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HUNTERIAN LECTURES.

LECTURES

ON

COMPARATIVE ANATOMY,

DELIVERED AT THE

ROYAL COLLEGE OF SURGEONS,

IN 1843;

BY

PROFESSOR OWEN, F.R.S. &c.

HUNTERIAN PROFESSOR TO THE COLLEGE;

FROM NOTES TAKEN BY

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FELLOW OF THE ROYAL MEDICAL AND CHIRURGICAL SOCIETY, ETC.

AND

REVISED BY PROFESSOR OWEN.

ILLUSTRATED BY NUMEROUS WOODCUTS.

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ADVERTISEMENT.

Having been imbued with a love for Comparative Anatomy by the Lectures delivered by Professor Owen at St. Bartholomew's Hospital in 1835 (the first I had attended on the subject), I have availed myself of the opportunities which have been afforded by the courses of Lectures that have since been annually delivered by the same distinguished Professor in the Theatre of the Royal College of Surgeons, to keep pace with the rapidly advancing sciences of Zootomy and Physiology.

Of these valuable Lectures I have been in the habit of taking full notes, many of which, having been kindly revised by Professor Owen, have received his approbation for their fidelity.

Having reason to believe that such notes would be acceptable to the members of the Profession and other scientific men, as well as the lovers of Natural History generally, I have obtained the sanction of Professor Owen to publish those of the Hunterian Lectures for the present year. The notes will be revised by the Professor, who has also kindly promised to furnish the subjects of the most instructive diagrams used in illustration of the Lectures, and which will be incorporated by means of woodcuts with the text.

I should not be doing justice to my own feelings did I not avail myself of the present opportunity of expressing the deep sense of gratitude I feel towards Professor Owen as well for this as for the many other favours I have received at his hands during a period of nearly ten years: and I shall endeavour, to the best of my abilities, to discharge my present undertaking in a manner which may not be unworthy of the importance of the subject.

WILLIAM WHITE COOPER.

2. Tenterden Street,
Hanover Square.

HUNTERIAN LECTURES.

1843.

INTRODUCTORY LECTURE.

CLASSIFICATION OF ANIMALS.

Mr. President and Gentlemen,

THERE are doubtless some now present who have not before attended the Hunterian lectures on Comparative Anatomy, which are appointed to be annually delivered in this theatre. I may therefore commence by stating the prescribed extent and subject of these lectures.

They are defined in the second clause of the trust-deed, which expresses the conditions on which the Hunterian Collection, purchased by Parliament, was transferred to the Royal College of Surgeons, as follows: viz. "That one course of lectures, not less than twenty-four in number, on Comparative Anatomy, illustrated by the Preparations, shall be given each year by some member of the College."

When I was honoured by the Council in 1837 with this arduous and responsible office, it seemed to me that the first obligation upon the professor was, to combine with the information to be imparted on the science of Comparative Anatomy an adequate demonstration of the nature and extent of the Hunterian Physiological Collection, and thus to offer a due tribute to the scientific labours and discoveries of its Founder.

The system adopted by Hunter for the arrangement of his preparations of Comparative Anatomy was therefore made that of the lectures which were to be illustrated by them; and this plan was closely adhered to until the whole of the physiological department of the Collection had been successively brought under your notice, and its demonstration completed, in the course of lectures which I had the honour to deliver last year.

It is, I believe, generally known that Hunter has arranged his beautifully prepared specimens of animal and vegetable structures according to the organs; commencing with the simplest form, and proceeding through successive gradations to the highest or most complicated condition of each organ.

These series of organs from different species are arranged according to their relations to the great functions of organic and animal life ; and the general scheme is closely analogous to that adopted by Baron Cuvier in his *Leçons d'Anatomie Comparée*, and in the best modern works on Physiology. The only difference seems to be, that the series of the organs subservient to the functions of animal life are interposed, by Hunter, between those which relate to the organic life of the individual and those which illustrate the great function of generation or perpetuation of the species.

The lectures which I delivered in this theatre in the years 1837, 1838, and 1839, were on the comparative anatomy and physiology of digestion, nutrition, circulation, respiration, excretion, and the tegumentary system. In 1840, the comparative anatomy of the generative organs, and the development of the ovum and fœtus in the different classes of animals, were treated of. The organs of the animal functions next engaged our attention, and a review of the fossil remains of extinct animals was combined with the osteology of existing species. The comparative anatomy and physiology of the nervous system, which was the subject of last year's course, terminated the series commenced in 1837 on the plan which I have just defined.

I have the pleasure to see the friendly countenances of some here present who have patiently, and I hope not unprofitably, listened to the whole of this series of lectures, and who may have discerned in it, notwithstanding the long and frequent intervals, the characters of a single and connected scheme of instruction in Comparative Anatomy and Physiology. But with regard to those gentlemen, the students of medicine and surgery in this metropolis, to whom I have the greatest wish to impart profitable and useful instruction, I have seen, with regret, that portions only of the extensive subject, which the fulness of its treatment compelled me to divide amongst different courses of lectures, have been listened to by successive tenants of the gallery.* The leisure left to the students of medicine, after the arduous task of acquiring the essential elements of their profession, has rarely allowed them to avail themselves of the privilege of admission to this theatre for more than one or two seasons; and I fear that none have been able to serve with us throughout our six years' siege of the city of physiological science founded by Hunter.

The advantage — the necessity, rather — of combining a general

* The gallery of the theatre is appropriated to the students; the body of the theatre to the members and council of the college. W. W. C.

knowledge of the organisation of the lower animals with that of man, which ought always to claim the first attention of the medical student, is now universally recognised. A great part, often the best part, of the proofs of the most important physiological doctrines are derived from Comparative Anatomy. The increasing taste for the natural sciences, and the rapidly diffusing knowledge of zoology and geology, render it scarcely pardonable in a member of a liberal profession to be wholly unversed in them; and almost discreditable to a medical man to be unable to offer any sound opinion on a fossil coral, shell, or bone which may be submitted to his inspection, or on the other surprising phenomena of animal life, as the animal origin of chalk and flint, which geology from time to time educes from the dark recesses of the earth, and makes a common topic of conversation.

There is no just ground to fear that the time required to gain the requisite elementary knowledge of Comparative Anatomy will detract from that which ought to have been exclusively occupied in the study of human anatomy and surgery; or that the subsequent pursuit of natural science will interfere with the proper professional duties.

There is generally a period of leisure during the first years of practice which may be most agreeably and profitably devoted to scientific pursuits; and the young provincial surgeon may be assured by the example of Gideon Mantell, that the researches and discoveries in palæontology and geology, which have added so many honourable titles to that name, are quite compatible with the most extensive, active, and successful practice.

It has been a subject of much consideration with me, having fulfilled, in one respect, the obligations to the memory of the founder of the Collection, how to present the general principles and leading facts of Comparative Anatomy with most profit and utility to my junior auditors; and I trust that the plan which I propose to adopt for the present course and that of next year will enable me to give a complete view of the science within that space, which shall not be less subservient to the illustration of Physiology than were the preceding lectures given on the system indicated by the arrangement of the Hunterian Preparations.

It is very true that, by tracing the progressive additions to an organ through the animal series from its simplest to its most complex structure, we learn what part is essential, what auxiliary to its office; and the successive series of preparations in Hunter's Physiological Collection strikingly and beautifully illustrate this connection between Comparative Anatomy and Physiology. But it is by the comparison of the particular grades of complication of one organ with that of another organ in the same body, by considering them in relation to the general nature and powers of the entire animal, together with its relations to other animals, and to the sphere of its existence, that we are chiefly enabled to elucidate the uses of the several super-additions which are met with in following out the series of complexities of a single organ.

Comparative Anatomy fulfils only a part of its services to Physiology, if studied exclusively in relation to the varieties of a given organ in different animals: the combinations of all the constituent organs in one animal must likewise be studied; and these combinations with the principles governing them, or the correlations of organs, must be traced and compared in all their varieties throughout the animal kingdom.

It is in this point of view that I now propose to bring before you the leading facts of Comparative Anatomy, to discuss and demonstrate the organs as they are combined in the individual animal, and, commencing with the lowest organised species in which the combination is of the simplest kind, to trace it to its highest state of complexity and perfection, through the typical species of the successively ascending primary groups and classes of the animal kingdom. In short, as my previous courses of Hunterian lectures, agreeably with the arrangement of the Hunterian Collection, have treated of Comparative Anatomy according to the organs, in the ascending order, so, in the present course, Comparative Anatomy will be considered according to the class of animals, and also in the ascending scale.

Many examples suggest themselves of the advantage of this mode of studying the organisation of animals for the purpose of acquiring just conceptions of the uses of the organs. In tracing, for example, the progressive complication of the heart, we first find the simple dorsal vessel; it is next concentrated into a ventricle, and to this single cavity an auricle is afterwards appended: then the auricle becomes divided; afterwards there are two ventricles: there are instances even in the animal kingdom where there are three ventricles and ten ventricles. Now, the two-cavitied, dicœlous, or bipartite heart is met with in the snail and in the fish; but the physiology of such conformation of the organ can only be explained by its connections with other organs, and by the general structure and habits of the animal.

First, then, as to the connections of the bipartite heart. In the snail it is so placed, in reference to the breathing organ, that it receives the aërated blood from that organ and propels it to the system: it is an organ for the circulation of arterial blood; in other words, a systemic heart. The bipartite structure of the central organ of circulation, compared with lower or higher conditions of the same organ, could never have taught that fact; — the knowledge of it necessitates and pre-supposes a knowledge of the relation of the heart to the lungs.

In the fish the bipartite heart is so connected with the breathing organs, that it transmits exclusively to them the blood which the auricle receives from the veins of the body: it is an organ for the circulation of venous blood; in other words, a "pulmonic heart." Another question then arises, Why is the dicœlous heart in one animal systemic, in another animal pulmonic? This can only be answered by a further insight into the organisation and powers of such animals. With respect to the instances adduced, both species are cold-blooded, and, compared with the warm-blooded classes, both have a low amount of respiration; but the fish and snail differ widely in the degree in which they exercise or enjoy the respiratory functions. The snail, proverbially sluggish and inactive, has its muscular system reduced almost to a single ventral disc, by the successive contractions of the parts of which it glides slowly along. The chief mass of its body is made up of the organs of the vegetative function. We see here a wide convoluted alimentary canal, an enormous liver, a large ovarium and as large a testis combined with many singular accessory generative organs, in the same common visceral cavity: they make up the great bulk of its body. The tissues of such viscera are endued with little of that action which assists in the acceleration of the currents of blood, through them; and, therefore, the greater circulation is aided by the contractions of a ventricle: whilst as the function of respiration bears ever a direct ratio to the energy and frequency of muscular action, it suffices that the venous blood should flow with an equable and unaccelerated stream over the oxygenating surface, and the energies of the heart are therefore confined to the service of the general circulation.

In the fish, the proportions of the muscular and visceral parts are reversed: the greater part of the body is composed of the vibrating and contractile fibre, by the action of which the fish is propelled through the liquid medium; while at the same time the systemic circulation is proportionally aided and accelerated. But this amount and energy of muscular action requires a proportional activity of the respiratory function, and the forces of the heart are, therefore, concentrated upon the gills.

Thus we perceive that a similar construction of an organ may, through its different relations with other organs, subserve different functions: whilst the conditions of such differences demand for their elucidation, a knowledge of the general organisation and endowments of the entire animal.

Permit me to give another instance of the necessity of studying the whole organisation and relations of an animal in order to learn the physiology of the modification of one of its organs.

In tracing the progressive complications of the stomach, we at length meet with it under that very singular condition which we term a gizzard; in which the cavity is reduced to a mere fissure, by the accumulation of muscular fibres in its walls, and by a thick and callous lining of dense horny matter. The physiologists who viewed this modification of a stomach, without reference to the rest of the organisation of the bird, and who contented themselves by experimenting upon the compressive and triturating force of the gizzard, were led to conclude that digestion was mainly a mechanical process. They were here misled by Comparative Anatomy; but it was by its abuse.

Graminivorous and granivorous birds — those species whose food demands the most complete comminution — have that mechanical process performed, it is true, exclusively by the gizzard; but near this triturating stomach we find another cavity as exclusively secretory in its functions, and which we know, by experiment, to furnish a powerful solvent in great quantities to act upon the comminuted food. But why the comminuting machinery should be transferred to the abdominal cavity in the bird requires for its explanation a review of the general structure, habits and sphere of existence, of this particular form of animal.

The most prominent quality in the bird is its power of flight — to lighten the extremities and accumulate the weight at the centre of gravity favour this power: it is especially requisite that the head, which is supported on a long and flexible neck, should be as light as possible. To this end the jaws, instead of supporting dense and heavy teeth, are wholly edentulous, and are sheathed with light horn; they are simply prehensile, not masticatory, organs; and the muscular masses, subserving mastication, are consequently uncalled for. The compensation is admirably adjusted in harmony with the exigencies of the bird: pebbles are swallowed to serve as teeth; are collected in the gizzard, near the centre of gravity, of the whole body, at which point the muscular mass required to operate upon them, and, by their means, to crush the grain, is likewise concentrated. Thus the teeth, and masticatory muscles are removed from the head, and concentrated in the stomach, at the centre of gravity of the bird; and the peculiarities of its stomach are thus found, by a general survey of the organisation and habits of the animal, to relate to the acquisition of certain mechanical advantages in the disposition of the weight of the body, so as to favour the act of flight.

I might easily multiply such instances, but I should thus only anticipate the illustrations of which the present course of lectures will mainly consist.

Not only the soundest and widest physiological generalisations, but those inductions which, from sometimes being based on a mere fragment of a bone, seem like a divination of the nature and affinities of an extinct species, depend entirely upon a knowledge of the laws of correlation of organic structures, and can only be made by the comparative anatomist, who has studied not only the gradations of structure, but the general combinations of organs which characterise the species of each particular class.

With these explanations of the grounds which have lead me to change the order in which I propose to bring before you the facts of Comparative Anatomy, I proceed to the proper business of the present course, which must commence by the definitions of the primary groups of animals whose general plan of organisation it is proposed to describe and compare.

Little useful progress can be made in Comparative Anatomy without some knowledge of Zoology. Zoology is the key to the nature and habits of the animals of which Zootomy unfolds the structure. Some knowledge of natural history and of the principles of classification, therefore, is essential to the comprehension of the connection between structure and habits, on which the utility of Comparative Anatomy in the advancement of Physiology mainly depends.

The classification of animals is not now what it was in the time of Linnæus. I do not mean merely to say that animals are differently arranged, but the object and principles of that arrangement are very different.

Linnæus in his *Systema Naturæ* wished to give, as it were, a Dictionary of the Animal Kingdom, by reference to which you might as readily ascertain the place of the animal in his system as that of a word in a lexicon, by merely knowing its first and second letters. To this end, Linnæus selected a few of the most obvious characters for the establishment of his groups.

Taking, for example, a certain number of incisor teeth, and the pectoral position of the mammæ, as the characters of his first order of animals, he thereby associated man with the monkeys and the bats. But, independently of the psychical endowments which place the human species far above the lower creation, it may readily be conceived that great differences of organisation must exist in animals which enjoy the erect position on two feet, in those which climb by having four hands, and in those which fly by virtue of a metamorphosis of their anterior members into wings.

External and arbitrary characters, selected merely for the convenience of their appreciation, thus tend to the association of very differently organised species; and, on the other hand, they are equally liable to separate into very remote groups of an artificial system, two animals which may have very similar anatomical structures. Of this we have several examples in the Linnæan subdivisions of the class of fishes, the orders of which are characterised by the easily recognisable position of the fins. Linnæus's attention was particularly directed to the very variable position of the ventral pair of fins, which are the analogues of the hinder limbs in land animals. In some fishes, as the pike and many other fresh-water species, the ventral fins are at some distance behind the pectoral fins, or in their usual place — these formed the order *Abdominales:* in others, as the perch, the ventral fins are attached beneath the thorax — these constituted the *Thoracic* order: in others, as the cod, you find the ventral fins in advance of the pectorals, or under the throat — such species formed the *Pisces jugulares* of Linnæus: lastly, those species in which the ventral fins are altogether wanting, as the eel, formed the *Apodal* order.

Such a system has the advantage of enabling the collector to refer with great facility any fish to its artificial order; but you can scarcely express any general proposition in comparative anatomy in reference to such groups. There are two sword-fishes, for example, having the same anatomical structure, and not easily distinguishable externally save by the height of the dorsal and the difference in the position of the ventral fins: but in the *Systema Naturæ* of the Swedish Naturalist, the *Xiphias* is placed in one order, and the *Istiophorus* in another; the variable and little influential fins prevailing over all the rest of the organisation in the artificial ichthyology of Linnæus.

Amongst the lower animals, we find the slug, placed in one class, viz. the *Vermes mollusca*, and the snail in a different class, viz. *Vermes testacea*, in the *Systema Naturæ;* whilst in their whole anatomy these two mollusca most closely resemble each other, the rudimental state of the shell being the main difference in the *Limax* or slug. Similar instances of the violation of natural affinities might be multiplied, and are, indeed, inevitable in an artificial system.

I confess that if the classifications of zoology of the present day continued to be of the same character as that to which I have just referred, which however, let it be remembered, was the best that could be made in the time of Linnæus, and a necessary transitional step to improved views on this subject, I should not have been justified in occupying the time of the auditors in this theatre of anatomy and physiology, by the details of such artificial helps to the recognition of the outward characters of the members of the animal kingdom.

But the principles on which animals are now grouped together are of a different and much higher kind: they are the fruits of the best results of the researches of all the great comparative anatomists since the time of Linnæus. The characters of the classes of animals have been rendered by the immortal Cuvier, the highest expressions of the facts ascertained in the animal organisation. I know not any thing more calculated to impress the stranger to anatomical science with the immensity of the labour that has been gone through, and with the vast number of careful and minute dissections that have been made, than the propositions which now form the definitions of the primary groups of the animal kingdom.

The whole organisation of one species has been compared with that of another, and this with a third, and so on, in order to ascertain in what organ, or system of organs, the greatest number of animals would be found to present the same condition: so that they might not be arbitrarily, but naturally associated together. In the terms of logic, the characters common to all animals having been ascertained, the anatomist, in the next place, has sought to discover the difference, which, added to the definition of *animal*, would form the most extended species of that genus.

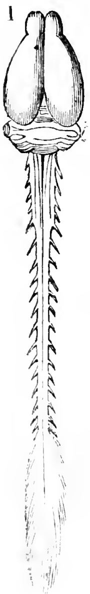
Aristotle thought he had found this differential or primary character in the blood, recognising as blood only the circulating fluid, which was red coloured. His first division of animals was accordingly into *Enaima* and the *Anaima*, or the sanguineous and exsanguineous animals. For a long time no advance was made beyond this early step in the primary arrangement of animals. It was at length discovered that many of the exsanguineous animals of Aristotle did actually possess blood, though differing in colour from that of the so-called sanguineous species. This led, however, only to a nominal improvement in the classification; the *Enaima* were called "red-blooded," the *Anaima* "white-blooded" animals. It was reserved for Cuvier to discover, in the course of his minute dissections of the lower animals, that an extensive class of worms had red blood circulating in a closed system of arteries and veins; and this discovery first materially affected the value of the character applied by Aristotle to the primary groups of the animal kingdom.

The Annelides, or red-blooded worms, could not, however, be combined with *birds*, *beasts*, and *fishes*, in a natural system, since they differed from them so widely in almost every other particular of their organisation.

Some other character was therefore sought for, since it became obvious that the colour of the blood led to an artificial combination of species. Lamarck thought he had discovered the desired character in the vertebral column, this structure being present in all the Enaima of Aristotle, and absent in all his Anaima. Lamarck proposed, therefore, the name of *Vertebrata* for the one class, and of *Invertebrata* for the other. Now it will be observed that the Invertebrata are grouped together by a negative character; and I know not any instance where such a character has been employed in zoology, in which very differently organised species have not been associated together. What indeed can be predicated in common of the snail, the bee, and the polype, than that they are animals, and have no vertebral columns, and the like negations. It was obvious also that there was no proportion or equivalency between the *Vertebrate* and the *Invertebrate* groups, and the idea of equivalency or proportion, as well as that of likeness, ought always to govern the labours of the classifier.

In the attempt to remedy this defect, the important discovery was made that the vertebral column was subordinately related to a condition of a much more important system in the animal body than the skeleton, viz. the nervous system. Cuvier thereupon applied himself with indefatigable industry to ascertain the arrangement of the nerves in the Invertebrata, and after a long series of minute and elaborate dissections, he discovered three modifications of that system, each of equal importance with that which governed the vertebral character of the red-blooded animals of Aristotle. Cuvier, accordingly, proposed to divide the animal kingdom into four primary groups or sub-kingdoms, viz. *Vertebrata*, *Mollusca*, *Articulata*, and *Radiata*.

1



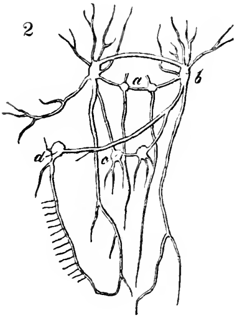
It is due to Hunter to state that the general results of his dissections of the nervous system are expressed in the definitions of the same leading types as those of Cuvier; but he made the minor differences which he had detected in the *Vertebrate* series equal to those primary types of the nervous system which now characterise the *Mollusca* and *Articulata* of Cuvier, — a view which would have led to erroneous results if applied to the classification of the primary groups of animals.

The sub-kingdom *Vertebrata*, or *Myelencephala*, is characterised by the disposition of the principal mass of the nervous system in a median axis, consisting of the brain and spinal chord (*fig.* 1.), situated in the dorsal aspect of the body, behind the heart and digestive system; and inclosed in a bony or cartilaginous case, constituting a vertebral column. The organs of the five senses, sight, hearing, smell, taste, and touch, are almost always present.

The respiratory organs communicate with the pharynx, or anterior part of the alimentary canal.

The mouth opens in a direction parallel with the axis of the body, is provided with two jaws, placed one above or in front of the other.

2



The blood is red.

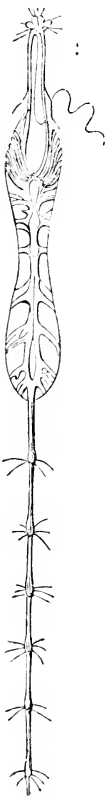
The heart is a compact muscular organ, having never fewer than two cavities, an auricle and ventricle.

The muscles surround the bony or gristly levers on which they act, or, in other words, the skeleton is internal.

The locomotive members never exceed two pairs.

The sexes are distinct.

In the sub-kingdom *Mollusca*, or *Heterogangliata*, the principal centre of the nervous system bears the form of a ring, surrounding the gullet, from which the nerves radiate, often unsymmetrically, to different parts of the body (*fig.* 2.): the brain is represented by ganglions above (*a*) or at the side (*b*) and below the gullet; other ganglions (*c d*) are developed in other parts of the body. The form of the body corresponds with the disposition of the nervous system, and is commonly unsymmetrical. In a single order (*Cephalopods*) the muscles originate from an internal rudimental cartilaginous skeleton: in the rest they are attached only to the skin, which forms a soft envelope in which there are developed in many species one or two calcareous plates, called shells.



The blood is colourless, or not red; the heart compact, muscular, and propelling the blood through a closed system of arteries and veins.

The respiratory organ is never wanting; and, with the exception of one family (*Ascidians*), the cavity containing it communicates with or opens near the anus.

The *Mollusca* are diœcious or hermaphrodite.

The third primary division of the animal kingdom, viz. the *Articulata*, has the brain in the form of ring, embracing the gullet: a double ganglion above the tube supplies the organs of sense: from the sub-œsophageal ganglions two chords are extended along the ventral surface of the abdomen, and are, in most species, united at certain distances by double ganglions, which give origin to the nerves of the extremities (*fig.* 3.). From the symmetrical disposition of the nervous centres, I have called this sub-kingdom *Homogangliata*. The body presents a corresponding symmetrical form. The skeleton is external, and consists of articulated segments, of frequently an annular form: the articulated limbs in those species which possess them have a similar condition of the hard parts, in the form of a sheath, which encloses the muscles.

The respiratory organs commonly open upon the sides of the body; rarely near the anus, and never communicate with the mouth.

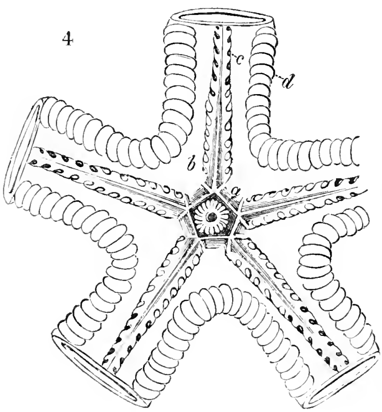
The jaws, when present, are lateral, and move from without inwards, and not from above downwards.

The heart is situated in the back, is often vasiform; and the veins are frequently in the form of large, irregular sinuses; there is always a circulation, and the blood is red in one class (*Anellides*).

Most *Articulata* are diœcious: a few are hermaphrodites.

The *Radiata*, or fourth primary division of animals in the system of Cuvier, is so called because most of the species comprising it have their parts arranged around an axis, on one or several radii, or on one or several lines extending from one pole to the other. The nervous system, when traces of it have been visible, is also arranged in radii (*fig.* 4.). It does not present the Homogangliate or Heterogangliate type. In one family only (*Holothuriadæ*) is there a distinct respiratory system: the other characters assigned by Cuvier are negative ones.

4



I have already observed, that there is no instance in which animals, grouped together by negative characters, have formed a natural assemblage; nor is the sub-kingdom *Radiata* of Cuvier an exception to this rule.

The truth is simply that the anatomy of this immense assemblage of low-organised animals is not yet sufficiently understood; and, consequently, general propositions, and at the same time positive ones, like those which define the Vertebrate, Molluscous, and Articulate sub-kingdoms, cannot be enunciated.

Much has unquestionably been done in this field of Natural History since the time of Cuvier, and attempts have been made, with various degrees of success, to subdivide the *Radiata* according to positive characters.

The binary division, which I proposed in 1835*, has been adopted in this country by my esteemed friend, the Professor of Comparative Anatomy at King's College. I found that those *Radiata* of Cuvier in which the nervous system could be most unequivocally traced in a filamentary form, likewise presented an alimentary canal as a distinct tube, with a mouth and anus, suspended in a distinct abdominal cavity: the well-defined nerves governed a corresponding development of the muscular system. Generation was by impregnated ova, never by spontaneous fission or gemmation.

The *Echinoderma*, *Rotifera*, *Cœlelmintha*, and *Ciliobrachiata*, are the classes of Cuvier's zoophytes, which were grouped together by positive characters, under the title *Nematoneura*.

I do not deny a filamentous condition of the nervous system in the rest of the zoophytes; each day brings with it testimony of its presence in animalcules where it had not before been detected. Nevertheless, in those classes in which the condition of the nervous system is most obscure, we find that the digestive cavity is generally excavated in the common parenchyma of the body, is devoid of free parietes, and has no anal outlet: particular organs are often indefinitely multiplied, as the stomach in the *Polygastria*, the generative organs in the *Tæniæ*, the prehensile mouth in the *Polypi*. Generation by gemmation and spontaneous fission is common in this lowest division of the animal kingdom, to which I have applied the name *Acrita*, which had been used in a more extended sense by Mr. Macleay. Two classes, the *Acalephæ* and *Anthozoa* (Ehrenberg), stand in an intermediate position between the *Acrita* and *Nematoneura;* and most of the classes in the lowest division of the *Radiata* lead by more or less gentle gradations into those of the higher one.

Nor is this surprising: the radiated animals are closely analogous to the embryo forms of the higher classes; and as the several changes of such embryos succeed each other more rapidly than the later one, so also each class of the *Acrita* more closely approximates some class of the *Nematoneura* than is observed in the classes of the higher groups, and the characters of the lowest or Acrite classes are the least definite and fixed. I have, therefore, endeavoured to express the relations of the higher and lower organised classes of the *Radiata* of Cuvier, by placing them in parallel lines under their former collective names, as in this tabular diagram of the provinces and classes of the animal kingdom.

* Syllabus of the Lectures on Comparative Anatomy, given at the Medical School of St. Bartholomew's. 8vo.

Kingdom ANIMALIA.

Sub-kingdom *Vertebrata*.

Class MAMMALIA.
AVES.
REPTILIA.
PISCES.

Sub-kingdom *Articulata*.	Sub-kingdom *Mollusca*.
Class CRUSTACEA.	Class CEPHALOPODA.
ARACHNIDA.	GASTEROPODA.
INSECTA.	PTEROPODA.
ANELLATA.	LAMELLIBRANCHIATA.
CIRRIPEDIA.	BRACHIOPODA.
	TUNICATA.

Sub-kingdom *Radiata*.

Nematoneura.	*Acrita*.

Class RADIÀRIA, Lamarck.

ECHINODERMA, Cuv.	ACALEPHA, Cuv.

Class POLYPI, Cuv.

CILIOBRACHIATA, Farre.	ANTHOZOA, Ehrenb.	NUDIBRACHIATA, Farre.

Class ENTOZOA, Rudolphi.

CŒLELMINTHA, Owen.	STERELMINTHA, Owen.

Class INFUSORIA, Cuv.

ROTIFERA, Ehrenb.	POLYGASTRIA*, Ehrenb.

LECTURE II.

POLYGASTRIA.

I PROPOSE first to invite your attention to a class of animals, the most minute and apparently the most insignificant of created beings. It might almost seem needful to apologise for the design of trespassing on your time and patience during one or two lectures with the Anatomy and Physiology of creatures which are wholly invisible to the naked eye. But we are too apt to let our judgments of the importance of objects be unduly influenced by first impressions, especially by those of magnitude or the contrary, which deeper insight into their true nature and value rectifies.

The active atoms about to be described, for the knowledge of whose

* A Glossary and explanation of the scientific terms will be added to the concluding Lecture.

very existence we are indebted to the microscope, are by no means the least complex of organised beings; they belong, in fact, to the higher division of organic nature, and manifest the distinctive properties of animals in the most striking and unequivocal manner.

If you skim a small portion of the green matter, which in summer time mantles the surface of a stagnant pool, place a drop of this in the object-holder of a microscope, and examine it with a glass of a quarter of inch focus, you will find it teeming with animal life; you will see numerous little objects, of one or other of the forms, depicted in this diagram, darting with rapidity across the field of view, or gyrating or revolving on their axes. If you examine in like manner a drop of water in which has been infused any vegetable or animal substance, and which contains the particles of such substances in a state of decay or decomposition, you will find such infusions similarly tenanted with these active animalcules; they have been termed from this easy and common mode of procuring them, the animals of infusion, or *Infusoria.*

The earlier microscopical observers confounded all the minute living objects which they thus met with under that term; but the progressively increasing pains and discrimination of later observers have removed the embryos of polypes, worms, and insects from this motly and heterogeneous group, and have restricted it to those animals which, in their fully developed states, manifest a form of body devoid of radiated arms or tentacles, more or less amorphous, without definite locomotive members, moving by means of minute superficial vibratile cilia more or less diffused over the surface of the body, or aggregated in circular groups near the head, where they produce by their successive action the appearance of rapidly rotating wheels. It is always the largest species of Infusoria which are provided with the last specified arrangement of vibratile cilia, and these "wheel-animalcules," as they are termed, being endowed with a higher type of organisation, more especially of the digestive system, constitute a distinct class of Infusorial Animalcules, to which I shall refer, after first noticing the anatomical characters of the lower organised and more diffusely ciliated group (*fig.* 5.).

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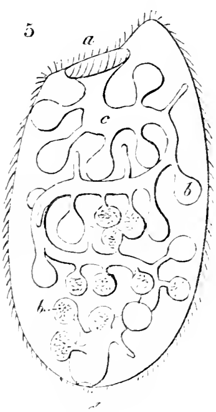

Leucophrys.

The species of this group possess numerous clear globular sacs in their interior, which rapidly receive coloured nutriment, when in a sufficiently subdivided state: these sacs are described as stomachs by Ehrenberg, who has thence proposed for this class the name of *Polygastrica.* The most minute forms, as the species called *Monas crepusculus,* Ehr. have been estimated at the $\frac{1}{2000}$ of a line in diameter.* Of such Infusoria a single drop of water may contain five hundred millions of individuals,—a number equalling that of the whole human species now existing upon the surface of the earth. But the varieties in the size of these invisible animalcules are not less than that which prevails in almost every other natural class of animals:—from the minutest *Monad* to the *Loxodes* or *Amphileptus,* which are one fourth or one sixth of a line in diameter, the difference of size is greater than between a mouse and an elephant. Within such narrow bounds might our ideas of the range of size in animals be limited, if the sphere of our observation was not augmented by artificial aids.

Many of the polygastric animalcules are naked, covered only by a delicate, transparent, and more or less ciliated integument. Others are protected by a secreted shell, which consists of pure, colourless, and transparent silex. This shell may present the form of a simple shield, indicating by its position the back of the animal, as in *Euplæa Charon;* others have their flinty armour resembling a minute bivalve shell: in some, as the *Navicula,* it has the form of an elongated case, or flattened cylinder, open at both extremities (*fig.* 6.): it is sometimes straight, sometimes bent like the Australian boomerang; it may present the form of a reticulated cone (*fig.* 7.), or a discoid case (*fig.* 8.); in short, the varieties of the silicious shells of the Infusoria surpass in number those of the calcareous shells of the Mollusca. But whatever their form, the superficies of these delicate microscopic objects is generally sculptured with a beautiful, well defined, and more or less complicated pattern, which makes it easy to recognise the species, and distinguish them from one another.

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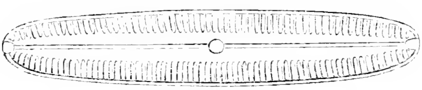

Navicula.

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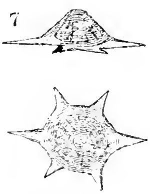

Dictyocha.

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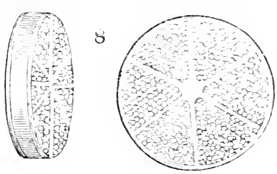

Actinocyclus.

Most of these animated minims are locomotive and free; a few, as the Vorticellæ, are attached to foreign bodies by a long and highly irritable and contractile pedicle; others, as the *Gomphonema,* are appended to the extremities of the branches of a dichotomously divided stem.

* A line is the twelfth of an inch.

The locomotive Polygastria propel themselves through the water by the action of their vibratile cilia, which are sometimes generally diffused, as in *Bursaria* and *Nassula*; sometimes aggregated, in longitudinal rows, as in *Amphileptus*; often limited to the region of the mouth, as in the *Vorticellæ*, indicating the passage to the higher or Rotiferous group. These cilia in some species, as in *Stylonychia* and *Euplotes*, are of such relative size as to give the species a myriapodous character, and are used, like little feet, to creep along the stems of the *Chara*, and other minute vegetable plants. True jointed locomotive members are never developed in any of this minute and primitive race of animated beings; but they retain, throughout life, those simple vibratile cilia which produce the rotatory movements in the ova of Mollusca whilst imprisoned in their nidus, which are probably the agents of analogous movements of the ovum of the Mammalia in the Fallopian tube, and which are doubtless common to the ova of all classes of animals at that early period which the Polygastric Infusoria seem permanently to represent.

These cilia, the outward instruments of locomotion in Infusoria, and which are retained in greater or less proportion on the epithelium-clad mucous surfaces of all animals, appear, notwithstanding their minute size and incalculable numbers, to owe their motions to the actions of definitely arranged muscles: Ehrenberg has seen the expanded base of the locomotive cilium in the *Polygastria*, and describes the radiated structure which he conceives to indicate the disposition of the muscular fibres moving such cilium.

If you watch the motions of the Polygastric Infusoria, you will perceive that they avoid obstacles to their progress; rarely jostle one another; yet it is difficult to detect any definite cause or object of their movements. Some species, it is true, prey upon animalcules of their own class, and will gorge an individual of nearly their own size, which they attract by the currents in the water caused by the oral vibratile cilia. But the greater number of the class subsist on the minute atoms of the decomposing animal and vegetable substances of the fluids or infusions in which they exist,—particles which do not require a definite pursuit, since they are inert and generally diffused throughout the infusion.

The motions of the Polygastria have appeared to me, long watching them for indications of volition, to be in general of the nature of respiratory acts rather than attempts to obtain food or avoid danger. Very seldom can they be construed as voluntary, but seem rather to be automatic; governed by the influence of stimuli, within or without the body, not felt, but reflected upon the contractile fibre; and therefore are motions which never tire. We may thus explain the fact which Ehrenberg relates—not without an expression of surprise—namely, that at whatever period of the night he examined the living Infusoria he invariably found them moving as actively as in the day-time; in short, to him it seemed that these little beings never slept. Nor did this appear to be merely the result of the stimulus of the light required to render them and their movements visible; since when they were observed upon the sudden application of light without any other cause of disturbance, they were detected coursing along at their ordinary speed, and not starting off from a quiescent or sleeping state.

Evidence of muscular action in the *Polygastria* is afforded by the contraction and change of form of the entire body. These changes are so rapid, extensive and various in certain species that it is impossible to refer their bodies to any definite shape: such form the genus *Proteus* of Müller, and the family *Amœbæa* of Ehrenberg. No definite arrangement of nervous matter has yet been detected in the Polygastric Infusoria; but its presence is indicated by the coloured eye-speck in certain genera: and nervous conductors of impressions are no less requisite for reflex than for voluntary motions.

Every Polygastric animalcule, like every other true animal, has a distinct mouth, which is sometimes placed upon a long extensile neck, as in *Lachrymaria;* in many of the monads it is provided with a long tentacle or a pair of tentacles (*fig.* 9. *a.*); in other species it is armed with a curious dental apparatus, consisting of a series of long, slender and sharp teeth, arranged side by side, in the form of a cylinder, as in *Chilodon* and *Nassula* (*fig.* 11. *a, a*).

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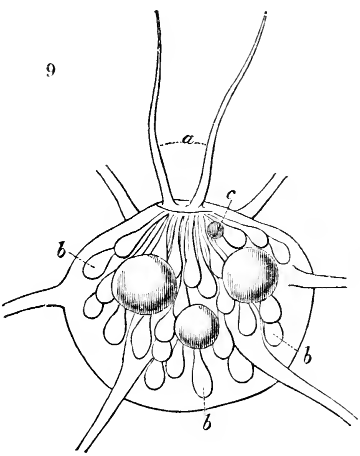

Monad of Volvox.

If you remove some of these animalcules from their native infusion to a drop of clear water, and, after they have fasted a few hours, add a drop of the solution of pure indigo or carmine, the fine particles of these colours will be greedily swallowed, and will soon be seen to fill successively a number of pyriform or spherical cavities (*fig.* 5. *b.*) in the interior of the animal. In some species these assimilative cells exceed 100 in number, and if, with Ehrenberg, we call them stomachs, they afford a very interesting example, in these early forms of animal life, of the irrelative repetition of this most essential and characteristic organ of the animal. Ehrenberg has observed and figured certain definite arrangements of these digestive sacculi, as well as of the alimentary canal, to which he states that they are appended. In the Monads, and many other of the more minute species of Polygastria, the stomachs are said to arise by separate tubular pedicles from the common dilatable cavity of the mouth itself (*fig.* 9. *b*, *b*). Such species have no intestine, no anus, and are said to be *anenterous*. In others, where the sacculi are appended to an alimentary canal (*Polygastria enterodela* Ehr.), that canal may be bent into a loop, and describe a circle with the anus, opening near the mouth, as in *Vorticella* (*fig.* 10.); or it may pass in a straight line through the axis of the body, as in *Enchelis;* or form several flexuous curves in its passage from the mouth to the opposite extremity of the body, as in *Leucophrys* (*fig.* 5.). But sometimes, as in the Kolpodæ, neither the mouth nor anus is terminal in position.

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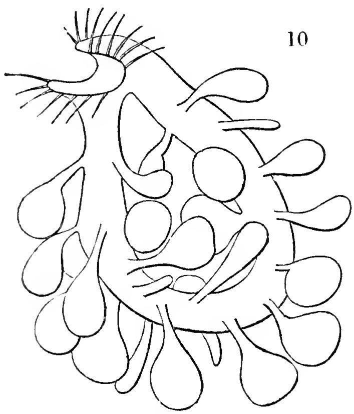

Vorticella.

It has been objected to this interpretation given by Ehrenberg of the nature of the sacculi which receive and assimilate the nutrient molecules that certain species, as the *Enchelis pupa*, will swallow another animalcule nearly equal to itself in bulk, and thereby undergo a total change in the form of its body; but this may only imply great dilatability of the œsophagus or common canal, such as we observe in the boa constrictor, which becomes in like manner deformed after gorging a goat or other animal much thicker than itself; doubtless the little sacculi successively receive and digest, like the stomach of the boa, the dissolved parts of the swallowed prey. Then again it is objected that the sacculi are not fixed in definite positions, but are seen constantly, though slowly, moving, and apparently rotating through the general cavity of the animal. But the peristaltic wave-like undulations of a common connecting canal, by drawing them successively in and out of the focus of the observer, is quite sufficient and very likely to occasion the deceptive appearance of their circulating movements. If these stomachs were actually separate and closed sacs imbedded in the transparent gelatinous plasma of the animalcule, and endowed with a circulatory movement, it is inconceivable that they should commonly present the characteristic arrangement which Ehrenberg has described and figured in particular species; as, for example, in the *Vorticella*, a circular arrangement, or the wavy disposition in *Leucophrys:* yet such a constancy in the arrangement of the assimilative sacs in these genera is the result of my experience. Add to this, if they have not orifices of communication with the alimentary tract, the difficulty of accounting for the rapid and ready transmission of the coloured aliment into their interior without the surrounding parenchyme being stained.

It is possible that, besides digestive organs, the Polygastria may have a vascular system for the conveyance of the assimilated fluid throughout their frame; their minuteness ought to be no objection to such a conjecture, for it is merely a relative idea. Probably the reticular markings on the superficies of certain species may indicate such vessels: it is certain that here is placed that mechanism for renewing the surrounding oxygenised medium upon that surface, which we find to be the essential respiratory dynamic of the gills in most of the molluscous animals. At all events, to no other part of the polygastric organism than to this ciliated superficies can the respiratory function be attributed. But the action of the vibratile cilia upon the water is necessarily attended in the free Infusoria with a reaction which rolls the little animalcule through its native element and produces the semblance of a definite voluntary movement.

Perhaps the most marvellous part of the organisation and economy of the Polygastric Infusoria is that which relates to the function of generation. This function, I may observe, is the only one which does not necessarily require a special organ for its performance. I am not aware that this proposition has been before enunciated, but it will be quite intelligible when the essential nature of the generative process is better understood.

Although both ovaria and testes have been unequivocally demonstrated in the *Polygastria*, yet their most common mode of propagation is quite independent of, and superadded to, the function of these organs. In a well fed *Monas*, *Leucophrys*, *Enchelys*, *or Paramecium*, the globular parenchyme may be observed to become a little more opake and apparently more minutely subdivided: then a clear line may be discerned stretching itself transversely across the middle of the body and indicating a separation of the contents into two distinct parts. The containing integument next begins to contract along this line, and the creature to assume the form of an hourglass (*fig.* 11.): this, though doubtless an uncontrollable, seems to be a spontaneous action, and the struggle of each division to separate itself from its fellow indicates an impulse in each to assume its individual and independent character; the which they no sooner effect than they dart off in opposite directions, and rapidly acquire the normal size and figure. In the *Vorticella* and some other species, we have examples of spontaneous division in the longitudinal direction, which commences at the mouth, and extends to the irritable and contractile stem, from which one or both of the new formed individuals detach themselves. In some species this spontaneous fission, which corresponds, as I stated in my Lectures on Generation in reference to the ova of the Medusa, in so interesting a manner with the earliest phenomenon in the development of the ovum in the higher animals, is arrested before its completion, but the partially separated individuals continue in organic connection and form compound animals, sometimes in the form of long chains, sometimes branched, sometimes expanding to form a spherical bag, as in the well-known *Volvox globator*, which was long deemed a single individual of a peculiar species. New spherical groups of Volvoces are thrown off into the interior of the parent monadiary, which is rent open to allow them to escape, as in *fig.* 12.

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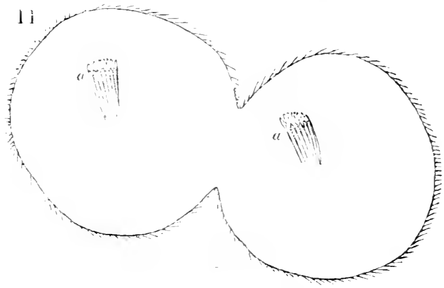
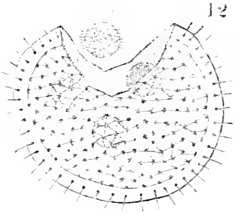


Nassula.

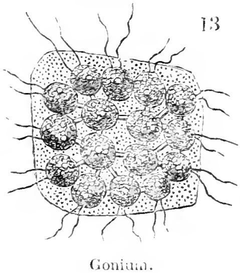
12



Volvox.

Another mode of generation is by gemmation or the development of buds, which in some species, as *Cheroma*, grow out of the fore part of the body, and in others, as *Vorticella*, from the hind part, near the stem, or from the stem itself, from which the young animal soon detaches itself. In most *Vorticellidæ*, as in *Carchesium* and *Epistylis*, the small liberated end of the body opposite the mouth is provided with a circle of vibratile cilia, so long as the individual swims freely: but these disappear when the pedicle is developed.

13



Gonium.

With regard to the more common fissiparous mode, Ehrenberg has figured gradations of this spontaneous division of the organised contents of the integument in the *Gonium* (*fig.* 13.) and *Chlamydomonas*, which may be compared with the earliest stages of the development of the germ, as figured by Siebold in the *Strongylus* and *Medusa,* by Baer in the frog, and by Barry in the rabbit. Dr. Martin Barry, who has discovered the very remarkable and complicated nature of this process in the mammalian ovum, was alone perhaps in the condition to fully comprehend and explain its analogy to the fissiparous generation of the Polygastria, to which, in 1840, I briefly alluded; and this he has done in a paper, replete with interesting generalisations, lately read before the Royal Society. I have been favoured by that indefatigable observer with the following notes of his ideas on this subject.

"Between the appearance presented by the mammiferous germ during the passage of the ovum through the Fallopian tube, and those met with in the young Volvox globator while within the parent, I find a resemblance which is very remarkable indeed, extending even to minute details. Not only do the cells of which the young Volvox is composed form a body resembling a mulberry, with a pellucid centre, but the cells gradually increase in number, apparently by doubling, at the same time diminishing in size, like the cells of the mammiferous germ; which they resemble also in being originally elliptical and flat.

