the exuviation commenced. The cast exoskeleton is so like the crayfish itself, when the latter is at rest, that, except for the brighter colour of the latter, the two cannot be distinguished.

After exuviation, the owner of the cast skin, exhausted by its violent struggles, which are not unfrequently fatal, lies in a prostrate condition. Instead of being covered by a hard shell, its integument is soft and flabby, like wet paper; though Réaumur remarks, that if a crayfish is handled immediately after exuviation, its body feels hard; and he ascribes this to the violent contraction which its muscles have undergone, leaving them in a state of cramp. In the absence of the hard skeleton, however, there is nothing to bring the contracted muscles at once back into position, and it must be some time before the pressure of the internal fluids is so distributed as to stretch them out.

When the process of exuviation has proceeded so far that the carapace is raised, nothing stops the crayfish from continuing its struggles. If taken out of the water in this condition, they go on moulting in the hand, and even pressure on their bodies will not arrest their efforts.

The length of time occupied from the first giving way of the integuments to the final emergence of the animal, varies with its vigour, and the conditions under which it is placed, from ten minutes to several hours. The chitinous lining of the stomach, with its teeth, and the "crabs'-eyes," are shed along with the rest of the cuticular exoskeleton; but they are broken up and dissolved in the stomach.

The new integuments of the crayfish remain soft for a period which varies from one to three days; and it is a curious fact, that the animal appears to be quite aware of its helplessness, and governs itself accordingly.

An observant naturalist says: "I once had a domesticated crayfish (*Astacus fluviatilis*), which I kept in a glass pan, in water, not more than an inch and a half deep, previous experiment having shown that in deeper water, probably from want of sufficient aëration, this animal would not live long. By degrees my prisoner became very bold, and when I held my fingers at the edge of the vessel, he assailed them with promptness and energy. About a year after I had him, I perceived, as I thought, a second crayfish with him. On examination, I found it to be his old coat, which he had left in a most perfect state. My friend had now lost his heroism, and fluttered about in the greatest agitation. He was quite soft; and every time I entered the room during the next two days, he exhibited the wildest terror. On the third, he appeared to gain confidence, and ventured to use his nippers, though with some timidity, and he was not yet quite so hard as he had been. In about a week, however, he became bolder than ever; his weapons were sharper, and he appeared stronger, and a nip from him was no joke. He lived in all about two years, during which time his food was a very few worms at very uncertain times; perhaps he did not get fifty altogether."*

It would appear, from the best observations that have yet been made, that the young crayfish exuviate two or three times in the course of the first year; and that, afterwards, the process is annual, and takes place usually about midsummer. There is reason to suppose that very old crayfish do not exuviate every year.

It has been stated that, in the course of its violent efforts to extract its limbs from the cast-off exoskeleton, the crayfish sometimes loses one or other of them; the limb giving way, and the greater part, or the whole, of it remaining in the exuviæ. But it is not only in this way that crayfishes part with their limbs. At all times, if the animal is held by one of its pincers, so that it cannot get away, it is apt to solve the difficulty by casting off

* The late Mr. Robert Ball, of Dublin, in Bell's "British Crustacea," p. 239.

the limb, which remains in the hand of the captor, while the crayfish escapes. This voluntary amputation is always effected at the same place; namely, where the limb is slenderest, just beyond the articulation which unites the basal joint with the next. The other limbs also readily part at the joints; and it is very common to meet with crayfish which have undergone such mutilation. But the injury thus inflicted is not permanent, as these animals possess the power of reproducing lost parts to a marvellous extent, whether the loss has been inflicted by artificial amputation, or voluntarily.

Crayfishes, like all the *Crustacea*, bleed very freely when wounded; and if one of the large joints of a leg is cut through, or if the animal's body is injured, it is very likely to die rapidly from the ensuing hæmorrhage. A crayfish thus wounded, however, commonly throws off the limb at the next articulation, where the cavity of the limb is less patent, and its sides more readily fall together; and, as we have seen, the pincers are usually cast off at their narrowest point. When such amputation has taken place, a crust, probably formed of coagulated blood, rapidly forms over the surface of the stump; and, eventually, it becomes covered with a cuticle. Beneath this, after a time, a sort of bud grows out from the centre of the surface of the stump, and gradually takes on the form of as much of the limb as has been removed. At the next ecdysis, the covering cuticle is thrown off along with the rest of the exoskeleton; while the rudimentary limb straightens out, and, though very small, acquires all the organization appropriate to that limb. At every moult it grows; but, it is only after a long time that it acquires nearly the size of its uninjured and older fellow. Hence, it not unfrequently happens, that crayfish are found with pincers and other limbs, which, though alike useful and anatomically complete, are very unequal in size.