"Some of the points of resemblance now mentioned were recognised in the delineations of the Volvox given by Professor Ehrenberg; others were noticed during some observations I have myself made on this very interesting microscopic object. Professor Ehrenberg has figured five pellucid globules in a young Volvox just escaped from the parent. These, the germs of another set, evidently resulted from division of the pellucid mass visible in an earlier state: so that here is to be recognised fissiparous generation of the kind I have described as reproducing cells.

"On examining the figures given by Ehrenberg of successive generations of the Chlamydomonas (*fig.* 14.), I see a resemblance to the twos four, eight, &c. groups of cells in the mammiferous ovum too striking, not to suggest that the process of formation must be the same in both: the essential part of this process consisting in division of the pellucid nucleus. And it is deserving of remark, that Ehrenberg describes his *Monas bicolor* evidently a nucleated cell, as possibly an early state of the *Chlamydomonas*.

14

Chlamydomonas.

"The curiously symmetrical forms of many of the *Bacillaria* appear to be due to this two, four, eight, &c. division of the nuclei of cells.

"The delineations of *Gonium, Monas vivipara,* and *Ophrydium* given by the great naturalist just mentioned, afford most satisfactory examples of a pellucid globule, dividing and subdividing like the hyaline in cells.

" In many other of Ehrenberg's figures of the Polygastric Infusoria, the corresponding part appears to me to be denoted by a blue, red, or green colour, according as there had been added either indigo, carmine, or sap-green. This accords with what has been mentioned in a former page, regarding cells, namely, that a foreign substance becomes added and assimilated through the hyaline.

" Fecundation of the ovum takes place in the same manner as nutrition of the cell, and seems, in some instances at least, comparable to the nutrition of one of the Infusoria.

" But farther, I recognise in Ehrenberg's delineations of the Infusoria, not merely a cell-formation, but everywhere the existence of transitory or assimilative cells.

" And farther still: the infusorial cells, like the cells of the larger organisms, have their origin in globules which become discs or " cytoblasts ; " these passing through stages such as those of ordinary cells. Thus in Ehrenberg's *Monadina* are to be found, I think, the following grades, perfectly analogous to the grades of cells: —

" 1. Globules and discs.

" 2. Discs with a pellucid point.

" 3. The point dividing.

" 4. Nucleated cells.

" 5. The nuclei dividing and thus giving origin to

" 6. Young cells, which are seen both within and escaped from parent cells.

" There really seems to have been much truth in the remark long since made by Oken, that animals are groups of bodies comparable to the Infusoria. The cell is itself a little organism; and cells coalesce to form a larger one.

" The remarks just made respecting fissiparous generation, I apprehend, may be applied to gemmiparous reproduction, or propagation by means of buds."

No doubt the minute Infusoria, which seem to have their development arrested at the first or nearest stage from the primitive cell-formation, offer close and striking analogies to the primitive cells out of which the higher animals and all their tissues are developed; but the very step which the Infusoria take beyond the primitive cell-stage invests them with a specific character as independent and distinct in its nature as that of the highest and most complicated organisms. No mere organic cell, destined for ulterior changes in a living organisation, has a mouth armed with teeth, or provided with long tentacula; I will not lay stress on the alimentary canal and appended stomachs, which many still regard as "sub judice;" but the endowment of distinct organs of generation, for propagating their kind by fertile ova, raises the Polygastric Infusoria much above the mere organic cell.

In many of the larger species of Polygastria, radiated vesicles, subtransparent and colourless, generally two in number, and situated near the two extremities of the body, of a highly irritable nature, rapidly contracting and dilating, have been observed. *Roesel* first figured this contractile vesicle in the *Vorticella.* In *Euodon,* in addition to these vesicles, Ehrenberg likewise discerned another organ, of an oval shape, of a dull white colour, and of considerable size, placed in the middle of the abdomen. It is easily detected by the want of colour, when the animal has been well fed and its stomachs filled. This organ is regarded as the testicle, and the contractile radiated bladders as the *Vesiculæ Seminales.* The ovarium occupies a more important share of the general cavity of the body: it fills all the interspaces of the stomachs and intestine which are not occupied by the male organs; and consists of a number of minute corpuscules, or nucleated cells, connected together in a reticulate form, generally of a green or pink, or some other bright colour, in well-fed healthy *Polygastria.*

The act of generation is attended with the destruction of the parent. The ripe ova burst through some part of the abdominal integument, and escape in a reticulated mass, together with the fertilising fluid.

By virtue of these diversified modes of multiplication, the powers of propagation of these diminutive organised creatures may be truly said to be *immense.* Malthusian principles, or what are vulgarly so called, have no place in the economy of this department of organised nature. To the first great law imposed on created beings, "increase and multiply," none pay more active obedience than the Infusorial animalcules.

Attempts have been made to calculate approximatively this rate of increase.

On the 14th of November, Ehrenberg divided a *Paramæcium aurelia,* a Polygastric animalcule measuring one twelfth of a line in length, into four parts: which he placed in four separate glasses.

On the 17th of November, the glasses numbered 1 and 4 each contained an isolated Paramæcium, swimming actively about. The pieces in numbers 3 and 4 had disappeared.

On the 18th there was no change.

On the 19th each animalcule presented a constriction across the middle of the body.

On the 20th No. 1. had propagated five individuals by transverse spontaneous division: in No. 4. eight individuals had in like manner been generated.

On the 21st no change had taken place.

On the 22d there were six nearly equal-sized individuals in No. 1., and eighteen individuals in No. 4.

On the 23d, the individuals were too numerous to be counted.

Thus it was demonstrated that this species of Polygastrian would continue for six days without any diminution of reproductive force, and that on one day a single individual twice divided, and one of its divisions effected a third fission.

A similar experiment on a *Stylonychia Mytilus*, an animalcule one tenth of a line in length, was attended with nearly the same results; it was supplied with the green nutrient matter, consisting of the *Monas pulvisculus*, and on the fifth day the individuals generated by successive divisions were too numerous to be counted.

And now you may be disposed to ask: To what end is this discourse on the anatomy of beings too minute for ordinary vision, and of whose very existence we should be ignorant unless it were revealed to us by a powerful microscope? What part in nature can such apparently insignificant animalcules play, that can in any way interest us in their organisation, or repay us for the pains of acquiring a knowledge of it? I shall endeavour briefly to answer these questions. The Polygastric Infusoria, notwithstanding their extreme minuteness, take a great share in important offices of the economy of nature, on which our own well-being more or less immediately depends.

Consider their incredible numbers, their universal distribution, their insatiable voracity; and that it is the particles of decaying vegetable and animal bodies which they are appointed to devour and assimilate.

Surely we must in some degree be indebted to those ever active invisible scavengers for the salubrity of our atmosphere. Nor is this all: they perform a still more important office, in preventing the gradual diminution of the present amount of organised matter upon the earth. For when this matter is dissolved or suspended in water, in that state of comminution and decay which immediately precedes its final decomposition into the elementary gases, and its consequent return from the organic to the inorganic world, these wakeful members of nature's invisible police are every where ready to arrest the fugitive organised particles, and turn them back into the ascending stream of animal life. Having converted the dead and decomposing particles into their own living tissues, they themselves become the food of larger Infusoria, as the *Rotifera*, and of numerous other small animals, which in their turn are devoured by larger animals, as fishes; and thus a pabulum, fit for the nourishment of the highest organised beings, is brought back by a short route, from the extremity of the realms of organic matter.

There is no elementary and self-subsistent organic matter, as Buffon taught: the inorganic elements into which the particles of organic matter pass by their final decomposition are organically recomposed, and fitted for the sustenance of animals, through the operations of the vegetable kingdom. No animal can subsist on inorganic matter. The vegetable kingdom thus stands, as it were, between animal matter and its ultimate destruction; but in this great office plants must derive most important assistance from the Polygastric *Infusoria*. These invisible animalcules may be compared, in the great organic world, to the minute capillaries in the microcosm of the animal body, receiving organic matter in its state of minutest subdivision, and when in full career to escape from the organic system, and turning it back by a new route towards the central and highest point of that system.

LECTURE III.

ROTIFERA.

The animal kingdom may be likened to a cone, the species of which it is constituted diminishing in number as they ascend in the scale of complexity. Rising from different parts of the basal circumference, the different groups reciprocally approximate, interweaving their mutual affinities within a progressively closer reticulation, until they finally culminate in the apex, which is crowned by Man.

The interest with which you listened to the anatomical details of those minute creatures, which, by their low grade of structure, their extensive distribution and incalculable myriads, form the base of the animal pyramid, encourages me again to invite you to condescend from the high sphere of your habitual studies and duties to this most remote and lowly region of animal life.

Low though the *Infusoria* be, and remote from man in the scale of organisation—literally at an invisible distance from us—yet, by the aid of the optician's science and skill, analogies may be discerned in them to the human structure, which ought to enlist your sympathies with the discoveries that have been made in their Microscopical Anatomy.

Time was, and not very long ago, in this country, when that term, Microscopical Anatomy, was almost regarded as synonymous with the anatomy of the imagination: but the numerous and highly important discoveries which have been made and confirmed by observers in almost every European state, by means of the greatly improved microscopes of the last ten years, have placed the value, the indispensability, of that instrument to the anatomist, beyond the necessity of vindication.

Some scepticism may be natural and pardonable, when the anatomy of an animalcule $\frac{1}{1000}$ of a line in diameter is attempted to be demonstrated: but trace it to its source, and you will find such incredulity to be essentially based, not merely on distrust in our means of observation, but in the difficulty of adequately conceiving the relations of size. Just ideas of these relations are essential to the acceptance and full appreciation of the discoveries which have extended for us the bounds of space; and I will ask permission to quote the words of one of our old philosophers, which bear directly on this subject, and, expressing a noble confidence in intellectual progress, shed a prophetic gleam upon the present improved powers of penetrating space.

"In consistency, I suppose some bodies to be harder, others softer, through all the several degrees of *tenacity*. In magnitude, some to be greater, others less, and many unspeakably little. For we must remember that, by the understanding, quantity is divisible into divisibles perpetually. And therefore, if a man could do as much with his hands as he can with his understanding, he would be able to take from any given magnitude a part which should be less than any other magnitude given. But the omnipotent Creator of the world can actually from a part of any thing take another part, as far as we by our understanding can conceive the same to be divisible. Wherefore there is no impossible smallness of bodies. And what hinders but that we may think this likely? For we know there are some living creatures so small that we can scarce see their whole bodies. Yet even these have their young ones; their little veins and other vessels, and their eyes so small as that no microscope can make them visible. So that we cannot suppose any magnitude so little, but that our very supposition is actually exceeded by nature.

"Besides, there are now," (the book was published in 1655) "such microscopes commonly made, that the things we see with them appear a thousand times bigger than they would do if we looked upon them with our bare eyes. Nor is there any doubt but that, by augmenting the power of these microscopes (for it may be augmented as long as neither matter nor the hands of workmen are wanting), every one of those thousandth parts might yet appear a thousand times greater than they did before. Neither is the smallness of some bodies to be more admired than the vast greatness of others. For it belongs to the same Infinite Power as well to augment infinitely as infinitely to diminish. To make the great orb, namely, that whose radius reacheth to the sun, but as a point in respect of the distance between the sun and the fixed stars; and, on the contrary, to make a body so little, as to be in the same proportion less than any other visible body, proceed equally from one and the same Author of Nature. But this of the immense distance of the fixed stars, which for a long time was accounted an incredible thing, is now believed by almost all the learned. Why then should not that other, of the smallness of some bodies, become credible at some time or other? For the majesty of God appears no less in small things than in great; and as it exceedeth human sense in the immense greatness of the universe, so also it doth in the smallness of the parts thereof. Nor are the first elements of compositions, nor the first beginnings of actions, nor the first moments of time more credible, than that which is now believed of the vast distance of the fixed stars." *

I have said, that in the diminutive *Polygastria*, there might be discerned structures analogous to our own. Vibratile cilia — their sole organs of locomotion — are the first actively moving parts with which the mammiferous ovum is endowed, with which, therefore, we ourselves commence life. They are retained throughout life as an essential part of the organisation of a very extensive tract of our internal mucous membranes; and these most minute and incalculably numerous vibrating filaments, like their analogues in the *Polygastria*, know no repose.

It might almost have been anticipated that this earliest possessed, and most extensively diffused, organical dynamic in every member of the animal kingdom, should be the most conspicuous, and the sole, moving power in the first-born of Fauna.

Is man liberated from one narrow spot in space, and enabled to move to and fro on the surface of his little world, by virtue of an internal receptacle of nutriment? So, likewise, is the Infusorial animal. Even some of the superadded complications of the digestive sac are present; the Polygastrian seizes food with tentacular lips, reduces it by the action of a hundred dental spines, arranged, as we have seen, like the teeth of the circular trephine: it is the very type of the digestive function: assimilating and re-organising the decomposing particles of

* Thomas Hobbes, Elements of Philosophy, Molesworth's Ed. vol. i. p. 445. 8vo. London.

animal and vegetable matter with a hundred-stomach power. That low delight, the bliss supreme of the civilised gourmand, is given most liberally where it ought to be, to the creatures at the lowest grade of animality.

Nor is the procreative function so abundantly or so variously enjoyed by any other animal as in the *Polygastria.* At once fissiparous, gemmiparous, and oviparous, the androgynous organs for the development of the fertile ova were, as shown in the preceding Lecture, of a sufficiently complicated character. In creatures whose most obvious and common mode of propagation is by spontaneous fission, a power so actively exercised, as, according to Ehrenberg's experiments, to be productive of an incalculably rapid rate of multiplication, it may be demanded: To what end were special organs of generation developed? Why should these fissiparous *Polygastria* be provided with male glands, vesiculæ seminales, and reticulated ovaria; with normal reproductive organs almost as complicated as in the snail, which has no other mode of generation than by fertile ova? I am apt to think that the fissiparous reproduction has reference principally to increasing the numbers of individuals in the infusions, or receptacles of decaying organisms, in which they at that time exist; whilst the development of fertile ova has relation to future and different localities or collections of such infusions, into which the ova may be conveyed more easily than the entire animals, and so lay the foundation of new generations of Infusoria. In the heats of summer, for example, many of the pools and stagnant collections of water in which Infusoria abound are dried up. Now, it is true, that certain Infusoria have the power of retaining their vitality for a long time in a state of desiccated torpidity. I shall presently have to allude to the experiments of Spalanzani and others on the wheel-animalcules, in illustration of this curious property. Some who have repeated his experiments have not succeeded in reviving the subjects after so long a period of inanimation: nevertheless, great tenacity of life is unquestionably, notwithstanding the delicate tissues of the Infusoria, a property of creatures of their grade of organisation; and what holds good of the parent, in regard to this property of latent life, must, *à fortiori,* be allowed to the ovum.

Now the act of oviparous generation, that sending forth of countless ova through the fatal laceration or dissolution of the parent's body, is most commonly observed in the well-fed *Polygastria,* which crowd together as their little ocean evaporates; and thus each leaves, by the last act of its life, the means of perpetuating and diffusing its species by thousands of fertile germs. When the once thickly tenanted pool is dried up, and its bottom converted into a layer of dust, these inconceivably minute and light ova will be raised with the dust by the first puff of wind, diffused through the atmosphere, and may there remain long suspended; forming, perhaps, their share of the particles which we see flickering in the sunbeam, ready to fall into any collection of water, beaten down by every summer shower into the streams or pools which receive or may be formed by such showers, and, by virtue of their tenacity of life, ready to develope themselves wherever they may find the requisite conditions for their existence.

The possibility, or, rather, the high probability, that such is the design of the oviparous generation of the *Infusoria*, and such the common mode of the diffusion of their ova, renders the hypothesis of equivocal generation, which has been so frequently invoked to explain their origin in new-formed natural or artificial infusions, quite gratuitous. If organs of generation might, at first sight, seem superfluous in creatures propagating their kind by gemmation and spontaneous fission, equivocal generation is surely still less required to explain the origin of beings so richly provided with the ordinary and recognised modes of propagation. Many experiments have, however, been detailed, in which adequate precautions appeared to have been taken to prevent the possibility of the entry of fertile germs into the fluid experimented on, after means had been taken to destroy all that it might contain. From these experiments, the mere access of atmospheric air, light, and heat to the infusions has been deemed to include all the conditions required for the primary formation of animal or of vegetable organisms. The results in favour of such a view are, however, explicable by supposing that due precautions had not been adopted at the beginning of the experiment to exclude every animal or germ capable of development in the infusion, or to gain satisfactory assurance that the air subsequently admitted contained nothing of the kind. The only experiment in which these difficulties appear to have been fully overcome, is that in which the requisite apparatus was conceived by Professor Schulze of Berlin. He filled a glass flask half full of distilled water, in which were mixed various animal and vegetable substances: he then closed it with a good cork, through which were passed two glass tubes, bent at right angles, the whole being air-tight: it was next placed in a sand bath, and heated until the water boiled violently. While the watery vapour was escaping by the glass tubes, the Professor fastened at each end an apparatus which chemists employ for collecting carbonic acid: that at the one end was filled with concentrated sulphuric acid, and the other with a solution of potash. By means of the boiling heat, it is to be presumed that every thing living and all germs in the flask or in the tubes were destroyed; whilst all access was cut off by the sulphuric acid on the one side, and by the potash on the other. The apparatus was then exposed to the influence of summer light and heat; at the same time there was placed near it an open vessel, with the same substances that had been introduced into the flask, and also after having subjected them to a boiling temperature. In order to renew constantly the air within the flask, the experimentor sucked with his mouth several times a day the open end of the apparatus, filled with the solution of potash, by which process the air entered his mouth from the flask through the caustic liquid, and the atmospheric air from without entered the flask through the sulphuric acid. The air was of course not at all altered in its composition by passing through the sulphuric acid in the flask; but all the portions of living matter, or of matter capable of becoming animated, were taken up by the sulphuric acid and destroyed. From the 28th of May until the beginning of August, Professor Schulze continued uninterruptedly the renewal of the air in the flask, without being able, by the aid of the microscope, to discover any living animal or vegetable substance; although, during the whole of the time, observations were made almost daily on the edge of the liquid; and when, at last, the Professor separated the different parts of the apparatus, he could not find in the whole liquid the slightest trace of *Infusoria* or *Confervæ*, or of mould; but all three presented themselves in great abundance a few days after he had left the flask standing open. The vessel which he placed near the apparatus contained on the following day *Vibriones* and *Monads*, to which were soon added larger Polygastric *Infusoria*, and afterwards *Rotifera*.* To the organisation of this higher form of *Infusoria*, which are always the last to appear in infusions, I now proceed.

The *Rotifera* are so called on account of the aggregation of their cilia into circular or semicircular groups upon lobes or processes of the head, which resemble rudiments of the ciliated tentacles of the higher or Ciliobrachiate Polypes.† By the vibration of these cilia, which occasions the appearance of little wheels in rapid motion, strong currents are produced in the surrounding water, and they thus serve as the instruments for locomotion and the prehension of food. The body in the *Rotifera* is more or less elongated or vermiform. It is provided, at its posterior extremity, with a pair of slender and pointed claspers, protected by a sheath, into which they can be retracted when not in

* This experiment was quoted from the Edinburgh New Philosophical Journal. Vol. xxiii. p. 165. Pl. 1. fig. 2. gives a representation of the simple and effectual apparatus devised by Prof. Schulze. W. W. C.

† Ehrenberg remarks that the *Rotifera* are "Bryozoa without the power of propagating by gemmation." — *Die Infusionsthierchen*, fol. 1838, p. 384.

use. These appendages are longer than the body in some species, as the *Notommata Tigris:* their sheath is much elongated and slightly annulated in the *Brachioni:* it is telescopiform in *Scaridium:* both claspers and sheath are wanting only in the *Anuræus.* The integument of the body is smooth, and never ciliated: although the parasitic jointed fibres of *Hygrocrocis,* which attach themselves sometimes to the integument of the larger species, as *Notommata centrura,* give it that appearance. The *Polyarthræ* have long jointed filaments, like the rays of a fish's fin, attached to the sides of the body.

Not any of the species are known to secrete a silicious shell; but many of them are provided with a transparent gelatinous case, into which they can contract their bodies; thus offering another analogy to the Ciliobrachiate Polypes, and also to the bivalve-sheathed Entomostraca. The loricate genera are *Noteus, Anuræa, Brachionus,* and *Pterodina.* In all the species the shell is a cylinder or case (*testula*), not a mere shield (*scutellum*).

Horn-like processes project from the front margin of the shell in some species of *Brachionus,* and from both front and back margins in other species. In some *Notei* and *Anuræa* the shell is ornamented by large pentagonal or hexagonal groups of granules.

The cephalic cilia are aggregated into from two to five groups, upon lobes (*fig.* 15, *a.*), which sometimes are developed into short tentacular processes, with a verticillate arrangement of cilia, as in *Stephanoceros.* These lobes or processes Ehrenberg regards as muscular. The movements of the ciliated quasi-wheels are under the control of the will. They can be instantly arrested, the whole apparatus drawn out of sight, again protruded, and as instantly set in motion. The muscles which protrude and retract of the ciliated lobes, which bend and modify the form of the body, and which throw out, attach, or heave in the anal anchors, are developed in the form of distinct fibrous fasciculi. You perceive in this diagram, for example (fig. 15.), the retractors of the oral cilia and of the anal forceps; the long and narrow longitudinal muscles (*b, b*), which shorten the whole body; and their antagonists the transverse

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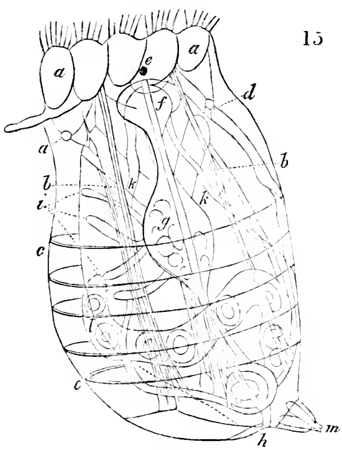


Notommata.

bands (*c, c.*), which diminish the breadth of the body and restore its length.

With this advanced condition of the muscular system the parts of the nervous system now likewise become distinctly visible. Ehrenberg delineates a large cerebral ganglion, which in some species is of a trilobate form, in close connection with the coloured, generally red, ocellus or eye-speck (*e.*). Some of the nervous filaments extend from this ganglion forwards to the muscular lobes supporting and moving the wheel-like cilia; other filaments of greater length stretch backwards into the cavity of the body, apparently attached to the ventral integument, on the outer side of the principal longitudinal retractor muscles.

In *Notommata clavulata*, Ehrenberg describes two radiated ganglions in the neck (*d, d*), superadded to the principal cerebral ganglion connected with the rotatory muscle, and other gangliform bodies on each side, developed upon the long abdominal nervous filaments. Besides these, other small enlargements are figured as ganglions upon the transverse bands or vascular circles of Ehrenberg, making altogether eight pairs of ganglions in this little animalcule, which measures one eighth of a line in length. With regard to the ganglions on the transverse vessels, both these and the vessels bear a striking analogy to those transverse muscles, with a middle swelling, which Dr. Arthur Farre* has described and figured in his Ciliobrachiate Polypes.

The movements of the *Rotifera* are of a more varied character than those in the *Polygastria;* they sometimes dart swiftly forwards; at others glide leisurely along, or, anchoring themselves by their little terminal claspers, employ their ciliated paddle-wheels to create the currents which prove so fatal to the minuter race of Infusories. When the *Rotifer* has attached itself to some fixed body by its hinder claspers, the vortices which it occasions in the water are so directed as to draw the smaller *Infusoria* and other particles of food towards the orifice of the mouth.

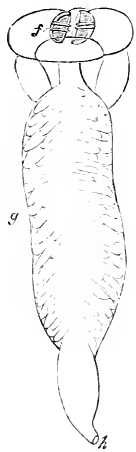
Having seized their prey, it is exposed in the pharynx (*f*) to the destructive action of a complicated dental apparatus (fig. 16, *f*). This consists of two jaws, acting horizontally upon a median piece, or anvil. The hard maxillæ are each bent upon themselves at a right, or, rather, acute angle; the transverse or dental part, which beats upon the surface of the anvil, being divided into two or more sharp spines. The muscles which work these dental hammers are inserted into the longitudinal portion, which may be regarded as the rudimental

* Philos. Transact. 1837.

jaw. The efficacy of these instruments in tearing to fragments the objects swallowed may be easily discerned in the living animal through its transparent parietes.

The condition of the alimentary canal is very similar in most of the genera, which are chiefly distinguished thereby from the Polygastric *Infusoria*. It is a more or less simple tube (*fig.* 15, *g*), extending longitudinally through the well-developed abdominal cavity, to terminate by a cloacal outlet (*h*) at the hinder end of the body, generally above the base of the sheath of the claspers. It is sometimes wider, sometimes narrower, sometimes with and sometimes without a constriction indicative of the stomach (*fig.* 15, *g*) : in *Rotifer* (*fig.*16.) and *Ptyura* there is a distinct terminal dilation or rectum ; sometimes the intestine is complicated with many cæca, as in *Diglena* and *Megalotrocha*. Most of the species have, just behind the pharynx, or continued from the stomach, two large oval glandular sacs, rarely cylindrical or bifurcated, to which sometimes filamentary cæca are appended, as in *Enteroplea*. These secerning sacs (*fig.* 15, *i*) may discharge the office of liver or salivary glands.

16.



Rotifer.

Ehrenberg recognises a vascular system in the parallel transverse slender bands which surround the body ; these are in close connection with the integument. With more probability we may regard as sanguiferous organs the free longitudinal vessels, likewise indicated by Ehrenberg, on the dorsal aspect, which are connected with a fine vascular network near the mouth, and which send filamentary tubes to the intestine.

The wheel-like organs, by rapidly changing the oxygenated fluid which bathes their surface, may be supposed to take the most potent share in the respiratory function. But Ehrenberg directs our attention to some peculiar ciliated vibrating oval corpuscules, which are attached to the free seminal tubes on each side the abdomen ; and to which corpuscules he assigns the name of internal gills. The water essential to the respiratory function discharged by these problematical bodies, and by the vascular surfaces of the viscera, is admitted into the interior of the body by an opening in the neck, which, in very many species, is prolonged upon one or two spear-shaped tubes, which are beset with vibratile cilia : the water is observed to pass to and fro in streams through these tubes. It consists of an expanded part and an appendage ; the expanded part consists of three folds or vesicles ; the vibrating appendage resembles a crotchet in music.

The *Rotifera* are androgynous : most of the species are oviparous, the ova being large and few in number: a few are ovo-viviparous. The fertilising principle is formed in and by two long and slender tubes (*fig.* 15, *k*, *k*), commencing each by a blind extremity at the anterior part of the abdominal cavity, and extending with a few slight folds to the neck of a single large spermatic vesicle, which communicates with the oviduct in the cloaca. The essential organ of the male apparatus is thus manifested under its most simple form, as a single *tubulus* in each *testis*, in these small animals. The singleness of the *vesicula*, which is characterised by the same remarkable irritability as the two contractile vesiculæ of the *Polygastria*, accords with the abrogation of the fissiparous property in the *Rotifera*.

The egg-forming organ consists of a simple wide sac, single in *Notommata* (*fig.* 15, *l*), but more commonly divided into two cornua, the body terminating by a short contracted cervix, which communicates with the cloaca. There can be no doubt about the proper function of this conspicuous viscus, for the structure of the ovum can be discerned through its transparent walls; and, in the *Rotifer vulgaris*, the young may be seen to escape from the eggs in the uterus, and leave the empty shells behind them: they issue from the parent after intervals of from five minutes to an hour.

In the *Hydatina senta* Ehrenberg carefully traced the development of the ova and embryons. The ova are first manifested as clear spots or vesicles filled apparently with albumen. In two or three hours a dark speck is seen in the middle of the clear vesicle, which he compares with the yolk. In five or six hours the yolk fills the clear space and pushes it to one side, and in this state the ova are fecundated and excluded from the cloaca.

The change in the position of the clear spot is important, from its interesting analogy with the change in the position of the germinal vesicle in relation to the yolk of the rabbit's ovum, and with the altered position of the entire ovum in relation to the ovisac, preparatory to impregnation; both being, to use Ehrenberg's expression, " pushed to one side ; " to that side, viz. which approximates the important vesicle or cell whence all subsequent development radiates, to the aperture which admits the fertilising principle.

Ehrenberg states that in the ovum of the *Hydatina*, three hours after its exclusion, the clear spot (germinal vesicle) has disappeared, and the egg is occupied by the yolk, which is granular at one end and clear at the other. A dark spot then appeared in the middle of the ovum, which, six hours after exclusion, could be distinguished as the head with the rudimental dental apparatus of the embryo. At the eleventh hour the wheel-like ciliated organs began to play, and the fœtus to move in the egg. At the twelfth hour the body was completely formed, and bent somewhat spirally, the bifurcated anal appendage being doubled backwards towards the head. The revolutions of the young Rotifer are now so powerful as to threaten every instant to burst the egg-shell, but they often continue two hours.

The average period of development of a young *Hydatina* under favourable circumstances is twenty-four hours; twelve within and twelve without the parent's body. When it proceeds more slowly, Ehrenberg recommends the liberal supply of the green monads (*Chlamydomonas pulvisculus*, and *Euglena viridis*).

Ova deposited in the cold early days of winter remain undeveloped until spring, and are protected by their dense double shell.

Ehrenberg watched during eighteen days successively an individual *Hydatina senta*, which was full-grown when singled out, and did not die of old age, which proves this species to live more than twenty days. Such an individual is capable of a four-fold propagation every twenty-four or thirty hours, bringing forth in this time four ova, which grow from the embryo to maturity, and exclude their fertile ova in the same period. The same individual, producing in ten days forty eggs, developed with the rapidity above cited, this rate, raised to the tenth power, gives one million of individuals from one parent, on the eleventh day four millions, and on the twelfth day sixteen millions, and so on.

Although this rate of production from fertile ova is the greatest hitherto observed, far exceeding that in the class of insects, it is much inferior to the propagative power in the *Polygastria*. We saw that in the *Paramœcium aurelia*, which lives several days, a transverse fissure took place, the individual becoming two every twenty-four hours. It also propagates by ova, which are excluded not singly, but in masses; which ova rapidly develop and repeat the acts of propagation; so that the possible increase in forty-eight hours is quite incalculable. Who can wonder that infusions should, with the brood of two or three days only, swarm with these animalcules!

All the ordinary *Infusoria* live through the winter beneath the ice. After having been once completely frozen, Ehrenberg found them dead when thawed. They, however, manifest considerable powers of resistance to this effect of extreme cold. Ehrenberg endeavoured to freeze some *Infusoria* in a watch-glass, and examined the clear ice in a cold room: he observed that those which appeared to be frozen and imbedded in the mass were actually inclosed in very minute vesicles in the ice. He conceives that they may remain torpid in this state through the winter, and revive when their little ice-houses have been melted away in spring.

Infusoria are destroyed generally by expanding and bursting, after a few minutes' subjection to the heat of boiling water.

In water subjected to a galvanic current strong enough to cause decomposition, the contained *Infusoria* are killed. When subjected to a weaker current, those only which came into its course were affected: some *Rotifera* were observed to be stunned only, and afterwards recovered; others were killed.

Tenacity of life is a very striking physiological character of the *Infusoria*.

The famous phenomena of the revival of *Rotifera*, after having been completely dried and apparently killed, certainly when reduced to the state of the most complete torpidity, were first observed by Leeuwenhoek in the year 1701. The father of microscopical anatomy had been engaged in examining some specimens of *Rotifer vulgaris* with *Euglena sanguinea*, and had left the water in which they were contained, to evaporate. Two days afterwards, having added some rain-water, which he had previously boiled, within half an hour he saw a hundred of the *Rotifera* revived and moving about. A similar experiment was followed with the same result after a period of five months, during which period the *Rotifera* had remained in a state of complete desiccation and torpidity. These observations were repeated by Baker and J. Hill. You will find all the experiments that were recorded before the time of Haller accurately quoted in his great "Physiologia Corporis Humani," vol. viii. p. 111. Fontana kept *Rotifera* two years and a half in dry sand, exposed to all the power of an Italian summer's sun: yet in two hours after the application of rain-water they recovered life and motion.

Gözé, Corti, and Müller record similar experiments; but those performed by the celebrated Abbé Spallanzani are perhaps most generally known.

He succeeded in reviving his *Rotifers* after four years' torpidity: he alternately dried and moistened the same animalcules twelve times with similar results, except that the number of the revivers was successively smaller; after the sixteenth moistening he failed to restore any of them to life.*

One of the essential conditions of the revival of the *Rotifers* appeared to Spallanzani to be their burial in sand: the access of air seems prejudicial to their retention of vitality. Müller, the famous

* Opusc. die Fis. Anim. vol. ii. p. 181.

Danish observer of *Infusoria,* only succeeded in reviving them when they were surrounded by foreign particles, and defended from the air. Both Oken and Rudolphi deny the revival of desiccated animals; but later observers have succeeded in producing the wonderful phenomena described by Spallanzani, especially Professor Schultze; and I myself witnessed at Freiburg, in 1838, the revival of an *Arctiscon* which had been preserved in dry sand by the Professor upwards of four years.

I have already, at the close of the previous lecture, alluded to the important functions, apparently so disproportionate to their size and powers, which the *Polygastria* perform in relation to the conservation of organic matter and of the purity of the atmosphere. They likewise take their share in modifying the crust of the earth. It has been shown that some *Polygastria* are naked, others loricated or defended by silicious shells, of definite and easily recognisable forms and patterns in different species. Prof. Ehrenberg had not long made these observations before he discovered that a certain kind of silicious stone, called Tripoli or Polierschiefer, was entirely composed of such cases; was in fact the *débris* of Polygastric Animalcules, chiefly of an extinct species, called *Gaillonella distans.* The substance alluded to has long been well known in the arts, being used in the form of powder for polishing stones and metals. At Bilin, in Bohemia, there is a single stratum of this substance, not less than fourteen feet thick, forming the upper layer of a Tripoli hill, in every cubic inch of which layer Ehrenberg estimates that there are *forty-one thousand millions* of individuals of the *Gaillonella distans.* It likewise contains the shells of *Naviculæ, Bacillaria, Actinocyclus,* and other silicious animalcules. The lower part of the stratum consists of the skeletons of these animalcules, united together without any visible cement; in the upper and more compact masses the infusory shells are cemented together, and filled by amorphous silicious matter, formed out of dissolved cases. Corresponding deposits of the silicious cases of these animalcules have since been discovered in many other parts of the world, some including fresh water, others marine species of Infusoria. A quantity of a pulverulent matter is deposited upon the shores of the lake near Uranea in Sweden, and which from its extreme fineness resembles flour. This has long been known to the poorer inhabitants under the name of *Berg-mehl,* or mountain meal, and is used by them mixed up with flour as an article of food: it consists almost entirely of the silicious shells of pulverised *Polygastria.* Most of the infusorial formations, as the polishing slates of Cassel, Planitz, and Bilin, are, in fact, extraordinary monuments, which have handed down to us the record of the existence of Polygastric Infusoria at remote periods of the history of the earth; and they are much more extensive, and will be more durable, than the proudest mausolea by which Egyptian kings have endeavoured to perpetuate the memory of their existence.

In another point of view the Polygastric Infusoria are highly remarkable. Their extremely minute size, simplicity of structure, tenacity of life, and extraordinary powers of reproduction, have enabled them to survive, as species, those destroying causes which have exterminated all the higher forms of animals. Several species, for example, still exist, which were in being at the period of the deposition of the chalk, and which contributed their silicious remains to the flinty masses which are always more or less intermixed with cretaceous matter. Before this discovery no remains of higher-organised animals at present in existence had been detected, with the same degree of certainty, in the cretaceous formation. A few existing zoophytes and testacea first make their appearance in the tertiary beds immediately above the chalk; hence called, by Mr. Lyell, Eöcene, from εος, the dawn, as indicating the first dawn of the creation of existing species. The number of existing species of shells increases in the Miocene, and is still greater in the Pliocene tertiary strata; but the higher animals, as the *Anoplotheria*, *Palæotheria*, *Mastodons*, *Mammoths*, and other mammalian contemporaries of the Eöcene, Miocene, or Pliocene testacea, have utterly perished. The discovery, therefore, by Ehrenberg, of several, at least twenty, species of silicious-shelled Infusoria, fossil, in the chalk and chalk marls, which are perfectly identical with those from the sands of the Baltic and North Sea, is a most interesting addition to the obscure history of the introduction of the successive species of animals on this planet, and must add greatly to the interest of this Infusorial class in the eyes of the naturalist and geologist. "For these animalcules," says Ehrenberg, "constitute a chain, which, though in the individual it be microscopic, yet in the mass is a mighty one, connecting the organic life of distant ages of the earth, and proving that the dawn of the organic nature coexistent with us reaches farther back in the history of the earth than had hitherto been suspected."

The still existing species are by no means rare or isolated, but fill in incalculable numbers the seas of Northern Europe, and are not wanting on the tropical coasts of the globe. With reference to the operations of the invisible *Polygastria* at the present day on these and other coasts, I have only time to refer you to the translation of a late paper by the indefatigable Berlin professor, entitled, "Observations upon the important Part which Microscopic Organisms play in the choking up of the Harbours of Wismar and Pillau;

also, in the Formation of the Mud which is deposited in the Bed of the Elbe at Cuxhaven, and upon the Agency of similar Phenomena in the Formation of the Bed of the Nile, at Dongolar, in Nubia, and in the Delta of Egypt."* "Truly, indeed," says Ehrenberg, "the microscopic organisms are very inferior in individual energy to lions and elephants, but in their united influences they are far more important than all these animals."

LECTURE IV.

ENTOZOA.

The ancient philosophers styled man the microcosm, fancifully conceiving him to resemble in miniature the macrocosm or great world.

Man's body is unquestionably a little world to many animals of much smaller size and lower grade of organisation, which are developed upon and within it, and exist altogether at the expense of its fluids and solids.

Not fewer than eighteen species of internal parasites, or of those which infest the internal cavities and tissues of the human body, have been enumerated; and of these, at least fourteen are good and well established species of Entozoa.

Hippocrates and Aristotle had distinguished the human intestinal worms by the names of "Helminthes stronguloi" and "Helminthes plateiai;" but the study of these parasites in general has been reserved for recent times. Since the time of Linnæus the stimulus which that great master gave to every branch of Natural History has been in no department more potent than in encouraging researches into the before neglected field of the Internal Animal Parasites.

To the labours of Bloch, Goeze, Zeder, and, above all, to those of Rudolphi, we are indebted for our knowledge of these animals as an extensive class, which Rudolphi has characterised, under the name of Entozoa, as white-blooded worms without respiratory organs, and (but less accurately) without nerves.

The number of these Parasites may be conceived when it is stated that almost every known animal has its peculiar species, and generally more than one, sometimes as many as, or even more kinds than, infest the human body.

* Edinb. Philos. Journal, vol. xxxi. p. 386

There are few common and positive organic characters which can be attributed to this very extensive and singular group of animals: they have generally a soft, mucous and colourless integument, which in a few species is armed with spines. That the integument should be uniformly white or whitish might, *à priori*, have been expected of animals which are developed and exist in the dark recesses of other animal bodies. The mature ova are almost the only parts which naturally acquire a distinct colour; and the subtransparent body sometimes derives other tints from the accidental colour of the food. Excluded also by the nature of their abode from the immediate influence of the atmosphere, no distinct respiratory organ could be expected to be developed in the *Entozoa;* but this negative character is common to the Entozoa with most of the other *Radiata* of Cuvier. In creatures surrounded by and having every part of their absorbent surface in contact with the secreted and vitalised juices of higher animals, one might likewise have anticipated little complexity and less variety of organisation. Yet the workmanship of the Divine Artificer is sufficiently complicated and marvellous in these outcasts, as they may be termed, of the Animal Kingdom, to exhaust the utmost skill and patience of the anatomist in unravelling their structure, and the greatest acumen and judgment in the physiologist in determining the functions and analogies of the structures so discovered. What also is very remarkable, the gradations of organisation that are traceable in these internal parasites reach extremes as remote, and connect them by links as diversified, as in any of the other groups of Zoophyta, although these play their parts in the open and diversified field of Nature.

Beginning with the lowest link we have to commence with a condition of organisation more simple than is presented by the lowest Infusory or Polype. We end with a grade of organisation, which, whether it is to be referred to the radiated or articulated types, zoologists and anatomists are not yet unanimous.

Amongst the vermiform animals with colourless integument, colourless circulating juices and without respiratory organs, two leading differences of the digestive system have been recognised: in the one it is a tube with two apertures contained in a distinct abdominal cavity; in the other it is excavated or imbedded in the common parenchyme of the body, and has no anal outlet. The first condition characterises the *Vers Intestinaux Cavitaires* of Cuvier; the second the *Vers Intestinaux Parenchymateux* of the same naturalist.

I have rendered the Cuvierian definitions of the two leading classes or groups of the Entozoa by the names "Cœlelmintha," and "Sterelmintha."

The cavitary worms of Cuvier include the cylindrical species or round worms which form the order *Nematoidea* of Rudolphi.

This great entozoologist, who devoted the leisure of a long life to the successful study of the present uninviting class, divided the parenchymatous Entozoa into four other orders. The *Acanthocephala*, in which the head has a retractile proboscis armed with recurved spines, the body round and elongated, and the sexes in distinct individuals. The *Trematoda*, in which the head is unarmed and has a suctorious foramen, the body rounded or flattened, and generally one or more suctorious cavities for adhesion, and in which the organs of both sexes are in the same individual. The *Cestoidea*, in which the body is elongated, flattened, and generally articulated. The head, variously organised, is generally provided with suctorious cavities and a central mouth, sometimes armed with a coronet of hooks, sometimes with four unarmed or uncinated tentacles. Both kinds of generative organs are combined in the same individual. Lastly, the order *Cystica*, in which the body is rounded or flattened, and terminates posteriorly in a cyst, which is sometimes common to many individuals. The head is provided with suctorious cavities; and the mouth, with a circle of hooklets, or with four unarmed or uncinated tentacles. No distinct generative organs are developed in the cystic Entozoa.

The anatomy of the Entozoa is so distinct in each of these orders that I shall describe it successively in a few typical species, selecting more especially for demonstration those which infest the human body; and which chiefly concern the medical practitioner.

In this category the common pathological product, called 'Acephalocyst' by Läennec, is by many received, and ought not, perhaps, in this place to be omitted. The acephalocyst (*fig.* 17, *b*) consists of a subglobular or oval vesicle filled with fluid. Sometimes suspended freely in the fluid of a cyst of the surrounding condensed cellular tissue (*a*); sometimes attached to such a cyst; developing smaller acephalocysts, which are discharged from the outer or the inner surface of the parent cyst. These acephalocysts vary from the size of a pea to that of a child's head. In the larger ones the wall of the cyst has a distinctly laminated texture. They are of a pearly whiteness, without fibrous structure, elastic, spurting out their fluid when punctured. Their tissue is composed chiefly of a substance closely analogous to albumen, but differing by its solubility in hydro-

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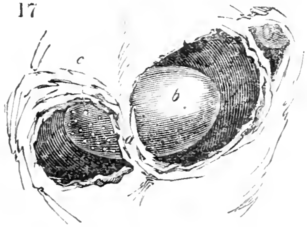


Acephalocyst.

chloric acid; and also of another peculiar substance analogous to mucus.* The fluid of the acephalocysts contains, according to Lobstein, a small quantity of albumen with some salts, including muriate of soda, and a large proportion of gelatin.

The tunic of the acephalocyst is usually studded with more or less numerous and minute globules of a clear substance (*c*), analogous to the "hyaline," whose remarkable properties in reproductive cells, Dr. Barry has recently described, and from which the young acephalocysts are developed. No contractile property, save that of ordinary elasticity, has been observed in the coats of the acephalocyst; no other organisation than that which I have just described; no other function than that of assimilation of the surrounding fluid by the general surface, and the development of new cells from the nuclei of hyaline. We see with how little reason such a body can be compared with the *Volvox globator*, as has been done by Professors Nitzsch and Leückart.† The discovery of the composite character of that low organised Infusory and the elucidation of the anatomy of each constituent monad prove the acephalocyst to stand on a still lower step in the series of organic structures. A better comparison is that which approximates the acephalocyst to the *Protococci* of the vegetable kingdom; these lowest forms of cryptogamic plants consisting of a simple transparent cyst, and developing embryo cysts from their external surface. The knowledge that we now possess of the primitive embryonic forms of all animals and of all animal tissues, places us in the position to take a true view of the nature of the acephalocyst. It seems to me to be most truly designated as a "gigantic organic cell," not as a species of animal, even of the simplest kind.

Yet these productions have not escaped the ingenuity and discriminative powers of the classifier. Of the numerous species, nominal or real, which are to be found in the works of naturalists and pathologists, I shall notice only two: — 1st, the *Acephalocystis Endogena* of Kuhn, likewise called *Socialis, vel prolifera*, by Cruveilhier: the "Pill-box Hydatid" of Hunter. It is the kind most commonly developed in the human subject, and in which the fissiparous process takes place usually from the internal surface of the parent cyst, the progeny being sometimes successively included: and, 2dly, the *Acephalocystis Exogena* of Kuhn, *Eremita, vel Sterilis*, of Cruveilhier, which developes its progeny generally from the external surface, and is found in the ox and other domestic animals.

And now I can well imagine that some may be tempted to ask,

* Collard, Dict. de Méd. et de Chir. prat. Art. "Acephalocystes."

† Tschudi, Die Blasenwurmer, 4to, 1837, p. 29.

having heard this description of a free and independent being, whose tissues are chemically proved to be of an animal nature, imbibing nourishment without vascular connection with the cavity containing it, and reproducing its kind, how is an animal to be defined if this be not one? The answer that the acephalocyst has no mouth may, perhaps, not be regarded as satisfactory. Definitions apart, our business is to discover to what organic thing the acephalocyst is most analogous.

The primitive forms of all tissues are free cells, which grow by imbibition, and which develope their like from their nucleus of hyaline. All the animal tissues result from transformations of these cells. It is to such cells that the acephalocyst bears the closest analogies in physical, chemical, and vital properties. When the Infusorial Monads are compared to such cells, and man's frame is said, by a figure of speech, to be made up of such monads, the analogy is overstrained, because no mere organic cell has its mouth, its stomachs, its testes, and ovaria. So also it appears to me that the analogy has been equally overstrained, which makes the acephalocyst a kind of monad, or analogous species of animal. We may, with some truth, say that the human body is primarily composed or built up of acephalocysts; microscopical, indeed, and which, under natural and healthy conditions, are metamorphosed into cartilage, bone, nerve, muscular fibre, &c. When, instead of such change, the organic cells grow to dimensions which make them recognisable to the naked eye, such development of acephalocysts, as they are then called, is commonly connected in the human subject with a lowering of the controlling vital energies, which, at some of the weaker points of the frame, seem unable to direct the metamorphosis of the primitive cells along the right road to the tissues they were destined to form, but permits them to retain, as it were, their embryo condition, and to grow by the imbibition of the surrounding fluid, and thus become the means of injuriously affecting or destroying the tissues which they should have supported and repaired.

I next proceed to consider the internal parasites, which present the characters assigned by Rudolphi to his Cystic Entozoa.

The name *Echinococcus* is given to a cyst resembling the acephalocyst, when, in addition to the sero-albuminous fluid, it contains a number of microscopic organised beings, floating, or freely swimming in it, or adhering by special prehensile organs to the internal surface of the cyst. They are quite independent of the acephalocyst, which merely forms their place of abode; and to them I would limit the generic name *Echinococcus*, which indicates one of their organic characteristics, namely, a coronet or cylinder of spines, which surrounds their mouth. In the *Echinococcus Veterinorum*, the species which infests the common domestic animals, the oral spines, when retracted, offer a close resemblance to the cylinder of teeth, which characterises the *Nassula* (*fig.* 11.) and many other Polygastria. The body of this *Echinococcus* likewise presents a number of clear globules resembling hyaline, and very similar to the so-called stomachs of the Polygastria. In an acephalocyst, from the abdomen of a recently killed hog, I observed these little creatures moving in the fluid, apparently by the action of superficial vibratile cilia, thus adding a remarkable feature to their resemblance to the Polygastria. The *Echinococci*, from a small musk-deer, lately dissected at the College, closely resemble those of the hog, which I have elsewhere described *; but, being dead, the ciliated structure is not indicated, and could not be detected. Each tooth or spine presents an elongated triangular form, a small process extending from the middle of its outer margin, probably for the attachment of the protractor fibres.

18
Echinococcus hominis.

The *Echinococci* of the human subject (*fig.* 18.), which have been accurately described by Professor Müller in a case where they were developed in the urinary bladder, and which have been carefully figured by Mr. Quekett in a case observed by Mr. Curling, where they were developed in the liver, were in both cases inhabitants of a cyst, rather the parasites of an acephalocyst than of the human body. These *Echinococci* differ from those of the hog in having suctorious cavities (*b*), external to the circle of teeth (*a*), and thus closely resembling the head of a Tænia, appended to a small cyst.

The hydatid developed in the substance of the brain of sheep and rabbits, called *Cœnurus cerebralis*, consists of a large cyst, with which many heads, like those of the Tæniæ, are in organic connection. These can be retracted within, or protruded without, the common cyst.

19

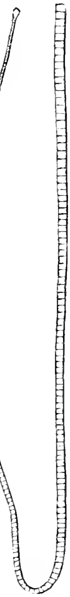

Cysticercus cellulosæ.

The genus *Cysticercus* is characterised by having only a single uncinated and suctorial head, connected by a neck or body, sometimes annulated, and of greater or less length, with the terminal cyst. Of this genus one species, *Cysticercus Cellulosæ* (*fig.* 19.), is occasionally developed in the human subject. It has been met with in the eye, the brain, the substance of the heart, and the voluntary muscles of the body. The peculiar inflammation which it excites leads to the formation of a

* Art. "Entozoa," Cyclopædia of Anatomy and Physiology, p. 158.

condensed bag of cellular tissue around it. The cysts are oval, and generally about half an inch in length. The most common hydatid in the ox and other ruminants, is a large species of the present genus, called *Cysticercus tenuicollis.* All these *Cysticerci* manifest their affinity with the *Cestoidea* by the organisation of their head. A species not uncommon in cysts in the liver of the rat and other rodents, completes the transition to the *Cestoidea,* by having the terminal bladder of small relative size, and the body of great length, and divided into joints or segments.

20



Head and neck, Tænia solium.

I proceed next to consider the organisation of the tapeworms, as the *Cestoidean entozoa* are commonly termed; and for this purpose I shall select the two species which infest the human intestines, namely, the *Tænia solium* and the *Bothriocephalus latus,* and which may be regarded as the types of the two leading genera of the order.

The *Tænia solium* is the only species which is likely to fall under the notice of the British medical practitioner. It appears to be the only species of tapeworm developed in the intestines of the natives of Great Britain; and it is equally peculiar to the Dutch and Germans. The Swiss and Russians are as exclusively infested by the *Bothriocephalus latus.* In the city of Dantzig, it has been remarked, that only the *Tænia solium* occurs; while at Konigsberg, which borders upon Russia, the *Bothriocephalus latus* prevails. The inhabitants of the French provinces adjoining Switzerland are infested with both species.

The *Tænia solium* attains the length of ten feet and upwards: it has been observed to extend from the pylorus to within seven inches of the anus. Its breadth varies from one fourth of a line at its anterior part (*fig.* 20.), to three or four lines towards the posterior part of the body, which then again diminishes. The head is small, and generally hemispherical, broader than long. The mouth is situated on a central rostellum, which is surrounded by a double circle of small recurved hooks (*fig.*21, *a*). Behind these are four suctorious cavities (*fig.* 21, *b*), by which the head is firmly attached to the intestinal membrane. The anterior segments are feebly represented by transverse rugæ; the succeeding ones are subquadrate, and as broad as long. They then become sen-

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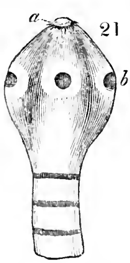
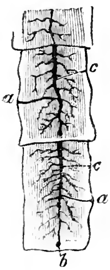


Tænia solium.

sibly longer, narrower anteriorly, thicker and broader at the posterior margin, which slightly overlaps the succeeding joint. The last series of segments are sometimes twice or three times as long as they are broad, proportions which are never observed in the Russian tapeworm. But the chief distinction between the *Bothriocephalus latus* and the *Tænia solium* is in the position of the generative orifices; which, in the *Tænia solium*, are placed near the middle of one of the margins of each joint, and are generally alternate (*fig.* 22, *a*, *a*).

22



Tænia solium.

The integument of the Tænia is soft, like a mucous membrane; beneath it is a layer of delicate transverse muscular fibres, and a more easily recognisable stratum of longitudinal fibres.

The condition of the nervous system is a matter of analogical conjecture. Its principal part, no doubt, exists in, or near, the well-organised head; where, as in the *Trematoda*, it may form a ring round the gullet, and send backwards two delicate filaments. The correspondence of the digestive system with that of many *Distomata*, may be stated with certainty. The alimentary tube, commencing at the minute central mouth, soon bifurcates; and each division is continued as a slender unvarying canal throughout the whole length of the worm, near the margin of the segments: the two longitudinal canals are connected together by transverse canals, one of which is situated at the posterior margin of each segment. The longitudinal nutrient canals have no communication with the marginal pores: they equally exist in those *Cestoidea* which have no marginal pores.

The tissue of the Tæniæ in which the alimentary canals are imbedded, is beset with numerous minute nucleated cells. These doubtless take an important share by their assimilative and reproductive powers in the general nutrition of the body.

The Tæniæ are androgynous, and each joint contains a complicated male and female apparatus equal to the production of thousands of impregnated ova. The ova are developed in a large, branched ovarium (*fig.* 22, *c*), occupying almost the whole space included by the nutrient canals, at least in the posterior segments, where it is very conspicuous from the amber colour of the more mature ova. The oviduct is continued from near the middle of the dendritic ovary to the marginal papilla, where it terminates by a small orifice posterior to that of the male organs. The parts of the male apparatus which have at present been recognised, consist of a small pyriform vesicle (*fig.* 22, *b*), situated near the middle of the posterior margin of the segment; this, however, is most probably only a seminal vesicle, and not the testis. The vas deferens is continued from the vesicle with slight undulations, to the middle of the segment, where it bends upon itself at a right angle, and terminates at the generative pore (*fig.* 22, *a*), from which the *lemniscus,* or rudimental penis, projects. The ova may be fecundated by intromission of the lemniscus into the vulva before they escape.

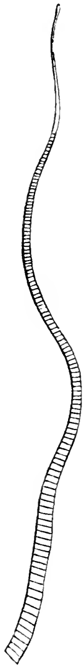
The segments containing the mature ova are most commonly detached and separately expelled. The development and metamorphoses of the embryo Tæniæ have not yet been completely traced out. In the *Tenia serrata* and other species in which the embryo has been observed, the head is first formed and is provided with six hooks; it rotates in the ovum, doubtless by means of superficial vibratile cilia.

For a knowledge of the minute anatomy of the *Bothriocephalus latus* (*figs.* 23, and 25), we are indebted to the admirable skill and patience of Professor Eschricht, of Copenhagen, whose work * on the subject has received the prize of the Academy of Sciences, at Berlin. His observations were made on a specimen of the worm, which, after various remedies, was dislodged from one of his patients.

In Denmark, as in Holland, the *Tænia solium* is the common tapeworm; but the case in question occurred in a female aged twenty-three, born at St. Petersburg, of Russian parents; who had spent almost all her childhood and youth at Copenhagen, with, however, occasional sojourns of three or four months' duration, in Russia. The usual symptoms of tapeworm, with occasional ejection of fragments, occurred in 1834. She had also distorted spine and other indications of a weakly constitution. Thrice, in that year, oil of turpentine with castor oil, and once some strong drastic pills and pomegranate rind, were administered; and, with the exception of the last medicine which produced no effect, each time from twelve to twenty feet of the worm were expelled, but without the head. In the spring of 1835, she was induced to try a remedy called "Schmidt's cure," which consists of strong coffee, and salt herring; and it was followed by the expulsion of a piece of the worm measuring ten yards, still without the head. She then paid a visit to Petersburg, and there parted with four or five pieces of the tapeworm measuring from two to four feet in length. She returned to Copenhagen in the winter of 1835, still suffering from her pertinacious parasite. Castor oil and turpentine were again administered on the 3d of December, and procured the ejection of two pieces of the tapeworm, measuring together twelve feet in length, but

* Anatomisch. Physiologische Untersuchungen über die Bothryocephalen. 4to. 1840.

23



Head and neck, Bothr. latus.

without the head. Eighteen days afterwards, Nouffer's remedy, which consists of a preparation of fern seed, was resorted to, whereupon the remaining part of the worm, twenty feet in length, with the neck and head, came away, and all the symptoms of the malady disappeared, and had not returned in 1838, when this instructive case was recorded.

The head and neck are represented in this diagram (*fig.* 24.). You will see that it closely resembles the figure which Bremser first gave of this important and characteristic part of the broad tapeworm. Instead of the coronet of hooks and circle of suckers which characterise the head of the *Tænia solium*, it forms a simple, elongated, sub-compressed enlargement, with an anterior obtuse prominence, perforated by the mouth (*fig.* 24, *a*), and having two lateral sub-transparent parts separated by a middle opake tract. According to Bremser, the margins are slightly depressed, forming what are termed the *Bothria* or pits (*fig.* 24. *b*, *b*), whence the generic name of this tapeworm. There was no trace of joints within two inches and a half of the head. These are at first feebly marked; then the segments expand posteriorly, and slightly overlap the succeeding ones: their length nearly equals their breadth. At sixteen inches from the head a slight prominence at the middle line, and near the anterior part of the ventral surface of the segment, indicates the genital apertures. These become conspicuous in the posterior segments, and are two in number, situated pretty close together on the same prominence (*fig.* 25.).

24

Bothr. latus.

The tegumentary and muscular systems appear to resemble closely those in the *Tænia solium*. Dr. Eschricht could not discern any trace of nerves. Of the nutrient system, he obtained evidence only of the two submarginal longitudinal canals: by placing the recent segments in dilute acetic acid, he coagulated the contents of these canals, which were then manifest by their opacity and whiteness. They were doubtless filled with the chyle of the unfortunate sufferer. How the chyle is absorbed by the *Bothriocephalus* Eschricht was unable to discern: he supposes, analogically, by an anterior suctorious mouth, leading to

25

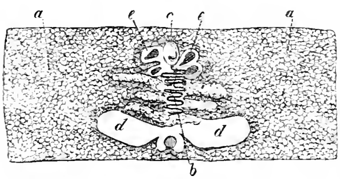
Bothr. latus.

a gullet, which bifurcates in the neck to form the two longitudinal canals. Eschricht could not detect the transverse anastomosing canals. We shall be justified, perhaps, by the analogy of this species of *Bothriocephalus* from the Python *, in which I succeeded in injecting with quicksilver both the longitudinal and transverse canals, in concluding that the anastomosing channels are present at the posterior margins of the segments in the *Bothriocephalus* of the human species.

Innumerable and very minute nucleated cells are apparently disseminated through the tissue of the *Bothriocephalus.* Eschricht points out their analogy to the blood-cells in the lower animals, but could not perceive any ramified system of blood-vessels.

At the deepest part of each segment there is a stratum of whitish granules or glands (*fig.* 26. *a*, *a*), composed of a cluster of minute blind sacculi, filled with opake fluid, each group or gland being suspended in a separate cell, the pedicle of which is, without doubt, the duct of the sacculated gland which Eschricht regards as a testis, and estimates at 400 in number at each joint. Their ducts unite to form a network, having the capsules of the gland in the interspaces. The vas deferens (*fig.* 26, *b*) is best seen on the dorsal aspect of the joint, along the middle of which it runs in close transverse folds, progressively increasing in breadth, until it terminates in a pyriform seminal receptacle or " bursa penis " (*fig.* 26, *c*). From this bursa a small lemniscus is protruded through the anterior of the two generative pores, situated upon the eminence near the middle of the anterior part of the ventral surface of the segment.

26



Bothr. latus.

The ovaria (*fig.* 26, *d*) are situated near the posterior margin of the segment. They consist of two large transversely oblong lobes, and a smaller median annular portion. They are composed of tubes in which the small germinal and vitelline rudiments of the ova are arranged in rows. The oviducts terminate in a long tubular uterus (*fig.* 26, *e*), which is considerably wider than the vas deferens, and advances forwards, making many transverse convolutions, the two last being wider than the rest, and extending on each side of the bursa penis. The ducts of a very complicated series of glands communicate with the uterus before its final termination at the vulva or pore, which is behind the male opening. The glands just alluded to form a stratum next

* Prep. No. 846. A.

beneath the skin at the sides of the joints. Eschricht calculates that there are 1200 of these glands in each joint. In the joints furthest from the head, containing the mature ova, these glands become filled with a thick yellow matter which they pour into a system of ramified ducts, which unite to discharge themselves in the dilated part of the uterus. Their office seems to be to cement together the ova in hard cylindrical masses by forming a crust around them, in which state they are found in the detached joints. This is the first example which we have yet seen of nidamental glands, which we shall subsequently find a conspicuous part of the generative organs in many oviparous Invertebrata.

From this description it will be seen that the proportions and almost the forms of the ovarium and testis, are reversed in the *Bothriocephalus* and *Tænia:* the positions of the sexual outlets are unquestionably very different in the two genera. Both, however, agree in presenting the most extensive development and preponderance of the generative system that is known in the Animal Kingdom. In fact there is scarcely space left in the hinder joints of the tapeworms for the organs of any of the other systems.

The natural rate of life of a tapeworm, the consequences to the remaining adherent part, of the repeated detachment of the ovigerous segments, the extent to which they are detached and subsequently renewed, have not yet been, nor are likely ever to be, the subjects of direct observation in these internal parasites of man.

Some highly interesting facts have, however, been made known by the same professor to whom we are indebted for a knowledge of the anatomy of the *Bothriocephalus latus*, in the economy of another species of *Bothriocephalus* which is extremely common in the small sea-fish called *Cottus scorpius*.

During midsummer, these tapeworms are fully developed, and their segments are laden with ova. They adhere by the fore part of the head to the mucous surfaces of the appendices pyloricæ, and cast off the ovigerous segments, sometimes in their whole length; so that headless tapeworms are found in the lower part of the intestine, whilst a number of heads without bodies may be observed adhering to the pyloric appendages between other tapeworms of very different lengths. The heads thus left behind generate a new series of perfect joints in the following way: the joint next the head is divided by a transverse fissure into two, each of which repeats the same process as soon as it is somewhat grown. Whilst the joints multiply in this way, they continue to increase in size, and so become removed from the head; but at a certain distance from the head, this mode of subdividing ceases, and the whole nutritive power is applied to the development of the organs of generation. During winter the *Bothriocephalus punctatus*, still adhering firmly to the mucous surface of the pyloric appendages, grows to its full length, and the generative organs are formed ; but no ova can be seen. These begin to appear at the commencement of spring in the posterior joints, and by degrees fill the uteri of all the joints, until they occupy those which are close to the head, when the separation from the head before described ensues, and this last-named member is left to repeat the important process.

No single joint of a tapeworm can develope a head, and form a new individual ; the transverse fission relates only to the dissemination of the fertile ova, from which alone new *Tæniæ* are developed.

The hypothesis of equivocal generation has been deemed to apply more strongly to the appearance of internal parasites in animal bodies than to the origin of animalcules in infusions. But if a tapeworm might be organised from a fortuitous concourse of organic particles, or by the metamorphoses of an organic cell in the animal it infests, why that immense complication and extent of the organs for the production of normal fertile ova?

" The division of the body into joints is intended," as Professor Eschricht well observes, " to produce a corresponding number of bunches of ova, just as the repeated ramification of plants is destined to provide space for the production of new bunches of seeds." The head of the tapeworm is fixed to the mucous surface, and thence it derives the nutritive juices required for the whole organism ; in the same manner as the root procures the nourishment of the plant from the soil. The ova having reached maturity, the joints rupture to liberate them ; or the whole joint will be thrown off in the same way as the seeds of plants are freed, sometimes one by one, sometimes in masses, according to the particular manner of life assigned to every species of plant. " And is there any one," asks Dr. Eschricht, " who, upon the contemplation of this wonderful apparatus, and the extraordinary results of its agency, can for a moment imagine that it is without an object or an end?"

The geographical distribution of the human Cestoidea is, likewise, opposed to the doctrine of their spontaneous origin. The organic particles, or alimentary mucus of a Swiss and Dutchman, are not so distinct in their nature as to account for the difference in their tapeworms. A native of one of these countries may be infested by the tapeworm peculiar to another region, if he sojourn there, just as the English sailor may be attacked by the Guinea-worm, if he visits the tropical regions where that entozoon is common.

The great anatomist Soemmering suffered from a *Bothriocephalus* *latus.* Now he was a German; but it was ascertained that he paid occasional visits to a friend in Switzerland. There, doubtless, the germ of the parasitic worm was introduced into his body. The countless ova of the tæniæ, with their hard crusts or shells, and tenacity of latent life, are, doubtless, widely dispersed, and need only the accidental introduction into an appropriate nidus for ulterior development.

LECTURE V.

ENTOZOA.

The essential anatomical character of the third order of Entozoa in the classification of Rudolphi may be represented by combining the head of an unarmed Tænia, with one of its joints, containing the fully developed androgynous organs. The digestive system would then be represented by a simple bifurcating canal, each fork ending in a cul de sac.

The *Trematoda* may be characterised as having a soft, rounded, or flattened body, with an indistinct head, provided with a suctorious foramen, and having generally one or more sucking cups for adhesion in different parts of the body; the organs of both sexes are in the same individual.

The great entozoologist Rudolphi, a pupil and ardent admirer of Linnæus, adopted external and easily recognisable characters for the generic subdivisions of the Trematode order, the species of which were distributed according to the number and positions of the suctorious orifices and cavities. When there is a single one, it constitutes the genus *Monostoma:* when there are two, which are terminal or at opposite ends of the body, you have the character of the genus *Amphistoma:* when the posterior of the two suckers is not terminal, but on the inferior surface of the body, this constitutes the genus *Distoma:* three suctorious cavities characterise the genus *Tristoma;* five, the genus *Pentastoma;* and a greater number that called *Polystoma.* Subsequent anatomical investigations have led to the formation of other genera of *Trematoda*, and have likewise shown that those species which were grouped together by the external and artificial characters of the Rudolphian system, manifest differences of organisation, indicating, at least, the generic distinction of such species: nay, most of the *Pentastomata* of Rudolphi appertain to the Cœlelminthic class of Entozoa.

I am compelled to limit my illustrations of the anatomy of this order almost to the two species which infest the human subject; these are the *Distoma hepaticum* (*fig.* 27.) and the *Distoma lanceolatum* (*fig.* 28.). Both are peculiar to the biliary ducts and gall bladder, but may pass thence into the intestine. Both, likewise, are more commonly found in the ordinary domestic animals, as the sheep and ox, than in the human subject.

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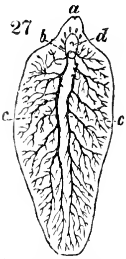

Dist. hepaticum' nat. size.

A full-grown *Distoma hepaticum* is of a flattened, ovate, or oblong-ovate form, broader and rounded anteriorly, attenuated posteriorly; from ten to sixteen lines in length, from four to seven in width: the broad end sends forward a sort of conical neck or head, convex above, flat below; one of the suctorial acetabula (*a*) is at the extreme apex of this process, a little turned downwards; the other (*b*) is at the under part of the body, at the base of the neck: the first sucker is perforated by the mouth; the posterior and larger one is imperforate, and serves merely as an organ of adhesion. You will observe, also, a small depression (*d*) between the characteristic suckers, in which the genital pores are placed: not unfrequently the curved or spiral penis may be observed projecting from the anterior of these orifices.

The body is of a whitish yellow colour, variegated near the margins by the yellow ova, and on the dorsal aspect by the brown colour of the double ramified alimentary tube. The integument is soft: traces of muscular fibres can hardly be discerned, except around the larger subventral sucker.

Dr. Mehlis, who has given the best anatomical account of the human *Trematoda*, describes and figures the nervous system of the *Distoma hepaticum* as a delicate œsophageal filamentary ring, with a slight ganglionic enlargement on each side, from which minute fibres pass into the suctorial sphincter; and two large filaments pass backwards, one on each side, as far as the ventral sucker.

I have tested this description by a dissection of the largest known species of *Distoma*, the *Dist. clavatum*, whose anatomy I have described in the Zoological Transactions. You may distinctly perceive in this dissection the œsophageal nervous circle, the small cephalic filaments, and the two widely separated nervous chords of the trunk. In this specimen also, you will see the integument raised as a distinct membrane from the outer transverse muscular fibres, and a portion of these is reflected from the inner longitudinal stratum. Feeble analogues of these parts of the muscular system are doubtless present in the smaller *Distomata* of the human subject.

The sole aperture of the alimentary system is that of the anterior pore, which is surrounded by the fibres of the suctorial organ. The alimentary canal is continued from this pore for a very short distance as a single tube, and then bifurcates; the divisions (*fig.* 27. *c, c*) diverge to enclose the bursa penis and the ventral sucker, again approximate, and afterwards run parallel with each other, with a narrow interspace, along the middle of the body to the caudal extremity. At their first bend, each tube gives off three or four branches from its outer, but none from its inner side. The parallel tubes send off a few short and simple branches from the inner side, and many larger ramified branches from their outer sides, which terminate in blind extremities near the margin of the body.

These canals seem, at first sight, to be simply excavated in the substance of the body; but, attentively examined, they present a delicate proper tissue. They are usually filled with a brownish chyme, which appears to be mucus stained with cholesterine.

A more minute system of ramified tubes, which by some have been regarded as the nutrient vessels, commences by a small foramen at the caudal extremity of the body. The trunk of this system runs forwards with a serpentine course, along the interspace of the forked alimentary canal, to the middle of the body, where it terminates in many finely ramified branches. It seems to represent, therefore, an excretory rather than a nutrient system.

The vascular system of *Diplostomum volvens*, so beautifully illustrated by Nordmann, is surely the equivalent of the excretory system of capillaries, described by Mehlis in the *Distoma hepaticum;* and the median trunk, which is compared by Nordmann to the dorsal aorta in the Anellides, must be the principal excretory conduit: it passes directly backwards to the terminal pore, distinctly recognised by Nordmann in the *Diplostomum* as an excretory outlet; and he does not positively deny, what his figures indicate, its continuity with the straight duct terminating at that pore. In the *Dist. clavatum* I have shown that the excretory system is complicated by a large terminal receptacle or bladder, of which the hinder pore is the outlet.*

The male organs of the *Distoma hepaticum* consist of the secerning seminal tubes, a vesicula seminalis, a penis, and its bursa: the convoluted tubuli testis equal the smallest branches of the alimentary canal in size; they occupy a great extent of the middle part of the body, are inextricably interwoven, are recognisable by their opaque white colour, and terminate by two trunks in a common canal, which ends at the base of the receptaculum penis. This

* Zool. Trans. i. p. 41. fig. 18. *g*.

appendage is spirally disposed when flaccid, is tubular, and distinctly perforated at the apex.

The ovaria occupy the whole margin of the body for a line in breadth: they consist of minute, branched tubes, in which the ova are developed, as in acini. The oviducts are close to the ventral integument, and terminate in a single large uterine canal, which is disposed in many convolutions between the subventral acetabulum and the bursa penis: it terminates by a vulva, or distinct pore, immediately behind the male bursa. The ovarian ova are colourless and pellucid, but become opaque as they approach the oviduct: having entered this tube they acquire a white glistening tunic, and afterwards a yellow colour, which becomes deeper as they approach the vulva.

The *Distoma lanceolatum* (*fig.* 28.) has been regarded as the young of the *Distoma hepaticum;* but it is of a different form, has a different anatomical structure, particularly as regards the alimentary canal, and its title to rank as a distinct species is sufficiently vindicated by its power of developing fertile ova without changing its characteristic shape or increasing in size. It rarely equals five lines in length, but is more commonly three lines long; flat, lanceolate, more attenuated anteriorly, and with an obtuse caudal apex.

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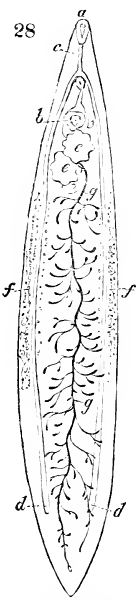


Dist. lanceolatum, magnified.

The suctorial pores are relatively larger than in the *D. hepaticum.* The anterior globose sucker (*a*) looks downwards, and is perforated in the centre by the mouth: the genital pores are half way between this and the hinder sucker (*b*). The transparency of the integument allows the internal parts to be readily discerned. The alimentary canal, commencing by a kind of pharynx, is continued as a very slender tube (*c*) to the bursa penis, where it bifurcates, each division (*d*) being continued without farther ramification along the right and left sides of the body to the tail, where it ends in a blind extremity. The minuter excretory system of vessels has not been discerned in this small *Distoma.* The simplicity of its digestive apparatus makes the analogy very close between the *D. lanceolatum* and the *Tæniæ.*

In the interspace of the two digestive tubes four opake whitish spots are visible, of which the three anterior or larger ones (*e*) form the testes. Each transmits from its anterior margin a very minute duct, which, advancing forwards, unite in a common vas deferens, terminating in a small vesicle at the base of the penis, which is provided with its proper bursa. The ovaria (*f, f*) are two in number, of a milk-white colour, situated at the margins of the middle third of the body, exterior to the alimentary tube. They present a dendritic form, small branches being given off chiefly from their outer side. The oviducts run transversely to the middle line, and form there, by their convolutions, a fourth white opake body behind the testes. From this subspherical body the common uterine tube (*g*) is continued. This is a simple and ample canal, very long and tortuous, occupying all the posterior part of the interspace of the alimentary forks, thence continued forwards with decreasing convolutions, and terminating at the vulva.

The digestive system in the species of *Diplostomum*, a genus which has two ventral suckers, is as simple as in the *Dist. lanceolatum ;* but the blind extremities of the two divisions of the alimentary cavity are each lodged in a sac, which, from the milky character of its contents, has been termed the chyle receptacle. It is supposed that the nutritious contents of the alimentary tubes exude through the parietes of their cœcal extremities into these receptacles. Two delicate vessels are continued from the anterior and outer angle of each chyle-receptacle, which extend forwards to the anterior third of the body, and are there brought into communication by a transverse vessel, which extends across the dorsal aspect of the body. From the point of union of the transverse with the external lateral vessels, a single trunk is continued forwards on each side to the anterior angles of the body, where they bend inwards and unite in the middle line to form a median trunk, which is continued to the posterior extremity of the body, distributing or receiving branches on each side throughout its entire length, and apparently terminating at the posterior excretory pore. Through the connections of this system of vessels with the chyle-receptacles, the terminal pore might be regarded as an anal outlet to the digestive system, and the capillary vessels, extending from the chyle-receptacles to that pore, as a ramified form of intestine, fulfilling at the same time the office of lacteals, lymphatics, arteries, and veins.

Dr. Nordmann, who has contributed to Comparative Anatomy many excellent illustrations of the vascular system of the *Trematoda*, was the discoverer of the most extraordinary form in the present class of animals, represented by the species which he has called *Diplozoon paradoxum.* This animal consists, in fact, of two bodies precisely resembling each other, and united, like the Siamese youths, by a narrow communicating band, through which, however, the digestive system of one body freely communicates with that of the other. This digestive system presents the dendritic type of the

Distoma hepaticum. Each half of the body has its own organs of circulation, or secretion, and of generation. But for the anatomical details of the *Diplozoon,* I must refer to Dr. Nordmann's elaborate work. This truly paradoxical species, which is about two or three lines in length, may be found attached to the gills of the bream.

The genus *Planaria,* a fresh-water vermiform animal, and not an internal parasite, is nevertheless referable, by its organisation, to the order *Trematoda.* In the *Planaria lactea* the mouth is situated upon a proboscis extending from the middle of the inferior surface of the body. The alimentary canal almost immediately divides into three principal branches, each of which is again subdivided into a number of ramified cœca. The two posterior dendritic divisions are obviously analogous to those in the *Distoma hepaticum;* the anterior division is azygos, and passes along the middle line to the anterior extremity of the body. The generative organs of the Planariæ are androgynous, and are essentially the same as in the *Distomata.* The ova of some species are attached by short filaments to the stems of aquatic plants. The *Planariæ* also propagate by spontaneous fission, and are remarkable for the facility with which detached or mutilated parts assume the form and functions of the perfect animal.

The young of those species of the parasitic Trematoda, whose development has been most satisfactorily observed, pass the first period of their existence, like the *Planariæ,* as free denizens of the watery element. The *Distomata tereticollis* and *cylindraceum* are however viviparous. The *D. hepaticum* and *lanceolatum* are oviparous. The egg-covering in these and many other species of *Trematoda* is provided with an operculum or lid. The young of the *Dist. hepaticum* are spherical and ciliated like the polygastric infusoria; and they are provided at this active stage of their existence with a dark coloured eye speck, and sometimes with a pair of ocelli. The young of the *Dist. globiporum* are of an ash-grey colour, and without an ocellus. All Trematoda appear first to present the ciliated infusorial state before they attain their appointed place of abode, where they undergo their final metamorphosis and develop their generative organs. There can be little doubt that the sheep, which become infested by the liver-fluke, swallow the ova or embryos that are ejected upon the pastures or in the drinking places; and the young flukes must instinctively pass from the duodenum up the ductus choledochus to the gall-bladder. Change of pasture, removal to uninfected grounds, are, therefore, the first steps in the cure and prevention of the rot-distemper caused by the *Distoma hepaticum.*

Of the order *Acanthocephala,* which includes the most noxious of the internal parasites, fortunately no species is known to infest the human body. They resemble the Nematoid Entozoa in outward form, and in the distinction of the sexes, but in their digestive system they still manifest the sterelminthic type.

The species of this order constitute but one genus, *Echinorhynchus*, characterised by a more or less elongated, round, subelastic body, the head having a retractile proboscis armed with recurved spines. The *Echinorhynchi* abound in the lower animals, and are, some cylindrical, and others sacciform. The largest known species (*Echinorhynchus gigas*) infests the intestines of the hog. As regards the tegumentary and muscular system, it resembles the Nematoid worms, as well as in its diœceous generation; but its digestive system is very different, and somewhat obscurely developed. The mouth is a minute pore, situated on the extremity of the uncinated proboscis: it leads to two long cylindrical canals, which adhere to the muscular tunic, and are continued to the posterior extremity of the body, where they terminate in blind ends; and two shorter cylindrical cœca are continued backwards from near the mouth, and are freely suspended in the anterior part of the generative cavity: they are called *lemnisci*. The male organs consist of two fusiform testes, two vasa deferentia, which unite together to terminate in a single vesicula seminalis, and a long intromittent organ provided with a bursa occupying the posterior extremity of the body, and having a special muscular apparatus for the retraction and extrusion of the contained organ. The male echinorhyncus is generally half the size of the female. The generative organs in this sex consist of two ovaries and one oviduct. The ovaries are long and wide cylindrical canals, which of themselves occupy almost the whole cavity of the body, extending from the proboscis to the tail, and the common slender oviduct terminates at that extremity by a very minute pore. The best details of the anatomy of this order are given by Dr. Westrum* and by Dr. Cloquet, in his prize Essay on the Anatomy of the Intestinal Worms.†

LECTURE VI.

ENTOZOA.

THE four orders of the class *Entozoa* which have already been described, are less natural than the order *Nematoidea*, which will

* De Helminthibus Acanthocephalis, fol. 1821.
† Anatomie des Vers Intestinaux. 4to. 1824.

chiefly occupy our attention in the present lecture. The *Cystica*, *Cestoidea*, *Trematoda*, and *Acanthocephala* are far from being respectively equivalent to the order *Nematoidea*, either as regards grade, difference, or circumscription of organic characters. The transition from the cystic to the tænioid Entozoa is so gradual and close, by the *Cysticercus fasciolaris*, for example, that they are combined in the same order "*Tænioidea*," in the "Règne Animal" of Cuvier. On the other hand, Cuvier separates the jointless *Ligulæ*, in which the head has neither suckers, bothria, nor uncinated proboscis, from the Tænioids, and limits the order *Cestoidea* to the *Ligulæ*. It is hardly possible, however, to separate from the Tænioids of Cuvier, the intestinal *Ligulæ* of birds, in which traces of both bothria and generative organs begin to manifest themselves. With respect to the higher organised *Cestoidea* of Rudolphi, it has been already observed that they are essentially a composite form of *Trematoda*. The extensive and natural group formed by the three androgynous orders of "Sterelmintha" form, therefore, the equivalent of the *Nematoidea*. The *Acanthocephala* constitute a more limited, yet natural order; and the *Linguatulæ* (*Pentastoma* of Rudolphi) are the type of an analogous circumscribed group with a higher type of organisation, which entitles them to rank in the class *Cœlelmintha*. This class includes all the cavitary intestinal worms of Cuvier, with the exception of the "Vers ridigules" or Epizoa, which are proved by their metamorphoses to belong to the siphonostomous Crustaceans.

The order *Nematoidea*, which forms the chief part of the class *Cœlelmintha*, must chiefly interest the physician, since it includes the principal internal parasites of the human subject: viz. *Trichina spiralis*, *Filaria medinensis*, *Filaria oculi*, *Filaria bronchialis*, *Trichocephalus dispar*, *Spiroptera hominis*, *Strongylus gigas*, *Ascaris lumbricoides*, and *Ascaris* or *Oxyurus vermicularis*. To the order *Nematoidea*, repeated examinations, since my first observation of the minute *Trichina spiralis* *, induce me to refer that singular microscopic parasite. I have satisfied myself of the accuracy of Dr. Farre's and Dr. Henle's description of the distinct alimentary canal. In a specimen of *Trichina* now under the microscope, a loop of the intestine may be seen protruding through a rupture of the abdominal wall. The vermicule is always contained in a cyst. The occurrence of these cysts in vast numbers in the muscular tissue was made known in a very interesting case published by Mr. Hilton † : and many others have since been recorded.

* Transactions of the Zoological Society, vol. i. p. 315.
† Medical Gazette, February, 1833.

The cysts are very readily detected, by gently compressing a thin slice of the infected muscle between two pieces of glass and applying a magnifying power of an inch focus. They are of an elliptical figure, with the extremities more or less attenuated, often unequally elongated, and always more opake than the body or intermediate part of the cyst, which is, in general, sufficiently transparent to show that it contains a minute coiled-up worm. The usual size of the cyst is $\frac{1}{50}$th of an inch in the long diameter, and $\frac{1}{100}$th of an inch across their middle part. The cysts are always arranged with their long axis parallel to the course of the muscular fibres, which probably results from their yielding to the pressure of the contained worm, and becoming elongated at the two points where the separation of the muscular fasciculi most readily takes place, and offers least resistance.

The innermost layer of the cyst can sometimes be detached entire, like a distinct cyst, from the outer portion, and its contour is generally well marked when seen by transmitted light. By cutting off the extremity of the cyst, which may be done with a cataract needle or fine knife, and gently pressing on the opposite extremity, the Trichina and the granular secretion with which it is surrounded, will escape; and it frequently starts out as soon as the cyst is opened.

When first extracted, the Trichina is usually disposed in two or two and a half spiral coils; when straightened out it measures $\frac{1}{30}$th of an inch in length and $\frac{1}{700}$th of an inch in diameter, and now requires for its satisfactory examination a magnifying power of at least 200 linear admeasurement.

The worm is cylindrical and filiform, terminating obtusely at both extremities, which are of unequal sizes; tapering towards one end for about one-fourth part of its length, but continuing of uniform diameter from that point to the opposite extremity.

Until lately it was only at the larger extremity that I have been able to distinguish an indication of an orifice; and this is situated in many specimens in the centre of a transverse, bilabiate, linear mouth.

The anterior third of the alimentary canal is more even than the remaining part, which presents a sacculated appearance; in this respect, the *Trichina* resembles the newly excluded young of *Ascarides* and *Strongyli.* A small rounded cluster of granules of a darker or more opake nature than the rest of the body is situated about one-fifth of the length of the animal from the larger or anterior extremity, and extends about half-way across the body.

The worm has no organic connection with the cyst: sometimes two *Trichinæ*, rarely three, occur in the same cyst.

The Medina or Guinea-worm (*Filaria medinensis* Gmel.) is developed in the subcutaneous cellular texture, generally in the lower extremities, especially the feet, sometimes in the scrotum, and also, but very rarely, beneath the *Tunica conjunctiva* of the eye. It appears to be endemic in the tropical regions of Asia and Africa.

The length of this worm varies from six inches to two, eight, or twelve feet; its thickness from half to two-thirds of a line; it is of a whitish colour in general, but sometimes of a dark brown hue. The body is round and sub-equal, a little attenuated towards the anterior extremity. In a recent specimen of small size, we have observed that the orbicular mouth was surrounded by three slightly raised swellings, which were continued a little way along the body and gradually lost; the body is traversed by two longitudinal lines corresponding to the intervals of the two well-marked fasciculi of longitudinal muscular fibres. The caudal extremity of the male is obtuse, and emits a single spiculum; in the female it is acute, and suddenly inflected.

The *Filaria medinensis*, as has just been observed, is occasionally located in the close vicinity of the organ of vision; but another much smaller species of the same genus of Nematoidea, infests the cavity of the eye-ball itself.

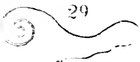
The *Filaria oculi humani* was detected by Nordmann in the *Liquor morgagni* of the capsule of a crystalline lens of a man who had undergone the operation of extraction for cataract under the hands of the Baron von Gräfe. In this instance the capsule of the lens had been extracted entire, and upon a careful examination half an hour after extraction there were observed in the fluid above mentioned two minute and delicate *Filariæ* coiled up in the form of a ring. One of these worms, when observed microscopically, presented a rupture in the middle of its body, probably occasioned by the extracting needle, from which rupture the intestinal canal was protruding; the other was entire, and measured three-fourths of a line in length; it presented a simple mouth without any apparent papillæ, such as are observed to characterise the large *Filaria* which infests the eye of the horse, and through the transparent integument could be seen a straight intestinal canal, surrounded by convolutions of the oviducts, and terminating at an incurved anal extremity.

The third species of *Filaria* enumerated among the *Entozoa hominis* is the *Filaria bronchialis;* it was described by Treutler* in the enlarged bronchial glands of a man: the length of this worm is about an inch; it is slender, subattenuated anteriorly, and emitting the male spiculum from an incurved obtuse anal extremity.

The next human entozoon of the Nematoid order belongs to the genus *Tricocephalus*, which, like *Filaria*, is characterised by an or-

* Opusc. Pathol. Anat. p. 10.

bicular mouth, but differs from it in the capillary tenuity of the anterior part of the body, and in the form of the sheath or preputial covering of the male spiculum. The species in question, the *Trichocephalus dispar* Rud. (*fig.* 29.) is of small size, and the male is rather less than the female. It occurs most commonly in the cæcum and colon, more rarely in the small intestines. Occasionally it is found loose in the abdominal cavity, having perforated the coats of the intestine. The capillary portion of this species makes about two-thirds of its entire length; it is transversely striated, and contains a straight intestinal canal; the head (*a*) is acute, with a small simple terminal mouth. The thick part of the body is spirally convoluted on the same plane, and exhibits more plainly the dilated intestine; it terminates in an obtuse anal extremity, from the inner side of which project the intromittent spiculum and its sheath.



Trichocephalus dispar. Nat. size.

The species called *Spiroptera Hominis* was founded by Rudolphi on some small nematoid worms expelled, with many larger elongated bodies of a solid texture, and with granular corpuscles, from the urinary bladder of a woman, whose case has been described by Mr. Lawrence in the Medico-chirurgical Transactions.* The *Spiroptera* varies from eight to ten lines in length; the head truncated, mouth orbicular, with one or two papillæ, body attenuated at both extremities; the tail in the female, thicker, and with a short obtuse apex; that of the male more slender, and emitting a small tubulus; a dermal aliform production near the same extremity determined the worms in question to belong to the genus *Spiroptera*.†

The most formidable, but, happily, the rarest of the Nematoid parasites of man, also infests the urinary system, but is developed in the kidney, where it has attained the length of three feet, with a diameter of half an inch; occasioning suppuration and destructive absorption of that important glandular organ.

The male *Strongylus gigas* (*fig.* 30.) is less than the female, and is slightly attenuated at both extremities. The head (*a*) is obtuse, the mouth orbicular, and surrounded by six hemispherical papillæ; the body is slightly marked with circular striæ, and with two longitudinal impressions; the tail is incurved in the male, and terminated by a dilated pouch or *bursa*, from the base of which the single intromittent spiculum (*g*) projects. In the female the caudal extremity is less attenuated and straighter, with the anus a little below the apex; the vulva is situated at a short distance from the anterior extremity.

* Vol. ii. p. 385.

† Rudolphi, Synopsis Entozoorum, p. 251.

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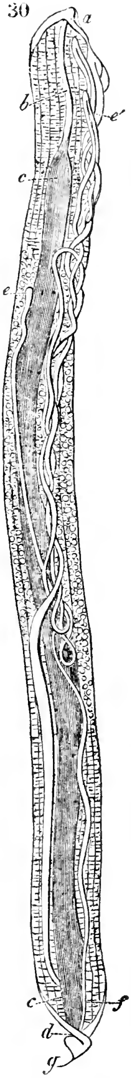

Strongylus gigas. Nat. size.

The *Strongylus gigas* is not confined to the human subject, but more frequently infests the kidney of the dog, wolf, otter, racoon, glutton, horse, and ox. It is generally of a dark blood-colour, which seems to be owing to the nature of its food, which is derived from the vessels of the kidney, as, where suppuration has taken place, the worm has been found of a whitish hue.

The round-worm (*Ascaris lumbricoides* Linn.) (*fig.* 31.) is perhaps the most anciently known * and common of the human Entozoa, and is that which has been subjected to the most repeated, minute, and successful anatomical examinations. It is found in the intestines of man, the hog, and the ox. In the human subject the round worms are much more common in children than in adults, and are extremely rare in aged persons. They are most obnoxious to individuals of the lymphatic temperament, and such as use gross and indigestible food, or who inhabit low and damp localities. They generally occur in the small intestines.

The body is round, elastic, with a smooth shining surface, of a whitish or yellowish colour; attenuated towards both extremities, but chiefly towards the anterior one (*fig.* 31, *a*), which commences abruptly by three tubercles, which surround the mouth, and characterise the genus. The posterior extremity (*d*) terminates in an obtuse end, at the apex of which a small black point may frequently be observed. In the female this extremity is straighter and thicker than in the male, in which it is terminated more acutely and abruptly and is curved towards the ventral side of the body. The anus is situated in both sexes close to the extremity of the tail, in form like a transverse fissure. In the female the body generally presents a constriction at the junction of the anterior with the middle third, in which the *vulva* (*e*) is situated.

The body of the *Ascaris lumbricoides* is transversely furrowed with numerous very fine striæ, and is marked with four longitudinal equidistant lines extending from the head to the tail. These lines are independent of the exterior envelope, which simply covers them; two are lateral, and are larger than the others, which are dorsal and ventral. The lateral lines

* It is the ελμινς στρογγυλος of Hippocrates.

commence on each side of the mouth, but, from their extreme fineness, can with difficulty be perceived; they slightly enlarge as they pass downwards to about one-third of a line in diameter in large specimens, and then gradually diminish to the sides of the caudal extremity. They are occasionally of a red colour, and denote the situation of the principal vessels of the body. The dorsal and abdominal longitudinal lines are less marked than the preceding, and by no means widen in the same proportion at the middle of the body. They correspond to the two nervous chords, hereafter to be described.

The last species of human Entozoon which remains to be noticed is the *Ascaris vermicularis* (*fig.* 32.), a small worm, also noticed by Hippocrates under the name of *ασκαρις*, and claiming the attention of all physicians since his time, as one of the most troublesome parasites of children, and occasionally of adults; in both of whom it infests the larger intestines, especially the rectum. The size of the male *Ascaris vermicularis* is two or three lines, that of the female is five lines.

The integument in the Nematoid parasites of the human subject, and in almost all the order, is smooth; it consists of a thin compact epidermis, and a cellular corium firmly attached to the outer transverse muscular fibres. The epiderm is developed in the *Strongylus horridus* of the water hen, into four longitudinal rows of reflected hooklets; and similar spines are arranged in circular groups upon the anterior part of the *Gnathostoma spinigerum*.

M. Cloquet, in his elaborate monograph on the *Ascaris lumbricoides*, correctly states that the exterior layers of muscular fibres are transverse, and the internal longitudinal. In this large specimen of the *Strongylus gigas*, which I have dissected for the muscular system, you will perceive that a very thin layer of transverse fibres adheres strongly to the integument, the fibres being imbedded in delicate furrows on the internal surface of the skin; within this layer, and adhering to it, but less firmly than the transverse fibres do to the integument, there is a thick layer of longitudinal fasciculi, which are a little separated from one another, and distributed not in eight distinct series, but pretty equally over the whole internal circumference of the body. Each fasciculus is seen under a high magnifying power to be composed of many very fine fibres; but these do not present the transverse striæ which are visible by the same power in the voluntary muscular fibres of the higher animals. The inner surface of the stratum of longitudinal fibres is covered with a soft tissue composed of small obtuse processes, filled with a pulpy substance, and containing innumerable pellucid globules.

Coincident with this higher development of the muscular system in the cœlelminthic Entozoa is the more obvious elimination of the nervous filaments, which in the *Linguatula* radiate from a distinct subœsophageal ganglion. Amongst the Nematoidea the great *Strongylus* is a favourable subject for the demonstration of the nervous system.