Injuries inflicted while the crayfish are soft after moulting, are apt to produce abnormal growths of the part affected; and these may be perpetuated, and give rise to various monstrosities, in the pincers and in other parts of the body.

In the reproduction of their kind by means of eggs the co-operation of the males with the females is necessary. On the basal joint of the hindermost pair of legs of the male a small aperture is to be seen (fig. 3, A; *vd*). In these, the ducts of the apparatus in which the fecundating substance is formed terminate. The fecundating material itself is a thickish fluid, which sets into a white solid after extrusion. The male deposits this substance on the thorax of the female, between the bases of the hindermost pairs of thoracic limbs.

The eggs formed in the ovary are conducted to apertures, which are situated on the bases of the last pair of ambulatory legs but two, that is, in the hinder of the two pair which are provided with chelate extremities (fig. 3, B; *od*).

After the female has received the deposit of the spermatic matter of the male, she retires to a burrow, in the manner already stated, and then the process of laying the eggs commences. These, as they leave the apertures of the oviducts, are coated with a viscid matter, which is readily drawn out into a short thread. The end of the thread attaches itself to one of the long hairs, with which the swimmerets are fringed, and as the viscid matter rapidly hardens, the egg thus becomes attached to the limb by a stalk. The operation is repeated, until sometimes a couple of hundred eggs are thus glued on to the swimmerets. Partaking in the movements of the swimmerets, they are washed backwards and forwards in the water, and thus aërated and kept free of impurities; while the young crayfish is formed much in the same way as the chick is formed in a hen's egg.

The process of development, however, is very slow, as it occupies the whole winter. In late spring-time, or early summer, the young burst the thin shell of the egg, and, when they are hatched, present a general resemblance to their parents. This is very unlike what takes place in crabs and lobsters, in which the young leave the egg in a condition very different from the parent, and undergo a remarkable metamorphosis before they attain their proper form.

For some time after they are hatched, the young hold on to the swimmerets of the mother, and are carried about, protected by her abdomen, as in a kind of nursery.

That most careful naturalist, Roesel von Rosenhof, says of the young, when just hatched :—

"At this time they are quite transparent; and when

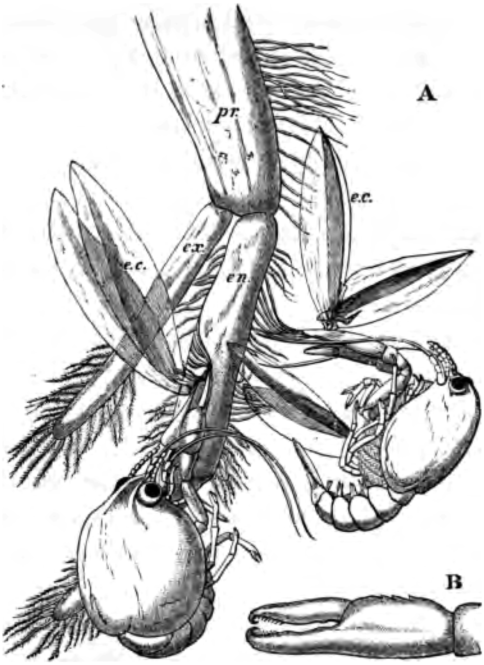

FIG. 8.—*Astacus fluviatilis.*—A, two recently hatched crayfish attached to one of the swimmerets of the mother (× 4). *pr*, protopodite; *en*, endopodite; and *ex*, exopodite of the swimmeret; *ec*, ruptured egg-cases. B, chela of a recently hatched crayfish (× 10).

such a crayfish [a female with young] is brought to table, it looks quite disgusting to those who do not know what the young are; but if we examine it more closely, especially with a magnifying-glass, we see with pleasure that the little crayfish are already perfect, and resemble the large one in all respects. When the mother of these little crayfish, after they have begun to be active, is quiet for a while, they leave her and creep about, a short way off. But, if they spy the least sign of danger, or there is any unusual movement in the water, it seems as if the mother recalled them by a signal; for they all at once swiftly return under her tail, and gather into a cluster, and the mother hies to a place of safety with them, as quickly as she can. A few days later, however, they gradually forsake her." *

Fishermen declare that "Hen Lobsters" protect their young in a similar manner.† Jonston,‡ who wrote in the middle of the seventeenth century, says that the little crayfish are often to be seen adhering to the tail of the mother. Roesel's observations imply the same thing; but he does not describe the exact mode of adherence, and I can find no observations on the subject in the works of later writers.

It has been seen that the eggs are attached to the swimmerets by a viscid substance, which is, as it were, smeared over them and the hairs with which they are

* "Der Monatlich-herausgegeben Insecten Belustigung." Dritter Theil, p. 336. 1755.

† Bell's "British Crustacea," p. 249.

‡ "Joannis Jonstoni Historiæ naturalis de Piscibus et Cetis Libri quinque. Tomus IV. 'De Cammaro seu Astáco fluviatili.'"

fringed, and is continued by longer or shorter thread-like pedicles into the coat of the same material which invests each egg. It very soon hardens, and then becomes very firm and elastic.

When the young crayfish is ready to be hatched, the egg case splits into two moieties, which remain attached, like a pair of watch glasses, to the free end of the pedicle of the egg (fig. 8, A; *ec*). The young animal, though very similar to the parent, does not quite "resemble it in all respects," as Roesel says. For not only are the first and the last pairs of abdominal limbs wanting, while the telson is very different from that of the adult; but the ends of the great chelæ are sharply pointed and bent down into abruptly incurved hooks, which overlap when the chelæ are shut (fig. 8, B). Hence, when the chelæ have closed upon anything soft enough to allow of the imbedding of these hooks, it is very difficult, if not impossible, to open them again.

Immediately the young are set free, they must instinctively bury the ends of their forceps in the hardened egg-glue which is smeared over the swimmerets, for they are all found to be holding on in this manner. They exhibit very little movement, and they bear rough shaking or handling without becoming detached; in consequence, I suppose, of the interlocking of the hooked ends of the chelæ imbedded in the egg-glue.

Even after the female has been plunged into alcohol, the young remain attached. I have had a female, with young affixed in this manner, under observation for five days, but none of them showed any signs of detaching themselves; and I am inclined to think that they are set free only at the first moult. After this, it would appear that the adhesion to the parent is only temporary.

The walking legs are also hooked at their extremities, but they play a less important part in fixing the young to the parent, and seem to be always capable of loosing their hold.

I find the young of a Mexican crayfish (*Cambarus*) to be attached in the same manner as those of the English crayfish; but, according to Mr. Wood-Mason's recent observations, the young of the New Zealand crayfishes fix themselves to the swimmerets of the parent by the hooked ends of their hinder ambulatory limbs.

Crayfishes, in every respect similar to those found in our English rivers, that is to say, of the species *Astacus fluviatilis*, are met with in Ireland, and on the Continent, as far south as Italy and northern Greece; as far east as western Russia; and as far north as the shores of the Baltic. They are not known to occur in Scotland; in Spain, except about Barcelona, they are either rare, or have remained unnoticed.

There is, at present, no proof of the occurrence of *Astacus fluviatilis* in the fossil state.

Curious myths have gathered about crayfishes, as about other animals. At one time "crabs'-eyes" were collected in vast numbers, and sold for medicinal purposes as a remedy against the stone, among other diseases. Their real utility, inasmuch as they consist almost entirely of carbonate of lime, with a little phosphate of lime and animal matter, is much the same as that of chalk, or carbonate of magnesia. It was, formerly, a current belief that crayfishes grow poor at the time of new moon, and fat at that of full moon; and, perhaps, there may be some foundation for the notion, considering the nocturnal habits of the animals. Van Helmont, a great dealer in wonders, is responsible for the story that, in Brandenburg, where there is a great abundance of crayfishes, the dealers were obliged to transport them to market by night, lest a pig should run under the cart. For if such a misfortune should happen, every crayfish would be found dead in the morning: "Tam exitialis est porcus cancro." Another author improves the story, by declaring that the steam of a pig-stye, or of a herd of swine, is instantaneously fatal to crayfish. On the other hand, the smell of putrifying crayfish, which is undoubtedly of the strongest, was said to drive even moles out of their burrows.

CHAPTER II.