In the *Strongylus gigas*, a slender nervous ring surrounds the beginning of the gullet, and a single chord is continued from its inferior part, and extends in a straight line along the middle of the ventral aspect to the opposite extremity of the body, where a slight swelling is formed immediately anterior to the anus, which is surrounded by a loop analogous to that with which the nervous chord commenced. The abdominal nerve is situated internal to the longitudinal muscular fibres, and is easily distinguishable from them with the naked eye by its whiter colour, and the slender branches which it sends off on each side. These transverse twigs are given off at pretty regular intervals of about half a line, and may be traced round to nearly the opposite side of the body. The entire nervous chord in the female of this species passes to the left side of the vulva, and does not divide to give passage to the termination of the vagina, as Cloquet describes the corresponding ventral chord to do in the *Ascaris lumbricoides*. In the latter species, and most other Nematoidea, a dorsal nervous chord is continued from the œsophageal ring down the middle line of that aspect of the body corresponding to the ventral chord on the opposite aspect.

In the *Linguatula tænioides* a proportionally large ganglion is situated immediately behind the mouth, and below the œsophagus: small nerves radiate from this centre to supply the muscular apparatus of the mouth and contiguous prehensile hooklets; and two large chords pass backwards and extend along the sides of the abdominal aspect of the body to near the posterior extremity, where they expand and are lost in the muscular tissue. I have already alluded to the evidences of the nervous system afforded by the ocelli in the young of some species of *Trematoda*, in the full-grown *Polystoma* of the urinary bladder of the toad and frog, and in the *Planariæ*. We have as yet no evidence that any species of *Cœlelmintha* possesses rudimental organs of vision, at any stage of existence.

The digestive organs are very simple, and are subject to little variety in the Nematoid worms; an ample alimentary canal, suspended to the parieties of an abdominal cavity, extends in nearly a straight line from the mouth to the anus, which are at opposite extremities of the body.

In the *Filaria* the mouth is a simple circular pore, sometimes surrounded by a circle of radiated papillæ; a short and slender œsophagus suddenly dilates into the stomach, which is fusiform, and indicates the beginning of the intestine by its posterior contraction.

The mouth of the *Trichocephalus dispar* is small and orbicular; the œsophagus is narrow and short; the intestinal tube is narrow and sacculated, where it occupies the filiform division of the body, dilated and simple in the thicker division of the body, at the posterior extremity of which it terminates in a contracted straight tube, which may be called the rectum : the anus is transverse and bi-labiate.

In the *Strongylus gigas* the mouth is surrounded by six papillæ. The œsophagus (*b*, *fig.* 30.) is round and slightly contorted, and suddenly dilates at the distance of about an inch from the mouth into the intestinal canal (*c*); there is no gastric portion marked off in this canal by an inferior constriction, but it is continued of uniform structure, slightly enlarging in diameter to the anus (*d*). The chief peculiarity of the intestine in this species is that it is a four-sided and not a cylindrical tube, and the mesenteric processes pass from the four longitudinal and nearly equidistant angles of the intestine to the abdominal parietes. These processes, when viewed by a high magnifying power, are partly composed of fibres, and partly of strings of clear globules, which appear like moniliform vessels turning around the fibres. The whole inner surface of the abdominal cavity is beset with soft, short, obtuse, pulpy processes, which probably imbibe the nutriment exuded from the intestine into the general cavity of the body and carry it to the four longitudinal vessels, which traverse at equal distances the muscular parietes. The analogous processes are more highly developed in the *Ascaris lumbricoides*, in which species I shall describe the digestive and nutritive apparatus more in detail.

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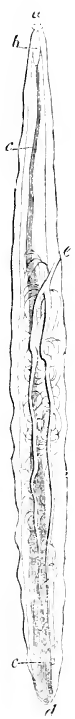

Ascaris lumbricoides.
Half nat. size.

The mouth (*fig.* 31, *a*) is surrounded by three tubercles, of which one is superior, the others inferior; they are rounded externally, triangular within, and slightly granulated on the opposed surfaces, which form the boundaries of the oral aperture. The longitudinal muscles of the body are attached to these tubercles; the dorsal fasciculus converges to a point to be inserted into the superior one; the ventral fasciculus contracts, and then divides, to be inserted into the two which are situated below. By means of these attachments the longitudinal muscles serve to produce the divarication of the tubercles and the opening of the mouth: the tubercles are approximated by the action of a sphincter muscle.

The œsophagus (*fig.* 31, *b*) is muscular, and four or five lines in length, narrow, slightly dilated posteriorly, and attached to the muscular parietes by radiated filaments. Its cavity is occupied by three longitudinal ridges, which meet in the centre of the canal. It is separated by a well-marked constriction from the second part of the alimentary tube (*c*, *c*), which extends to the terminal outlet (*d*), without presenting any natural division into stomach and intestine. The lower third of the tube is the widest. Numerous long pyriform villi project from the mucous lining of the alimentary canal. Many minute filaments pass from the intestine to the soft obtuse papillæ which project from the walls of the abdomen into that cavity, and which are called "the nutritious appendages" by Cloquet. The nutriment which these processes or appendages are presumed to imbibe, is collected, according to the same author, into two canals, situated each in a narrow tract of opaque substance, which extends along the sides of the body, and has sometimes been mistaken for a nerve, and which Vallisnieri believed to be a trachea. Morren has lately described and figured the nutritive appendages as hollow vesicles: he calls them "*Vésicules aériennes*," because, he says, "they evidently subserve respiration by furnishing air to the blood." Few physiologists are likely to acquiesce in this view, which makes the respiratory apparatus of an animal having no other atmosphere than the mephitic gases of the intestinal tube, the largest and most extensively developed organ in the whole body.

With reference to the organisation of the Nematoid Entozoa, not parasites of the human subject, I shall limit my remarks to those structures which offer interesting approximations and analogies to the organisation of higher vermiform animals, and of the existence of which we must have remained ignorant if our attention had been wholly confined to the human Entozoa. I may first refer to a secreting apparatus, consisting of four slender blind tubes, each about two lines in length, which are placed at equal distances around the commencement of the alimentary canal in the *Gnathostoma spinigerum*, a small nematoid worm closely allied to *Strongylus*, which I discovered in the tunics of the stomach of a tiger.* The mouth of this Entozoon is a vertical fissure, bounded on each side by a jaw-like lip, the anterior margin of which is produced in the form of three straight horny points. The secerning tubes terminate at the mouth by their smaller extremities, and there pour out a semi-pellucid secretion. They are analogous to the similarly simple salivary cæca in the *Holothuria*; and their coexistence with a structure of the mouth,

* Proceedings of the Zoological Society, November, 1836.

better adapted for trituration than any that seems hitherto to have been detected in the Entozoa, is conformable with the laws which regulate the coexistence of the salivary apparatus in higher animals. Cloquet supposes that the thickened glandular parietes of the œsophagus in the *Ascaris lumbricoïdes* may provide a secretion analogous to that of salivary organs. Diesing * has described secerning cæcal tubes analogous to those in *Gnathostoma* in species of his genus *Cheiracanthus*, in which he, likewise, considers them to be salivary organs. Mehlis has also described, in the *Strongylus hypostomus*, two white organs with blind extremities, which are extended into the abdominal cavity on each side the intestine, and which appeared to him to terminate in the animal's mouth. These glands Mehlis supposed to pour out an irritating liquor, which excited an increase of the secretion of the mucous membrane, to which the parasite was attached. Dr. Bagge † has more recently described and figured a pair of blind secerning tubes in the *Strongylus auricularis* and in the *Ascaris acuminata*, which unite and terminate by a common transverse fissure on the exterior of the animal, at a short distance behind the mouth, and to which he assigns the same irritating office as that attributed by Mehlis to the glands in the *Strongylus hypostomus*.

The alimentary tube in a species of *Ascaris* infesting the stomach of the Dugong is complicated by a single elongated cæcum, arising at a distance of half an inch from the mouth, and continued upward, so that its blind extremity is close to the mouth. From the position where the secretion of this cæcum enters the alimentary canal, it may be regarded as a primitive rudiment of the liver.

The generative organs of the Cœlelmintha are more simple than in androgynous *Sterelmintha*, or even than in the diœcious *Echinorhynchi*; yet they are adapted for the production of a surprising number of fertile ova. In the *Linguatula* the organs of both sexes, and especially of the female, are more complex than in the *Nematoidea:* I shall, however, briefly notice them before proceeding to demonstrate the parts of generation in the human parasites.

The male *Linguatula*, as in other diœcious Entozoa, is much smaller than the female: the generative apparatus consists of two winding seminal tubes or testes, and a single vas deferens, which carries the semen from the testes by a very narrow tube, and afterwards grows wider. It communicates anteriorly with two capillary processes, or *penes*, which are connected together at their origin by a

* Annalen des Wiener Museums, Bd. ii. 1839.
† De Evolutione Strongyli auricularis, &c. 4to. 1841, p. 13.

cordiform glandular body, representing a prostate or vesicula seminalis. The external orifices of the male apparatus, according to Miram, are two in number, and are situated on the dorsal aspect of the body just behind the head. Diesing, however, describes the male *Pentastoma* as having only a single penis, which protrudes just behind or below the oral aperture.

The female generative organs of the *Linguatula tænioides* present a structure in some respects analogous to that of the *Distoma perlatum:* the ovary is a part distinct from the tubular oviduct, and is attached to the integument or parietes of the body, extending down the middle of the dorsal aspect. It consists of a thin stratum of minute granules, clustered in a ramified form to minute white tubes, which converge and ultimately unite to form two oviducts. These tubes proceed from the anterior extremity of the ovary, diverge, pass on each side of the alimentary canal, and unite beneath the origins of the nerves of the body, so as to surround the œsophagus and these nerves as in a loop. The single tube formed by the union of the two oviducts above described, descends, winding round the alimentary canal in numerous coils, and terminates at the anal extremity of the body. The single oviduct, besides receiving the ova from the two tubes, communicates at its commencement with two elongated pyriform sacs, which prepare and pour into the oviduct an opaque white secretion.

The male organs in the Nematoidea consist of a single and simple, slender, elongated tube (*fig.* 30, *e*, *e*, *f*) or testis, under its most elementary form, a seminal reservoir, and an intromittent organ, consisting of a single or double spiculum and its prepuce, or bursa.

The spiculum is simple in the genus *Filaria*. According to the observations of Dr. Leblond, the male-duct in the *Filaria papillosa* terminates at the anterior extremity of the body, close to the mouth. From this aperture the slender duct, after a slight contortion, is continued straight down the body to a dilated elongated sac, which represents the testis.

In the *Trichocephalus dispar* the testis, a single tortuous tubule, commences by a blind extremity near the rectum, passes forwards to a dilated seminal receptacle at the anterior part of the thick portion of the body, from which it bends backwards nearly the whole length of the thick part, constricted at irregular intervals, and terminating in a narrow straight canal, which is continued into the inverted pyramidal appendage, or bursa, attached to the hinder extremity of the body, from which the single spiculum projects.

In the *Strongylus gigas*, the bursa or sheath of the penis, terminates the posterior extremity of the body, and is a cutaneous production of a round, enlarged, truncated form, with the spiculum projecting from its centre, as at *fig.* 30. In other species of *Strongylus*, as in the *Strong. inflexus*, the bursa penis is bifid, and the intromittent organ is double. In the *Strongylus armatus* the bursa is quadrifid. The *Spiropteræ* are distinguished by the aliform membranous caudal appendage in the male.

In the *Ascaris lumbricoides* the penis projects from the anterior part of the anus in the form of a slender, conical, slightly curved process, at the extremity of which a minute pore may be observed with the aid of the microscope. The base of the penis communicates with a seminal reservoir, and is attached to several muscular fibres, destined for its retraction and protrusion: the reservoir is about an inch in length, and gradually enlarges as it advances forwards: the testis or seminal tube extends to the anterior third of the body, forming numerous convolutions or loops about the intestine: its attenuated cæcal extremity adheres closely to the dorsal wall of the abdomen. The total length of the seminal tube is about three feet. The essential part of the fluid consists of nucleated cells, which, in the *Ascaris lumbricoides*, present an irregular, triangular, sub-compressed form. In the *Strongylus* they are subspherical, with a clear nucleus; but undergo, according to Dr. Bagge *, a marked change of form when introduced into water; they then become elongated, and assume a wedge-shape.

From the examples which have been adduced of different genera of the Nematoidea, we may perceive that although there are many varieties of structure in the copulative part of the male generative apparatus, the essential or secerning portion uniformly consists of a single tube. A like uniformity of structure does not obtain in the essential parts of the female organs: in a few instances the ovary is single, corresponding to the testis in the male, but in the greater number of the nematoid worms it consists of two filamentary tubes.

The *Strongylus gigas* is an example of the more simple structure above alluded to. The single ovary commences by an obtuse blind extremity close to the anal extremity of the body, and is firmly attached to the termination of the intestine; it passes first in a straight line towards the anterior extremity of the body, and, when arrived to within a short distance from the vulva, is again attached to the parietes of the body, and makes a sudden turn backwards; it then forms two long loops about the middle of the body, and returns again forwards, suddenly dilating into an uterus, which is three inches in length, and from the anterior extremity of which a slender cylin-

* Loc. cit. p. 12.

drical tube or vagina, about an inch in length, is continued, which, after forming a small convolution, terminates in the vulva, at the distance of two inches from the anterior extremity of the body. In the *Trichocephalus dispar* the ovarium and uterus are continuations of one and the same single tube, which by its folds more or less conceals the intestines; the vulva is situated nearly at the junction of the filamentous with the thick part of the body.

The theory which had suggested itself to Rudolphi of the correlation of a simple oviduct in the female with the spiculum simplex of the male, and of the double oviduct with a spiculum duplex, is disproved by the circumstance of the uteri and oviducts being double in the *Strongylus armatus* and in the *Ascaris lumbricoides*. In the *Strongylus inflexus*, which infests the bronchial tubes and pulmonary vessels of the porpesse, each of the two female tubular organs may be divided into ovary, oviduct, and uterus; the ovary is one inch in length, commences by a point opposite the middle of the body, and, after slightly enlarging, abruptly contracts into a capillary duct about two lines in length, which may be termed the oviduct or Fallopian tube, and this opens into a dilated moniliform uterus three inches in length. Both tubes are remarkably short, presenting none of the convolutions characteristic of the oviducts of *Ascaris* and *Filaria*, but extend in a straight line (with the exception of the short-twisted capillary communication between the ovaria and uteri) to the vulva, which forms a slight projection below the curved anal extremity of the body.

The reason of this situation of the vulva, seems to be the fixed condition of the head of this species of *Strongylus*. In both sexes it is commonly imbedded so tightly in a condensed portion of the periphery of the lung, as to be with difficulty extracted; the anal extremity, on the contrary, hangs freely in the larger branches of the bronchi, where the coitus, in consequence of the above disposition of the female organs, may readily take place.

In the *Strongylus armatus* the two oviducts terminate in a single dilated uterus, and the vulva is situated at the anterior extremity of the body, close to the mouth.

I find a similar situation of the vulva in a species of *Filaria*, about thirty inches in length, which infests the abdominal cavity of the *Rhea*, or American ostrich. The single portion of the genital tube continued from the vulva, is one inch and a quarter in length; it then divides, and the two oviducts, after forming several interlaced convolutions in the middle third of the body, separate; one extends to the anal, the other to the oral extremities of the body, where the capillary portions of the oviducts respectively commence.

In the *Ascaris vermicularis*, the vulva (*fig*. 32, *e*) is situated about one fourth of the length of the body from the head.

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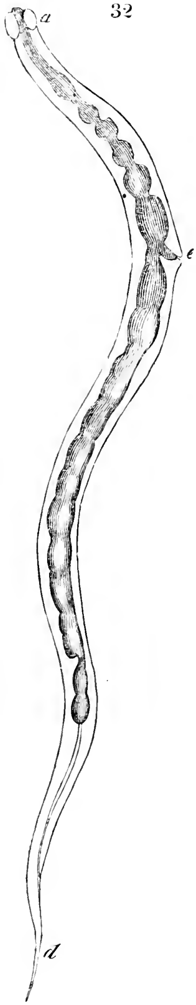


Ascaris vermicularis.

In the *Ascaris lumbricoides* the female organs (*fig*. 31.) consist of a vulva, a vagina, and a uterus, which divides into two long tortuous oviducts, gradually diminishing to capillary tubes, which may be regarded as the ovaria. All these parts are remarkable in the recent animal for their extreme whiteness. The vulva is situated on the ventral surface of the body, at the junction of the anterior and middle thirds of the body, which is generally marked at that part by a slight constriction. The *vagina* is a slightly wavy canal five or six lines in length, which passes beneath the intestine and dilates into the uterus. The division of this part soon takes place, and the cornua extend with an irregularly wavy course to near the posterior extremity of the body, gradually diminishing in size; they are then reflected forwards, and form numerous, and apparently inextricable, coils about the two posterior thirds of the intestine.

In the *Nematoidea* the male individual is always smaller, and sometimes disproportionately so, than the female. At the season of reproduction the anal extremity of the male is attached to the vulva of the female, by the intromission of the single or double spiculum, and the adhesion of the surrounding tumid labia; and, as the vulva of the female is generally situated at a distance from either extremity of her body, the male has the appearance of a branch or young individual sent off by gemmation, but attached at an acute angle to the body of the female.*

The evidence of the fertility of the compound cestoïd Entozoa, was sufficiently marvellous: that which I have now to adduce, from a calculation made by Dr. Eschricht, in reference to the *Ascaris lumbricoides*, the commonest intestinal parasite of the human

* See Figures of such Nematoid Entozoa in Bremser, Icones Helminthum, tab. iii. fig. 8. 15.; and Gurlt, Lehrbuch der Patholog., Anatomie der Haus-Saügethiere, tab. vi. fig. 35.

species, is scarcely less surprising. The ova are arranged in the ovarian and uterine tubes like the flowers of the plantago, around a central stem or rachis. There are fifty in each circle, that is to say, you might count fifty ova in every transverse section of the tube. Now the thickness of each ovum is $\frac{1}{500}$ of a line, so that in the length of one line there are 500 wreaths of 50 eggs each, or 25,000 eggs! The length of each division or horn of the uterus is 16 feet or 2304 lines, which for the two horns gives a length of 4608 lines. The eggs, however, gradually increase in size so as to attain the thickness of $\frac{1}{60}$ of a line: we, therefore, have at the lower end of the horn 60 wreaths of ova, or 3000 ova in the extent of one line. The average number through the whole of the extraordinary extent of the tube may be taken at 14,000 ova in each line, which gives *sixty-four millions* of ova in the mature female *Ascaris lumbricoides!*

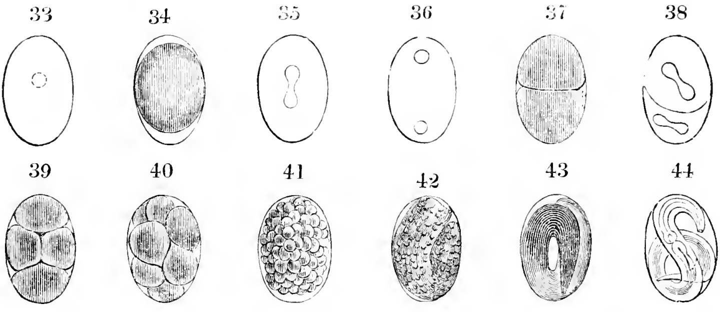
The embryo is not developed within the body in this species; the ova may be discharged by millions, and most of them must, in large cities, be carried into streams of water. An extremely small proportion is ever likely to be again introduced into the alimentary canal of that species of animal which can afford it an appropriate habitat. The remainder of the germs doubtless serve as food to numerous minute inhabitants of the water; and the prolific Entozoa may thus serve these little creatures in the same relation, as the fruitful *Cerealia* in the vegetable kingdom stand to higher animals, and minister less to the perpetuation of their own species than to the sustenance of man.

The oviparous Entozoa present, perhaps, the most favourable subjects for studying with the requisite attention the successive steps of that process by which the germinal vesicle and yolk become finally transmuted into the young and active worm.

I described and showed diagrams of some of these changes in the ova of the *Strongylus inflexus* in my Lectures on Generation in 1840. Mr. Quekett * has since added other observations on the development of the same species of Entozoon; but the most accurate and complete illustrations of the process had previously been published by Professor Siebold † and Dr. Bagge ‡, from observations made upon the ova of the *Strongylus auricularis* and the *Ascaris acuminata*, both of them viviparous species of *Nematoidea*. Dr. Bagge finds at the delicate blind extremities of the ovaria the germinal vesicles, which are at first few and scattered, but become more closely aggregated as they descend along the tube; whilst the ovum is progressively

* Trans. of the Microscop. Society, vol. i. p. 44.
† Burdach, Physiologie, vol. ii. p. 208.
‡ De Evolutione Strongyli, &c. 4to. 1841

enlarged, by the multiplication of the opake granules of the yolk around the essential vesicle: then the delicate, smooth, and polished membrana vitelli is acquired. Towards the fundus, Dr. Bagge describes the germinal vesicle as being obscured by the aggregation of the vitelline granules around it; and he thinks it probable that the vesicle bursts and pours its contents over those granules. At all events it ceases to be visible as a clear central cell.* The ovum is now apparently occupied by the opake and minute vitelline granules, which become aggregated or condensed, so as to leave a clear narrow interspace between the vitelline mass and the smooth outer membrane (*fig.* 34.). In the centre of this mass, however, Dr. Bagge detects



a clear cell (33), but much more minute than the primitive germinal vesicle. This clear cell becomes lengthened, and its rounded extremities mutually recede; while the middle part becomes attenuated (*fig.* 35.), and finally breaks; whereby two pellucid cells are developed, which recede towards the opposite poles of the egg (*fig.* 36.); and this process immediately precedes the first division of the yolk into two parts (*fig.* 37.), each of which has the pellucid cell for its centre. This preliminary division of the clear central cell to the spontaneous fission of the yolk is closely analogous to that division of the central cell in the polygastrian animalcule, preparatory to the spontaneous division of its body into two individuals, which Ehrenberg has described. Dr. Bagge next traces the changes of the pellucid central cell of each primary division of the yolk, and describes it as undergoing the same change of form and division (*fig.* 38.) which he had observed in the primitive cell: and these changes are followed by the spontaneous fission of each primary division of the yolk, whereby the quadripartite character of the ovum is produced (*fig.*39.),

* Dr. M. Barry's description of the true processes which, at this stage, obscure the germinal vesicle will be found in the Philos. Transactions, 1839, p. 307.

analogous to that stage in the generation of the *Chlamydomonas*, which is represented at page 24. *fig.* 14.

There is a close and interesting analogy between the above phenomena, which were published in 1841, and some of those communicated by Dr. M. Barry, to the Royal Society, in January 1841, and published in the Philosophical Transactions of the same year. The clear central nucleus of the blood corpuscle is there shown to form two discs *, which give origin to two cells. We may, likewise, discern in the pellucid nucleus of the yolk, dividing and giving origin to two yolk-cells, according to the German author, the hyaline nucleus of Dr. M. Barry, whose important properties and changes have been so ably elucidated and generalised by that accomplished and patient observer.

Dr. Bagge traces and illustrates the subsequent divisions of the yolk in the ova of the Entozoa, through the four, eight (*fig.* 40.), and sixteen fold divisions, until the number of yolklets (*fig.* 41.), like those of the young of the *Paramecium* in Ehrenberg's experiment, becomes incalculable. A division of the hyaline nucleus has doubtless preceded the formation of each of these divisions; and the subdivided yolk granules have clustered themselves around their respective centres like the working bees around their royal parent. Thus the subdivisions of the yolk decreasing in size as they augment in number the vitelline matter is at length, by the reiterated processes of development, liquefaction and assimilation of nucleated cells, sufficiently subdivided and refined, and each subdivision or cell, by the concomitant partition of the hyaline, has become adequately vitalised, to be capable of its further metamorphosis into the appropriate tissue of the embryo worm.

The minutely subdivided mass is now observed to present a lateral indentation; and, as this deepens, it assumes the form of a short thick cylinder, bent upon itself (*fig.* 42.). By the lengthening and attenuation of the cylindrical mass, the bend assumes the character of a coil (*fig.* 43.); and now something like an integument, containing a fine granular tissue, may be discerned. Further elongation, attenuation, more complicated coiling, and a greater clearness of the tissues of the embryo worm make its character plainly manifest, and the alimentary canal can be distinguished from the integument, both having been formed, by the subdivision and metamorphosis of the primitive cells (*fig.* 44.). The young animal thus built up, now begins to move briskly within the

* See Philos. Trans. 1841. Pl. xviii. fig. 37.

egg-membrane, assimilates the remaining vitelline mass, and is soon strong enough to burst its prison, and commence its independent career of existence.

The Entozoa are hardly less remarkable for their tenacity of life and revival from a state of apparent death than the Infusoria, and the knowledge of this property is indispensable to a fair estimation of the chances of the re-introduction of the ova of Entozoa into the bodies of living animals. In no class of animals has the origin from equivocal generation been more strenuously contended for than in regard to the Entozoa. The great entozoologists Rudolphi and Bremser were advocates of this doctrine; and Bremser did not scruple to charge the Berlin professor with a physiological heresy, when he ventured to account for the high organisation of certain Ligulæ infesting piscivorous birds, by the hypothesis that they had been developed from the lower grade which they previously exhibited in the cold-blooded fishes swallowed by the birds, through the stimulus of the heat and nutritious secretions of the more comfortable intestinal domicile to which they had thus been accidentally introduced.

The advocates for the equivocal generation of the Entozoa adduce the fact that herbivorous mammals are not less subject to Entozoa than carnivorous ones: and how, they enquire, could the ova of Entozoa be preserved in the water that serves as the drink of such animals? Or how, having become dried in the air, could such ova afterwards resume the requisite vitality for embryonic development? We may admit that the ova of Entozoa could not, like the much more minute ova of Pologastria, remain suspended in the atmosphere, since they are specifically heavier than water; but, with respect to their powers of retaining dormant life, we have sufficient analogical evidence to reject the assumption that they soon fall into decomposition.

Mr. Bauer * has recorded many experiments on the *Vibrio tritici*, or parasite of wheat, a minute worm possessing the essential organisation of the Nematoidea, not less remarkable in their results than those of Spalanzani on the Rotifer: the Vibriones were dried, and when re-moistened, after the lapse of four to seven years, they resumed their living and active state. Dr. Blainville states that the *Filaria papillosa* revives from a similar state of torpidity produced by desiccation.

It has been proved that the mature Entozoa will resist the effects of destructive agents, as extremes of heat and cold, to a degree

* Philos. Trans. 1823, p. 1.

beyond the powers of endurance of the *Rotifera*, and which would be truly surprising were not the simplicity of the organisation of the Entozoa taken into account. A Nematoid worm has been seen to exhibit strong contortions—evident vital motions—after having been subjected above an hour to the temperature of boiling water, with a cod-fish which it infested; and, on the other hand, Rudolphi relates that the Entozoa of the genus *Capsularia*, which infest the herrings that are annually sent to Berlin, hard frozen and packed in ice, do, when thawed, manifest unequivocal signs of restored vitality. If, then, the fully developed and mature Entozoa can resist such powerful extraneous causes of destruction, how much more must the ova possess the power of enduring such without losing their latent life.

Burdach, who has summed up the evidence at great length in favour of the equivocal generation of the Entozoa, adduces the example of the ovoviparous species as involving the limitation of the offspring to the lifetime of the individual which they themselves infest; but on this point Dr. Eschricht * has well observed that the transmission of the living young of the *Strongylus inflexus* from one porpoise to another is readily explicable. This species of *Strongylus* lives in the bronchial tubes, with its head immersed in the substance of the lungs, and its tail extended into the larger branches of the trachea. The living young must naturally escape into the mouth, and, as porpoises are gregarious, the young worms would, by a short passage through the water, readily be introduced into the mouth of another porpoise, and so reach the trachea.

The young of most Entozoa are subject to metamorphoses. I have already alluded to those of the Cestoidea in which the head in all the species seems first to be provided with six hooks.† Those of the Trematoda are the most astonishing, and the locomotive condition of the young *Distomata* evidently relate to the securing their entry into the animal's body which they are destined to infest. Dr. Siebold has noticed the difference of form between the young of the Echinorhynchi and their viviparous parents; and this difference was so great in regard to the viviparous *Filaria medinensis*, that Dr. Jacobson was led to suppose its multitudinous progeny to be parasites of the parasite. Dr. Eschricht has observed that the flesh of fishes in summer is often studded with small worms, which, in one instance, he ascertained to be *Echinorhynchi;* and he suggests whether it may not be the breeding place of such species,

* Essay on Spontaneous Generation, Edinb. Philos. Journal, vol. xxxi. p. 345.
† Dujardin, in Annales de Science Nat. 1838.

and whether the *Trichina spiralis* may not belong to the same category. But how these embryos (if they be embryos) are diffused through the intermuscular cellular tissue, can only be known after long and laborious investigations: and nothing is more true than that a particular enquiry will be required for each particular species.

LECTURE VII.

POLYPI.

The two great divisions of the sub-kingdom *Zoophyta,*—viz. the *Infusoria* and *Entozoa,* which have hitherto engaged our attention, approximate to the vermiform type; and each ascends by rapid steps to the confines of the articulate sub-kingdom. The remaining classes of the *Zoophyta* are constructed on the radiated type, and some of them, as the *Bryozoa* and *Acalephæ,* conduct to the molluscous series.

To-day I have to request your patient attention to the history of a race of animalcules as widely diffused, almost as numerous, and some of them hardly less minute than the *Infusoria,* with which we commenced the survey of the vermiform zoophytes. Our present subjects form at least three classes of radiated zoophytes, which have been grouped together under the common name of *Polypi,* on account of their external resemblance to the many-armed cuttle-fishes, which were so denominated by the ancient Greek naturalists. But the knowledge of the organised beings now called *Polypi,* as members of the Animal Kingdom, is of comparatively recent introduction: it cannot be dated further back than the time of Imperato * and Peyssonel.† Amongst those naturalists who have subsequently contributed to improve and extend the history of the Polypes, our countryman Ellis will always take a high rank.

A polype generally presents a cylindrical or ov l body, with an aperture at one of its extremities, which is surrounded by a coronet of long tentacula. In most of the class this aperture leads to a simple digestive cavity, consisting of a stomach without intestine: in the higher organised species, the digestive sac is prolonged into an intes-

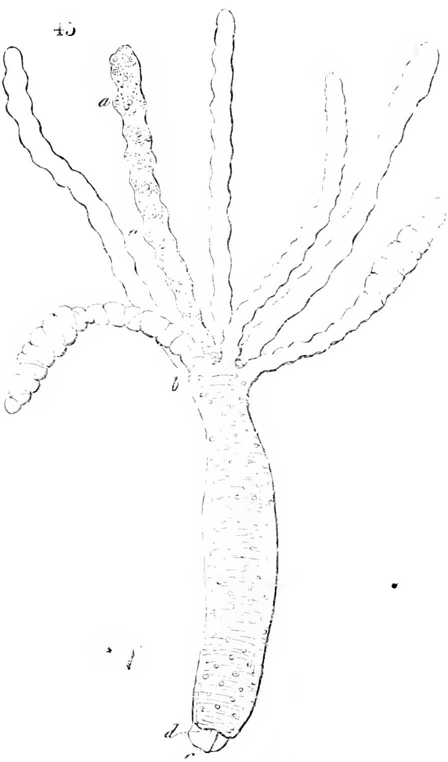
* Historia Naturale, fol. 1599.

† Traité du Corail, Phil. Trans. 1756; communicated to the French Academy, 1727.

tinal canal, which is bent upon itself, and terminates by a distinct anus opening upon the external surface. The organisation of the polypes is in general very simple, and their faculties or vital phenomena seem feeble and inconspicuous. Nevertheless, the influence of their combined powers in modifying the crust of the earth, is neither slight nor of limited extent.

This great division of the radiated animals is divided into three groups or classes, according to the modifications of the alimentary canal. In the first and lowest organised class, which I have called *Hydrozoa* *, digestion is performed by the secretion of a simple sac, excavated in the gelatinous and granular parenchyme of the body. In the second class, called *Anthozoa*, the digestive sac, which, like the first, throws out the rejectamenta by the same aperture as that which receives the nutriment, is suspended by a series of vertical folds of membrane in a distinct abdominal cavity, to the outer parietes of the body. In the third and highest class, called *Bryozoa*, the alimentary canal, which is likewise suspended loosely in an abdominal cavity, is provided, as has been already stated, with a distinct mouth and anus.

45



Hydra fusca. * Nat. size.

It is remarkable that the most locomotive of the Polype tribe, is at the same time the type of the lowest organised group. The *Hydra*, or common freshwater Polype (*fig.* 45.), consists, when magnified even with a moderately high power, apparently of a granular substance of a greenish or reddish hue, the granules or cells being loosely connected by a semifluid matter. The external

* *Dimorphæa* of Ehrenberg; *Sertulariens* of Milne Edwards; *Nudibrachiata* of Farre.

cells are condensed, and elongated in the axis of the body, so as to form two tegumentary layers: the internal cells are elongated transversely to the axis of the body, and form a stratum of villi, projecting into the abdominal cavity: the thick intermediate mass of nucleated cells seems to fulfil the ordinary functions of muscular or contractile tissue.

The hydra commonly adheres by a small prehensile disc or rudimentary foot (*fig.* 45. *d*), situated at the extremity of the stem or body opposite to the mouth. When the little animal would change its position it slowly bends its body, and, fixing one or more of its tentacula to the supporting surface, detaches the posterior sucker, approximates it to the head, and advances by a succession of these leech-like motions. The hydra can make progress in water, as well as on a solid plane; when it would swim it suspends itself to the surface of the water by its foot or terminal sucker, which it expands, and exposes to the air: the disc soon dries, and in this state, repelling the surrounding water, it serves as a float, from which the hydra hangs with its mouth downwards, and can row itself along by means of its tentacula. Its ordinary position is one of rest, adhering to an aquatic plant by its terminal sucker, with the dependent oral tentacula spread abroad in quest of prey.

Should a small Näis or Entomostracan, or any of the larger Infusories, come within the reach of the little carnivorous polype, they are immediately seized, pulled towards the mouth (*fig.* 45. *b*), and swallowed. The rapidity of the digestive process is manifested by the diffusion of any characteristic colour of the animalcules swallowed, through the gelatinous parenchyma of the devourer; and when this process is completed, the indigestible *débris* of the prey are rejected by the same aperture which had just gorged it. Although the indigestible parts of the food are palpably rejected by the mouth, yet a careful investigator, Corda*, affirms the existence of an anal outlet (*fig.* 45. *c*), and figures it of small size, close to the hind sucker or foot. It may give passage to certain excretions of the villous lining membrane of the alimentary cavity.

Each tentaculum in the *Hydra grisea*, acording to this observer, is a slender membranaceous tube, filled with a fluid albuminous substance mixed with oil-like particles. This substance swells out at certain definite places into denser nodules, which are arranged in a spiral line (*fig.* 45. *a*, *a*). Each nodule is furnished with an organ of touch, and another singularly constructed one for catching the prey. The organ of touch consists of a fine sac,

* Nova Acta Physico Medica, &c. Bonn, vol. xviii, 1836, tab. xvi.

inclosing another with thicker parietes, and within this there is a small cavity. From the point where the two sacs coalesce above, there projects a long spine, which is non-retractile. The seizing organ consists of an obovate transparent sac, immersed in the nodule with a small aperture. At the bottom of the sac, and within it, there is a solid corpuscule, which gives origin to a calcareous sharp sagitta or spine, that can be pushed out at pleasure, or withdrawn until its point is brought within the sac. When the hydra wishes to seize an animal, the sagittæ are protruded, by which means the surface of the tentacula are roughened, and the prey more easily retained: Corda believes that a poison is at the same time ejected. The nodules of the tentacula are connected together by means of four muscular bands, which run up, forming lozenge-shaped spaces by their intersections: these are joined together by transverse bands. There is no communication between the tube of the tentaculum and the cavity of the body. The lip of the mouth is armed with spines, similar to those of the tentacula; but the rest of the body is destitute of them.

That the tentacula have the power of communicating some benumbing shocks to the living animals which constitute the food of the Hydra, is evident from the effect produced, for example, upon an Entomostracan, which may have been touched, but not seized, by one of these organs. The little active crustacean is arrested in the midst of its rapid, darting motion, and sinks, apparently lifeless, for some distance; then slowly recovers itself, and resumes its ordinary movements. These and other active inhabitants of fresh waters, whose powers should be equivalent to rend asunder the delicate gelatinous arms of their low-organised captor, do, nevertheless, perish almost immediately after they have been seized, and so countenance the opinion of Corda of the secretion of a poison; unless, indeed, the little polype may have the power of communicating an electric shock.

The most extraordinary properties of the Hydra are, however, those which best accord, and might be expected to be associated, with its low and simple grade of organisation; although they excited the greatest astonishment in the physiological world when first announced by their discoverer, Trembley, and are often still called wonderful.

If a polype be transversely bisected, both halves survive; the cephalic one developing a terminal sucker, the caudal one shooting forth a crown of tentacula; each moiety thus acquiring the characters of the perfect individual. But in a healthy and well-fed *Hydra*, the same phenomena will take place if it be divided into ten pieces. The *Hydra*, notwithstanding the want of a nervous centre thus indicated, and the absence of any hitherto recognised nervous filaments, manifests an obvious predilection for light, and, when confined to a glass, always moves itself to the brightest side. Trembley succeeded in inverting one of these delicate animalcules, and the creature soon accommodated itself to this singular change in its condition: digestion being effected as actively by the surface which before was external, as by that which had been the digestive surface; whilst this as readily assumed the ordinary gemmiparous function of the skin.

The Hydræ are not less remarkable for their power of generation than for that of regenerating mutilated parts. They have been observed to multiply by spontaneous fission, dividing themselves transversely: but the most ordinary process of generation is by the development of young polypi, like buds, from the external surface of the old one. It is, however, most probable that in these cases the gemmation is preceded by the development and fecundation of the true ovum, beneath the integument. The Hydra unquestionably presents a periodical development of sexual organs of two kinds: one, at the anterior or oral extremity of the body consists of small nodules or sacs, which Ehrenberg discovered to contain moving filaments, or seminal animalcules: another series of cells, developed in the posterior part of the stem, contain ova, which, after impregnation, are discharged, but sometimes are retained, and then grow out like buds. Sometimes one individual Hydra developes only the male cysts, or sperm-vesicles; sometimes only the female ones, or ovisacs; but the rule is generally to have both kinds.

The seas which wash our own shores are tenanted by numerous forms of minute *Polypi*, having essentially the same simple organisation as the Hydra; but which are protected from the dense briny element surrounding them by an external horny integument. Now these likewise develope new polypes by gemmation; but, as the external crust grows with the growth of the soft digestive sac, the young polype adheres to the body of the parent, and, by successive gemmations, a compound animal is produced. Yet the pattern according to which the new polypes and branches of polypes are developed is fixed and determinate in each species; and there consequently results a particular form of the whole compound animal or individual by which the species can be readily recognised. This hydriform polype-animal, or association of polypes, resembles a miniature tree; but consists essentially of a ramified tube of irritable animal matter, defended by an external, flexible, and frequently jointed, horny skeleton; fed by the activity of the tentacula and by the digestive powers of the alimentary sacs of a hundred polypi, the common produce of which circulates through the tubular cavities for the benefit of the whole animal. These currents of the nutrient fluid have been observed and described by Cavolini, and more recently by Mr. Joseph Lister. The genera *Sertularia*, *Campanularia*, *Tubularia*, &c., which form the principal subjects of Ellis's beautiful and classical work on Corallines, compose the present division of the compound *Hydrozoa*, or hydriform polypes.

The peculiar external horny defence prevents, as I have just observed, the exercise of the gemmiparous faculty from effecting any other change than that of adding to the general size, and to the number of prehensile mouths and digestive sacs, of the individual coralline. It is equally a bar to propagation by spontaneous fission; so that the ordinary phenomena of generation by ova are more conspicuous in the composite than in the simple *Hydrozoa*. At certain points of these ramified polypes, which points are constant in, and characteristic of, each species, there are developed little elegant vase-shaped sacs, which are filled with ova, and are called the "ovigerous vesicles." These are sometimes appended to the branches, sometimes to the axillæ, of the ramified coralline: they are at first soft, and have a still softer lining membrane, which is thicker and more condensed at the bottom of the vesicle: it is at this part that the ova are developed, and for some time they are maintained in connection with the vital tissue of the polype by a kind of umbilical cord. The ova undergo a certain amount of development in this situation, and acquire a ciliated surface. By virtue of those primitive and universal organs of motion, the vibratile cilia, they detach themselves from the umbilical stem, and effect their escape from the cell. Having rowed to a convenient distance from the parent, the ciliated bulb subsides into an amorphous depressed mass, which shoots out its tissue in irregular rays upon the supporting body, to form the roots of attachment, and sends upwards a pyramidal process or stem, which, at a little distance, expands into a hydriform polype. The supporting stem continues to ascend, divides, and proceeds to develope other polype mouths, according to the prescribed pattern, and finally the ova and ovigerous sacs. In some species the ovigerous cell is provided with a distinct lid or operculum, which defends the ova from the sea-water in their tender stages of development; then drops off, and, allowing ingress to the water, occasions an increased activity in the ciliated gemmules. Sometimes a small polypus is developed from the mouth of the ovigerous cell, in which state they have been described by Lowen as the female polypes, the smaller and ordinary food-catching and digesting polypes being regarded as the males. In all the compound *Hydrozoa*, the ovigerous sacs are deciduous, and, having performed their functions in relation to the development of the new progeny, drop off like the seed-capsules of plants. This phenomenon afforded to the early botanists an additional argument in favour of the relation of these ramified and rooted animals to the Vegetable Kingdom.

The *Anthozoa* (*fig.* 46.), or polypes of the second great class, characterised by a distinct abdominal cavity in which their simple digestive sac is suspended, constitute the most numerous and important part of the whole race, and include the largest individuals. They are principally the inhabitants of the warmer or tropical seas.

46

Corallium rubrum.

They are subdivided according to the number of their oral tentacula. Most of the species have only eight of these radiated prehensile organs: the rest have a greater number. To this latter group belong the soft-bodied and solitary species called Sea-Anemonies or *Actiniæ*, which are common upon our own coasts.

In the species here dissected, you will see that the skin is thick and opake: in the living Actinia, it is lubricated by a mucous secretion: the disposition of the muscular fibres by which it is acted upon, is indicated by the superficial striæ. In the middle of the circle of the tentacles is situated the mouth, from which a short œsophagus leads to a large gastric cavity, the parietes of which are connected by a great number of membranous vertical folds with the external wall of the body. The tentacula are tubular; they are perforated at their free extremity, and communicate with the interspaces of the mesogastric lamellæ. They absorb the sea-water into these spaces, and are elongated by the injection of that water into their interior. The extended surface of the abdominal cavity is beset with innumerable minute cilia, through the action of which it is bathed by a constant current of the admitted medium of respiration, the sea-water.

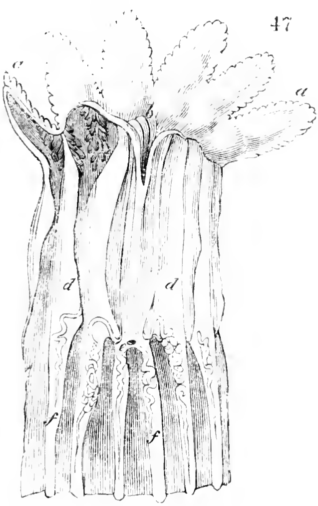
The ova are formed within the mesogastric folds: beneath the folds is situated an equal number of sacs or bodies composed of convoluted tubes which contain granules and spermatozoa, demonstrating the androgynous nature of the Actinia. The impregnated ova are developed into ciliated gemmules in the abdominal reservoir of sea-water: then make their way by the small inferior aperture of the stomach into that cavity, and escape by the mouth of the parent.

Many of the large actiniform polypes of the tropical seas combine with a structure which is essentially similar to our own sea-anemonies, an internal calcareous axis or skeleton, which, penetrating the interior of the mesogastric folds, presents the lamellated and radiated structure which we recognise in the enduring support of the large *Fungiæ* and in the polype cells of the skeletons of the *Caryophilleæ*, *Madreporæ*, &c.

The species of polypes which take the most important share in the fabrication of the coral islands and reefs, belong to the present group, and have esentially the organisation of the sea-anemony, which has just been described.

To the eight-armed division of the Anthozoic Polypes belong those species which have an internal ramified calcareous or jointed axis, as the red coral polype (*fig.* 46. *c*), the gorgonia, and the isis. To this division likewise belongs our common *Alcyonium*, or dead-man's-toes, in which the hard axis is wanting; and the phosphorescent Sea-pens, the *Veretillum*, and other *Pennatulidæ*, in which it is in detached pieces.

These are all examples of compound *Anthozoa*, differing from the compound hydriform polypes in having an internal instead of an external skeleton. The body of each polype (*fig.* 47.) is relatively longer than in the *Actiniæ*; the prehensile tentacles (*a*, *a*) are broad and pectinated: at the centre of their base is situated the mouth (*b*), which leads to a straight membranous alimentary cavity, fixed by vertical septa (*d*, *d*) to the external integument; which septa are continued down the general visceral cavity. The digestive canal communicates with this cavity by a small orifice (*e*) at its inferior part. Ovaria and tortuous filamentary secreting organs (*f*) analogous to the testes in the Actinia, are developed in the common visceral cavity. A delicate network of vessels conveys the nutrient fluid to the common connecting parenchyma of the entire compound animal.



Polype of the red coral.

This parenchyma is strengthened in our common *Alcyonium* by numerous minute calcareous spiculæ. Analogous spiculæ, but of varying and characteristic forms, strengthen likewise the animal crust of the red corals, jointed corals, and Gorgoniæ; but to these is superadded the internal branched axis, which, according to its composition and structure, characterises the different genera of this group. In one genus, the external position of the skeleton which characterises the hydriform compound polypes is repeated, viz. in the *Tubipora* *musica;* but the organisation of the polypes, protected by the crimson pipes of this beautiful coral, is essentially the same as in the *Alcyonium*, *Gorgonia*, and *Pennatula*.

The most important productions of the apparently insignificant race of Polypi are the accumulations of the calcareous skeletons of the *Anthozoa*, which form the coral islands and reefs; — the dread of the navigator, — the admiration of the lover of the picturesque, — the subjects of the closest and most interesting speculation to the naturalist and geologist.

That masses of rock many leagues in extent should be founded in the depths of the ocean, and built up to the height of hundreds of feet by minute, frail, gelatinous animalcules, is indeed a phenomenon calculated to stagger the unversed in zoological science, and which has demanded the repeated observation of the most accomplished and enlightened voyagers to render intelligible.