THE PHYSIOLOGY OF THE CRAYFISH. THE MECHANISM BY WHICH THE PARTS OF THE LIVING ENGINE ARE SUPPLIED WITH THE MATERIALS NECESSARY FOR THEIR MAINTENANCE AND GROWTH.

AN analysis of such a sketch of the "Natural History of the Crayfish" as is given in the preceding chapter, shows that it provides brief and general answers to three questions. First, what is the form and structure of the animal, not only when adult, but at different stages of its growth? Secondly, what are the various actions of which it is capable? Thirdly, where is it found? If we carry our investigations further, in such a manner as to give the fullest attainable answers to these questions, the knowledge thus acquired, in the case of the first question, is termed the *Morphology* of the crayfish; in the case of the second question, it constitutes the *Physiology* of the animal; while the answer to the third question would represent what we know of its *Distribution* or *Chorology*. There remains a fourth problem, which can hardly be regarded as seriously under discussion, so long as knowledge has advanced no further than the Natural History stage; the question, namely, how all these facts comprised under Morphology, Physiology, and Chorology have come to be what they are; and the attempt to solve this problem leads us to the crown of Biological effort, *Ætiology*. When it supplies answers to all the questions which fall under these four heads, the Zoology of Crayfish will have said its last word.

As it matters little in what order we take the first three questions, in expanding Natural History into Zoology, we may as well follow that which accords with the history of science. After men acquired a rough and general knowledge of the animals about them, the next thing which engaged their interest was the discovery in these animals of arrangements by which results, of a kind similar to those which their own ingenuity effects through mechanical contrivances, are brought about. They observed that animals perform various actions; and, when they looked into the disposition and the powers of the parts by which these actions are performed, they found that these parts presented the characters of an apparatus, or piece of mechanism, the action of which could be deduced from the properties and connections of its constituents, just as the striking of a clock can be deduced from the properties and connections of its weights and wheels.

Under one aspect, the result of the search after the *rationale* of animal structure thus set afoot is *Teleology;* or the doctrine of adaptation to purpose. Under another aspect, it is *Physiology;* so far as Physiology consists in the elucidation of complex vital phenomena by deduction from the established truths of Physics and Chemistry, or from the elementary properties of living matter.

We have seen that the crayfish is a voracious and indiscriminate feeder; and we shall be safe in assuming that, if duly supplied with nourishment, a full-grown crayfish will consume several times its own weight of food in the course of the year. Nevertheless, the increase of the animal's weight at the end of that time is, at most, a small fraction of its total weight; whence it is quite clear, that a very large proportion of the food taken into the body must, in some shape or other, leave it again. In the course of the same period, the crayfish absorbs a very considerable quantity of oxygen, supplied by the atmosphere to the water which it inhabits; while it gives out, into that water, a large amount of carbonic acid, and a larger or smaller quantity of nitrogenous and other excrementitious matters. From this point of view, the crayfish may be regarded as a kind of chemical manufactory, supplied with certain alimentary raw materials, which it works up, transforms, and gives out in other shapes. And the first physiological problem which offers itself to us is the mode of operation of the apparatus contained in this factory, and the extent to which the products of its activity are to be accounted for by reasoning from known physical and chemical principles.

We have learned that the food of the crayfish is made up of very diverse substances, both animal and vegetable; but, so far as they are competent to nourish the animal permanently, these matters all agree in containing a peculiar nitrogenous body, termed *protein*, under one of its many forms, such as albumen, fibrin, and the like. With this may be associated fatty matters, starchy and saccharine bodies, and various earthy salts. And these, which are the essential constituents of the food, may be, and usually are, largely mixed up with other substances, such as wood, in the case of vegetable food, or skeletal and fibrous parts, in the case of animal prey, which are of little or no utility to the crayfish.

The first step in the process of feeding, therefore, is to reduce the food to such a state, that the separation of its nutritive parts, or those which can be turned to account, from its innutritious, or useless, constituents, may be facilitated. And this preliminary operation is the subdivision of the food into morsels of a convenient size for introduction into that part of the machinery in which the extraction of the useful products is performed.

The food may be seized by the pincers, or by the anterior chelate ambulatory limbs; and, in the former case, it is usually, if not always, transferred to the first, or second, or both of the anterior pairs of ambulatory limbs. These grasp the food, and, tearing it into pieces of the proper dimensions, thrust them between the external maxillipedes, which are, at the same time, worked rapidly to and fro sideways, so as to bring their toothed edges to bear upon the morsel. The other five pairs of jaws are no less active, and they thus crush and divide the food brought to them, as it is passed between their toothed edges to the opening of the mouth.