These zoophytic productions have been recently classified by Mr. Darwin * under three heads: 'atolls,' 'barrier reefs,' and 'fringing reefs.' The term *Atoll* is the name given to the coral-islands, or lagoon-islands by their inhabitants in the Indian Ocean. An atoll consists of a wall or mound of coral rock (*fig.* 50. r'', r''), rising in the ocean from a considerable depth, and returning into itself so as to form a ring, with a lagoon, or sheet of still water (*fig.* 50. n) in the interior. The wall is generally breached in one or more places, and when the breach is deep enough to admit a ship, the atoll affords it a convenient and safe harbour. The outer side of the reef usually sinks to a depth of from two to three hundred fathoms, at an angle of forty-five degrees or more: the internal side shelves gradually towards the centre of the lagoon, forming a saucer-shaped cavity, the depth of which varies from one fathom to fifty. The summit of the exterior margin of the reef or wall is usually composed of living species of *Porites* and *Millepora*. The *Porites* form irregularly rounded masses of from four to eight feet broad, and of nearly equal thickness; other parts of the reef are composed of thick vertical plates of the *Millepora complanata* intersecting each other at various angles, and forming an exceedingly strong honey-combed mass. The dead parts of these calcareous skeletons are often cemented over with a layer of the marine vegetable called *Nullipora*, which can better bear exposure to the air.

This strong barrier is well fitted to receive the first shock of the heavy waves of the fathomless ocean without; and what at first appears surprising, instead of wearing away at its outer edge, it is here only that the solid reef increases. The coral animals thrive

* Structure and Distribution of Coral Reefs, 8vo. 1842.

best in the surf occasioned by the breakers. Through this agitation an ever-changing and aërated body of sea water washes over their surface, and their imperfect respiration is maintained at the highest state of activity. Abundant animalcules, and the like objects of food, are thus constantly brought within the sphere of the tentacula of the hungry polypes. Their reproductive gemmules are rapidly and extensively dispersed amongst the crevices of the calcareous mass.

By the force of unusual storms this outer reef is occasionally breached, and huge masses are torn off and driven towards the lagoon, where they form an inner barrier or reef. The broken surface becomes the seat of attachment of the young of the neighbouring corals, the successive generations of which, by the rapid growth and development of their calcareous skeleton, soon repair the damage of the storm. The masses of broken coral thus driven inward towards the lagoon, accumulate in time to the height of some feet above high water. These fragments are mixed with sand and shells, and form a favourable soil for the development and growth of vegetables, as cocoa palms, the large nuts of which may be borne hither by currents of the ocean, from Sumatra or Java, 600 miles distant. Turtles likewise float to the nascent island, browse on the sea weeds which grow in the lagoon, and breed there. Numerous species of fish and shell-fish flourish in the same still water, which abounds with animal life. Man comes at length and takes possession of the island; and the cocoa-nut, the turtle, and the fish afford him abundant and wholesome food. But you will ask how he supplies himself with that necessary of life fresh water? This is obtained in a very simple and unexpected manner from shallow wells, dug in the calcareous sand, which ebb and flow with the tides, yet are almost wholly free from the saline particles of the ocean. Some have supposed that the sea water lost its peculiar salts by infiltration through the calcareous mass. Mr. Darwin thinks that it is derived from the rain water, which, being specifically lighter than the salt, keeps floating on its surface, and is subject to the same movements: howsoever this may be, the fact is certain. A fit and convenient abode for the human species is fabricated by the action of the feeble, gelatinous polypes, and a wild and almost boundless waste of waters is enlivened by oäses which navigators have described as earthly paradises.

A Barrier Reef (*fig.* 49. *r′*, *r′*) is essentially similar to the Atoll or Coral-Island. It runs parallel with the shores of some larger island or continent; separated, however, from the land, by a broad and deep lagöon channel (*n*, *n*), and having the outer side as deep and steep as in the Lagoon Islands. Here likewise the skeletons of the Zoophytes, of which the reef is composed, are found on the outer precipitous wall as deep as sounding line can reach.

The third class of coral productions which Mr. Darwin terms "Fringing Reefs" (*fig.* 48. *r*, *r*), differ from the Barrier Reefs in having a comparatively small depth of water on the outer side, and a narrower and shallower lagöon channel between them and the main land.

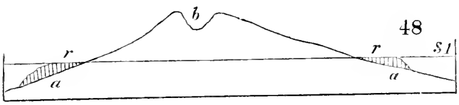
These differences in the characters of the wonderful fabrications of the coral animalcules are explicable by the following facts in their physiology. The animals of the *Porites* and *Milleporæ* cannot exist at a greater depth than twenty or thirty fathoms; beyond this the stimuli of light and heat derived from the solar beams become too feeble to excite and maintain their vital powers. On the other hand, their tissues are so delicate, that a brief direct exposure to the sun's rays kills them; and unless they are constantly immersed in water or beaten by the surf, they cannot live. Thus, in whatever position the calcareous skeleton of a Madrepore or Millepore, may be found it is certain that it must have been developed within thirty fathoms of the surface of the ocean. If it coats the summit of the lofty mountains of Tahiti*, it must have been lifted above the sea by the elevation of the rock on which it was originally deposited. If it is brought up from the depth of 200 or 300 fathoms, as at Cardoo Atoll or Keeling Atoll, it must have been dragged down to that depth by a gradual subsidence of the foundation on which the living madrepore once flourished. It is by these movements of upheaval and subsidence of the earth's crust, that Mr. Darwin explains the different forms which characterise the extraordinary productions of the coral animal. The *Atolls* or Lagöon Islands, according to this author, rest on land which has subsided, and part of which was once dry. *Barrier reefs* indicate the islands or continents, which they encircle, to be the remains of land now partly submerged, and perhaps in progress towards final disappearance. *Fringing reefs*, on the contrary, indicate either that the shores are stationary, or that they are now rising, as in most of the Sandwich Islands, where former reefs have been raised many yards above the sea.

Elizabeth Island, which is eighty feet in height, is entirely composed of coral-rock. The coral animals, thus progressively lifted above their element, are compelled to carry on their operations more and more remote from the former theatres of their constructive energies, but cannot extend deeper than their allotted thirty fathoms: the direction of their submarine masonry is centrifugal

* Mr. Stutchbury here found a regular stratum of semifossil coral at 5000 and 7000 feet above the level of the sea.

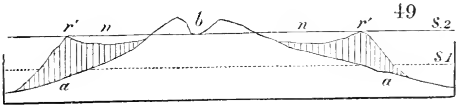
and descending. Where the land that supports them is, on the contrary, in progress of submergence, they are compelled to build their edifices progressively higher and in a narrower circuit; in other words the direction of their growth is centripetal and ascending. The terms ascending and descending of course only here apply to the relation of the coral-builders to the land, not to the level of the unchanging sea.

The formation of an atoll by the upward growth of the corals during a gradual sinking of the land forming their supporting base is illustrated by these diagrams from Mr. Darwin's work.



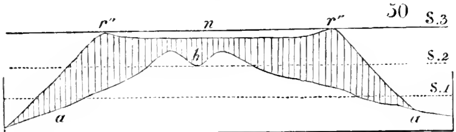
48

Figure 48. represents the section of an island (*a*, *b*), surrounded by a fringing reef, *r*, rising to the surface of the sea, s. 1. As the land sinks down, the living coral, bathed by the surf on the margin of the reef, builds upwards to regain the surface. But the island becomes lower and smaller, and the space between the edge of the reef, *r*, and the beach proportionately broader. A section of the reef and island, after a subsidence of several hundred feet, is given in figure 49.



49

The former living margin of the reef, *r*, is now dead coral, dragged down to depths at which the polypes cease to exist; but their progeny continue in active life at *r′*, now the margin of a barrier-reef, separated by the lagoon channel *n*, from the remnant of the land *b*. Let the island go on subsiding, and the coral reef will continue growing up on its own foundation, whilst the water gains on the land, until the highest point is covered, and there remains a perfect atoll, of which figure 50. represents a vertical section.



50

In this diagram *r″* is the living and growing outer margin of the encircling reef, and the lagoon channel is now converted into the calm central lake *n*, of the atoll. Thus by the process of subsidence the fringing reef (*fig.* 48.) is converted into the barrier reef (*fig.* 49.), and this into the atoll (*fig.* 50.).

If the movement of the land should now be reversed, and the level of the sea be again brought back by elevation of the island, to the line (s. 1, *fig.* 50.), an island apparently composed exclusively of coral rock, like Elizabeth Island, would be the result.

The prodigious extent of the combined and unintermitting labours of these little world-architects must be witnessed in order to be adequately conceived or realised. They have built up a barrier-reef along the shores of New Caledonia for a length of 400 miles, and another which runs along the north-east coast of Australia 1000 miles in length. To take a small example, a single atoll may be 50 miles in length by 20 in breadth; so that if the ledge of coral rock forming the ring were extended in one line it would be 120 miles in length. Assuming it to be a quarter of a mile in breadth, and 150 feet deep, here is a mound, compared with which the walls of Babylon, the great wall of China, or the pyramids of Egypt, are but children's toys; and built too amidst the waves of the ocean and in defiance of its storms, which sweep away the most solid works of man. The geologist, in contemplating these stupendous operations, appreciates the conditions and powers by which were deposited in ancient times, and under other atmospheric influences than now characterise our climate, those downs of chalk which give fertility to the south coast and many other parts of our native island. The remains of the corals in these masses, though similar in their general nature, are specifically distinct from the living Polypes which are now actively engaged in forming similar fertile deposits on the undulating and half submerged crust of the earth, washed by the Indian and Pacific Oceans. Again, those masses of limestone rocks which form a large part of the older secondary formations, give evidence, by their organic remains, that they are likewise due to the secretions of gelatinous polypes, the species of which perished before those that formed the cretaceous strata were created. As the polypes of the secondary epochs have been superseded by the *Porites*, *Milleporæ*, *Madreporæ*, and other genera of calcareous Anthozoa of the present day, so these, in all probability, are destined to give way in their turn to new forms of essentially analogous Zoophytes, to which, in time to come, the same great office will be assigned, to clothe with fertile lime-stone future rising continents.

LECTURE VIII.

BRYOZOA.*

If a deeper and truer insight into the structure and vital properties of the low-organised, ramified, composite, hydriform polypes, which,

* *Ciliobrachiata*, Farre.

like little trees adorned with polypetalous flowers and supporting their annual crop of deciduous fruit or seed-capsules, deceived such clear-sighted observers as Tournefort and Ray as to their real nature, and were classed by them with vegetables; if organised beings, so obviously like plants in external form and in some of their most conspicuous changes, can be proved by the anatomist to belong unequivocably to the Animal Kingdom, without the determination being vitiated or obscured by any real or essential vegetable character: — if the calcareous masses of Madrepores and Millepores, classed by Boccone and Guison as species of minerals, and which once were the subjects of curious speculations on the growth of stones, have been proved by the recognition of the more complicated organisation of the polypes which they support, to be the products of the vital actions of such polypes, and as essentially a part of those animals as the skeleton of a man is a part of his body — still more does the anatomical structure of the third division of polypes prove how inadequate is a superficial survey of an organised being to lead to true notions of its nature and affinities. The *Bryozoa*, which coat, as with a delicate moss, fuci, shells, or other marine productions, or which rise in dendritic forms, like the hydrozoic corallines, with which they have been confounded by Ellis, with which they would equally have passed for plants with Ray, are, perhaps, the most striking examples of how complicated an animal structure may be masked by mere outward form.

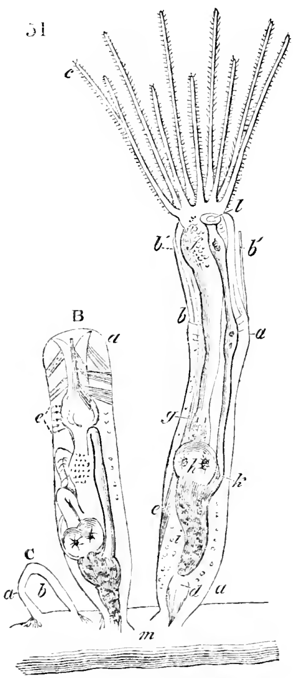
An animal differs from a plant in having a stomach and a mouth, it is thereby qualified to exert its most conspicuous animal property, that of locomotion.

A locomotive organised being must possess an internal digestive store-room; but the converse of the proposition does not hold good, — a digestive cavity does not imply the powers of locomotion.

The Bryozoon has not merely the characteristic digestive cavity, like the Hydra and the Actinia: it has not merely a mouth and prehensile organs for the capture of living prey; but it has also an œsophagus for deglutition, an intestine for the separation of the nutrient chyle, and a distinct external outlet for the indigestible refuse of the food: it may possess a stomach with strong muscular walls and a dentated lining for trituration, and a second stomach with glandular walls for digestive solution or chymification, and thus present an alimentary canal as complicated and as highly elaborated as in the bird. Yet the microscopic polypes which manifest this high condition of the digestive apparatus are fettered to the spot, where, as ciliated gemmules, they finally rested after their brief early locomotive stage: the complex digestive apparatus is developed for the service of an organised being as immovable as the plant which is rooted in the soil.

But we shall, hereafter, meet with animals of higher grade of organisation than the Bryozoic polypes, as the Barnacle, the Oyster, and the Spondylus, which are equally fettered to the spot on which they grow, and which more strikingly demonstrate how secondary a character of animal life is mere locomotion.

The complicated and characteristic condition of the alimentary canal in the Bryozoa was discovered independently, and nearly about the same time, by Ehrenberg, Milne Edwards, and Dr. V. Thompson. The ciliated structure of the arms was observed by Steinbuch and Dr. Fleming. The ciliated gemmules, and their development, have been well described in the *Flustra carbesia* by Dr. Grant. All these observations have received a welcome confirmation, and many highly interesting facts in the organisation and properties of the *Bryozoa*, have been added, by Dr. A. Farre; a careful perusal of whose admirable Memoir in the Philosophical Transactions for 1837 *, will amply repay the reader.



Bowerbankia.

Most of the Bryozoa are microscopic; but, being composite or aggregated animals, they sometimes form sufficiently conspicuous masses. The most familiar and common species constitute the substance called sea-mat (*Flustra*), which incrusts, by its little hexagonal cells, as by a delicate mosaic pavement, sea-weed, shells, and other marine bodies. The calcareous sea-mat is called *Eschara*. Some species rise from their surface of attachment and form amorphous masses, like sponge; or are regularly and delicately ramified, like the little hydriform corallines.

Each polype presents an oblong depressed, or elongated and cylindrical figure, and is protected by a dense integument in the form of a cell or case (*fig.* 51. *a*, *a*), to the mouth of which is attached a sac (*b*, *b′*) composed of

* P. 387. plates xx. to xxvii.

very delicate and flexible membrane. This constitutes the upper or anterior integument of the polype when it is protruded, and is reflected, like the inverted finger of a glove, into the firmer portion of the cell when the polype is retracted, as at *B*. In general the integument forming the firm cell is of a horny texture; but in the *Escharæ* it is hardened by the deposition of particles of carbonate of lime in the organised animal basis; so that the external skeletons of the *Bryozoa* offer analogous conditions to the cartilaginous and bony states of the internal skeletons of fishes.

In the cylindrical *Bryozoa*, as the *Bowerbankia*, the flexible part of the integument consists of two portions; the lower half being a simple continuation of the cell; the upper one consisting of a cylindrical series of setæ (*b′*), connected together by an extremely delicate and elastic membrane, permitting a certain extension of the cylinder, which, at the same time, supports and allows free motion to the upper part of the body in its expanded state. The mouth of the polype is situated at this extremity of the body, and is surrounded by a radiated series of slender, ciliated, tentacula (*c*), eight, ten, twelve, or more in number, according to the genus.

The muscular system is developed in the present highly organised class of polypes, in the form of distinct groups of fibres. Their arrangement, and the actions by which they effect the protrusion and retraction of the polype, are minutely and clearly described by Dr. Farre. The retractor muscles form two series, one acting upon the alimentary canal, and the other upon the flexible part of the cell. One series rises from the bottom of the cell, and is inserted about the base of the stomach (*d*); the other (*e*) arises from the opposite side of the bottom of the cell, and passes upwards to be inserted near the base of the tentacula. The muscles which retract the flexible integument, arise near the upper margin of the cell, and are disposed in six fasciculi, three of which act upon the membrane, and the other three upon the bundle of setæ by which it is crowned. When the animal is retracted, the setæ, which are drawn in after the tentacula, converge and form a kind of defensive operculum. The œsophagus and intestine are bent into folds.

The protrusion of the animal is effected, partly by the action of short transverse muscular filaments (*e*), which tend to compress the inclosed viscera, and partly by the action of the alimentary canal itself. The bundle of setæ first rises out of the apex of the cell, and is followed by the rest of the flexible integument: the tentacula next pass up between the setæ, and separate them; the folds of the œsophagus and intestine are straightened, and when the act of protrusion is completed, the crown of tentacles expands and their cilia commence vibrating.

The advantage to Physiology of the researches of the comparative anatomist in the minute forms of animal life, is often very great, in consequence of the favourable conditions which the transparency of the integument, and the distinctness of the contained parts of such animalcules, afford for the direct observation of some of the most recondite and important vital actions. As regards the *Bryozoa*, the muscles are, as it were, naturally dissected or separated into their component filaments. Each filament generally presents a small knot upon its middle part: this is most apparent when the filament contracts, at which time the whole filament is obviously thicker. When the action ceases and the filament is relaxed, the distance between its fixed points being diminished, as happens to the longitudinal fibres when the polype is retracted into its cell, such fibre falls into undulations. The thickening of the muscular fibre in the act of contraction, and its folded state when it relaxes, before the antagonising muscles have restored the extremities of the contracted fibre to their ordinary distance, has been observed in other low organised animals, as small *Filariæ*. The higher organised subjects selected by MM. Prevost and Dumas, were less favourable for this delicate experiment, and they consequently mistook the zig-zag relaxation of the muscular fibre for its act of contraction.

No trace of a nervous system has yet been detected in the *Bryozoa;* but the reaction of stimuli upon the contractile fibre is a striking phenomenon. The animal retires into its cell on the slightest alarm, and refuses to expose itself to water which has become in the least degree deteriorated. Dr. Farre has observed the creeping of a very small animalcule over the top of one of the closed cells to be followed instantly by the shrinking of the soft parts beneath. But the nervous system is indicated in these little polypes by something more than reflex phenomena: they seem to exercise a certain caution before emerging from their cells. One or more of the tentacles have been seen to be protruded and turned over the side of the cell, as if to ascertain the presence or absence of an enemy.

I must now proceed to describe these tentacula (*c, c*), which are the means by which the *Bryozoa* obtain their food. They differ considerably from the corresponding tentacula in the *Hydrozoa* and *Anthozoa*, in being stiffer and provided with vibratile cilia. These cilia are arranged on opposite sides of the tentacle, along which sides they occasion, by their active vibration, opposite currents of the surrounding water. In some species a few fine hair-like processes, which are motionless, project from the back of the tentacula. The action of the tentacular cilia appears under the control of the animal, and they are sometimes seen completely at rest. The arms are tubular throughout, and have an aperture at each extremity. The ring upon which they are set forms a projecting edge around the mouth. The particles of food are carried down the inner surface of each arm, and the mouth and pharynx expands to receive such as are appropriate, as if by an act of selection. The rejected particles pass out between the bases of the tentacula, or are driven off by the centrifugal currents.

The pharynx (*fig.* 51, *f*) is less dilatable than the mouth of the *Hydra* or *Actinia*. The constriction of the pharynx, by which the food is driven into the œsophagus, is a very well-marked action. The cardiac orifice (*g*) seems to project into the œsophagus upon a valvular prominence; it opens into a small globular cavity (*h*), which has the construction of a gizzard: the interior of this cavity is lined by a strong epithelium, the cells of which project into the cavity like pointed teeth, and the food is subject to comminution in this cavity. With the gizzard is associated, as in birds, a distinct glandular compartment of the stomach (*i*); but this is situated between the gizzard and intestine, not between the gizzard and œsophagus: its walls are studded with follicles filled with a rich brown secretion, which may be regarded as hepatic follicles. The intestine is continued from a distinct pyloric orifice (*k*), which is situated at the upper part of the glandular stomach near the gizzard. This orifice is surrounded by vibratile cilia. The food is frequently regurgitated into the gizzard, and, after having undergone additional comminution, is returned to the stomach. Here it is kept in constant agitation, and the particles pass by a rotatory action from the pylorus into the intestine. The indigestible particles are there formed into little pellets, which are carried rapidly upwards to the anal orifice (*l*), and, after being expelled, are immediately whirled away in the current produced by the ciliated tentacula.

A small filament, conjectured to be tubular, which passed from the base of the glandular stomach to the common stem (*m*) supporting the cell of the polype, is the only trace of the nutrient or vascular system which Dr. Farre could detect. When the common stem of a ramified Bryozoon is cut across, it seems to be nearly homogeneous, and does not present that obvious distinction between hard and soft parts, nor the canal with circulating particles, which are observed in the stems of the compound Hydrozoa. Yet it can scarcely be doubted but that nutrient currents must traverse the common connecting organic medium or stem of the Bryozoa, both for its own support and growth, and for the supply of the means of growth to the young animals (*C*) which are developed from it by the process of gemmation.

The function of respiration must be referred to that part of the body which is provided with the means of effecting a constant renewal of the surrounding oxygenized medium upon its surface. In the ciliated tentacula, whose currents, Dr. Farre observes, seem much beyond what is necessary to afford a sufficient supply of food, we, therefore, recognise the principal respiratory as well as prehensile organs. The currents of the nutrient fluids which may traverse their interior canal would thus be more effectually exposed to the influence of the surrounding medium.

The individuals of the Bryozoa are multiplied by two processes of generation; the one by gemmæ or buds from the common stem, which appears to be uninfluenced by season, and which increases the size of the aggregate mass of the Bryozoon; the other by the liberation of the young in the form of locomotive ciliated gemmules, which takes place at certain seasons, generally in spring.

In the *Flustra* the gemmæ are developed from the cells of the pre-formed individuals; but in those Bryozoa which have connecting stems the buds arise from the stem. They are at first homogeneous; then a distinction may be observed between the cell (*fig.* 51. C, *a*) and the visceral contents (*b*); afterwards the tentacles may be discerned, which are at first short and stumpy; finally, the cavity, walls, and divisions of the alimentary canal become distinguishable.

In regard to the generation by locomotive gemmules, these are doubtless originally developed from fertile ova.

Certain phenomena have been observed in the Bryozoa which justify the belief that the individual polypes are male and female. Dr. Farre has figured a specimen of the *Valkeria cuscuta*, in which he observed a very remarkable agitation of particles in the visceral cavity, caused by a multitude of minute cercariæ swimming about with the greatest activity in the fluid with which that cavity is filled: they consisted simply of a long slender filament with a rounded extremity, by which they occasionally fixed themselves. Similar moving filaments were not unfrequently observed in other species. On one occasion Dr. Farre observed them in a specimen of *Halodactylus*, drifting rapidly to the upper part of the visceral cavity, and issuing from the centre of the tentacula, indicating an external communication with the cavity of the body. The analogy of these cercariæ with the spermatozoa discovered by Wagner in the tortuous generative tubes of the Actinia, indicates their real nature and importance in the generative economy of the Bryozoa.

The development and vital phenomena of the reproductive gemmules have been studied with most completeness in the *Halodactylus*. They appear in spring as minute whitish points just below the surface.

If one of these points be carefully turned out with a needle, it is found to consist of a transparent sac, containing generally from four to six of the gemmules. These are of a semi-oval form, with the margin of their plain surface developed into tubercles supporting groups of vibratile cilia. The body presents a simple granular structure; the gemmule swims about actively by the vibration of its cilia, the motion of which seems to be under its control. They generally swim with the convex part forwards; sometimes they simply rotate upon their axis, or execute a series of summersets; or, selecting a fixed point, they whirl round it in rapid circles, carrying every loose particle after them; or they creep along the bottom of the watch glass upon one end with a waddling gait: but at the expiration of forty-eight hours they attach themselves to the surface of the glass, and the rudiments of a cell may be observed.

In the *Flustra*, the gemmules are developed between the cell and the body of the polype, which yields to, and is destroyed by, them as they are developed. These likewise escape, and, after a short term of locomotive life, settle and subside, the outline of the cell being first formed, and the polype with its tentacula, muscles, and alimentary canal being afterwards developed in a distinct small closed sac.

There are a few genera of fresh-water polypes, as the *Plumatella* and *Cristatella*, which have the ciliated tentacula in the form of crescentic or horse-shoe lobes. The *Cristatella* has been observed to produce ova of a flattened discoid form, with their outer surface singularly beset with long bifurcated hooks like the infusorial *Xanthidia*. The young *Cristatella* undergoes its metamorphosis from the ciliated gemmule-state to the mature form of the polype in the ovum, from which it escapes by splitting it into two parts.

In thus tracing upwards the organisation of the animals which present the common external character of a circle of radiated oral tentacula, we have met with modifications of anatomical structure which clearly indicate three classes, and conduct us from a grade of organisation as low, at least, as that of the monad, to one as high as the wheel-animalcule. We have already seen that certain forms of the Rotifera, as the *Stephanoceros*, combine the external characteristic of the Bryozoa, as the cell and ciliated tentacula, with an equally complicated type of internal organisation; but no rotiferous animal developes buds. The Bryozoa still retain this common characteristic of the whole race of polypi.

The Bryozoa make a still closer approximation to the compound Ascidians, which form the lowest step of the molluscous series; but in the compound Mollusca we find the ciliated tentacles rereduced to mere rudiments at the entrance of the alimentary canal;

whilst the pharynx, or first division, is disproportionately enlarged and, being highly vascular, and beset with vibratile cilia, performs the chief part of the respiratory function.

But before proceeding to the great primary group of heterogangliate animals, to which we are thus conducted, it will be necessary first to consider the larger forms of *Radiata*, which seem to diverge from the Anthozoic division of the Polypi of Cuvier.

LECTURE IX.

ACALEPHÆ.

Cuvier, after having allocated a certain proportion of the *Vermes* of Linnæus in his two great primary groups, *Mollusca* and *Articulata*, left the remainder to form a fourth sub-kingdom of animals under the name of *Radiata*, of which we have now to consider the highest organised species.

It is true that the animals which last occupied our attention have a radiated arrangement of the prehensile organs about the mouth; but the only classes containing species with a radiated form of the entire body, are those to which the term *Radiaria* has been applied by Lamarck. These are animals of more complicated organisation than the Anthozoic polypes, the large, soft, gelatinous species of which lead to the still larger, softer, and more gelatinous forms of the present class.

The true radiated Invertebrata have been divided into two groups, according to the nature of their integuments, which, in the one, is soft and gelatinous, in the other coriaceous, or calcareous, and generally armed with spines. The species of both classes are aquatic and marine, and both are extensively diffused through all the climates of the globe. The soft-bodied Radiaria float in the free and open sea: to the shores and fathomable depths are limited the better defended groups, as being better able to bear the brunt of the ceaseless conflict between land and water.

The gelatinous oceanic Radiaries are remarkable for the singularity and beauty of their forms and colours: they give variety and animation to the otherwise monotonous waste of waters which are most remote from land. They there surprise and delight the weary navigator by their mimic fleets, glistening with all the brilliant hues of the rainbow. They tantalise the naturalist-collector both by their bright colours and the pure, glassy, transparency of their tissues, which baffle all his arts of preservation, and can never be displayed in the cabinet. They often leave upon the unwary hand of the captor pungent evidence of their singular power of inflaming the skin. It is this stinging or urticating property which has procured for the "Radiares Mollasses" of Lamarck the name of *Acalephæ* amongst the ancient Greek naturalists, and "Sea nettles" from our own fishermen and sailors.

The *Acalephæ* are represented on the British coasts by numerous discoid and spheroid gelatinous animals, varying in size from an almost invisible speck to a yard in diameter, known by the name of "Sea blubber," "Jelly fish," or by the Linnæan generic term "*Medusa*."

Occasionally some of the singular forms of *Acalephæ* of the tropical seas are stranded on the south-western shores of England. I have picked up on the coast of Cornwall the little *Velella*, which had been wafted thither, unable to strike its characteristic lateen-sail. There also I have seen wrecked a fleet of the Portuguese men-of-war (*Physalia*), which had been buoyed by their air-bladders to that iron-bound coast.

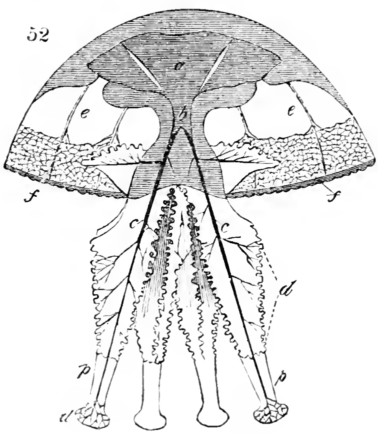
The most characteristic features in the organisation of the Acalephæ, may be exemplified by the anatomy of the larger *Medusæ* of our own seas.

The first thing which astonishes us in commencing the dissection of these creatures is the apparent homogeneity of their frail gelatinous tissue; secondly, the very large proportion of the body, which seems to consist of sea water, or a fluid very analogous to it: for let this fluid part of a large Medusa, which may weigh two pounds when recently removed from the sea, drain from the solid parts of the body, and these, when dried, will be represented by a thin film of membrane, not exceeding thirty grains in weight. The art of the anatomist would seem to be baffled by the very simplicity of his subject, instead of, as in other cases, by the inability to pursue and unravel all the intricate combinations of the created mechanism. Peron and Lesueur, two experienced French naturalists, who, during the circumnavigatory voyage to which they were attached, paid great attention to the floating *Acalephæ*, have thus summed up the results of their experience in regard to their organisation. "The substance of a Medusa is wholly resolved, by a kind of instantaneous fusion, into a fluid analogous to sea water; and yet the most important functions of life are effected in bodies that seem to be nothing more than, as it were, coagulated water. The multiplication of these animals is prodigious; and we know nothing certain respecting their mode of generation. They may acquire dimensions of many feet diameter, and weigh occasionally from fifty to sixty pounds; and their system of nutrition escapes us. They execute the most rapid and continued motions; and the details of their muscular system are unknown. Their secretions seem to be extremely abundant; but we perceive nothing satisfactory as to their origin. They have a kind of very active respiration; its real seat is a mystery. They seem extremely feeble, but fishes of large size are daily their prey. One would imagine their stomachs incapable of any kind of action on these latter animals: in a few moments they are digested. Many of them contain internally considerable quantities of air; but whether they imbibe it from the atmosphere, extract it from the ocean, or secrete it from within their bodies, we are equally ignorant. A great number of these Medusæ are phosphorescent, and glare amidst the gloom of night like globes of fire; yet the nature, the principle, and the agents of this wonderful property remain to be discovered. Some sting and inflame the hand that touches them; but the cause of this power is equally unknown."*

In this series of lively paradoxes, the general and obvious characters of the *Acalephæ* are strikingly exemplified, and the observers, labouring under the disabilities and inconveniences of shipboard life, may be excused if they failed to solve problems of such unusual difficulty.

With respect to the organs of nutrition of the Medusæ, let us see what Hunter was able to demonstrate, and leave for our instruction. In these specimens †, which belong to the genus *Rhizostoma*, he has inserted his skilful injecting apparatus into the stomach (*fig.* 52, *a*), plunged, so to speak, "in medias res," and made conspicuous by his coloured injection, both the extraordinary route by which the nutriment reaches the digestive cavity, and also the channels by which the digested aliment is distributed for the support of the general system.

52



Rhizostoma.

* Annales du Muséum, tom. xiv. p. 219.
† Nos. 847. 982, 983.

The œsophagus (*b*) divides into four canals (*c*), which enter the base of four processes (*p, p*), which are continued from the centre of the under part of the animal's body. These peduncles divide and subdivide like the roots of a plant; the œsophageal canals follow these ramifications, and ultimately terminate in numerous pores (*d, d*), upon the margins of the branches and clavate ends of the ramified peduncles. These pores are, in truth, the commencement of the nutritive system; they are, in this respect, analogous to the numerous polype-mouths of the compound coral zoophyte; but in the Rhizostome a common central sac is interposed between the ingestive conduits and the vascular system of the body. Minute animalcules, or the juices of a decomposing and dissolving larger animal, are absorbed by these pores, and are conveyed by the successively uniting œsophageal canals to the stomach. Digestion being completed, the chyle passes at once into the vascular system, which is in fact a continuation and ramification of the gastric cavity. The nutrient fluid passes by vessels (*e*), which radiate from that cavity, to a beautiful network (*f, f*) of large capillaries, which is spread upon the under surface of the margin of the disc. The elegance and precision with which the injections of Hunter have demonstrated this network in his preparations cannot be surpassed; but it is to Cuvier that we owe the first description of the very remarkable and interesting system of nutrition in the Rhizostome.*

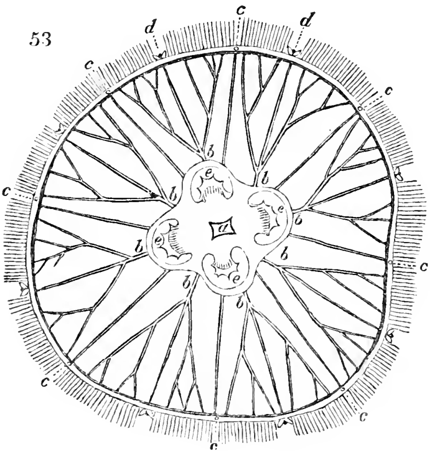
The rich development and reticular disposition of this part of the vascular system, in which the circulating fluids are exposed to the surrounding medium in a state of minute subdivision, upon that surface of the body which rests upon the water, prove that the respiratory interchange of the gases, and the absorption of the oxygen from the air contained in the sea water, take place principally at this vascular surface of the gelatinous disc; and that Hunter is correct in placing it amongst the series of respiratory organs. It stands, indeed, at the lowest step of that series, since the organ is not specially eliminated, but only indicated or sketched out, as it were, by a modification of part of the common integuments.

In the *Cyanæa aurita*, another species of our coasts, another modification of the digestive system has been detected. The digestive sac (*fig.* 53, *a*) opens immediately upon the under surface of the body by a single four-lipped mouth; sixteen canals radiate from the central cavity, eight of which (*b, b*) form, by their ramifications, the systems of nutrient and respiratory capillaries; whilst the alternate eight terminate without dividing, each by a minute orifice or anus (*c*) at the margin of the disc.

* Journal de Physique, tom. xlix. 1799, p. 436.

We must suppose the mouths of these excretory vessels to be endowed with an irritability of a different kind from that of the nutrient canals, like the mouths of the different cavities of a ruminating stomach. For, as the orifices of the third and fourth stomachs contract upon the coarse unmasticated food, whilst those of the first and second open to receive it, and close when it is presented to them in its remasticated state, so the nutrient diverticula of the stomach of the Cyanæa receive the digested and exclude the excrementitious part of the food, which passes along the anal canals, and is thus rejected from the system. But, it may asked, why the Cyanæa should have intestines and vents, whilst the Rhizostoma has neither? The difference, doubtless, relates to the different organisation of their mouths. In the Rhizostoma, only finely comminuted matter, as animalcules and fluids, can obtain access to the digestive sac; no solid excrements are formed, or require to be expelled; but the Cyanæa with its single and larger mouth can swallow crustacea and small fishes.

53



Cyanæa.

The discovery of the precise condition of the nutrient apparatus in the *Cyanæa aurita* is due to the ingenuity and perseverance of Prof. Ehrenberg, who induced the living animals to swallow indigo with their food. He has represented the canals so injected, in the elaborate plates of his memoir on the anatomy of this species.* Prof. Wagner† saw the currents of the nutrient fluid in the vascular system of the Oceania: they were produced, not by contraction of the canals, but by the vibration of the cilia lining them.

The Medusæ swim by the contractions of the margin of their gelatinous disc; and Mr. Hunter has put up a corrugated portion of the disc ‡, which he seems to have considered as indicative of the arrangement of muscular fibres of the part. Prof. Wagner states that the muscular fibres which he detected in *Oceania* and *Pelagia*, had

* Abhandl. der Konigl. Akad. der Wissen zu Berlin, 1835.
† Ueber den Bau der Pelagia noctiluca, fol. 1841
‡ No. 55.

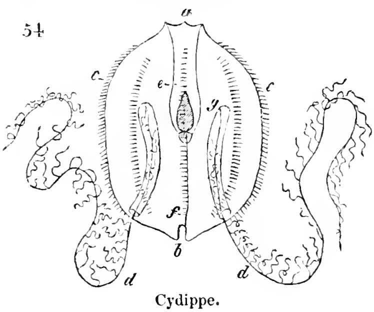
the transverse striæ which characterise the ultimate fibres of the voluntary muscles in the Vertebrata.* In the integument of the Pelagia he distinguishes an outer epithelium, and beneath this pigmental cells, with small colourless vesicles in their interspaces: each of these vesicles contains a spiral filament, the fine extremity of which projects from the surface, and is probably the duct of the gland, which Dr. Wagner conceives to be the organ of the urticating property. He does not find these spiral glands in the Cassiopeia, which does not sting.

Ehrenberg has detected and figured certain coloured specks (*d*) placed at definite distances round the margin of the disc of the Cyanæa, which he regards, with much probability, as organs for the special reception of the stimulus of light. He finds each ocellus connected with a small ganglion or mass of nervous matter, from which delicate filaments may be observed to radiate, which probably form a nervous circle around the margin of the disc. Nothing more authentic has been observed relative to the muscular or nervous systems of the Medusæ. These Acalephæ, which swim by the contraction of this muscular and vascular margin of their body-disc, have been termed "Pulmogrades."

With respect to the Acalephæ which enjoy other modes of locomotion, and especially those that swim by the action of superficial vibratile cilia, very conflicting evidence has been adduced of their nervous system.

Dr. Grant† has described and figured a double filamentous chord connecting a chain of eight ganglions around that extremity of the *Beroë* (*Cydippe*) *pileus* (*fig.* 54, *b*), from which the two long cirrigerous tentacula (*d d*) are protruded. Whatever analogy such nervous system may bear to that of the Echinoderms in the circular disposition of the central filaments, and the radiation of nerves from that centre, it has none in regard to its situation, for the mouth of the Beroë (*a*) is at the opposite end of the body.‡

54



Cydippe.

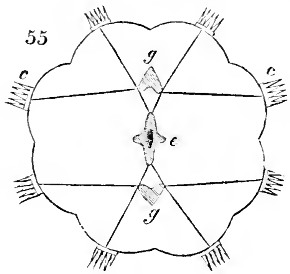
Dr. Milne Edwards§ describes and figures part of the nervous system in a larger species of Beroë (*Lesueura vitrea*) as radiating

* Loc. cit.
† Zool. Trans. vol. i. p. 10. Pl. 2. fig. 1.
‡ Forbes, in Annals of Natural History, vol. iii. p. 149.
§ Annales des Sciences Nat. n. s. tom. xvi. p. 206. Pl. 4.

from a single small ganglion, which is closely connected with a coloured eye-speck, situated at the middle of the superior extremity of the body.

The principal locomotive organs in the Beroë consist of unusually large cilia, aggregated in lamelliform groups (*figs.* 54 and 55, *c c*), which seeming plates are arranged, like the paddles of a propelling wheel, along eight equidistant bands, extending along the surface from near one end of the body to near the other.

55



Cydippe.

The organs by which the Beroë can attach itself to, or poise its body on, a solid surface, are the two long tentacles which are fringed with spiral cirri. These tentacles can be entirely withdrawn into the two cavities *g*, *g*, which extend along each side of the slender intestine *f*. This is continued from the simple elongated vertical digestive sac (*e*), the form of which, in transverse section, is shown in *fig.* 55. The Acalephæ, which, like the Beroë, swim by the action of vibratile cilia, are termed "Ciliogrades."

The *Physalia* or Portuguese man-of-war has a large air-bag to aid its swimming; the *Physophora* floats by many smaller air vesicles: the species so provided are called "Hydrostatic Acalephæ."

Two genera of Acalephæ have an oval or circular gelatinous body supported by an internal solid, cartilaginous, or albuminous plate: numerous extensile tentacles or cirri depend from the under surface of the body, in the centre of which is the mouth. These form the order "Cirrigrades." There is no evidence, however, that they swim by any action of their prehensile cirri. One of the genera, *Velella*, has a process of the firm internal skeleton, rising from the upper surface of the body-disc or deck, to which it is set at the same angle as the lateen-sail of the Malay boat: it is wafted along by the action of the wind upon this process, and may have been mistaken for the fabled Cephalopodic paper-sailor (*Argonauta*).

The generative system and the development of the ovum in the Medusæ have received very satisfactory elucidation by the observations of Gaëde, Cuvier, Ehrenberg, Sars, Siebold, and Wagner.

Propagation by gemmation has been observed in the pulmograde genus *Cytaeis*. An incomplete gemmation takes place in *Stephanonia* and others; but this simple vegetative mode of propagation, which is so common in the lowest Infusories and Polypes, is here the exception.

The Medusæ are highly prolific, and propagate in the ordinary manner of animals from impregnated ova, the germs of which are developed in organs or ovaria peculiar to one set of individuals, while the fertilising filaments are prepared by testes peculiar to other individuals; the Acalephæ being male and female or *diœcious.* The generative organs in *Rhizostoma*, *Cyanœa*, and many other Medusæ, are situated in both sexes in four cavities (*fig.* 53. *e*, *e*), which open on the under part of the disc, near the mouth. The testes and ovaria have the same form and colour, but are different in structure. The females of *Cyanœa aurita* are distinguished by having numerous small flask-shaped sacs developed from the under surface of the oral peduncles or arms. The sexes do not differ in size.

Each testis consists of a plicated band of membrane, bent in the form of a bow, with the convexity attached to the concave wall which divides the generative cavity from the stomach. If a probe be inserted in the generative cavity, it immediately touches the under surface of the testis; if it be inserted in the digestive cavity, it touches the upper surface of the testis, but not immediately, because the epithelium of the digestive cavity covers that surface. The testis is much longer than the cavity containing it, but is adapted thereto by its numerous convolutions. Its concave side gives off a numerous series of highly irritable coloured tentacles, having the same structure as those on the arms. They are richly ciliated, and contain many peculiar hyaline rounded corpuscules immediately beneath the surface. The spermatic tentacles are capable of only moderate extension, and, at the breeding season, they project from the mouth of the generative cavity, leaving only a small passage at their centre. By their powerful ciliary apparatus they keep up a strong current of sea water, and thus aid in the expulsion of the semen.

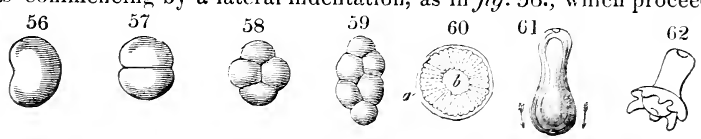
The parenchyma of the testis consists of a transparent granular substance, in which are imbedded innumerable pyriform sacs, having their bases turned towards the upper surface of the testis, and their apical orifices opening upon their under surface, which they render uneven by their tumid margins. The spermatozoa are developed in these sacculi, which permanently represent the earliest rudiments of the extremely elongated seminal tubes in the higher animals. The parietes of the seminal sacs are pretty thick, and perhaps contractile. A terminal enlargement, or body, and a ciliated appendage may be distinguished in the spermatozoa: the latter part manifests an undulatory movement. The fasciculus of spermatozoa does not exhibit these parts, in the same degree of development, in each sperm sac. Those nearest the cervix of the sac are the most perfect. The ciliary appendages of the spermatozoa are always directed towards the opening of the sperm-sac. The bundles of these filaments follow each other, and frequently the apical tails of one are infixed in the central interspace of the bodies of the preceding bundles; and a chain or string of bundles of spermatozoa are thus formed, which are easily detected by a moderate microscopic power.

In Cyanææ of an inch and a half in length, the males may be distinguished by the sperm sac in the plicated testis; and the females by the germinal vesicle and spot in the corresponding ovarium. But the band-like genital organ in both is small, and the folds are indicated by slight risings and depressions.

The ovarium, like the testis, consists of a band with many folds attached to the septum dividing the generative from the digestive cavity. Its concave border is beset with similar tentacles; but the thin epithelium, on the under surface of the ovarium, is here and there slightly ciliated, which has not been observed in the testis. The tissue of the ovarium is looser, and it has more the aspect of a cavity, than the testis. The minutest germs of the ova are nearest that surface of the ovarium which is attached to the membranous septum; the most mature ova are on the opposite or free surface, from which they project, covered only by a very thin membrane, and giving it a coarse granular character.

The ova at first consist of a germinal vescicle with its spot or nucleus. They increase in size by the addition of a violet-coloured yolk. In this state they are transferred from the ovarium to the marsupial vesicles on the under surface of the arms; but how they get there is not known: they are doubtless impregnated "in transitu." In the ova of the marsupial sacs, Siebold could no longer discern the germinal vesicle, and he conceived, in conformity with the prevalent notion, that that important body had been destroyed as the first effect of fecundation. No doubt its primitive character had been altered and obscured by the cell-building processes which had radiated from its nucleus, like those observed by Dr. M. Barry in the ovum of the rabbit.

The marsupial ova next assume an increase of size, and the yolk begins to divide, by a spontaneous fission, which Dr. Siebold* describes as commencing by a lateral indentation, as in *fig.* 56., which proceeds



Medusa.

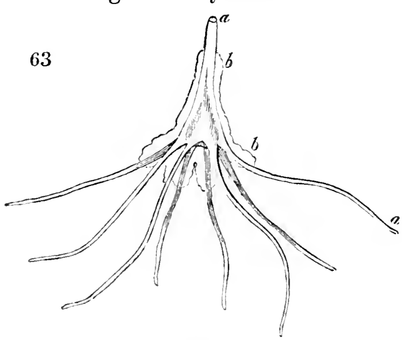
across until the bipartition is complete, as in *fig.* 57. At all events, the vitelline mass is divided into two parts. Subsequent subdivisions, analogous to those of the ova of the Strongylus (p. 77.), are de-

* Beiträge zur Naturgesch. der Wirbellosen Thiere, 4to. 1839.

scribed and figured by Dr. Siebold, from whose Memoir I have selected the four-fold (*fig.* 58.) and the eight-fold (*fig.* 59.) generation of yolklets represented in the diagrams. These are progressively multiplied by fissures, which are represented as proceeding by a diverging or radiating course from the centre, until the whole surface of the vitelline mass presents a granulated character. And now the ovum loses its violet colour and transparency, and becomes a dark yellow. The membrana vitelli acquires an epithelium (*fig.* 60, *a*) of the same colour, on which traces of cilia are perceptible. These at length cover the whole ovum, which may then be said to have taken on its embryonic state. A cavity (*b*) is next observed to be developed in the centre of this yellow-coloured ciliated gemmule. It rapidly changes the round for the oval form, and then becomes elongated like the infusorial *Leucophrys* (*fig.* 61.). In this state it quits the maternal pouch, and swims with the great end foremost. The liberated and locomotive young Medusæ sometimes re-enter the generative cavity, and get entangled between the folds and tentacles of the ovarium, which led Ehrenberg to describe them as ovarian ova; but Dr. Siebold observes, that if they were produced there as gemmules with the power of swimming, the marsupial sacs, in which they actually acquire that development, might have been dispensed with.

The young Medusa, having swam through its polygastric stage, attaches itself to some firm body, preparatory to its next metamorphosis. The great or cephalic end is shortened and thickened, and a depression is observed in its centre, which is the commencement of a digestive cavity; then the margin of this cavity expands, and is developed into four processes, richly furnished with vibratile cilia (*fig.* 62.). A small cavity or disc for adhesion is formed at the opposite extremity of the body, and thus the metamorphosis from the polygastric to the rotiferous form of infusory is effected in the embryo Medusa. During these changes the yellow colour is lost, and the body becomes colourless and transparent; it also manifests a more general irritability, sometimes elongating, sometimes contracting itself.

63



Cyanæa.

Four other ciliated cephalic processes or arms next appear in the interspaces of the first four, and all increase in length; these eight arms have the power of remarkably shortening and elongating themselves, as at *a* and *b*, *fig.* 63.; their superficial cilia create vortices in the surrounding water, which carry the nutritive molecules to the mouth of the young Medusa, which is now metamorphosed into an eight-armed ciliobrachiate polype. The arms or tentacula are very like those of the ovaria and testis in the adult. Their cilia are not placed in two regular rows as in the true Bryozoa. They contain clear corpuscules, arranged in regular bracelets, as in the tentacles on the margin of the disc of the fully developed Medusæ. The whole tissue is highly contractile; the change from the extended state (*a*, *a*) to the contracted one (*b*, *b*) is instantaneous when the polype is irritated. The mouth of the polype-shaped young is very contractile and expansible; they feed on Infusoria and on their infusory-like younger brethren, one half of whose body may often be seen hanging out of the mouth of the little devourer.

The young Medusæ remain in the polype state five months, from September to the following February, and probably attach themselves to rocks in the more tranquil depths of the ocean during the stormy months of winter. M. Sars, who confirms the preceding observations of Dr. Siebold, has traced the remainder of the metamorphoses of the Medusa.* The number of tentacula is augmented by the development, in October, of additional ones in the interspaces of the eight primitive series: the body increases, but more in thickness than in length; it even developes buds, which grow into young polypes, with the power of completing their change into the Medusa state,—that change being essentially a subdivision of the thickened body of the many-armed pseudo-polype by spontaneous transverse fission, at several equidistant points, into from ten to fifteen young Medusæ, which present the form described and figured by M. Sars in 1829 as a new genus of Acalephan, under the name of *Strobila*. This most extraordinary process takes place in February. It was observed by Sir J. G. Dalyell in 1835†, and described as one of the generative phenomena of the *Hydra tuba*, under which name that acute observer had designated the polype-like larva of the Medusa. The *Hydra tuba* is not, however, the masked form of one, but the potential aggregate of numerous Medusæ. We thus see that a Medusa may actually be generated three successive times, and by as many distinct modes of generation,—by fertile ova, by gemmation, and by spontaneous fission,—before attaining its mature condition. When finally liberated by the third and last process they rise to the surface, and swim about as small Medusæ, rapidly increasing

* Archiv. fur Naturgesch. 1841, p. 9.
† Edinb. New Philos. Journal, vol. xxi. 1836, p. 92.

in size under the influence of the light and warmth, and the abundant food, which result from the stimulus of the rays of the summer sun upon the surface of the ocean.

In comparing the several stages in the very interesting development of the *Cyanæa aurita* to the Infusoria and Polypes, it must be understood that such comparisons are warranted only by a similarity of outward form, and of the instruments of locomotion and prehension. The essential internal organisation of the persistent lower forms of the *Zoophyta* is entirely wanting in the transitory states of the higher ones. A progress through the inferior groups is sketched out, but no actual transmutation of species is effected. The young Medusa, before it attains its destined condition of maturity, successively resembles, but never becomes, a Polygastrian, a Rotifer, and a Bryozoon.

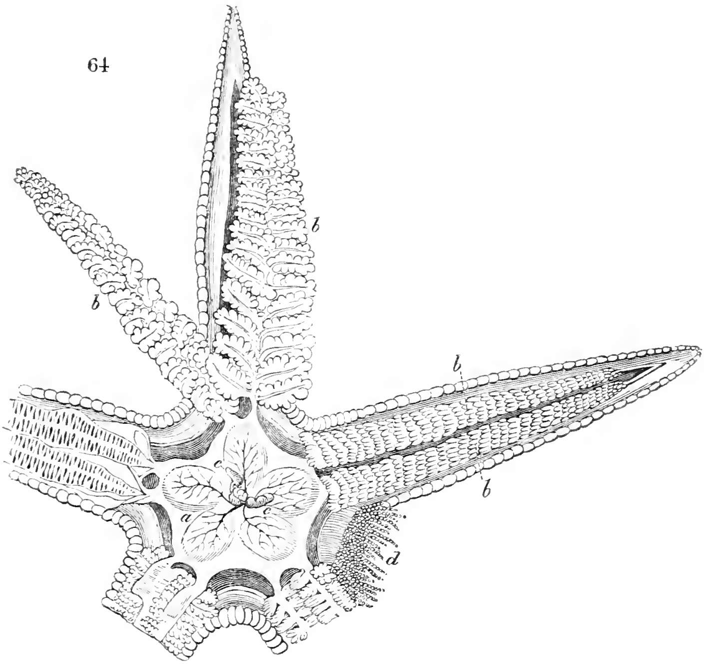
LECTURE X.

ECHINODERMA.

The soft and gelatinous Radiaries have often baffled the anatomist by the seeming simplicity and uniformity of their texture; the harder, spine-clad, or Echinodermal species, perplex the most patient and persevering dissector by the extreme complexity and diversity of their constituent parts.

This class of animals, the organisation of which I shall endeavour to explain in the limits of the present Lecture, includes species in which the form is most strictly or typically radiate: in it, also, the *Zoophyta* of Cuvier attain their highest conditions of organisation. With a radiated filamentary system of nerves, we find not only a distinct abdominal cavity with an alimentary canal suspended therein by a vascular mesentery, and having a distinct anal outlet, but likewise a large and well-defined respiratory organ. This organ, however, may be regarded as the exceptional condition of the radiated type of structure, and is found only in the highest and aberrant forms of the present class, which indicate the transition from the Echinoderms to the Annelides. At the opposite extreme of the *Echinoderma*, the digestive sac (*fig.* 64. *a*), though suspended freely in an abdominal cavity, has yet but one aperture common to the reception of food and the ejection of excrement. These anenterous Echinoderms belong to the family (*Stelleridæ*), in which the radiated form is most complete and general, whence the species have received the common appellation of star-fish.

64



Asterias.

In certain *Stelleridæ* we trace a shortening, flattening, and expansion of the rays, until the body assumes a pentangular discoid form. In the next family (*Echinidæ*), the angles disappear, and the disc expands until a spheroid or globular form is obtained, which characterises the Echinoderms commonly called " Sea-urchins," and *Echinoi* by the Greeks.

The third tribe of Echinoderms (*Holothuriidæ*) may be described as being constituted by a softening of the calcareous skin of the spheroidal species, the globe being then drawn out by the two opposite poles into an elongated cylindrical form. These vermiform Echinoderms conduct to the true worms, which stand on the lowest step of the Articulate division of the Animal Kingdom.

The name *Echinoderma* has been applied to these diversified forms of the higher organised Zoophytes of Cuvier, because in many of the species the integument is defended by spines: they, however, possess, and are associated together by, another and more general tegumentary character; the skin is perforated in most of the species by minute foramina, through which a multitude of small tubes or hollow tentacula can be protruded and retracted, and these constitute the common organs of adhesion and locomotion in the Echinoderms.

Before commencing the demonstration of the principal characters of the *Stelleridæ*, or *Star-fishes*, I may observe that in one existing species of an allied family (*Crinoideæ*), the radiated disc is fixed by a long jointed stem to some foreign body, as you perceive in this *Pentacrinus Caput Medusa*, the type of a very numerous assemblage of analogous pedunculated star-fishes, which existed in countless myriads during some of the ancient periods of geology: their remains sometimes constitute extensive tracts of marble-limestone, and are known by the names of Stone-lilies, or Encrinites.

The stem is composed of numerous joints or segments having a central aperture, which, when insulated, are called wheel-stones, or "Entrochi:" casts of their cavity remaining after the calcareous walls have been dissolved away constitute the "screw-stones" of the Derbyshire chert, and other transition limestones. The jointed column supports at its summit a series of plates forming a cup-like body, containing the viscera, and from whose upper rim proceed five jointed arms, which radiate and divide into delicate tentacula. The upper side of the arms support numerous short jointed cirri. Groups of five long and slender cirri radiate at nearly equidistant points from the stem of the recent species.

The form of star-fish to which the radiated capital of the crinoideal column bears most resemblance is that which is presented by the species of *Comatula*, the ova of which have been discovered by Dr. V. Thompson to pass through a pedunculated pentacrinite state, before their final metamorphosis into a free star-fish.

In the condition of their digestive system, the Pentacrinites and Comatulæ correspond with the Bryozoa among the polypes. The Pentacrinus may be regarded as a gigantic form of pedunculated Bryozoon. The free Comatula is a step in advance, and manifests its affinity to the gelatinous Radiaria by its mode of swimming: the movements of its pinnate arms exactly resemble the alternating stroke given by the Medusa to the liquid element, and with the same effect of raising the animal from the bottom, and propelling it back foremost.

The rays of the ordinary star-fishes are not cirrigerous or bifurcated: their soft external integument is supported by a tough coriaceous membrane, strengthened by calcareous matter disposed in a coarsely reticulate form upon the dorsal and lateral aspects of the radiated body, and arranged in series of more compact and regularly-formed transverse pieces, which bound each side of a longitudinal furrow, extending along the under surface of each ray from its attached to its free extremity. The sides of this groove are perforated by alternating rows of minute foramina, and external to these are situated the largest and most numerous spines.

The tubular feet or tentacles are protruded through the marginal pores of the furrows, which are termed Ambulacra. These feet have muscular parietes, and they communicate with internal vesicles, full of fluid, which form, in fact, the bases of the feet. By the contraction of the parietes of the vesicle the fluid is injected into the tentacle, and protrudes and extends it: when the muscular parietes of the tentacle contract, the fluid is returned into the sac, and the tentacle is shortened and retracted. The basal vesicles are in communication with, and are supplied by, a system of tubes and larger pendent pyriform sacculi, which are lodged in the central disc or body of the star-fish, and surround the oral aperture.

There are other kinds of soft contractile appendages to the integument, some tufted, others of simple form; but the tentacula just described are the most important organs for prehension and locomotion. The tegumentary processes called "pedicellariæ," which resemble miniature pincers, will be more particularly described in connection with the skeleton of the Echinus.

There are certain species of star-fish called *Ophiuræ*, in which the rays are extremely attenuated and elongated, and have neither ambulacral grooves nor tentacula. Nor is this complicated mechanism here needed, for the flexile and spinous rays can twine around and seize other objects so as to perform directly the offices of prehension and locomotion. The facility with which the Ophiura casts off a ray which may be touched and even all the rays, leaving only its central disc, when it is seized, is very surprising; it is consequently very difficult to preserve specimens of this genus entire. To do this it is recommended to plunge them suddenly into fresh water when they instantly die in a state of the most rigid extension. I may state that the Ophiura is one of the most ancient forms of animal life that has yet been met with in the fossiliferous strata of our climate. Professor Sedgwick has lately discovered it in one of the oldest members of the Silurian system of rocks.

The mouth of the star-fish (*Asterias*) is situated at the middle of the under surface of its body; it is edentulous, and leads by a short gullet into a large stomach, (*fig.* 64. *a*), which sends off a pair of sacculated cæcal appendages (*b b*) into each of the rays. The small terminal pouches of these appendages appear to secrete a substance subservient to chylification; two or more small glandular sacs (*c c*) of a yellowish colour open into the bottom of the stomach, and have been regarded as a rudimental form of liver.

Cæcal appendages are not continued from the central stomach into the rays of the *Ophiura* or *Comatula*. In the latter genus the alimentary canal presents a higher type of structure: there is a slightly convoluted intestinal canal which terminates by a distinct tubular anus.

Professor Tiedemann, in his celebrated monograph on the *Echinoderma*, has successfully demonstrated the vascular system in all the leading forms of that class. In the *Asterias rubens* the vessels which absorb the chyle from the digestive sac terminate, after a series of reticulate anastomoses, in a circular trunk, which likewise receives branches from the radiated cæca. The venous circle communicates by means of a dilated tube, regarded as a rudimental form of heart, with an arterial circle surrounding the mouth, from which branches diverge to the rays and other parts of the body. I have not been able to trace any direct communication between the true vascular system of the *Asterias* and the system of canals, which, by their connection with contractile divreticula, govern the supply of fluid to the vesicles at the base of the hollow tentacles protruded through the ambulacral pores. Tiedemann and Dr. Sharpey also agree in rejecting the continuation of the erectile system of the feet from the intestinal vascular system.

There is a small tube, called by Tiedemann the sand-canal; its position is indicated by the circular prominence or nucleus on the dorsal aspect of the disc of the Asterias, near the angle between two of the rays, which prominence resembles a miniature brain-stone madrepore. The problematical calcareous column in question is continued from the nucleus into the interior of the body, and consists of minute hexagonal plates, which are united into larger joints. From its analogy with the jointed column of the crinoid star-fishes, it has been suggested by Dr. Coldstream that it may be the analogue or remnant of that column; but, according to the observations of M. Sars, the Asteriæ are not fixed animals in the young state. Dr. Sharpey has conjectured that it may serve as a filter in the admission of sea water to the tubular system of the ambulacral feet. Such a mechanism is not, however, present in the *Echini* or *Holothuriæ*, which equally possess the systems of tubular feet.

As the sea water is freely admitted into the general cavity of the body, and bathes all the viscera, their vascular surfaces thus stand in the relation of a respiratory organ to the aerated medium, and they are every where provided with vibratile cilia, which maintain the currents of oxygenated fluid.*

The nervous system of the Asterias (p. 14, *fig.* 4.) consists of a

* Sharpey, in Cyclopædia of Anatomy and Physiology, art. *Cilia.*

slender chord surrounding the mouth (*g*), from which three delicate filaments are sent off opposite the base of each ray: the middle one is continued along the middle of the ambulacral groove, and swells, according to Ehrenberg, into a small terminal ganglion, immediately behind that bright coloured speck at the extremity of the ray which the same acute observer regards as a rudimental organ of vision.

The organs of generation consist of groups of ramified tubes (*fig.* 64. *d*), arranged in pairs in each ray, and opening upon the calcareous circle which surrounds the mouth. In the males these sacculi are distended with a white fluid abounding in spermatozoa: in the females they are laden with ova of a bright yellow or orange colour, which distend the rays during the breeding season.

The five pairs of generative organs are restricted to the central disc in the *Ophiuræ*, which part in the breeding season is distended with the milky fluid of the testis in the male, and with the round yellow eggs in the female. They are discharged by orifices on the ventral surface. In the *Comatula* the ovarian receptacles are much more numerous, and are of smaller size: they occupy the inner side of each of the pinnæ or articulate processes sent off from the rays.

Echinidæ. The calcareous pieces entering into the composition of the complex skeleton of the Echinus are those of the shell, of the buccal apparatus called the "lantern," of the ambulacral tubes, and of the pedicellariæ.

All the Echini are admirable for the regular and beautiful pattern in which, as in a tesselated pavement, the numerous calcareous pieces composing their globular crust are arranged; many of the species are formidable from the size and form of the spines with which the shell is beset. The component plates of the shell are divided into several series, called oral, anal, genital, ocular, ambulacral, and interambulacral plates. The proper shell, one half of which is exposed by removal of the spines in figure 65, is built up of the two latter kinds, which constitute a hollow spheroid, having a large aperture at each pole, where the first four kinds of plates are situated. The ambulacral plates (*a*, *fig.* 65.) are perforated for the passage of the tubular feet, the parallel rows of which intercept and overshadow spaces compared by Linnæus to avenues or ambulacra; these plates likewise support spines. The interambulacral plates (*i*, *fig.* 65.), which support a greater number

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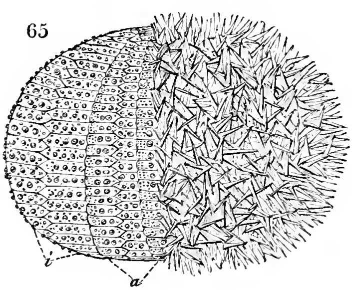


Echinus.

of the spines, are characterised by more numerous tubercles, and are not perforated. Both kinds of plates are of a pentagonal form, and are arranged each kind in five alternate pairs of vertical rows. The plates of each pair are united together by a zigzag suture, and increase in size as they approach the equator of their living globe. These twenty series of ambulacral and interambulacral plates constitute the chief part of the spheroidal skeleton of the Echinus. The large oral aperture is partly occupied by the small irregular oral plates, which have no tubercles or spines, and are suspended in the oral integument, from the middle of which project the points of the five teeth. At the opposite aperture, immediately surrounding the vent, are the small anal plates; external to these are the five genital or oviducal plates, so called because each is perforated by the duct of an ovarium or testis; the ocular plates are wedged into the external interspaces of the genital plates, and are pierced near the apex by a very minute pore, which lodges the ocellus and its little nerve.

One of the genital plates is larger than the rest, and bears a tubercle corresponding with the nucleus or madreporiform tubercle on the back of the star-fish. M. Agassiz, assuming this plate to be at the back part of the Echinus, shewed that the other four genital plates were in symmetrical pairs, and thus discovered the right and left sides of the animal.

The calcareous constituent of the shell of the *Echinus lividus*, has the following chemical composition, according to the analysis of Professor Brunner, quoted by Professor Valentin.*

Carbonate of lime -	96·27
Sulphate of lime -	1·53
Carbonate of magnesia	0·93
	100·00

The small anal plates are united together like the oral ones by an extensile and contractile membrane. Both the internal and external surface of the rest of the complicated shell is covered by a similar organised membrane, which likewise extends through all the numerous sutures of the shell. With this explanation of the general structure of the crust of the Echinus we are in a condition to understand the manner of its growth, which otherwise would be a difficult physiological problem.

The Echinus maintains nearly the same spheroidal figure from its earliest formation to full maturity; and, notwithstanding that its soft

* Monographies D'Echinodermes, d'Agassiz. No. I. 1841.

parts are almost entirely confined by a fragile and inflexible globular crust, this is never shed and reproduced, like the shells of the crab and lobster. At the same time the calcareous plates possess not more power of inherent growth than the crusts of the Crustacea, which they resemble in both physical and chemical properties. By the subdivision of the hollow globe into many pieces, and the apposition of a formative membrane to all their margins, addition is gradually made to the circumference of each component plate, and by the plan of their arrangement the spheroidal shell gradually expands, with little change in its figure and relative proportions.

The amount of change in the form of the shell, which differs in different species, depends upon the addition of new plates to the ambulacral and interambulacral series. These are developed near the oral and anal poles, but chiefly near the latter, where, in the young *Cidaris*, for example, the plates are more loosely connected together, and support incomplete spines. In the membrane connecting such plates may be seen small irregular pieces, without tubercles or spines, which grow by accretion to their margins, and then have the tubercles developed upon their outer surface. The spines are at first immoveable, and stand out like processes from the tubercle; the joint is not developed until after they have acquired a certain size. The growth of the globe in the direction of its poles is chiefly by the development of the new plates; its expansion at the equator is by the addition to the sutural margins of the old plates.

The spines of the *Echini* vary in form and relative size in different genera; their proximal extremity is adapted, by an excavation, to the tubercles on the outer surface of the plate, to which it is attached by a capsular ligament, and upon which it can be rotated by muscular fibres external to the capsule. In the species of *Cidaris*, where the spines are unusually large, an internal ligament extends from a little pit upon the centre of the tubercle to the centre of the articular cavity of the spine, analogous to the round ligament in the hip joint. The spines grow by successive additions, through calcification of that part of the common organised membranous covering of the shell of the Echinus, which is attached to their base. The varied cellular organisation of the spines, affords beautiful microscopical objects, when viewed in thin transverse slices.

The tubes that issue from the ambulacral pores can be extended beyond the longest spines in the *Echinus Sphæra* of our own coasts; they terminate in suckers, which appear to be highly sensitive, and by which the Sea-urchin attaches itself to foreign bodies, and moves along them with a rotatory course, in which the spines serve to balance and direct the progress of the animal. The bases of the tubes communicate with the cavities of the internal vesicles or branchiæ. The terminal sucker of the tube is supported by a circle of five or, sometimes, four reticulate calcareous plates, which intercept a central foramen, and by a single delicate reticulated perforate plate on the proximal side of the preceding group. The centre of the suctorial disc is perforated by an aperture conducting to the interior of the ambulacral tube.

I have reserved the notice of another class of appendages to the integument, not only of the Echini, but of the Asteriæ, for this part of my discourse, because they are most developed, most varied in structure, and have been most minutely investigated in the species of the globular family of Echinoderms. The appendages to which I allude are called "Pedicellariæ," and consist of a dilated end or head, usually prehensile, supported by a slender stem or pedicel. They present different forms, which hold constant and determinate positions in the crust of the Echinus: they seem at no season to be absent, and must therefore form part of the integral organisation of the Echinoderm. They have however been conjectured by some naturalists to be parasitic animals; by others to be the young of the Echini, to which they are attached.

In the *Ech. lividus*, Professor Valentin, to whom we owe the most minute descriptions of these bodies, divides them into gemmiform, tridactyle, and snake-headed pedicellariæ. They are all composed of an internal calcareous axis, and a soft external tissue.

The gemmiform pedicellariæ * are placed around the tubercles, especially the largest ones; their pedicel is long and slender; their capital resembles the bud of a flower, defended by three sepals, the apex of each of which is produced inwards in the form of two pairs of long and slender teeth. The quadridentate sepaloid plates can be divaricated and approximated, and constitute a very effective prehensile instrument: they are highly irritable; a needle introduced into their grasp is instantly seized. The ciliated gemmule of any parasitic coralline, which might settle about the base of a spine, and there commence its growth, would be liable to be seized and uprooted by the prehensile gemmiform pedicellariæ, which are of microscopic minuteness.

The tridactyle pedicellariæ are of larger size, are visible to the naked eye, and fit to grapple with and dislodge young sedentary parasites of larger species, as Cirripeds and Conchifers. They are found more particularly around the large tubercles of the interambulacral plates which support the largest spines. Their capital is longer, narrower,

* *Pedicellaria globifera* Muller.

and more pointed than in the gemmiform kind; and the three pieces are dentated and close upon each other, like the blades of pincers.

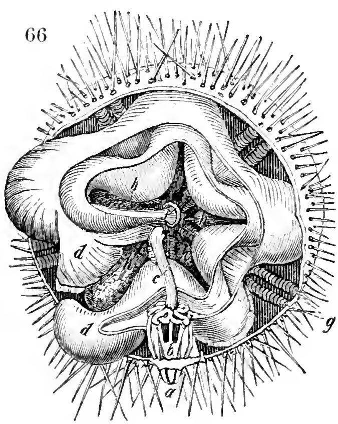
The "pedicellariæ ophicephalæ" are aggregated principally upon the buccal membrane.

The pedicellariæ of the star-fishes are diffused generally over the surface, and form dense groups round the spines: they consist of a slender contractile stem; but the head resembles a forceps with two blades: they are continually in motion, opening and shutting their blades. They would wage as effective and serviceable a war in defence of the integument of the Asterias against the attacks of the host of parasites which the sea engenders, as their tridactyle analogues in the Echini may do. In some species of *Goniaster* the pedicellariæ resemble the vane of an arrow, and are so numerous as to give a villous appearance to the integuments.

The muscular system of the Echinus, into the details of which the limits of the present lecture forbid me to enter, includes the muscles of the spines, those of the jaws or lantern, of the buccal membrane, of the anus, of the ambulacral tubes, of the internal branchiæ, and of the pedicellariæ. The muscles of the lantern and spines have their ultimate filaments collected into primitive fibres or fascicles, which are marked by transverse striæ at regular distances as in the muscles of insects.*

The digestive apparatus of the Echinus (*fig.* 66.) consists of a mouth armed with teeth, surrounded by a muscular labial membrane, and five pairs of pinnate tubular tentacula, of an œsophagus and stomach, and of an intestine suspended by a mesentery to the interior of the shell, and which, after performing a few circumgyrations, terminates by a distinct outlet opposite to the mouth. The outer margin of the lip is fringed by a circle of the ophicephalous pedicellariæ, visible to the naked eye.

66



Echinus.

The teeth (*a*) are five in number; they are calcareous, three sided prisms, dense at the working apex, softer at the base, with the inner edge sharp and fit for cutting; they are each implanted in a larger

* Valentin, l. c. p. 101.

triangular pyramid (*b*), two sides of which are in close apposition with opposite sides of the adjoining pyramids, and are transversely grooved like a file, so as to operate upon the alimentary matters which have been divided by the incisor plates, and which are thus minutely comminuted before they pass into the membranous œsophagus.

The secretion of some simple salivary follicles assists in completing the mastication of the food. These singular representatives of molar and incisor teeth are moved upon each other; and the entire pyramidal mass, which has been called *Aristotle's lantern*, can be protruded and retracted by certain muscles, which have their fixed points of attachment in five calcareous ridges and arches which project from the inner surface of the plates near the margin of the oral vacancy of the shell. For the particular description of these masticatory muscles, which are classed under the following heads, 1. Musculi interarcuales, s. comminutores ciborum, 2. Musculi arcuales, s. dilatores orificii dentium, 3. Musculi interpyramidales (sphincter oris), 4. Musculi transversi,—I must refer to the *Leçons d'Anatomie Comparée* of Cuvier, and the monograph of Professor Valentin, already cited.

The pharynx occupies the cavity of the lantern, and is divided by five longitudinal folds, most prominent at their commencement; the small salivary cæca are placed close to its continuation with the œsophagus, from which it is separated by a marked constriction. A slender œsophagus (*c*) conducts to the gastric or cæcal portion of the intestine (*d*); and that canal twice performs the circuit of the abdominal cavity before its final termination. The vent, its membrane, and the anal plates have appropriate muscles for constriction and dilatation. The intestine is generally found more or less loaded with fine sand; its surface and that of its mesentery is covered with a rich vascular network, which conveys the nutrient fluid eliminated from the organic particles swallowed with the sand, to a large vessel or vein, which accompanies the intestine from the anus to the mouth, where it terminates in the vascular circle around the œsophagus, from which the arteries are given off for the supply of the whole body.

The sea water is admitted into the peritoneal cavity; and its constant renovation over the surface of the vascular membranes of the Echinus, is provided for by the same mechanism of vibratile cilia as in the Asterias.

There are external as well as internal organs of respiration: the former are the short, pyramidal, branched or pinnate hollow processes, attached by pairs to the oral extremities of the interambulacral areæ, and consequently ten in number. Their outer surface is highly vibratile.

The internal branchiæ are the transversely extended hollow bases of the tubular feet; which are covered with so rich a network of vessels that Valentin compares them with the lungs of the Salamander. The chief office of these sacs, according to Tiedemann, is to protrude, by contracting upon their fluid contents, the tubular feet, continued from them through the ambulacral pores; but as the terminal sucker of these feet is unquestionably perforated, Valentin * rejects this explanation; he thinks the tubular feet imbibe the sea water by their terminal pore, and convey it to the internal basal sac, for the oxygenation of the blood, circulating over its parietes.

The external branchiæ are a more complicated form of respiratory sac everted and extended; they float in the external respiratory medium, while the internal sacs receive it into their interior.

The sea water can be admitted into the interior of the visceral cavity through the interspaces of the teeth; if it be actually introduced by the tubular feet it must pass by exosmose through the pores of the basal sacculi, which is contrary to analogy.

Cuvier, Tiedemann, and Della Chiaje have given more or less accurate descriptions, but conflicting explanations, of the vascular system of the Echinus.

There is no doubt that the fusiform dilated contractile vesicle, situated near the œsophagus, and surrounded by a double fold of the mesentery, is the central organ or heart. Its cavity is subdivided by muscular walls. From its oral end a trunk proceeds, which forms a circle around the œsophagus at the base of the lantern, from which the vessels of that part proceed. A second trunk is continued from the opposite end of the heart, in the opposite direction, and forms a corresponding circle around the anus. A vessel called the intestinal artery runs along the concave margin of the intestine; another trunk called the intestinal vein accompanies the outer or convex contour of the intestine, and receives many branches from the membrane of the shell. The vascular circle round the anus (*e*), receiving the veins of the ovaria, sends off five trunks which run in the interspaces of the internal branchiæ; the capillaries of these branchiæ return into five other trunks, accompanying the preceding five along the median interspace. One set must fulfil the office of branchial arteries, the other that of branchial veins. The blood is of a deep yellow colour; the blood-cells are granular and irregular, but generally manifest a nucleus.

Prof. Valentin, after a minute and searching scrutiny into the anatomy of the vascular system of the *Echinus*, is unable to deduce from that alone the course of the circulation. The ascertained facts

* Valentin, p. 85.

will permit of two explanations. In the first and most probable mode the heart transmits arterial blood to the artery proceeding to the lantern and from its arterial ring to its soft parts, to the pharynx and to the buccal membrane. From these parts the blood will return into the venous ring of the lantern, and thence into the intestinal vein, where, mingling with the venous blood from the intestine, it is conveyed to the annular vessel of the rectum, which also receives the venous blood of the ovaria. The blood thence passes into the five trunks which represent the branchial arteries. These distribute the blood over the internal gills, or bases of the tubular feet, where it acquires the arterial character. Thus changed the blood returns by the branchial vein into the arterial ring of the anus, whence it is distributed in part to the ovaria, and the remainder by the intestinal artery to regain the heart. In this view the vessel called by Tiedemann the intestinal artery performs the office of a vein.

According to the second explanation, the heart transmits the arterial blood by the intestinal artery to the œsophagus, intestine, and rectum, and then supplies the ovaria, and perhaps also the membrane of the shell. The venous blood collected into the intestinal vein is poured into the anal venous ring, which receives the ovarian veins, and distributes the blood through the five branchial veins: these will disperse it over the branchial sacs, where it will be oxidized. Thus changed the blood returns by the branchial vessels towards the auricles, and would be continued by their apertures into the vessel of the internal oblique ligament, would then pass along the pharynx, gain the arterial circle of the lantern, and re-enter the heart by the vessel which passes from the lantern to it.

The nervous system consists in the *Echinidæ*, as in the *Asterias*, chiefly of a chord surrounding the pharynx, and of five trunks extending along the ambulacral interspaces. The pharyngeal ring is an equilateral pentagon in the *Echinus*, and an oblong pentagon in the *Spatangus*. In the Echinus it is situated close upon the inner side of the apices of the calcareous pyramids which support the teeth; the ambulacral trunks are flattened, and may be distinguished from the overlying branchial vessels by the connection of the latter with the internal branchiæ. Smaller nervous branches are sent off from each arch of the pentagon to the inter-pyramidal muscles and the œsophagus. The ambulacral or branchial nerves diminish in size as they proceed, supplying the internal branchiæ and the ambulacral tubes; they finally terminate by penetrating the pore of the ocular plate to gain the base of the red ocellus.

The generative apparatus of the Echinus consists of five membranous sacs, the efferent ducts of which perforate five plates, surrounding the anal plates, and thence called genital or ovarian plates. This structure is common to both sexes, which are in distinct individuals in the Echini, as in the Star-fishes. The ovaria, when distended with the mature ova, which generally present a bright orange colour, fill a great part of the cavity of the shell, and resemble the ovaria or roe of fishes. They have at all periods constituted a favourite article of food with the inhabitants of the Mediterranean shores.

The ova consist of a vitelline membrane, vitellus, the transparent germinal vesicle, and its simple nucleus.

The spermatic corpuscles are elongated, oval, rounded anteriorly, pointed behind. They abound in the opake milky fluid, distending the five secerning sacculi at the breeding season.

In the multiplicity of the pieces of which the shell of the Echinus is formed, we may discern, by the contrast which it presents with the bivalve and univalve characters of the shells of the Mollusca, the same low vegetative condition of an external skeleton which is exemplified by the frequent repetition of similar parts in the multiplied mouths of the Polypi, the multiplied stomachs of the Polygastria, and the multiplied ovaria in the Tæniæ. If we view the articulated moveable spines and the extensile and prehensile tubes in the light of primitive forms of locomotive extremities, we shall see in their great numbers and irrelative repetition, an illustration of the same law.

Holothuriidæ. The *Holothuria*, the highest of the *Echinoderma*, may be compared, as has been already observed, to an Echinus deprived of its spines, with its shell softened and elongated by divarication of its poles. The coriaceous integument continues to be perforated by innumerable apertures, which give passage to tubular feet of precisely the same structure as those in the sea-urchins and star-fishes. These tentacles are likewise in some species of *Holothuriæ* disposed in five longitudinal ambulacral series; in a few species (*Psolus* Oken) they are confined to a sort of ventral disc: in other species the suckers are generally diffused over the integument. The only calcareous substances in this coriaceous integument consist of a circle of osseous pieces, which partly defend the nervous ring, and which afford a firm attachment to the branched retractile tentacles which surround the mouth. These tentacula may be likened to a more complicated form of the ordinary tubuli of the body, each being connected at its base with a long hollow sacculus, and being distended and protruded by the injection of the fluid contained in that sacculus.

The alimentary canal is closely analogous to that of the Echinus; but its disposition is accommodated to the vermiform character of the Holothuria: its anal termination dilates into a cloaca, from which two long ramified cæca are continued; but these admit only sea water from the cloaca. The alimentary canal in the *Sipunculus** differs from that in the *Holothuria* in being reflected from the posterior extremity of the body to terminate near the anterior end, without dilating into a cloaca, and without the development of any anal cæca. The intestine is longer and more convoluted in its course.

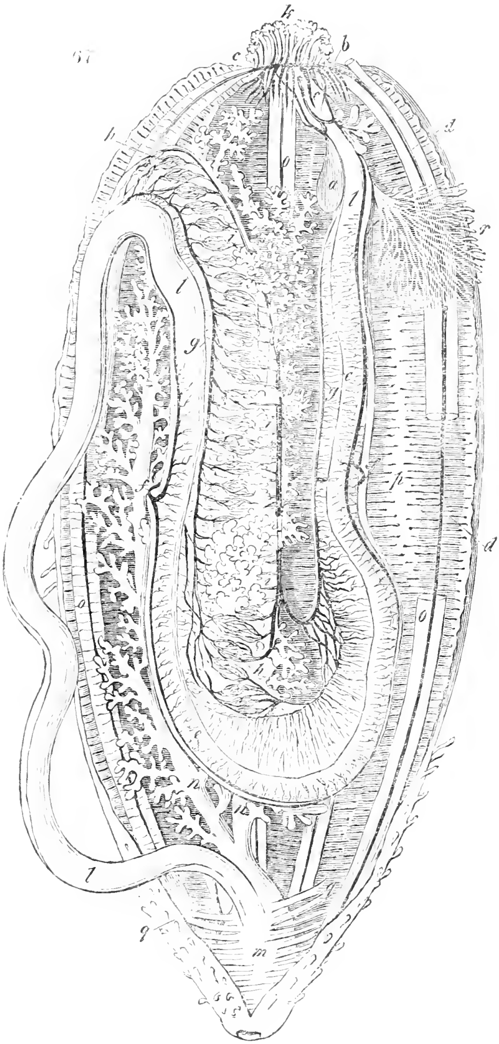
The *Sipunculus* is a marine vermiform animal which burrows in sand, and, although it has no tegumentary tubular feet nor organs of respiration, is most closely allied to the *Holothuria*, and is therefore retained in the class *Echinoderma*, in which it makes the nearest approach to the true Vermes. The anterior position of the vent in the *Sipunculus* precludes the necessity of the worm quitting the retreat, which its safety demands on account of its integument being less thick and coriaceous than in the Holothuria.

The rich vascular system of the Holothuria is most conspicuous upon the intestine and mesentery, and has been beautifully illustrated by the injections and drawings of Hunter.† Here, however, we find the intestinal vessels carrying the nutrient fluid to those cloacal cæca which are transformed into a distinct respiratory organ, and which presents the form of two long and beautifully arborescent tubes.

The complex circulating system in the Holothuria is in great part represented in this diagram in connection with the equally extensive system of sinuses and canals which regulate the protrusion and retraction of the numerous tubular feet.

The ampulla Poliana (*fig.* 67. *a*), which is double in some species, is the analogue of the blind sacculi, which supply the canal of the bases of the feet in the Asterias, but is called the heart by Della Chiaje. It transmits its fluid principally to an annular reservoir round the pharynx (*b*), whence proceed the canals of the oral tentacula (*c*) and those supplying the tubes which perforate the coriaceous integument. The latter canals (*d*, *d*) run down in the interspaces of the pairs of muscles, and distribute transverse branches to the bases of the tubes as they proceed. The most important part of the unequivocal circulating system is the trunk (*e*), which runs along the free border of the intestine, and which is characterised by the short and wide anastomotic trunk (*f*, *f*) analogous to the heart in the Echinus, and which connects the corresponding vessels of the two principal folds of the intestine. The intestinal capillaries reunite,

* Prep. No. 438. A.
† See Preps. Nos. 437, 438, 984.



performing at the same time the office of absorbents and conveying the chyle to the great intestinal vein (g), from which proceed the singular and beautiful respiratory plexuses (h, h), which are submitted to the influence of the sea water by contact with the branchial trees.

The aerated blood is conveyed to a great mesenteric trunk (i, i), or branchial vein, from which it is transmitted to the parietes of the body, and returns by the cloaca to form the intestinal artery.

Hunter has figured certain glandular sacs opening into the stem of the hollow branchiæ, which may be regarded as a rudimental form of an excretory or renal system.

The chief divisions of the nervous system consist of the pharyngeal ring, which is closely applied against the inner side of the calcareous circle, and of the flattened chords which proceed along the groove or middle interspace in each of the pairs of longitudinal muscles, which traverse the interior of the integument of the animal through its entire length. The integument is also acted upon by transverse fibres which run external to the longitudinal bands; and such is the irritability of this muscular system, that when the *Holothuria* is disturbed or captured it will sometimes eject its sand-laden intestine and most of the other viscera by the clöacal aperture, and very effectually unfit itself for anatomical investigations.

The generative organs constitute, as in other Echinoderms, a very considerable part of the abdominal viscera in the breeding season ; but they present a more complicated form : they consist of a branched system of long and slender cæcal tubes (*fig.* 67. *r*), opening externally by a single common canal, whose orifice is near the mouth. The generative organ of the male Holothuria resembles that of the female in structure; but the sexes may be readily recognised at the breeding season by the different character of the contents of the tubes, which are white or colourless in the male, whilst the ova present a reddish or yellowish hue.

The generative organs of the Sipunculus are two straight, slender, unbranched, blind tubes, symmetrically disposed, and terminating each by a distinct orifice at the anterior third of the body.

Among the few observations which have hitherto been recorded of the development of the Echinoderms, are some which are of great interest.

According to M. Sars, the star-fish, immediately after exclusion from the egg, presents a depressed, round form, with four short club-shaped appendages at the anterior extremity ; the young animal moves by vibratile cilia with the four arms in advance: at the end of twelve days the five rays begin to grow, and in eight days more the hollow feet appear. The swimming motions have now ceased altogether; the four original ciliated arms shrink, and in a month they have entirely disappeared, and the animal exchanges its binary for the radiated figure.

The ova of the Comatulæ escape from each receptacle, through a round aperture, about the month of July, adhering together in a roundish cluster of about one hundred. About the time of the dispersion of these ova, the minute Pentacrini appear, attached to the stems and branches of corallines, and occasionally to sea-weed. This is attached by a convex calcareous plate, from the centre of which arises the column composed of about twenty-four joints. The capital of the column or body bears five bifurcating arms, which are at first simple, but afterwards acquire the pinnæ, and subsequently the dorsal cirri. They further resemble small Comatulæ in having a separate mouth and lateral prominent vent. These small Pentacrini attain the height of about three-fourths of an inch.

The small Pentacrini entirely disappear in September, at which season the young Comatulæ make their appearance. It is the opinion of Mr. Thompson, the discoverer of the *Pentacrinus Europæus*, that this pedunculated star-fish is a transitional state of the young Comatula, an opinion which is adopted by Mr. Thompson, Mr. Ball, and Mr. Forbes, experienced naturalists, who have each obtained and compared the Pentacrini and young Comatulæ. The actual metamorphosis of the Pentacrinus into the Comatula has not yet been seen: we must suppose that it enters life at first in the active stage of a ciliated gemmule; that it next selects the appropriate situation for its sedentary pentacrinite stage of existence, and, finally dropping from the stalk, by an act of transverse fission, a second time assumes a free condition of existence under its mature form. Nor are these metamorphoses a whit more extraordinary than those of the gelatinous Medusæ: nay, the parallel would be extremely close, since we saw that the *Cyanæa* entered life as a ciliated locomotive infusory, then became a sedentary polype, supported on a central stem, which, finally, resolved itself into the freely swimming Acalephans by several transverse fissions.

Other highly interesting considerations arise out of the predominance of the Pentacrinite forms over the Asteriæ or Echini, in the limestones of the ancient transition epoch in Geology. As we advance in our survey of the organisation and metamorphoses of animals, we shall meet with many examples, in which the embryonic forms and conditions of structure of existing species have, at former periods, been persistent and common, and represented by mature and procreative species, sometimes upon a gigantic scale.

LECTURE XI.

ANELLATA.

In both the Infusorial and Entozoic classes the body assumes a more perfect linear and bilateral form as the species advance in the scale of organisation; and we have seen in the subjects of the preceding discourse, that even the typical radiated class of the zoophytic sub-kingdom conducts by the Holothurian and Sipuncular families to the vermiform type of the articulated sub-kingdom, in which the vegetative principle of development, by the frequent repetition of similar parts, is still conspicuously manifested, but exercises its energies in a linear direction, and forms successive segments from before backwards. We find, in fact, at the lowest step of the great Homogangliate series of the Animal Kingdom an extensive group of vermiform animals, some of which very closely resemble the Trematode, and others the Nematoid, Entozoa, and all are devoid of jointed limbs: but they possess a distinct circulating system of arteries and veins, and in almost all the species the blood is red. They have therefore been called "red-blooded worms," "vers à sang rouge," and "anellides," by the French naturalists; in Latin *Anellata*, from *anellus*, a little ring, because the entire body of these worms is made up of a succession of segments like little rings.

The mind is not easily liberated from the sway of opinions that have long been held as authoritative; although Cuvier seems to have been the first to detect the exaggerated importance of the zoological character derived by Aristotle from the colour of the blood, yet the judgment of the great modern reformer of zoology continued to be so far biassed by that character, that in his latest edition of the "Règne Animal," he continued to place the Anellides, on account of the colour of their circulating fluid, at the head of the articulate series, above the Crustaceans, above the Arachnidans, above the Insects, whose transitory larval condition these apodal worms seem permanently to represent.

The body of an Anellide is always very long, soft, and subdivided into a number of segments, for the most part closely resembling or identical with each other. In many species the first segment is so slightly modified as scarcely to deserve the name of head; in others it is the seat of higher senses and more varied functions, and is at once recognisable as the cephalic segment.

In the lowest forms of the *Anellata* the locomotive instruments are suctorial discs, as in the Trematode worms; but the suckers are always two in number, and are terminal in position. The species next in order have stiff hairs or minute hooks projecting from each segment. In most Anellides there is on each side of the body a long row of tufts of bristles, supported upon fleshy tubercles, which indicate the rudiments of lateral and symmetrical locomotive members. (*fig.* 68.) There are often two such organs, placed one (*a*) above the other (*b*), on each side of the segments of the body. In some species the two setigerous tubercles

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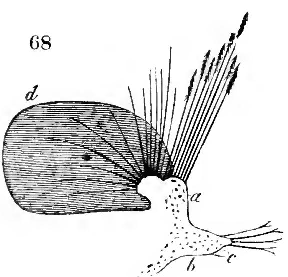


Aphrodita.

are confluent, and in almost all there exists at the base of each a long soft cylindrical appendage called the "cirrus (*c*)." The bristles in the setigerous Anellides are their chief organs of locomotion, and at the same time their weapons of attack and defence. They are generally sharp, or barbed, and hard enough to readily penetrate the soft bodies against which they strike.

The nervous system of the Anellides presents a marked advance beyond its condition in the white-blooded parasitic worms; it consists of a double median central chord or chain of small ganglions, extending from one end of the body to the other; the two chords diverge anteriorly to allow the passage of the œsophagus, and again unite above that tube to form a distinct, though small, bilobed cephalic ganglion.

Most of the Anellides are provided with ocelli, and in many of them the head supports soft cylindrical tentacules called "antennæ:" they are obviously organs of touch, but differ from the antennæ of insects in the absence of joints. In the first appearance of these not yet well understood organs of sensation, which form so remarkable and conspicuous a character, and so important an endowment of the higher articulate classes, we have again an interesting illustration of the principle of vegetative repetition; for every setigerous tubercle in the Anellides with cephalic antennæ, has a similar organ of sensation: the distinction is merely local and nominal; the feelers on the first segment being called "antennæ;" those on the other segments "cirri."

The mouth is at the lower surface of the head, or at the anterior extremity of the body in the acephalous Anellides; in some species it is provided with a protractile proboscis, and with lateral jaws in the form of curved dentated horny plates; and the alimentary canal is generally straight, and in some species simple; in others, provided with a greater or less number of lateral cæcums. The anus is situated above, or at the posterior extremity of, the body, and the degree of redness of the circulating fluid varies considerably; in some species it is very pale: in one or two it even presents a greenish hue: it circulates in a closed and very complicated system of vessels, of which the chief dorsal one is distinguished by its undulatory pulsations; and in some species the circulation is further aided by contractile sinuses, called hearts.

All Anellides have organs of respiration, adapted in a few species for extracting oxygen directly from the atmosphere; and in the rest of the class through the medium of water: in these the gills are usually external, and vary considerably in form and position.

Such are the general anatomical characters of the class *Anellata*, and such the progress each system of organs has made in the transit from the Nematoneurous to the Homogangliate types. The Anellides are distributed into orders, according to obvious and easily recognisable modifications of the locomotive and respiratory organs; which characters fortunately coincide with the general conditions and grades of their organisation, and are therefore natural ones. Dr. Milne Edwards, the pupil of Cuvier who has devoted most attention to the Vermes thus grouped together by his great master, divides them into four orders.