As the alimentary canal stretches from the mouth, at one end, to the vent at the other, and, at each of these limits, is continuous with the wall of the body, we may conceive the whole crayfish to be a hollow cylinder, the cavity of which is everywhere closed, though it is traversed by a tube, open at each end (fig. 6). The shut cavity between the tube and the walls of the cylinder may be termed the *perivisceral cavity;* and it is so much filled up by the various organs, which are interposed between the alimentary canal and the body wall, that all that is left of it is represented by a system of irregular channels, which are filled with blood, and are termed *blood sinuses.* The wall of the cylinder is the outer wall of the body itself, to which the general name of *integument* may be given; and the outermost layer of this, again, is the *cuticle,* which gives rise to the whole of the exoskeleton. This cuticle, as we have seen, is extensively impregnated with lime salts; and, moreover, in consequence of its containing *chitin,* it is often spoken of as the *chitinous cuticula.*

Having arrived at this general conception of the disposition of the parts of the factory, we may next proceed to consider the machinery of alimentation which is contained within it, and which is represented by the various divisions of the alimentary canal, with its appendages; by the apparatus for the distribution of nutriment; and by two apparatuses for getting rid of those products which are the ultimate result of the working of the whole organism.

And here we must trench somewhat upon the province of *Morphology*, as some of these pieces of apparatus are complicated; and their action cannot be comprehended without a certain knowledge of their anatomy.

The mouth of the crayfish is a longitudinally elongated, parallel-sided opening, in the integument of the ventral or sternal aspect of the head. Just outside its lateral boundaries, the strong mandibles project, one on each side (fig 3, B; *4*); their broad crushing surfaces, which are turned towards one another, are therefore completely external to the oral cavity. In front, the mouth is overlapped by a wide shield-shaped plate termed the upper lip, or *labrum* (figs. 3 and 6, *lb*); while, immediately behind the mandibles, there is, on each side, an elongated fleshy lobe, joined with its fellow by the posterior boundary of the mouth. These together constitute the *metastoma* (fig. 3, B; *mt*), which is sometimes called the lower lip. A short wide gullet, termed the œsophagus (fig. 6, *oe*), leads directly upwards into a spacious bag, the *stomach*, which occupies almost the whole cavity of the head. It is divided by a constriction into a large anterior chamber (*cs*), into the under face of which the gullet opens, and a small posterior chamber (*ps*), from which the intestine (*hg*) proceeds.

In a man's stomach, the opening by which the gullet communicates with the stomach is called the *cardia*, while that which places the stomach in communication with the intestine is named the *pylorus*; and these terms having been transferred from human anatomy to that of the lower animals, the larger moiety of the crayfish's stomach is called the *cardiac division*, while the smaller is termed the *pyloric division* of the organ. It must be recollected, however, that, in the crayfish, the so-called cardiac division is that which is actually furthest from the heart, not that which is nearest to it, as in man.

The gullet is lined by a firm coat which resembles thin parchment. At the margins of the mouth, this strong lining is easily seen to be continuous with the cuticular exoskeleton; while, at the cardiac orifice, it spreads out and forms the inner or cuticular wall of the whole gastric cavity, as far as the pylorus, where it ends in certain valvular projections. The chitinous cuticle which forms the outermost layer of the integument is thus, as it were, turned in, to constitute the innermost layer of the walls of the stomach; and it confers upon them so great an amount of stiffness that they do not collapse when the organ is removed from the body. Furthermore, just as the cuticle of the integument is calcified to form the hard parts of the exoskeleton, so is the cuticle of the stomach calcified, or otherwise hardened, to give rise, in the first place, to the very remarkable and complicated apparatus which has already been spoken of, as a sort of *gastric mill*