The first is the *Anellata suctoria*, and comprises the leeches, which are provided with a suctorial disc at each extremity of the body, and have neither bristles nor tuberculate feet.

The second order is the *Anellata terricola*, which includes the earth-worms; these have neither tubercular feet, nor external gills, nor suckers, but are provided with short stiff bristles fulfilling the function of feet.

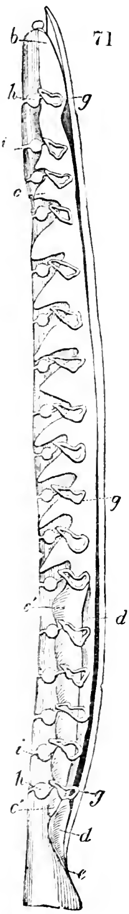
The third order is the *Anellata tubicola*, and includes all those which are provided with setigerous feet and have the respiratory organs at the anterior extremity of the body. The Anellides of this and the two preceding orders can scarcely be said to have a distinct head.

The highest organised Anellides are also the most locomotive: they have been called *Errantes* by Dr. Edwards. In them, the respiratory organs are most developed, and from their position, Cuvier, who first defined the order, has denominated it *Dorsibranchiata*, the gills being attached to the sides of the body on the dorsal aspect, along the middle part, or through the whole length of the body. They are provided with setigerous processes for locomotion, and have always a distinct head. They are commonly known by the name of Sea-centipedes, Sea-mice, or Nereids, from the Linnæan generic name *Nereis*, which is almost equivalent to the present ordinal term, *Errantes*.

The tubular sheaths and protractile bundles of bristles which constitute the organs of locomotion in this order have been already noticed in the general characters of the class. The integument is naked, soft, vascular, and highly susceptible of impressions in all the Anellides. It is sometimes red, sometimes the epidermis reflects iridescent tints. In the tubicular order the habitations are commonly formed of foreign substances, as particles of sand or shells agglutinated together by the mucous secretions of the worm, which is sometimes done with a considerable degree of neatness and apparent skill, as in the *Pectinariæ* and *Terebellæ*. The Serpula secretes a calcareous tubular shell, consisting of carbonate of lime and animal matter, like the shells of Mollusca; but differing in being quite external to the integument, and not organically attached to the animal, which can quit and return to its tube. Most species of *Serpulæ*, as the *Serp. contortuplicata*, which coats the shells of oysters and other bivalves with its characteristic dwelling, have a pedunculated operculum for closing the entry of the tube.

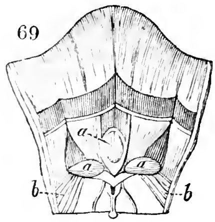
The organisation of the integument has been studied chiefly in the naked Anellides. It consists, in the leech, of a strong, smooth whitish epithelium, and of a cellular corium divided into short segments, and having many pigmental cells of a brown or greenish colour, except in the intervals of the rings. The muscular fibres have a tendinous lustre: those of the outer layer are transverse; those of the next layer cross each other diagonally, and form a fine regular reticulation: beneath these are the longitudinal fasciculi, which form the most conspicuous stratum. There are also other smaller muscular fasciculi in the under surface of the body, besides those which specially regulate the action of the terminal suckers and the dentated jaws (*fig.* 69. *b*). The mouth of the leech (*fig.* 69.) is triangular, and is armed with three crescentic jaws (*a*, *a*), presenting their sharp convex margin towards the oral cavity, which margin is beset with sixty small teeth (*fig.* 70.). It is by the action of these little saws upon the tense integument seized by the labial sucker, that the characteristic triradiate bite of the leech is made.

71



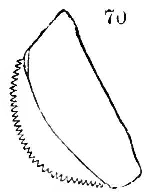
Leech.

69



Leech.

70



Jaw and teeth.
Leech.

The œsophagus (*fig.* 71. *b*) is short, and terminates in a singularly complicated stomach, divided by deep constrictions into eleven compartments, the sides of which are produced into cæcal processes (*c*, *c′*), progressively, though slightly, increasing in length to the tenth, and disproportionately elongated in the eleventh, compartment. The first gastric chamber is the smallest. In the eight posterior compartments the anterior part of each slightly expands to form a pair of small accessory cæca. The middle part of the eleventh division extends backwards, in the form of a small funnel-shaped process, and opens into the commencement of the slender intestinal canal (*d*, *d*); this is situated between the two last and longest gastric cæca (*c′*); it terminates by a small anus (*e*) above the terminal sucker.*

There is a whitish glandular stratum in the coats of the œsophagus, representing the salivary system. A peculiar brown tissue extends along the alimentary canal between the nervous chord and the mucous glands, and also upon the dorsal aspect of the anterior part of the cavity. It is composed of a congeries of elongated, convoluted, and irregularly constricted follicles, which are united in groups by the confluence of their ducts into a single slender excretory tube. These tubes unite with those of other groups of the follicles, and pour a secretion, analogous to bile, into the posterior divisions of the stomach and into the intestine. The confluence of the hepatic ducts is very remarkable and conspicuous when they lie upon the testes.†

The mouth is furnished in the earth-worm with a short proboscis, but is without teeth: the decaying parts of animals and vegetables are swallowed with the soil, and conveyed by a short and wide œsophagus to a muscular compartment of the digestive canal, analogous to a gizzard. The œsophagus is sometimes dilated, like a crop, above this part. The long and wide intestine is continued straight to the terminal vent, and is constricted in its course by the transverse septa of the common cavity of the body; but the sacculi are not produced into cæca.‡ It contains a long and slender blind tube, called the typhlosole, attached to the inner surface, in which the chyle is strained off from the coarse contents of the wider intestine.

The obliquity of the constrictions of the alimentary canal in the *Sabella pavonina* § give it the appearance of being a long and narrow tube disposed in a series of close spiral coils; but it is merely sacculated. In most other tubicolar anellides the intestine is less constricted than in the Sabella.

In the *Terebellæ nebulosa* and *conchilega* the wide œsophagus is separated from the slightly sacculated gastro-intestinal tube by a constriction, which lodges an annular vessel. In the *Hermella* there is a short oval dilatation or stomach between the œsophagus and intestine.

In the sand-worm (*Arenicola*) the gastro-intestinal canal (*fig.* 73.) commences at the termination of the œsophagus (*b*) by a sudden dilatation, into which two cæcal glandular pouches (*c*) pour their secretion: the rest of the canal is simple in its outward form; but

* See Preps. Nos. 442. 466, 467, 468, 569. 595. A.
† Brandt, Medizin Zoologie, Bd. ii.
‡ Prep. No. 595. B.
§ No. 441.

its walls are thickened by a stratum of minute secerning cells (*d*), which prepare a greenish-yellow fluid.

The alimentary canal commences in many of the Nereids by a proboscis formed by a loose and muscular cylinder, which can be inverted and protruded like the finger of a glove; its extremity in some species is encircled by smal papillæ; in some it supports a rasp-like horny plate; in others it is armed by one or more pairs of lateral horny dentated jaws.

In most of the Nereids there is no distinction between stomach and intestine; in some species the canal is provided with lateral pouches. In the *Aphrodita aculeata* the part analogous to the projectile proboscis of the Nereids is converted into a kind of gizzard, by the thickening of the muscular coat. The alimentary canal, continued from its posterior extremity, bends forward at first for half the length of the gizzard, a disposition which indicates the occasional protrusion of this part. The canal then bends backwards, and is continued straight to the anus. Through the whole length of the intestine, cæcal processes are sent off on each side, to the number of about twenty pairs. They commence of a slender diameter, but gradually enlarge, send off many short branches, which subdivide, and terminate in fusiform cæcal pouches. These productions of the intestinal canal seem obviously analogous to the gastric cæca of the leech; but they are more isolated from the common canal, and more distinct in their functions. It is thought that the chyme passes into them, and that the chyle is separated from it by a secretion of the terminal cæca analogous to bile. Hunter has placed this preparation * at the commencement of his series of hepatic organs, as one of the early forms of that system.

In the majority of the Anellides the blood is red; in some of a brilliant red, as in the *Arenicola, Nereides, Glycera, Nephtys*. In the *Aphrodita aculeata* and in the *Polynoë*, the blood is of a pale yellow colour; in a species of *Sabella* it is olive green; so that, as Milne Edwards well observes, the colour of the blood is far from being a character of such physiological importance as to justify the location of the Anellides at the head of the articulate sub-kingdom. In all the species the blood is characterised by granulated circular corpuscles, of very variable dimensions, in the same animal. It circulates in a closed system of arteries and veins, the modifications of which are considerable when examined in the different genera of the class.

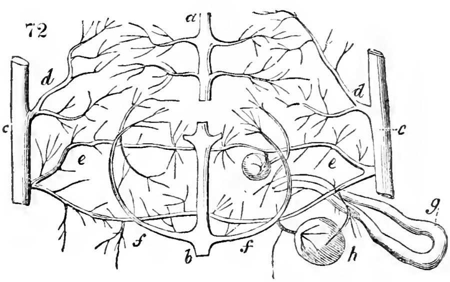
A large vessel which rests on the digestive tube, is the seat of

* No. 782.

undulating contractions, by which the blood is propelled from behind forwards; it fulfils the functions of the heart, and is very obviously the analogue of the dorsal vasiform heart in insects. A corresponding venous trunk conveys the blood in an opposite direction from the head to the tail, along the under or ventral surface of the abdominal cavity. The circulation is often aided by the contractile walls of partial dilatations of certain of the vessels, and by the actions of the gills themselves in the higher anellides.

In the leech the vascular system consists principally of four great trunks, none of which present any local dilatations meriting the name of heart; one of these trunks is situated on each side, a third above, and a fourth below, the alimentary canal. They are shown in transverse section, as connected together in two of the middle segments of the leech in this diagram, from Brandt's Monograph (*fig.* 72.) The lateral trunks (*c*, *c*) are the largest; they are widest in the posterior third of the body; their anterior end terminates in branches to the head; the posterior end unites with that of its fellow more conspicuously than at the anterior part, and supplies the terminal sucker. Branches are given off at each ring, which almost immediately divide into a dorsal (*d*) and ventral (*e*) ramulus; the six posterior dorsal branches unite with those of the opposite side, and the six arches thus formed are joined together by two nearly parallel longitudinal vessels near the middle line of the back.

72



Leech.

The dorsal vessel (*fig.* 72. *a*), in which the blood moves from behind forwards, is formed by the union of the dorso-intestinal vein and of the dorso-dermal vessel, which run parallel with each other along the posterior third of the body. The trunk is thence continued forwards, sending outwards a pair of transverse branches at each ring, and bifurcating behind the mouth to enclose the œsophagus. From the under part of the œsophageal ring the great ventral vein (*fig.* 72. *b*) begins, which is continued along the nervous ganglionic chord, and swells at each ganglion, forming a sinus around it; the nervous matter being thus, as it were, bathed in the nutrient fluid.* From

* Johnson On the Medicinal Leech, 8vo. 1816. p. 114.

each of these swellings a transverse branch is sent off to either side (*f, f*), and from the seventh to the fifteenth ganglionic sinus a second pair of transverse vessels of smaller size is given off, just behind the ganglionic sinus.

The respiratory function would seem to devolve partly upon the tegumentary capillaries, and partly upon those capillaries which spread upon the mucous sacculi. These latter capillaries are not, however, more numerous than those of the other organs of the body. The more important office of the sacculi would seem to be as the recipients of the secretion of peculiar loop-shaped glands, which they receive by a very short and slender duct. There are seventeen pairs of these mucous glands (*figs.* 71, 72. *g, g*), the five posterior of which lie on each side the long terminal gastric sacculi, and the rest in the interspaces of the shorter cæca. Each gland pours its secretion into a circular sac (*figs.* 71, 72. *h, h*), which opens externally (*fig.* 71. *i, i*) upon the skin. These dermal pouches have commonly been described as the respiratory organs; they are evidently analogous in their position to the respiratory organ of the higher *Articulata;* but in function they seem to be reduced to supplying the skin with its abundant mucous secretion, and the ova with their cocoon-like coverings at the season of generation.

Morren has minutely described the circulating system of the earthworm; in a species of which (*Lumbricus variegatus*) Bonnet * saw the red blood propelled forward by the systole and diastole of the dorsal vessel towards the head, and noticed its accelerated course near that part.

In the tubicolar anellides, according to Dr. M. Edwards †, the dorsal contractile artery is unusually short. In the *Terebella* it receives numerous veins from the intestine, and a large accession of the circulating fluid from two wide transverse venous trunks, which encircle the commencement of the intestine, and which receive recurrent veins from the œsophagus, also a small vein from the integuments of the back. This short dorsal vessel is, in fact, the general receptacle of the venous system, and, by its function, it represents a pulmonic heart. It transmits the venous blood almost exclusively to the cephalic branchiæ by three pairs of branchial arteries, which arise from its anterior extremity. The oxygenated blood is returned by the branchial veins to a large ventral trunk, situated immediately above the ganglionic nervous chord. This vessel supplies a pair of transverse branches to each ring of the body, which distribute filaments to the integuments and the feet, and then ascends to supply the intes-

* Observations sur les Vers, Œuvres, i. p. 121.
† Sur la Circulation dans les Anellides, Annales des Sciences, Nat. X. p. 193.

tine, where, with the absorbent veins of that canal, it returns again into the dorsal vessel. In some other species of Terebella, as the *Ter. conchilega*, the lateral branches of the ventral trunk do not ascend in loops upon the upper surface of the intestine, but terminate almost exclusively in a vascular network situated on each side of the abdominal cavity near the base of the feet. The principal organs of impulsion of the circulating fluid in the tubicolar anellides seem to be the contractile branchiæ, which thus combine, as it were, the functions of both heart and lungs.

Cuvier has noticed the alternate expansion of the branchiæ of the *Arenicola* when they are coloured by the bright red blood, and their contraction, when, by expelling the blood to the internal vessels, they become of a pale grey colour.

In the *Eunice sanguinea* * there is, as in the *Terebella*, a large and short dorsal vessel, which rests upon the pharyngeal part of the alimentary tube, and which communicates, by its posterior extremity, with a vascular ring surrounding the commencement of the intestine. This ring receives two vessels, which run parallel and close together along the dorsal aspect of the intestinal canal, and correspond with the single vessel in the *Terebella*. The dorso-pharyngeal contractile trunk receives other branches from the parietes of the digestive tube, and a small medio-dorsal cutaneous vessel. It gives off by its anterior extremity several branches to the head, and others which surround the pharynx, and anastomose with the ventral vessel. From this vessel a pair of lateral branches is given off at each ring of the body. These branches immediately dilate, and are bent upon themselves in a strong sigmoidal curve, appearing at first sight to be simple oval vesicles. They send an ascending branch to the digestive tube, form a small plexus at the base of each of the feet, and penetrate the branchial filaments. The blood is returned from these respiratory organs by transverse veins, which terminate on each side in the dorso-intestinal vessel of that side. Here therefore the respiratory circulation is removed further from the dorso-pharyngeal heart, which consequently receives a greater quantity of blood in its arterial or oxygenated state. The principal dynamical organs are, however, the curved dilated sinuses at the bases of the branchiæ, which pulsate with strong contractions, and propel the blood at once to the branchiæ, the feet, the skin, and the intestine. If we call these pulsatile reservoirs by the name which their functions would claim for them, there will be several hundred hearts in one of these gigantic Nereids.

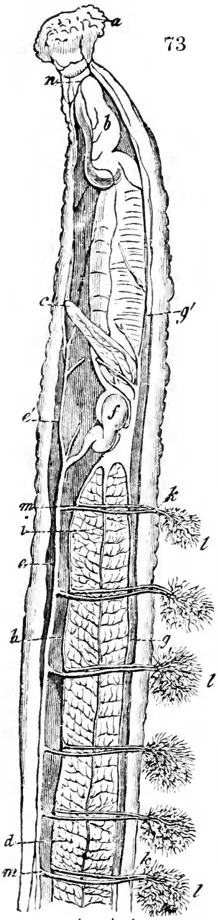
In the *Amphinome capillata*, which Hunter has here † dissected for

* Edwards, loc. cit. p. 204. † Preps. Nos. 875. 889.

the vascular system, this is chiefly remarkable for the size and complexity of the branchial plexuses.

In the *Arenicola* (*fig.* 73.) there is, on each side the base of the œsophagus, an ovoid contractile sac (*f*), which sends off a large and short vascular trunk downwards and backwards to the medio-ventral line, where, uniting with its fellow trunk, a ventral vessel (*e*), analogous to that in the *Eunice* and *Terebella*, is formed. This median vessel furnishes a pair of transverse branches to each ring, which at the seventh segment begin to penetrate the ramified branchia, attached to the sides of that and succeeding middle segments of the body. The pulsations of the two œsophageal sinuses, or ventricles, propel the blood into the ventral vessel from before backward through these vessels (*m*, *m*) to the gills, where it receives a new impulse by the contractions of these organs, and, after having been oxygenised, it is returned, partly by cutaneous vessels, which form many anastomoses, and chiefly by a direct and continuous lateral vessel (*k*, *k*) to the medio-dorsal intestinal artery (*g*). This artery extends from one end of the body to the other. At its middle part it receives many transverse branches from the digestive tube, and through them anastomoses with the inferior intestinal vein (*h*). The vascular network thus formed around the intestine, gives origin anteriorly to two lateral veins (*i*), which terminate in the dorsal vessel immediately behind the œsophageal ventricles. The blood from the inferior intestinal vein is conveyed to the same point or sinus. After the communication of this common sinus with the two hearts, a slender median vessel (*g′*), a continuation of the dorsal one, extends forwards towards the head, and terminates by forming two vascular rings around the base of the proboscis, from the lower part of which the ventral vessel arises, which vessel (*e*), passing backwards, receives the great accession of blood from the two contractile hearts, and thus the circulation is completed.

73



Arenicola.

This has much analogy with the circulation of the blood in the earth-worm, in which the blood travels from behind forwards in the dorsal vessel, and descends in great part towards the ventral vascular system through the pairs of anterior beaded contractile sinuses or hearts *, which differ only from the two ventricles in the *Arenicola* by their greater number. In the lateral vascular canal, which extends along the anterior part of the body, at the base of the feet in the *Arenicola*, and which is formed by the anastomoses of one of the branches of the cutaneous arteries, we have the analogues of the lateral vessels in the leech tribe, which are wanting in most of the higher Anellides. The dorsal and ventral trunks are common to all.

The most striking physiological character of the circulation in the Anellides as a class, is the continuity of their capillary system, and the difficulty of determining which is the arterial, and which the venous trunk of any one of the organs or parts of the body, excepting the branchiæ. There alone, we find that the blood received from the distinct artery is sent back by as distinct a vein, which returns along the same route as the artery, as it does in the limbs of the higher animals. By the rapid division and general system of anastomoses of the arteries and veins, it follows that almost all the parts of the body are supplied by a mixture of arterial and venous blood.

The position and general relations of the branchial organs have already been incidentally pointed out; and it seems only necessary here to allude to their different forms. In the leech and earth-worm, a series of pores or stigmata on each side of the body lead to as many simple sacculi (*fig.* 71. *h*, *h*), formed by an inward folding of the integument. Carry the duplicature further in, divide and subdivide ti, and ramifications of air tubes, like the tracheal respiratory system of insects, would be produced. We may perceive in the lateral air sacs of the leech and earth-worm, the first step in the development of the very peculiar air-breathing organs of the higher Articulata. The air sacs of the abranchiate anellides, in their actual rudimentary form, have their respiratory functions reduced to the lowest state, and serve chiefly the office of excretory organs, preparing and discharging mucus.

The respiratory organs of the Tubicolar anellides are in the form of long, and sometimes tortuous, filaments † which radiate from the head, generally in two lateral fasciculi. When not coloured by the red circulating fluid, they are often barred and variegated by bright purple, green, and yellow tints, forming a rich and gorgeous ornamental crown.

* See Preps. 876, 877, 878.

† Prep. No. 990.

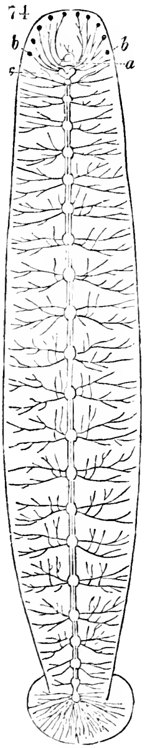
The branchiæ of the *Anellata errantia* * are usually in the form of shorter tufts than the cephalic ones of the *Tubicola;* and they are attached to the upper part of the sides of a greater or less number of segments. In some species, as the *Nereis lamelligera*, the branchia is formed by a flattened vesicle, including the ramifications of the branchial vessels, and attached to the base of the upper tubular foot. We shall afterwards see the homologue of this respiratory plate taking an important share in the locomotive functions in the higher organised forms of Articulata.

LECTURE XII.

ANELLATA.

Hitherto the highest condition of the nervous system which we have observed has been that of detached unganglionic filaments diverging from a single sub-œsophageal ganglion or from a simple œsophageal ring, continued unconnectedly along the abdomen, or diverging in rays down equidistant tracts of the common parietes of the body. If we have met with ganglionic masses in connection with coloured ocelli, these have been as in the Acalephæ, either so situated as to give no indication of a head, or so multiplied as to lose all significance as a common cerebral centre of sensation.

74



Leech.

In the class *Anellata* the nervous system has reached a higher type and more constant plan of arrangement. It always commences by a symmetrical bilobed ganglion, which, both by its situation above the mouth, and by the parts which it supplies, merits the name of brain, which it has commonly received.

In the medicinal leech there are sent off from this ganglionic centre (*fig.* 74. *a*) ten distinct optic nerves (*b b*), besides many smaller filaments to the integument and other parts of the head: each optic nerve or filament terminates by expanding upon the base of a black eye-speck or ocellus, ten of which you will easily distinguish by the aid of a moderate magnifying power, dotting at equal distances the upper margin of the expanded suctorial lip.

* Preps. Nos. 987, 988, 989.

The principal nervous productions of the brain of the leech are what may be termed its crura, which diverge as they descend to embrace the œsophagus, and are called the œsophageal chords; they then converge and reunite to join the large cordiform subœsophageal ganglion (*c*). From this ganglion the muscles of the three serrated jaws, as well as the principal muscles of the oral sucker, derive their nervous influence. Those who have watched the vigorous workings of this part in a hungry leech, beginning its parasitic feast, will not be surprised at the great development of the nervous centre of the suctorial and maxillary mechanism. Two chords, in such close apposition as to seem a single nervous band, are continued from the subœsophageal ganglion along the middle of the under part of the abdomen, attached to the ventral integument, and inclosed, as it were, by the great ventral vein. Twenty-one equidistant rhomboidal ganglions are developed upon these chords, which distribute their filaments to the adjoining segments by two powerful diverging trunks on each side. The segments indicated by the external circular indentations of the integument are much more numerous than the ganglions. Dr. Brandt has detected a simple nervous filament continued from the œsophageal ganglion along the dorsal aspect of the alimentary canal. This is an interesting structure, since it offers the first trace of a distinct system of nerves, usually called the stomato-gastric in Entomology, and to which our great sympathetic and nervus vagus seem answerable.

The structure of the abdominal ganglion in the leech has been illustrated by the microscope and pencil of Ehrenberg: in the centre of the ganglion are several clavate corpuscles, the enlarged end of each being formed by a nucleated cell, the tapering extremity is continued into the diverging nervous chords: the clavate cells are arranged in eight groups, two groups being continued into each of the four diverging chords of the ganglion: one of these groups may be supposed to be the recipient, the other the transmitter, of impressions.

In the earth-worm the brain or supraœsophageal ganglion consists of two lateral lobes, which send off small nerves to the proboscis, and the two large chords to the subœsophageal ganglion: some small filaments are derived from the œsophageal collar. The two ventral nervous trunks are more distinct from each other than in the leech; but the ganglions are relatively smaller and more numerous, corresponding in number with the segments of the body. Two pairs of nerves are given off from each ganglion, and a third pair comes off from the intermediate chords. The terminal or anal ganglion distributes a plexus of nerves to that termination of the body.

In the Nereis the abdominal ganglions are more distinctly bilobed than in the earth-worm, and the supra-œsophageal ganglion is relatively larger, having to furnish nerves to both antennæ and ocelli. The pairs of ganglions developed upon the ventral chord correspond with the segments of the body in number, and are very close together. In the *Eunice gigantea* there are upwards of 1000 ganglia; but this complicated condition of the nervous system is more apparent than real, and, like the multiplication of the pulsatile sinuses of the vascular system in the same animal, depends upon the vegetative repetition of like parts without any mutual subordination in reference to the performance of a special office.

In the Aphrodita the body is broader and thicker than in other Anellides, and begins to exhibit that concentration which characterises its form in the higher Articulata. But the segmental nervous ganglions, though more closely approximated, are yet not confluent at any central part. The brain is heart-shaped, having its bilobed base turned backwards and connected in the usual manner by large œsophageal columns with the inferior ganglion. The antennal nerves are continued from the apex. The visceral nerves are given off from the œsophageal circle, and pass to the upper surface of the intestine, and there swell into a small ganglion. The sub-œsophageal ganglion is of large size, and bifurcates anteriorly : the second ganglion is situated close by the first, and gives off two pairs of nerves : the third to the fifteenth ganglions send off respectively three pairs of nerves, the first of which corresponds with the inter-ganglionic nerve in the earth-worm, and supplies the branchial organs; the second pair is distributed to the ventral muscles; the third to the lateral and dorsal muscles. The abdominal ganglions, which succeed the fifteenth, send off each two pairs of nerves, and gradually diminish and approximate at the posterior extremity of the body. In this highly organised Anellides the nerves may be distributed into those of special sense (antennal), the excito-motory, the sympathetic or stomato-gastric, and the respiratory.

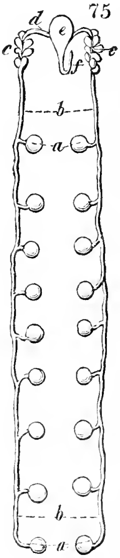
The power of repairing injuries and reproducing mutilated parts is considerable in the Anellides, and especially in the species of *Lumbricus* and *Nais*, in which it has been variously and extensively tested by the experiments of Bonnet and Spalanzani. A worm cut in two, was found to reproduce the tail at the cut end of the cephalic half, and form a new head upon the caudal moiety. Bonnet* progressively increased the number of sections in healthy individuals of a small worm (*Lumbricus variegatus*): and when one of these had been divided into twenty-six parts, almost all of them reproduced the head and tail, and became so many new and perfect individuals.

* Œuvres, vol. i. pp. 117—245. 4to. 1779.

It sometimes happened that both ends of a segment reproduced a tail. Wishing to ascertain if the vegetative power was inexhaustible, Bonnet cut off the head of one of these worms, and, as soon as the new head was completed, he repeated the act; after the eighth decapitation the unhappy subject was released by death, — the execution took effect, — the reproductive virtue had been worn out: this series of experiments occupied two summer months. Since many of the smaller kinds of worms and Naids frequently or habitually expose a part of their body, the rest being buried in the earth, both they and their enemies profit by the power of restoration of the parts which may be bitten off.

With this power of reproduction of lost extremities is associated that of spontaneous fission in the genus *Nais*. In these little red-blooded worms, the last joint of the body gradually extends and increases to the size of the rest of the animal: its anterior part begins to thicken and to be marked off by a deeper constriction from the penultimate joint. In the *Nais proboscidea* a proboscis shoots out from it, like that on the head, and it is then detached from the old Nais. It often shoots out, previously to its separation, another young one from its own last joint in a similar way, and three generations of Naids may thus be seen organically connected, and forming one compound individual. Distinct sexual organs are developed in the Nais for both the formation and fertilisation of ova: but the illustrations of the generative system in the preparations before you are derived from the leech, the earth-worm, and a few of the dorsibranchiate Anellides.

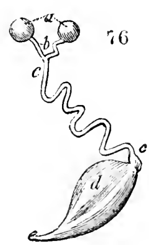
75



Leech.

The medicinal leech is androgynous, like the rest of the *Anellata;* it has nine pairs of testes (*fig.* 75, *a*, *a*), two vasa deferentia (*b*, *b*), and two sacculated vesiculæ seminales (*c*, *c*), which send their ducts to a common prostatic body (*d*), from which the penis (*e*) is continued: this filament projects from the middle of the ventral surfaces of the twenty-fourth ring, between the sixth and seventh ganglion: a distinct slender ejaculatory tube is continued along the middle of the intromittent organ. Each testis is a round whitish sac, containing a milky fluid abounding with clear spherical corpuscles: a short duct carries the secretion to the common longitudinal vas deferens. The female organs (*fig.* 76.) lie between the seventh and eighth nervous ganglia, and consist of two spherical ovaria (*a*) and two short oviducts

76



Leech.

(*b*), which unite into a single longer tortuous tube (*c*), terminating in an expanded fusiform uterus (*d*), which opens externally at the twenty-ninth segment. The ovaria contain numerous round corpuscles, in which there are several germinal vesicles; the parietes of the uterus present both longitudinal and transverse muscular fibres.

The fertile ova of the medicinal leech are discharged in groups of from six to fourteen, enveloped in a nidus or cocoon of mucus. The cocoon is ovate, two thirds of an inch in length and half an inch in diameter. It has a rough outer surface, but is smooth and slightly tuberculate within. In the month of August conical excavations may be observed in the slime at the sides of the reservoir, in each of which there is a cocoon. In a few days after the ova have been thus expelled and protected, the young leeches are extruded. The formation of the cocoon has been observed by Dr. Johnson in the rivulet leech (*Hirudo vulgaris*). In this species, when a cocoon is about to be formed, the body is observed to be greatly contracted both above and below the uterus; the included part swells, then becomes milky white, from the formation of a film into which the animal, having attached itself by its anal sucker, forces, with some effort, the whole contents of the uterus. This being done, the leech elongates the anterior part of the body, and thus loosening the enveloping membrane, withdraws its head as from a collar. It sometimes bends back its head, and, drawing the collar forwards, gently aids in its removal. The process generally occupies about twenty minutes. The cocoon is at first very elastic, and has no determinate figure. After the leech has attached it to some adjoining substance, it fashions it with its mouth into an oval form. The points of the cocoon from which the leech withdrew its head are weaker than the rest, and from these the young escape.

The earth-worm, like the leech, is androgynous: the testes are four in number, of a subglobular figure, granular texture, and opake white colour: their ducts open upon the external surface. Two other parts are to be reckoned among the accessory organs of the male sex; the first are the imperforated penes or stimulating filaments, which may be developed from the thirty-second to the thirty-eighth ring inclusive; their base adheres intimately to the cellular tissue: they have no communication with the genital apertures, are developed only at the breeding season, and are deciduous. The second accessory organ is that thickened part of an earth-worm which is situated between the thirtieth and the fortieth segments: it is called the clitellum, and when two earth-worms are disturbed, the adhering clitella are the last parts to give way. The ovaria are eight in number, arranged four on each side. The ducts of each lateral series unite to form a convoluted oviduct, which opens upon the sixteenth segment of the body. In spring the vitelline cells begin to multiply around the germinal vesicle, in the form of minute dark specks; towards autumn the ova become red coloured, and, by their increase in size and number, they render the surface of the ovarium irregular. At this season the fertilising fluid reaches the ovaria by the ducts above described, which are then filled with spermatozoa. The only function of the ducts is to afford a route or passage to these moving filaments which, like the pollen tubes in plants, attach themselves to the ova, and in such numbers as, according to the observations of Dr. A. Farre, to give the impregnated ova the appearance of a ciliated gemmule. The ova escape, like the seeds of plants from the ovaria, by dehiscence of the coats of those organs, not by passing outwards through the so-called oviducts, which are analogous to the tubes in the style of a flower, which give passage to the pollen filaments, but not an exit to the seeds. The ova, after being expelled from the ovaria, pass into the interspace between the sub-muscular membrane and the muscular integument, and, by a series of strong undulations of the body, are ultimately propelled to a receptacle near the arms. Here they undergo a certain amount of development, and are frequently expelled, like chrysalids, enveloped in a hard, yellow, pellucid, and slightly elastic integument, probably an exuvial skin. Sometimes they are expelled from the parent in this state: sometimes the young are excluded from their case before parturition.

With regard to those ciliated corpuscles already alluded to, as discovered by Dr. A. Farre, in the ovaria of the earth-worm, similar bodies have been detected by Mr. Quekett in the testes of the rivulet leech. They occur with more numerous unciliated spherical corpuscles, and appear to represent groups of spermatozoa, analogous to the bundles in which the same filaments are aggregated in the sperm sacs of the medusa.

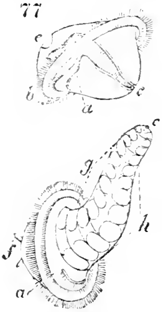
In the *Arenicola*, or sand-worm, the testes are situated in pairs at the anterior part of the body, and the ova are discharged by dehiscence of the ovaria into the abdominal cavity.

In the genus *Eunice*, every segment, save the first, has its ovarium and testes attached to either side, which reminds one of the multiplication of these organs in the *Tæniæ*. The *Aphroditæ* are stated to be of distinct sexes.

The development of the ova in the class Anellata, has been hitherto but little studied. Some of the few observations on record in reference to the dorsibranchiate order, indicate that they undergo, during their development, a metamorphosis almost as remarkable as that of insects. Dr. Loven obtained in the month of August in the Baltic

Sea, a discoid animalcule (*fig.* 77.), which rapidly moved by means of two rows of vibratile cilia: the principal row being situated upon a projecting ring (*b*), at the margin of the disc. This ciliated body differed from the gemmules of the Polypi, in being provided with a mouth (*a*) and an anus, the latter occupying the apex of the cone (*c*). The course of the alimentary canal (*d*), which extended from one to the other aperture, was detected by feeding the little animal with indigo. In a short time the cone began to elongate and to be divided into segments, which were developed in four parts, the two principal pieces forming half-rings, one upon the upper, the other upon the lower surface, which were united by two shorter lateral pieces. Coincident with the elongation and segmentation of the body, was the development of the head from the discoid surface (*e*), upon which first the black ocelli, and then two pointed filaments, or antennæ (*f*), made their appearance. The length of the body, and the number of segments, continued to increase, the disc with its vibrating cilia still existing. This disc is afterwards reduced to an appendage on each side of the head, and finally disappears. The new rings are added in front of, and not behind, the older ones, agreeably with the order of development of the segments in the *Bothriocephali*, described in a former lecture. Each ring originally consists of an upper (*g*) and an under half ring (*h*), analogous to the tergum and sternum in the external skeletons of Insects. The tubular and setigerous feet are lastly developed from the small lateral pieces. These observations beautifully exemplify the repetition of structures and phenomena, characteristic of mature animals widely separated in the natural scale, in the immature states of an intermediate species.

77



Embryo of Nereis.

LECTURE XIII.

EPIZOA AND CIRRIPEDIA.

The naturalist has often been baffled or led astray in his attempts to discover the real nature and affinities of an animal by investigations limited to the structure and habits of such animal in its mature state. There are some species which undergo such extraordinary metamorphoses before attaining that state as to mask their true relations, not only to the class, but to the primary division of animals to which they belong. This is especially the case with the creatures whose organisation and development will form the subject of the present lecture.

This elongated, cylindrical, unarticulated Lernæa* (*fig.* 78.), whose smooth soft body seems devoid of any other appendages than the two long slender ovisacs, might be regarded as one of the Entozoa of the fish to which it is attached, and on the nutrient juices of which it subsists.

87

This barnacle, imprisoned in its conical calcareous shell, and cemented to the stone on which it grew, might seem as naturally to belong, like its neighbour the limpet, to the testaceous Mollusca.

The most vivid imagination of the boldest generaliser or speculator upon the unity of organisation in the Animal Kingdom could never have divined that the Lernæa and the Cirripede were at one period of their lives locomotive animals, swimming about under very similar forms, and by almost identical natatory instruments; not under the common ciliated infusorial form, in which the young of certain Entozoa and Mollusca first enter into active life; but with symmetrical pairs of jointed setigerous legs like those of the lower organised Crustaceans, to which the *Epizoa* and *Cirripedia* are, in fact, essentially and most closely allied, although they end their career as sedentary animals under such different, such diversified, and, as regards the Epizoa, such grotesque forms.

These metamorphoses lead to very different results from those of the Medusa and Comatula. The Epizoa and Cirripedes acquire increase of bulk and organs of generation; but, in every other respect, the varied course of their development ends in a retrograde movement. This development would seem to have been at first, as it were, hurried forward at too rapid a pace, and the young parasite, starting briskly into life, ranging to and fro by the highest developed natatory organs we have yet met with, and guiding its course by visual organs, must lose its eyes and limbs before it can fulfil the destined purpose of its creation.

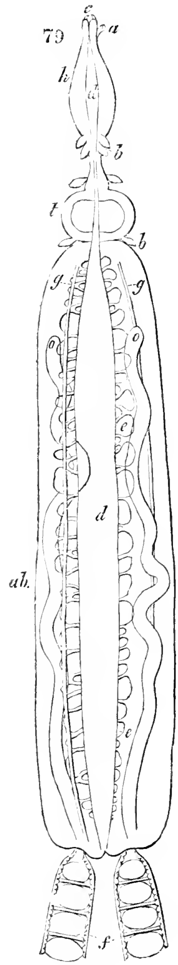
The *Epizoa*, by which name we recognise the singular class of animals which infest the skin, the eyes, and the gills of fishes and other marine animals,—these external parasites, which are as numerous as, and perhaps more numerous than, the whole class of fishes, — are

* This name was applied by Linnæus to the genus or group including the parasitic animals now termed *Epizoa*, which are classed with the Mollusca in the Systema Naturæ.

distinguished in their mature state by a body of a more or less elongated or sub-cylindrical form, defended by a smooth, semi-transparent, parchment-like integument, having a more or less distinct head, and generally a pair of long cylindrical ovisacs, dependent from the opposite extremity of the body.

In this low organised class of Articulate animals, as in the classes which commence all other great primary groups, there is an extensive gradation of forms by which we pass from species slightly elevated above the cavitary Entozoa to the true Crustaceans.

79



Peniculus.

The lowest or most simple Epizoa adhere by a suctorious mouth (*fig.* 79. *a*), and traces of extremities exist only in the form of a few minute pairs of obtuse inarticulate processes (*b b*). In the highest organised species, the adhesion is effected by jointed mandibles with terminal hooks or forceps. The head, in most of the species, is found, when closely examined, to present a pair of jointed antennæ (*fig.* 81. *e*), which, in the experienced naturalist, cognisant of the value of such characters, might excite the suspicion that relations to higher *Articulata* than the Anellides were hidden under the bloated form which indolent and gluttonous habits had superinduced upon the pendent parasite. Observation of it during its early and independent state has proved this to be actually the case to an extent which could scarcely have been anticipated.

The Epizoa are of distinct sexes: the male (*fig.* 82.) appears always to retain his freedom, and is, perhaps on that account, singularly smaller than the female, generally not more than a fifth part of her size; consequently, for a long time, the males escaped recognition. They adhere to the vulva with one antenna usually inserted. The individuals of the productive sex, distinguished throughout a great part of the year by their pendent ovisacs, are the examples usually seen of this curious class; and in these I shall proceed to describe the anatomical characters of the Epizoa.

The body, independently of the ovisacs, is generally divided into two segments: the anterior and smaller division sometimes supports a distinct head, but more commonly corresponds with the cephalothorax of the Crustacea; the larger segment is called the abdomen, and in it the ovaria are developed. You will not unfrequently find adhering to the eye of the sprat an Epizoon or Lernæa *, which is a nearly allied species of the same genus (*Peniculus*), as the specimen figured and described by Nordman (*fig.* 78.), which infests the boar-fish (*Zeus aper*). In the *Peniculus fistula* the head (*fig.* 79, *h*) is oval, and notched anteriorly, each division being armed with an inwardly bent hook, or rudimental jaw. The mouth (*a*) is immediately beneath these, in the form of a circular orifice, supported by a short cartilaginous tube. At the posterior contracted part of the head are two pairs of short, oval, flattened processes: a constriction or neck separates them from the thorax (*t*), at the commencement of which there is a third pair of similar rudiments of locomotive appendages. The thorax is round, and separated by a constriction from the abdomen (*ab*), a fourth pair of appendages being developed from the interspace. The alimentary canal (*d*, *d*) is much contracted in the neck and thorax, but expands in the abdomen into a moderately wide and uniform intestine, which again slightly contracts to terminate at the hinder extremity. The alimentary canal has the same simple straight course in other species of Epizoa. One cannot be surprised at this correspondence with its general condition in the cavitary Entozoa, when the similarity of their easily assimilable nutriment is remembered. It is, however, complicated in the Epizoa, with a conglomerate or minutely-lobed glandular mass, developed from nearly the whole extent of the abdominal tract of the intestine, and which may fulfil the function of a liver.

In some species which attach themselves to the gills and the like favourable positions for an abundant supply of the most nutritious fluid, the body is frequently deformed, as it were, by excessive growth, and cæcal productions from the simple straight intestine are continued into the prolongations of the thoracic or abdominal walls. The Nicothoë †, a small parasite of the gills of the lobster, is an example of this condition of the digestive organ. The first segment of the body is produced into two lateral symmetrical wing-shaped lobes, each four times the length of the segment to which they are attached, and they contain corresponding cæcal prolongations of the straight intestine.

In the species of Lernæa exhibited (*Peniculus fistula*), the abdomen contains, in addition to the alimentary canal, two slender tubes (*o*, *o*), commencing by blind extremities near the anterior part of the dilated intestine, and continuing with a slightly wavy course to terminate at the two apertures, to which the ovisacs (*f*) are attached.

* No. 287. A.

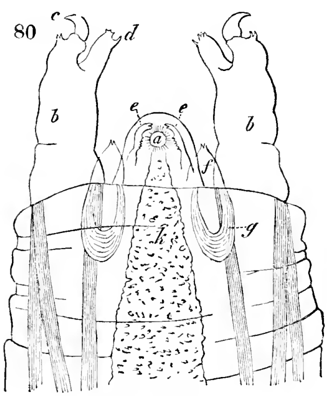
† Audouin and Edwards, *Crustacées*, 1829, 8vo. p. 1.

These ovisacs singularly resemble the seed-capsules of certain plants, especially the *Cassia fistula*, being divided into a series of cells or chambers by transverse septa, placed at regular distances. Each cell contains an elliptical or lenticular ovum.

Two slender white filaments (*g*, *g*) running almost parallel with, but at a distance from, each other, through the whole length of the under surface of the abdomen, nearer the margins than the middle line, form the chief and most conspicuous part of the nervous system.

The most common mechanism of adhesion in the Epizoa is a circular sucker, developed upon the confluent extremities of a pair of obscurely jointed tubular feet, as in this *Lerneopoda* of the Shark *, in the *Achtheres* of the Perch (*fig.* 81.), the *Tracheliastes* of the Chub, &c. In the last-named parasite, which may be found adhering to the fins of the Chub in the months of October and November, the head and thorax are confluent, unless the segment to which the bases of the before-mentioned feet are attached be held to represent the thorax. The abdomen is, as usual, the largest segment. The mouth (*fig.* 80. *a*) is a circular aperture, fringed with minute short bristles; on each side there is a maxilla (*e*) dentated at the inner margin, and terminated by a bifid hook. The antennæ (*f*) are represented by two short lancet-shaped processes terminated at the apex by a few extremely short bristles. The most conspicuous appendages of the head are, however, a pair of mandibles (*b*), which consist of two obscure joints, the second of which has a bifid extremity; the outer division (*c*) is armed by a strong curved spine, which is opposed to two short straight spines; the inner division (*d*) is tipped with four small spines. Immediately behind the large tubular prehensile process is a short rudimental extremity, supporting a moveable hook, which is opposed, as in the mandibles, by two short spines. The muscular system is sufficiently conspicuous in the head of this Epizoon in the form of distinct fasciculi of fine fibres (*g*.)

80



Tracheliastes.

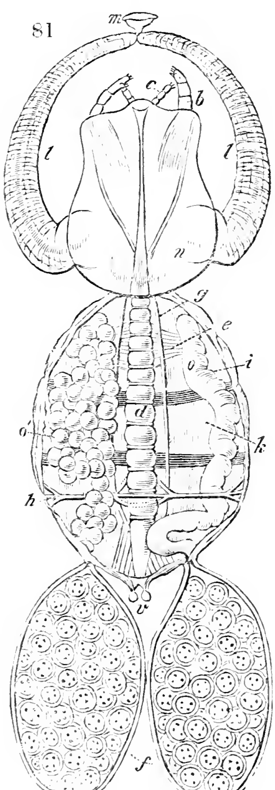
In this *Penella* † the head resembles a cauliflower, swelling out into a globose group of slightly branched and obtuse wart-like processes,

* No. 286. A. † No. 286.

which must have grown after the head had become imbedded in the flesh of the fish to which it is attached. Two long tubular processes or extremities are developed at the junction of the thorax with the abdomen; but their extremities are free, simple, slightly attenuated, and obtuse. On the under surface of the body in the interspaces of these appendages there are four pairs of simple, small, oval, flattened feet; their pointed extremities extend only half way to the sides of the part of the body to which they are attached. The body is prolonged beyond the ovisacs in the form of a tail, which is provided on each side with a series of sixteen slender cylindrical appendages, close set in an oblique position, like the barbs of a feather, or the vane of an arrow, whence the specific name *Sagitta*, given to this parasite. The caudal lamellæ of the higher Crustacea would seem to be here sketched out.

The anatomy of the Epizoa has been most elaborately traced out by Nordmann in the parasite of the common perch, called *Achtheres*. In this species two lateral teeth project from the circular mouth, the labial margin of which is fringed with bristles. Here also we have mandibles and maxillæ, the latter provided with palpi; and besides these, a pair of jointed antennæ (*fig.* 81. *a*), each terminated by three setæ. The hepatic organ (*e*) is more concentrated than in the *Peniculus*, and surrounds the anterior part of the canal. The alimentary canal is, as usual, straight, and terminated by a bituberculate vent at the opposite extremity to the head. The abdominal intestine (*d*) is fusiform, and, divided by a series of slight constrictions, into sacculi. It is maintained in its position by a transverse muscle (*h*). The walls of the abdomen are distinctly provided with longitudinal (*i*) and transverse (*k*) fasciculi of muscular fibres. The nervous system consists of a single cephalic ganglion, from which are continued two principal chords (*g g*) extending along the under surface of the body.

81



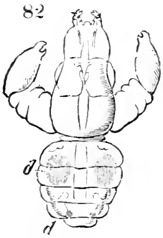
Achtheres, female, magnified.

The circulating fluid consists of a clear plasma, with granular corpuscles of different forms and sizes. The pulsatile vasiform heart may be seen at the middle line of the cephalo-thorax propelling the blood forwards by rythmical contractions. Two canals (*n*, *n*) pass from it into the hollow prehensile feet. The rest of the blood is distributed to the head, and along each side of the commencement of the alimentary canal to the under part of the body, where it passes backwards in the vessel which accompanies the intestine.