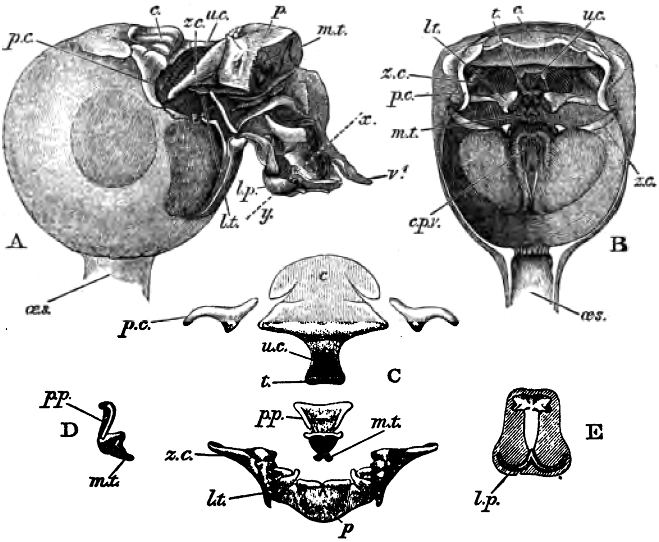

FIG. 9.—*Astacus fluviatilis.*—A, the stomach with its outer coat removed, seen from the left side; B, the same viewed from the front, after removal of the anterior wall; C, the ossicles of the gastric mill separated from one another; D, the prepyloric ossicle and median tooth, seen from the right side; E, transverse section of the pyloric region along the line *xy* in A (all × 2). *c*, cardiac ossicle; *cpv*, cardio-pyloric valve; *lp*, lateral pouch; *lt*, lateral tooth, seen through the wall of the stomach in A; *mg*, mid-gut; *mt*, median tooth, seen through the wall of the stomach in A; *œs*, œsophagus; *p*, pyloric ossicle; *pc*, pterocardiac ossicle; *pp*, prepyloric ossicle; *uc*, uro-cardiac process; *t*, convexities on the free surface of its hinder end; v^1, median pyloric valve; *zc*, zygocardiac ossicle.

or *food-crusher;* and, secondly, to a *filter* or *strainer*, whereby the nutritive juices are separated from the innutritious hard parts of the food and passed on into the intestine.

The gastric mill begins in the hinder half of the cardiac division. Here, on the upper wall of the stomach, we see a broad transverse calcified bar (figs. 9–11, *c*) from the middle of the hinder part of which another bar (*uc*), united to the first by a flexible portion, is continued backwards in the middle line. The whole has, therefore, somewhat the shape of a cross-bow. Behind the first-mentioned piece, the dorsal wall of the stomach is folded in, in such a manner as to give rise to a kind of pouch; and the second piece, or what we may call the handle of the crossbow, lies in the front wall of this pouch. The end of this piece is dense and hard, and its free surface, which looks into the top of the cardiac chamber, is raised into two oval, flattened convex surfaces (*t*). Connected by a transverse joint with the end of the handle of the crossbow, there is another solid bar, which ascends obliquely forwards in the back wall of the pouch (*pp*). The end which is articulated with the handle of the crossbow is produced into a strong reddish conical tooth (*mt*), curved forwards and bifurcated at the summit; consequently, when the cavity of the stomach is inspected from the fore part of the cardiac pouch (fig. 9, B), the two-pointed curved tooth (*mt*) is seen projecting behind the convex surfaces (*t*), in the middle line, into the interior of that cavity. The joint which connects the handle of the crossbow with the hinder middle piece is elastic; hence, if the two are straightened out, they return to their bent disposition as soon as they are released. The upper end of the hinder middle piece (*pp*) is connected with a second flat transverse plate which lies in the dorsal wall of the pyloric chamber (*p*). The whole arrangement, thus far, may be therefore compared to a large cross-bow and a small one, with the ends of their handles fastened together by a spring joint, in such a manner that the handle of the one makes an acute angle with the handle of the other; while the middle of each bow is united with the middle of the other by the bent arm formed by the two handles. But, in addition to this, the outer ends of the two bows are also connected together. A small, curved, calcified bar (*pc*) passes from the outer end of the front crosspiece downwards and outwards in the wall of the stomach, and its hinder and lower extremity is articulated with another larger bar (*zc*) which runs upwards and backwards to the hinder or pyloric crosspiece, with which it articulates. Internally, this piece projects into the cardiac cavity of the stomach as a stout elongated reddish elevation (*lt*), the surface of which is produced into a row of strong sharp, transverse ridges, which diminish in size from before backwards, and constitute a crushing surface almost like that of the grinder of an elephant. Thus, when the front part of the cardiac cavity is cut away, not only are the median teeth already mentioned seen, but, on each side of them, there is one of these long lateral teeth.

There are two small pointed teeth, one under each of the lateral teeth, and each of these is supported by