The ovaria (*o*, *o′*) at first appear in the form of a slightly flexuous, long, blind tubes, sacculated along one side. As the ova are developed, the ovarium takes on the form of a bunch of grapes, and occupies the whole cavity of the abdomen external to the intestine: each ovarium terminates by a triangular, and somewhat prominent orifice, to which the external ovisac (*f*) is appended.

In the minute male (*fig.* 82.), the testes are indicated by four dark-coloured and finely granulated bodies situated in the posterior segment or abdomen.

82



Achtheres, male, magnified.

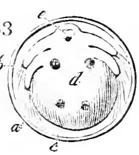
The first remarkable circumstance in the natural history of the aquatic Epizoa is the constancy with which particular species infest particular fishes or crustacea. And how, it may be asked, can creatures so devoid of means of transport, nay, in most instances, of the power of detaching themselves from the animals whence, like fœtuses, they derive their means of growth, originally reach the precise species of animal and organ to which they are habitually attached?

Are certain of the ova accidently retained near the parent after the rupture of the ovisac, and there grow, like seeds of plants fallen in a favourable soil? Or, do some of the liberated ova, by a happy fortuity, arrive at the appropriate organ of the appropriate species, and are they there accidentally retained until the prehensile instruments are developed? Such hypotheses may be permitted in reference to the ova of an Entozoon which are developed by millions, and need only to be swallowed by the animal in whose intestine they are adapted to exist, but the ova are too few in the Epizoa, and the parts to which they are attached are too exposed, to allow of the supposition that their parasitic growth is dependent on such accidental circumstances. M. M. Audouin and Edwards appear to have been the first to suggest that the sedentary Lernæan Epizoa might enjoy at a previous period of existence locomotive powers, and the hypothesis was supported by the discovery, made by Dr. Surriray, of the embryo of a *Lernæocera*, still in the ovum, which, instead of resembling the parent, presented the characters of a locomotive Entomostracous monoculous Crustacean.

The singular metamorphosis thus indicated has been traced out and generalised by the careful observations of Dr. Nordmann. The following is the general course of development of the Lernæan parasite of the Perch.

The female Achtheres is devoid of ovigerous appendages in the months of December, January, and February. In March they are developed by the eversion of a membrane prepared in the ovarian sac. Each sac hangs by a short tubular peduncle which is in direct communication with the short oviduct. The outer membrane of the ovum or chorion is moderately thick and transparent; the inner membrane is thinner, and includes both the vitelline mass and albumen. The yoke forms the largest proportion of the contents of the ovum, and is finely granular. One of the first parts of the embryo discerned by Nordmann was the dark ocellus (*fig.* 83. *a*). A pair of cylindrical processes shoot out from each side of the fore part of the embryonic or vitelline mass; and a pencil of hairs is developed from the extremity of each process. The body slightly elongates; the exterior albuminous fluid inceases, the inner membrane expands, and the outer one bursts and is shed. The movements of the imprisoned embryo increase in force until it bursts the remaining membrane of the ovum and escapes from the ovigerous sac. It then presents the form represented in figure 84.; the digestive sac (*h*) is now discernible, together with a peculiar tortuous tube (*g*), which is continued from the eye-speck. In the course of half an hour the young *Achtheres* undergoes its second stage: the first integument is loosened by the formation of a second beneath it, which now incloses a body, altered in its shape and in the number and nature of its appendages.

83



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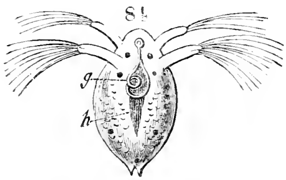

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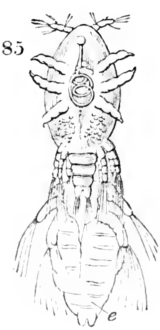


The process of moulting lasts from eight to ten minutes. The body (*fig.* 85.) is divided into an anterior and a posterior segment, the latter consisting of four joints. A pair of four-articulate setigerous antennæ diverge from the anterior part of the body. Between the antennæ is the large single median eye, as in the monocular Entomostracous Crustacea. The little Epizoon is now provided with five pairs of feet, the first three pairs terminate by a simple hook; the last two pairs are bifurcated, one division being hooked and prehensile, the other tubular and emitting tufts of bristles: these natatory feet strike the water together, and propel the body forward with a jerk: they are aided by the last segment, which is terminated by four setigerous tubercles.

The antennæ probably serve to indicate to the young parasite its appropriate object, to which it then proceeds to attach itself. The second pair of feet increases in size, and the terminal hook enlarges: the feet of the third pair lengthen and unite together to form a cartilaginous circular sucker. The first pair of feet is approximated towards the mouth, and forms the uncinated mandibles.

The two sexes are alike in their young and locomotive state: the male at its final metamorphosis retains the first pair of feet as mandibles, very similar in form to those in the female: the second pair is shorter and thicker: the legs of the third pair always remain separate from each other, and consists usually each of two large joints, the last one terminated by a claw. The posterior natatory feet disappear in both sexes.

Cirripedia.

Many of the *Cirripedia* are parasitic animals, like the *Epizoa*, but are dependant upon the organised bodies to which they are attached for their place of residence, not for their food: those species which do not infest other animals are attached to sea-weed, floating timber, or rocks. The Cirripedes are symmetrical animals, with a soft unarticulated body enveloped in a membrane: they are provided with six pairs of rudimentary feet, obscurely divided into three joints, and terminated each by a pair of long and slender many-jointed, ciliated tentacles, curled towards the mouth, and thence giving origin to the name of the class.

The mouth is provided with a broad upper lip, with two palps or feelers, and three pairs of dentated and ciliated jaws. The opposite extremity of the body is prolonged into a slender many-jointed ciliated caudal appendage, which is traversed by the generative canal. The mouth is situated near the anterior extremity of the body, which is modified to form the organ of attachment of the animal. It is sometimes produced to a considerable extent, and is of contracted diameter, forming a long and flexible peduncle; sometimes it expands at once into a broad disc or basis of adhesion. The Cirripedes are divided according to these modes of attachment into two primary groups, — viz. the pedunculated, or *Lepadoids*, and the sessile, or *Balanoids*. The first are commonly known by the name of Barnacles; the second by that of Acorn-shells.

Most of the Cirripedes have their visceral cavity protected by a calcareous shell composed of many pieces; but in some, as the *Otion*, the membranous or pallial investment of the viscera is protected only by an elastic horny sheath, continued from the epidermal covering of the peduncle. Two small calcareous bodies, developed in the substance of the outer envelope, just above the brachial fissure, are the sole rudiments of a shell in this genus, the horny covering of which is produced at its free extremity into two cylindrical processes. In the genus *Cineras*, the external tunic is strengthened by five calcareous bars, two at the ventral fissure, giving outlet to the arms, two along the terminal margin of the tunic, and one along the dorsal aspect. In the common Barnacle (*Lepas anatifera*) the calcareous matter extends from fine centres, so as to protect the whole of the body, which is appended to the peduncle: the cephalic pair of valves, or that which is attached to the peduncle and defends the head, is the largest: the single dorsal piece has been compared by Cuvier, who retained the Cirripedes among the Mollusca, with the symmetrical dorsal valve in the shell of the Pholas. All the valves are strongly marked with lines of growth, formed by successive additions to their margins, as in the shells of Mollusca. In the Pollicipes there are other smaller calcareous plates arranged round the junction of the body with the peduncle.

All the sessile Cirripedes are strongly defended by a multivalve conical shell. The base of the shell is usually formed by a calcareous plate, and the walls are apparently divided into twelve conical compartments, six of which rise from the margin of the base, and terminate in a point at the free margin of the shell; whilst the other six, in the form of inverted cones, occupy the interspaces of the preceding series. This calcareous citadel is divided into six pieces by six sutures: the symmetry or bilaterality of the shell is determined by the dorsal piece being actually what each of the six pieces of the first series seem to be, viz. a simple triangular plate with its apex upwards: the two lateral pieces on each side consist each of the erect and inverted triangular piece closely united together: the ventral piece consists of one erect and two inverted triangular pieces, united inseparably in the mature Balanus. The whole shell has a cellular and organised texture, and its gradual expansion is provided for by the successive growth and calcification of processes of the mantle which penetrate the uniting sutures. The cone is lengthened and widened below by successive additions to its base, and is widened superiorly by the gradual increase in breadth of the wedge-shaped pieces of the second, or inverted series. In the *Tubicinella* *, a parasitic

* Prep. No. 279.

Balanoid of the whale, the compound shell is long, subcylindrical, and wider above than below. The upper aperture is closed by an operculum of two or more shelly plates.

The animal in both sessile and pedunculate Cirripedes, is fixed to the bottom of the shell with its head downwards. The head is therefore superior in the ordinary pendant position of the Barnacle.

The movements of the peduncle in such species are effected by a strong muscular tunic, as shown in these preparations.* The action of these muscles is antagonised by the elasticity of the external horny tunic. The common Barnacle approximates its large pair of valves by a strong transverse adductor muscle; the body or visceral mass of the Barnacle is moved towards the aperture of the shell, which is thereby at the same time widened by longitudinal muscular fibres, and is retracted by shorter fibres attached to its base. The cirrigerous arms have powerful muscles for their actions, which are of the utmost importance to the animal, inasmuch as the food is obtained by the currents which they produce, and almost incessantly maintain, in the surrounding water. The sessile Barnacles are provided with a series of muscles attached to the margin of the conical shell, which act on the opercular calcareous pieces, and close the opening of the shell.

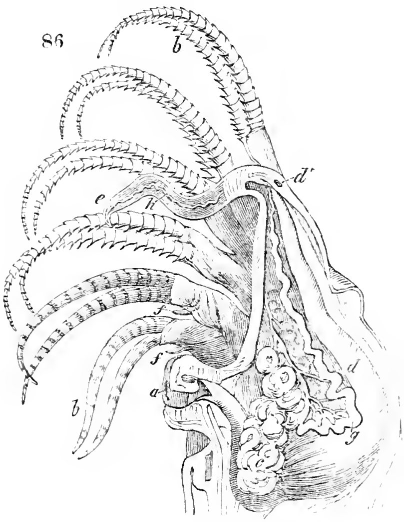
The nervous system, as shown in this dissection of the *Lepas vitrea* by Mr. Goadby, corresponds with that which has been described and figured by Cuvier in the common *Lepas anatifera*. The œsophagus is surrounded by a wide oval ring, at the sides of which are placed the small ganglions, which supply the first pair of feet. The ring is completed below by the ganglions of the second pair of feet. The fifth and sixth pairs of ganglions are approximated to each other: there is no cerebral ganglion; but filaments are given off from the supra-œsophageal loop, to the peduncle and sides of the head: two of these branches pass to a small ganglion on either side near the stomach, from which the digestive system is supplied: the tubular extensile tail receives the two last pairs of nerves. The nervous system is perhaps the only part of the organisation of the mature animal which unequivocally indicates the relations of the *Cirripedia* to the primary divisions of the Animal Kingdom; it is homogangliate: inferior to that of the Anellides in the low development of the cerebral or supra-œsophageal part, but nearer the crustaceous type in the large size of the ganglions on the abdominal chords. In the degree of approximation of the two chords to each other, the *Lepades* most resemble the lower isopodous Crustacea, for example, the Talitrus. The neurilemma is stained by a dark brown pigment in the *Lepas vitrea.*

* Nos. 62. 68, 69.

Although the Cirripedes in their mature state possess no distinct organs of sight or hearing, yet they are endowed with sufficiently acute sensation to retract their cirri, and, if sessile, to close their opercules, at the sound or vibration of an approaching footstep; the same actions indicate that they appreciate the atmospheric movements produced by the approximation of the hand, even, according to Dr. Coldstream, when it is not brought nearer the shells than twelve or fourteen inches.

The marine animalcules brought to the mouth (*fig.* 86. *a*), by the currents of the cirrigerous feet (*b*) and seized by the lateral jaws, are conveyed by a short œsophagus to a dilated stomach (*c*), which receives the ducts of two salivary glands. Groups of hepatic cæca are developed from the walls of the stomach. The intestine (*d*') is bent upon the stomach, and tapers with a slightly sinuous course to terminate at (*d*) the base of the caudal appendage (*e*). According to M. St. Ange, the intestinal canal of the *Lepas* contains a membranous tube, which is continued above into the secerning cells in the walls of the stomach; it may be the detached epethelium; it has been deemed analogous to the typhlosole in the earth-worm's intestine.

86



Lepas.

A dorsal vessel and circulating currents along a double canal in the arms have been recognised; but the circulating system has not been thoroughly investigated. In the pedunculated Cirripedes slender conical branchiæ (*f*) are attached to the base of the maxillary foot, and to that of some of the cirrigerous feet. The ordinal distinction between the pedunculated and sessile Cirripedes is not less strongly manifested by their outward forms than by the branchial organs, which, in the Balanoids, consist of two or more broad, transversely plicated, vascular membranes, attached to the inner surface of the mantle.

The organs of generation in the Cirripedes have been differently described by different authors. If the Cirripede be diœcious, and the males be free and of a disproportionately minute size, as in the Epizoa and in most Entomostraca, to which the Cirripedes are closely allied, we must then regard the organs of generation in the large attached individuals under a different and more simple point of view than they have hitherto been described. The males are, however, wholly hypothetical: they have not, hitherto, been seen, or at least recognised, as such. In the pedunculated Cirripede, a large granular, glandular mass, covers the viscera immediately beneath the muscular tunic of the body, extending from the mouth to the anus. Its numerous ducts successively unite into three or four principal trunks, which terminate in a lateral receptacle (*g*) at the side of the intestine. In *Lepas* a duct is continued from this receptacle on each side, which ducts unite to form a common tube (*h*), which passes through the canal of the extensile tail. In *Otion* the two canals are continued distinct to the extremity of the process. The walls of the receptacle, which is the common termination of the ducts of the lateral glandular body, are thick and glandular.

According to Cuvier and Dr. Burmeister these glandular parietes of the ducts of the gland constitute the testis, and the glandular mass itself is the ovary. The ova are impregnated in the course of their passage through the common receptacle, and the duct continued from it.

On the diœcious hypothesis, we must suppose that the large fixed individuals are females; that the ovarium exists under the form and situation in which it is described by Cuvier; and that the supposed testis, which makes its appearance in a very questionable form as a glandular tunic of the oviduct, is actually a nidimental gland, and adds an exterior covering to the essential part of the ovum.

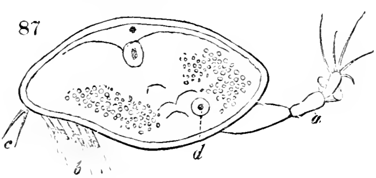
But ova are certainly developed in the pulpy substance of the peduncle. These, however, in Cuvier's view of the organs, are supposed to be impregnated ova, conveyed by the extensile tail or ovipositor into the cellular texture of the peduncle. On the diœcious hypothesis the ova of the peduncle must also be supposed to be conveyed by the ovipositor from the lateral ovaria, but to be impregnated by the males *in transitu*.

Another explanation of the parts in question has been offered, on the assumption that both sexes are combined in the same individual: the part described by Cuvier as the ovarium is held to be the testis; the dilated canal into which its ducts converge is a spermatic receptacle; its glandular walls a prostatic organ; and the terminal flexible and extensile tube (*fig.* 86. *e*), the penis. The true ovarium is situated in the peduncle, to the soft tissue of which the ova unquestionably adhere when first developed. It is here that they acquire the azure or violet-coloured yolk; and from this part they subsequently pass into two leaf-shaped receptacles, placed one on each side, between the body of the animal and the lining membrane of the shell. The ova are doubtless impregnated in attaining this situation: here they increase in size, and change their colour to pink and then to white: the embryos are here developed, and, after their escape, all traces of the temporary receptacles disappear. This view of the generative organs seems to be the true one, provided the Cirripedes be androgynous.

When we reflect on the uniformity of distribution of the Cirripedes, particular species being attached to particular objects, and these not always stationary and extended bodies, but often living animals, and sometimes animals with quick powers of locomotion; when we further call to mind that they adhere, not by prehensile jaws or feet, but by the growth of a pedunculated root, or by the gradual application of a layer of cement forming the base of their shell, we must be convinced, that the organization and properties of the sedentary Cirripede are wholly inadequate to afford an insight into the process by which it acquired its resting place, and, that a knowledge of its previous career from the time of quitting the egg is not less essential to an explanation of the subsequent attachment of the *Cirripedia*, than it was for the elucidation of corresponding phenomena in the *Epizoa*.

No fortuitous dispersion of ova giving origin at once to a pedunculated or sessile multivalve can account for the invariable attachment of the *Coronula* to the skin of the whale, and of the *Otion* to the shell of the parasitic *Coronula*; of the *Chelonobia* to the carapace of the turtle, of the *Cineras* to the tail of the sea-serpent, or of the imbedding of the *Acasta* in the substance of a sponge. These remarkable phenomena have been explicable only since the discovery of the singular metamorphoses which the Cirripedes undergo, and of the power which they possess at one period of their existence of attaining and selecting their peculiar and appropriate place of permanent abode. Nor were the real nature and affinites of this singular shell-covered class of animals less problematical and doubtful before the phenomena of their development had been traced out.

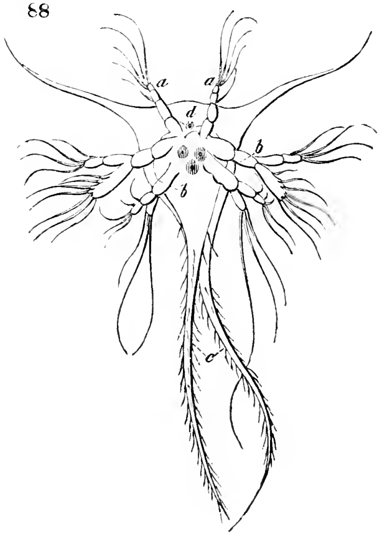
87



Young of Balanus.

Mr. V. Thompson, whose minute and careful researches into the natural history of marine animalcules have thrown so much light on the structure and development of radiated animals, was also rewarded by the discovery of the metamorphosis of the Cirripedes. On the 28th April, 1823, he captured, with a small muslin towing net, a number of translucent animalcules (*fig.* 87.), about the tenth of an inch in length, of a sub-elliptic form, slightly compressed, and of a brownish tint: the body of each was defended by a shell composed of two valves, joined by a hinge along the back, and opening along the opposite margin for the protrusion of a large and strong anterior pair of limbs (*a*), provided with an adhesive sucker and hooks, and of six pairs of posterior jointed members (*b*), terminated by a pencil of bristles. These natatory limbs acted in concert, so as to cause the animal to swim by a succession of bounds like the water-fleas (*Daphnia*). The body was terminated by a short tail (*c*), composed of two setigerous joints. A pair of pedunculated compound eyes (*d*) was attached to the anterior and lateral part of the body. Other specimens of this little seeming crustaceous animal were taken on the first of May and preserved alive in a glass vessel of sea-water. On the night of the eighth two of them had thrown off their outer skin, and were firmly adhering to the bottom of the vessel, where they rapidly assumed the form of the young of the sessile Barnacle called *Balanus pusillus*. The sutures between the valves of the shell and of the operculum were visible, and the arms, though not yet perfectly developed, were seen moving within. The eyes also were still perceptible, although the principal part of the black colouring matter appeared to have been thrown off with the exuvium. On the tenth of May another individual was seen in the act of throwing off its exuvium and attaching itself to the bottom of the glass. As the calcification of the shell proceeds, the eyes gradually disappear and the visual ray is extinguished for the remainder of the animal's life. The arms at the same time acquire their usual ciliated structure.

88



Young Lepas.

The *Lepas*, in its transitory locomotive stage (*fig.* 88.), does not, like the young *Balani*, resemble the bivalve *Ostracoda*, but rather approximates to the genus *Cyclops*.* It has a single median sessile eye-speck (*d*); three pairs of members, the most anterior of which (*a*, *a*,) are simple, the others (*b*, *b*,)

* See Mr. Thompson's Memoir, Philos. Trans. 1835.

bifid. The back of the animal is covered, like the *Argulus armiger*, by an ample shield, terminating anteriorly in two extended horns, and posteriorly in a simple elongated spinous process (*c*).

The discoveries of Mr. Thompson have been confirmed by Audouin, Wägner, and Burmeister. The latter entomologist divides the development of the Cirripedes into five stages. The first is that of the ovum, the second of the locomotive embryo, the third when the young attaches itself and becomes encased in a shell, in the fourth stage it gradually assumes the character of the adult, and the fifth stage is that of perfect development.

The locomotive embryo is developed before the ovum quits the parent: the shell, in the first stage of its growth, is coriaceous, and formed of one piece, which is placed on the back. The organs by which the young animal fixes itself are the long antennæ, or setigerous legs, situated near the mouth: in the *Lepas anatifera* the peduncle is formed by a sac-shaped process of the mantle filled with yellowish matter.

The general course of this metamorphosis, and the enjoyment of locomotive and visual organs for a brief period, which are wholly denied to the full-grown animal, characterize a condition which is closely analogous to that of the young in the Epizoa, in the Trematoda, and, with the exception of the visual organ, to the metamorphosis of the sessile Polypes.

LECTURE XIV.

CRUSTACEA.

In the part of the Animal Kingdom which we have hitherto surveyed, we have seen the organs of the vegetative functions rapidly acquiring high and complex conditions, and again sinking to a primitive and simple type. The digestive canal may present an œsophagus, a gizzard, a glandular stomach, and an intestine in a polype, and then be reduced to a radiated sac, with one aperture in the star-fish. The development of the organs for the propagation of the species is subject to a like oscillation; the diœcious condition is early acquired, and all the accessories to the essential glands, even marsupial sacs; but the generative system again subsides to an androgynous combination of simple ovaria and testes in the red-blooded worms.

The organs of the animal functions manifest a steadier and more constant progress, although it be slow and gradual. We have seen the external skeleton assuming a symmetrical and jointed structure in the Anellides, although consisting as yet only of a simple series of rings: we have seen it provided with jointed organs of locomotion and exploration in the Epizoa; though here, indeed, the advance was but transitory, and both organs and faculty of spontaneous motion were quickly lost. In the Cirripedes, jointed appendages to the body are retained, but their rapid actions are subservient to the acquisition of food, not to locomotion.

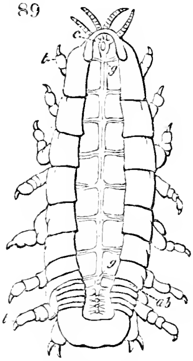
We now arrive at a class of articulated animals in which the annular segments of the skeleton of the body are constantly provided with articulated limbs or appendages; in which all the species are free and locomotive, and are provided with distinct respiratory organs. These animals are still, however, aquatic; only a part of the class can support themselves and move with their jointed limbs on dry land; the highest act of locomotion is that of climbing reeds or trees, which a few species of the present class are enabled to effect by long prehensile claws. But the breathing organs in all the species are organised for aquatic respiration; in other words, are branchiæ; and it is the combination of branchiæ with jointed limbs and distinct sexes which constitute the essential characters of the class *Crustacea.*

The name of this class refers to the modification of the external tegument by which it acquires due hardness for protecting the rock-dwelling marine species from the concussion of the surrounding elements, from the attacks of enemies, and likewise for forming the levers and points of resistance in the act of supporting the body, and moving along the firm ground. In the crab and lobster tribes the external layer of the integument is hardened by the addition of earthy particles consisting of the carbonate, with a small proportion of the phosphate of lime. This crust is coloured by a pigmental substance, diffused more or less irregularly through it; and it is formed upon and from a vascular organised membrane, or corium, which is lined by the smooth serous membrane of the visceral cavities. In the smaller Crustacea the tegument retains a flexible, horny, or pergameneous texture.

Whatever be the consistence of the external integument or skeleton, it is always disposed in a series of segments, either actually separate and moveable on each other, or confluent in a variable extent and degree, so as more or less to obliterate the traces of their primitive distinctness. The results of very laborious and extensive study and comparisons of the modifications of the external crust of the diversified forms of the present class have been generalised with much success by Dr. M. Edwards, who has shown that most of the Crustacea manifest their peculiarly distinctive forms by different combinations and proportions of the same number of primary rings or segments. Each ring, again, consists of certain elementary parts, which, by varying their proportions, contribute to the peculiar form of the region of the body, into the formation of which they enter.

There may be distinguished in the annular segment of a Crustacean, a dorsal arch and a sternal arch, each consisting of a median and two lateral elements: the lateral elements in the upper arch are called "epimeral," and in the lower one "episternal," pieces; the middle element above, or "tergum," consists of two pieces united in the middle line, and that below, or the "sternum," has the same structure. In a great proportion of the class the body consists of twenty-one of these rings, of which seven are more or less blended together to form the head (*fig.* 89, *c*), seven more obviously enter into the formation of the thorax (*g*, *g*), and the remaining seven constitute the abdomen or tail (*a b*).

89



Cymothoa.

The Crustacea, with seven thoracic and seven abdominal segments, form the sub-class *Malacostraca;* but a few large species and a very great proportion of the smallest members of the class have the thorax and the abdomen composed respectively of a greater or a less number of constituent segments than seven: these Crustacea form the class *Entomostraca*, which is subdivided into the *Xiphosura*, in which the last segment of the body forms a long three-edged sharp-pointed weapon, and into the *Entomostraca* proper.

The Xiphosura, typified by the *Limulus* or Molucca crab, have the head and thorax more completely blended together than in the true crabs, which they resemble in the general form of the body; but they are peculiarly distinguished from all other Crustacea by having the office of jaws performed by the first joint of the thoracic legs, which surround the mouth. The large cephalo-thoracic segment is protected above and laterally by an expanded semilunar shield, obscurely divided by two longitudinal impressions into three lobes, supporting the organs of vision on their highest part. The tergal parts of the segments of the second division of the body are also blended into one trilobate clypeiform piece, their original separation being indicated by the branchial fissures, and the number of the segments by that of the lamelliform appendages attached to their inferior surface. The termination of the intestine beneath the last segment of the second division of the body of the Limulus proves that division to answer to the abdomen in the Malacostraca: but, admitting the sessile eyes to indicate a distinct segment, not more than sixteen segments can be determined by the appendages to enter into the composition of the entire crust of the Limulus, including the sword-shaped appendage, which is analogous to the last or post-anal segment of the higher Crustacea, and consists of a single modified segment.

In the small Entomostraca, the number of the thoracic and abdominal segments generally exceeds that in the Malacostraca. The *Branchipus stagnalis*, for example, has eleven thoracic segments, and nine abdominal or caudal rings, besides a distinct head protected by a cephalic shield. In the *Isaura*, in which this shield is developed, as in the *Cypris*, *Daphnia*, and other Entomostraca, to the extent, and in the form, of a bivalve shell, enveloping the whole body, the number of thoracic and abdominal segments exceeds twenty-four.

The distinction between the Entomostraca and Malacostraca in the number of the segments of the body is of the first importance in determining the affinities of the ancient extinct Crustacea, called Trilobites. These remarkable animals were almost the sole representatives of the present class in the periods which intervened between the deposition of the earliest fossiliferous strata to the end of the coal formation.* They appear to have been without antennæ and feet; the structure of the tergal part only of their body-segments is yet known; but these are grouped together to form a distinct head, thorax, and abdomen or tail. The head is formed by a large semicircular or crescent-shaped shield; the thorax consists of from ten to fifteen segments; and the abdomen or tail includes at least eight segments in this *Calymene* †, in which it is bent under the thorax, as in the crab: the abdomen, post-abdomen or tail, as the third segment is variously termed, contains fifteen fettered segments in the *Asaphus caudatus*: the segments of both thorax and abdomen are very similar to each other, and gradually decrease in size. They are divided by two longitudinal furrows into three lobes. The head supports a pair of large compound eyes situated near the sides, like the large outer pair of eyes in the *Limulus*, which they resemble in form and structure.

The Malacostraca are divided into two groups, according to the attachment of the eyes: those with immoveable sessile eyes form the *Edriophthalma*, those with moveable pedunculated eyes the *Podophthalma*.

The lower organised or edriophthalmous forms of malacostracous Crustacea resemble the Trilobites in the non-confluence and uniformity

* Buckland, Bridgwater Treatise, i. p. 390.

† Prep. No. 208.

of the segments of the thorax, and abdomen. Certain genera, as *Serolis* and *Bopyrus*, have the tergal arcs of the segments trilobed; but they exceed not the characteristic number in the Malacostraca, and the seven rings of the thorax are clearly indicated in each by the seven pairs of articulated feet which they support, although these are very small in the parasitic *Bopyrus*. In the *Cymothoa* (*fig.* 89.) the seven thoracic and seven abdominal segments are more distinctly characterised.

The seven segments of the head are rather indicated by the appendages of that part than demonstrable in any of the Crustacea. The Stomapoda afford, in the genus *Squilla*, the most favourable examples for studying the conformation of the head. The first segment supports the pedunculated eyes: the second the smaller antennæ: the third and fourth segments are confluent, but indicated by the larger pair of antennæ and a pair of mandibles; the tergal part of these confluent segments is greatly developed, and extends over the rest of the head and part of the thorax. Three other pairs of jaws indicate the rest of the seven cephalic segments; and these are succeeded by the seven thoracic rings and their articulated appendages. Of these the first two pairs, which are organised for locomotion in the isopods and amphipods, are now modified to serve as jaws; and the remaining five pairs are reserved for locomotion in all the podophthalmous Crustacea. The first of these five ambulatory thoracic legs is commonly the largest, and didactyle. They all consist of six joints, and have usually two appendages attached to their base, called the palp and flagellum: analogous appendages are attached to most of the thoracic and cephalic articulated appendages, which subserve as jaws.

The tergal arc of the third and fourth cephalic segments extends over all the thoracic segments in the macrourous and brachyurous Crustacea, and constitutes the broad carapace in the crab. In most Macroura the thoracic shield is formed of the lateral or epimeral elements of the fourth cephalic ring, which meet along the back, and give way preparatory to the moult. The tergal elements of the thoracic rings are not developed in either crabs or lobsters; when these rings are exposed by lifting up the cephalo-thoracic shield, the epimeral parts alone are seen converging obliquely towards one another but not joined at their apices. The thoracic legs, besides serving for mastication, prehension, and locomotion, usually support more or less of the branchial apparatus, and certain pairs are perforated by the generative ducts, except in certain crabs, in which the sternal arc, which is of unusual breadth, supports the generative outlets.

The external arcs of the thoracic segments send inwards certain processes, called apodemata, which include spaces for protecting the abdominal nervous chords and the branchiæ, and give origin to the muscles of the legs.

The seven abdominal segments are always united by flexible joints, and have no apodemata. In those Crustacea in which the thorax and its cephalic shield are small, the abdomen is long, and characterizes the great tribe of Podophthalma called *Macroura;* in those in which the thorax and its shield are greatly expanded, the abdomen is very short, as in the crabs, or the tribe hence called *Brachyura;* this alternating excess and arrest of development of the opposite divisions of the trunk well illustrate the law of organic equivalents.

The appendages of the abdominal segments are developed, like those of the thoracic ones, from the inferior arcs: they are usually broad, flat, ciliated plates, which may sometimes aid in respiration, are more commonly organs for swimming, form a temporary place of attachment and protection to the ova, and are restricted to this use in the females of the Brachyura, in which the abdomen or tail is concealed by being bent forwards upon the sternum. In the hermit crabs, which present an anomalous softness of their abdominal segments, the last pair of appendages form the claspers by which the parasite holds fast by the columella of the shell it may have selected for its abode.

The calcified integument of the Crustacea being inelastic, inextensile, and not endowed with inherent powers of growth; being likewise so disposed in the Podophthalma, as to inclose and protect the greater part of the body by a few large shield-like plates, must needs be thrown off to allow of the growth of the animal. This moult of the external integument has been observed in a few species of Crustacea to take place annually; and a like ecdysis is probably common to all the class. Reaumur has given the best account of the process in the craw-fish (*Astacus fluviatilis*). It takes place generally in the month of August. The animal previously retires to some place of concealment, is quiet and fasts for a few days, during which time the old calcified epiderm is loosened from the corium by the formation of a new membranous layer beneath. As this begins to harden, the animal takes measures to rid itself of its old crust; it rubs its legs against each other, throws itself upon its back, contracts and swells out the body, with alternate violent inflections and intervals of rest. The carapace is thus separated from the abdominal segments, is pushed upwards, and the animal liberates its head with the eyes and antennæ, which are provided with new sheaths: then the more difficult operation of freeing its extremities takes place, the old solid coverings of which split lengthwise, and are shaken off. Finally, the crawfish creeps out of the remainder of its old shell by withdrawing the abdominal segments;

when the parts of the cast-off shell frequently return so nearly to their old positions as to represent the outward form of the animal with all its appendages, even the hairs and lining of the stomach. In one or two days the calcification of the new crust is completed, and the animal is restored to health and activity. During this period two very remarkable accumulations of calcareous matter, situated at the sides of the stomach, and known in the old pharmaceutical works as "Oculi Cancrorum," have disappeared: it would seem that the hardening material had been previously accumulated in readiness for the rapid calcification of the new crust, in order to reduce to the shortest period the defenceless state of the craw-fish after its moult.

The Crustaceous Homogangliata are not less remarkable for the different conditions of their nervous system, arising out of the progressive concentration of its central masses, than for the diversity of their outward forms. Even in the higher, or Malacostracous division, a very extensive series of modifications are presented, which lead from the Anellidous to the Brachyurous type, or that of the crab.

In the lowest vermiform, isopodous, and isocyclous Crustacea, the dermal skeleton has become sufficiently firm and resisting to enable the trunk to be raised by the articulated members above the ground. The muscular system attains a proportionate increase of volume and force: so that when we contrast the conditions of the sensitive integument and of the motor system in these Crustacea with those of the same systems in the Anellides, we obtain most instructive tests of the value of that hypothesis which ascribes sensation exclusively to the ganglions, and the motive energy to the non-ganglionic nervous columns of the *Articulata*. The same hypothesis will be more severely tried by the comparative anatomy of the nervous system in the higher species of the Crustacea, on account of the varying conditions as to sensation and motion which different parts of their more diversified forms of body present.

We find in the lowest Isopoda, as the woodlouse (*Oniscus*) and the sandhopper (*Talitrus*), that the supposed sensitive organs, the ganglions of the abdominal chords, are more developed than in the highest Anellides: they are likewise more distinctly bilobed; each lateral chord presenting its own ganglionic enlargements, which are in juxtaposition, but not confluent, so that there is a distinct pair of ganglia for each segment. If these ganglions be microscopically examined, three orders of nervous filaments may be distinctly perceived in them. The first is longitudinal, and extends over the dorsal aspect of the ganglia; the second is also longitudinal, and originates from, and terminates in, the ganglia; the third is transverse, and connects the two ganglions of each pair with each other, and with the transverse nerves. The *Talitrus* presents ten pairs of nearly equidistant sub-abdominal ganglions, the two first and the two last being most approximated. In the *Cymothoa* (*fig.* 89.), a species in which the tapering terminal segments of the body have begun to be concentrated by longitudinal approximation, the corresponding nervous ganglions at the posterior part of the abominal chord present a corresponding change, advancing forwards like the caudal part of the spinal column in the metamorphosed larva of the frog.

In the higher Crustacea, with a thorax covered by the cephalic shield, and supporting disproportionately large and prehensile anterior extremities, the thoracic ganglia exhibit proportionate increase of size, with a tendency to unite, or with actual confluence. The ganglions of each lateral abdominal chord have now more completely coalesced by transverse approximation. In the *Squilla mantis*, the supra-œsophageal ganglion or brain sends off five nerves on each side, those to the long antennæ being recurrent in their course. Stomatogastric nerves arise from the œsophageal chords, which unite below into a long sub-œsophageal ganglion, apparently formed by a confluence of three originally distinct pairs. This is succeeded by three other ganglions in the thorax, supplying three pairs of thoracic legs; and there are six ganglions in the muscular tail.

The neurology of the Crustacea has been most completely illustrated in those species which are covered by a dense insensible crust. Succow, in 1818, and Brandt, in 1833, published excellent descriptions of the nervous system of the *Astacus fluviatilis* (*fig.* 3. p. 13.). The cephalic ganglion sends branches to the eyes, to the large and small antennæ, to the antennal sheaths, and to the organs of hearing. A nearly straight chord is continued from this ganglion, on each side of the œsophagus, to the first of the sub-abdominal series. An azygous nerve arises from the middle of the posterior surface of the cephalic ganglion, and passes backwards to the stomach, where it communicates with two nerves given off one from each of the œsophageal chords to supply the stomach. The sub-œsophageal ganglion distributes nerves to the masticatory organs and to the pharynx, just as the medulla oblongata sends off the fifth pair and glosso-pharyngeal in the vertebrate animals. The second to the sixth thoracic ganglia inclusive, supply the feet and gills with nervous influence; the generative organs receive long filaments from the fourth, the fifth, and the sixth thoracic ganglions. The ventral or sternal artery, descending from the heart, passes between the nervous columns at the interspace between the fourth and fifth ganglions. Six ganglions are developed on the abdominal chords, which are continued along the muscular tail: the last, which is above the anus, is the largest, and radiates the nerves to the terminal swimming plates of the tail. This is probably a coalescence of the originally distinct ganglions of the sixth and seventh segments of the abdomen or tail.

The nervous system of the lobster is displayed in these dissections by John Hunter* and Mr. Swan, in whose work on Comparative Neurology it is beautifully illustrated. The nerves of the lobster closely correspond with those of the fresh-water species, or craw-fish. The non-ganglionic tracts are shown in this dissection of the lobster by Mr. Newport† ; but the distinctions of the origins of the nerves from the dorsal and the ventral tracts are, as Mr. Swan remarks, by no means clear. The œsophageal columns are united in both species of *Astacus* by a transverse commissural chord.

In the prawn (*Palemon*) and rock-lobster (*Palinurus*), the thoracic ganglia coalesce to form a long, elliptical, perforated nervous mass. In this dissection of a hermit-crab (*Pagurus*)‡, the cephalic ganglion presents a transversely quadrate form, and sends off the usual nerves to the eyes, the ears, and the antennæ. The lateral œsophageal chords, after supplying the digestive system with the stomato-gastric nerves, unite below to form the ganglion which distributes nerves to the maxillary apparatus and pharynx. This is succeeded by a large oblong ganglion, situated at the base of the great nippers, and of the second pair of feet, both of which pairs it supplies. The lateral chords diverge for the passage of the artery, re-unite to form a third thoracic ganglion, smaller than the second, supplying the third pair of thoracic legs, and sending off three pairs of nerves posteriorly. Of these the lateral pair goes to the fourth diminutive pair of feet; the median pair supplies the fifth feet: the two remaining dorsal nerves, which are of minute size, form the continuations of the abdominal chords, and pass along the under or concave side of the soft, membranous, and highly sensitive abdomen to the anus, anterior to which the last small ganglion is situated: this supplies the nerves to the muscles of the caudal plates, here converted into claspers, and enabling the animal to adhere to the columella of the univalve shell, which it may have selected to protect that portion of its body which nature has left undefended by the usual dense and insensible crustaceous covering.

Experiments have been made, and repeated, in order to determine whether the ganglionic portions of the abdominal chords of the *Articulata* have the same restricted function which the posterior

* Preps. Nos. 1301, 1302, 1303. † Prep. No. 1302, A.
‡ Prep. No. 1303. B.

roots of the spinal nerves in the *Vertebrata* have been proved to possess. With respect to the anatomical grounds which were first adduced in proof of this correspondence of function, they are invalidated by the fact that the presence of ganglions in the sensitive roots of the spinal nerves is not their constant character.

The results of the experiments alluded to, though somewhat contradictory, are, upon the whole, as might have been anticipated, hostile to the conclusions founded upon a partial anatomical analogy. A more extended investigation of the Comparative Anatomy of the Nervous System has remedied the imperfections of the experimental inquiry, has supplied the answers which were in vain attempted to be gained by mutilating the living Crustacea, and has brought the hypothesis in question to the test of deductions which may be legitimately drawn from those surer experiments which Nature herself has left for our instruction in the modifications of the crustaceous type of structure. We have here * two opposite conditions of a large and important part of the trunk of two nearly allied Crustacea. In the lobster (*Astacus*) the abdomen or tail is encased in a series of calcareous rings, forming a hard and insensible chain armour: but in the same degree as sensibility is lost, motility is acquired; a great proportion of the muscular system of the animal is concentrated in the tail, which forms its most powerful and almost exclusive organ of swimming. In the hermit-crab (*Pagurus*), on the other hand, the muscular system is almost abrogated in the long abdomen; for this, in fact, takes no share in the locomotive functions of the body: it is occupied by part of the alimentary canal, and by glandular organs: the sensibility of the external integument is not impaired or destroyed by the deposition of calcareous particles in its tissue; but it retains the necessary faculty of testing the smooth and unirritating condition of the inner surface of the deserted shell, which the animal chooses for its abode: minute acetabula are developed in groups upon this sensitive integument†, to which, also, delicate ciliated processes are attached. The muscular system is reduced to a few minute fasciculi of fibres regulating the action of the small terminal claspers. Now, if, as has been conjectured, the ganglionic enlargements of the abdominal chords monopolise the sensorial functions, and the non-ganglionic tracts the motor powers, we ought to find the nerves, which supply the muscles of a tail constructed almost exclusively for locomotion, to be derived from non-ganglionic columns; whilst in the tail, which is almost as exclusively sensitive, the ganglions ought to have been large and numerous, for the supply of nerves to the integument. The contrary,

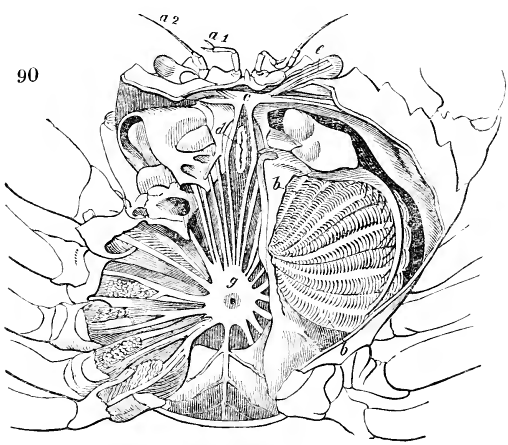
* Preps. Nos. 1301. and 1303. B.

† Broderip, Zool. Journ. vol. iv. p. 200.

however, is the fact; six well developed ganglions distribute nerves to the muscular fibres of the lobster's tail; non-ganglionic columns supply the sensitive tail of the hermit-crab. One ganglion, indeed, is present in the Pagurus, but both its situation and office alike militate against the hypothesis of its special subserviency to sensation: it is developed upon the end of the smooth abdominal chords, and seems to have been called into existence solely to regulate the actions of the muscles of the claspers by which the hermit keeps firm hold of the columella of its borrowed dwelling.

The general progress of the development of the nervous system in the Crustacea has been, as we have seen, attended with increased size, and diminished numbers of its central or ganglionic nerves. The divisions of each pair of ganglia first coalesce by transverse approximation: distinct pairs of ganglia approximate longitudinally, conjoining as usual from behind forwards: confluent groups of ganglia are next found in definite parts of the body, as on the thorax of those species which have special developments and uses for particular legs. In the crab, in which the general form of the body attains its most compact form (*fig.* 90.), the ventral nervous trunks are concentrated into one large oval ganglion (*g*), from which the nerves radiate to all parts of the trunk, the legs, and the short tail.

90



Cancer.

This condition of the nervous system has been described by Cuvier in the common crab, and is illustrated by Mr. Swan's dissections, from which his beautiful plates have been taken. The corresponding structure of the nervous system is also well displayed by Audouin and Edwards in the *Maia*. An analogous concentration of the nervous system, but with interesting modifications, has been described by Professor Van der Hoeven*, in the *Limulus* or King-crab, the most gigantic form of the Entomostracous tribe, and probably the

* Recherches sur l'Anat. des Limules. Fol. 1838.

only existing genus from which we may derive an insight into the organisation of the extinct Trilobitic Crustaceans. This consideration has induced me to select for the exercise of the peculiar skill of Mr. Goadby, our anatomical assistant, the well preserved specimens of *Limulus* for which the College is indebted to Mr. Boott of Boston, U. S. In these beautiful dissections by Mr. Goadby, the details of the nervous system are clearly displayed, and will, with the rest of the Anatomy of the Limulus, be published by the Council of the College.

Three principal divisions of the nervous system of the Crustacea may be defined according to the views which I entertain of their functions. Thus, admitting, from analogy, that the supra-œsophageal ganglionic centre (*figs.* 89. and 90. *c*) is that in which true sensation and volition reside, then those nervous filaments which are exclusively connected therewith, and some of which would seem to extend the whole length of the animal along the dorsal aspect of the ganglionic columns, would form with their ganglionic centre the true sensori-volitional system; whilst any other ganglions superadded to the abdominal columns, with the nervous filaments terminating in or originating from them, would constitute the system for the automatic reception and reflection of stimuli. The stomato-gastric nerves, connected partly with the brain and partly with the œsophageal columns, will form a third system analogous to the great sympathetic or organic nerves of the Vertebrata. In these views I coincide with the ingenious physiologist, Dr. Carpenter, and shall feel happy if their accuracy and soundness have received any additional proof from the facts of Comparative Anatomy, which, in the Hunterian Lectures of 1842, were for the first time brought to bear upon this interesting problem.

The sense of touch can be but very feebly exercised by the common integument of the Crustacea, can hardly, indeed, exist except in those parts of the surface of the body which remains soft and undefended by the hard crust, such as the joints of the under part of the body, and the surface of the soft tail in the hermit crabs. The fine hairs which project from many parts of the integument may compensate for its low endowment of the tactile sense: the two pairs of jointed antennæ (*fig.* 90. *a*) are instruments fitted for the most delicate exploration; and the smaller but similar organs attached to the jaws, and called palpi, may also receive some impressions analogous to those of savour or smell. The Crustacea have no true tongue, but the sensations of the membrane lining the interior of the mouth and the œsophagus may guide them in the selection which they make of objects of food.

The sense of hearing is referred to a cavity with a round orifice closed by a membrane, excavated in the first joint of the second pair of antennæ, in the lobster and other Macroura. In most of the Brachiura the membrane is stated by Dr. Edwards to be replaced by a small moveable calcareous disc, which is pierced with a small oval opening, over which there is stretched a thin and elastic membrane. The external opening of the ear is closed by this bony disc. A second small plate is so situated as to regulate the tension of the auditory membrane, whilst the rigid stem of the antennæ, in which the whole organ is situated, is well adapted to render the auditory vibrations more distinctly perceptible. These vibrations are conveyed through the medium of a vesicle filled with fluid to a branch of the antennal nerve which expands in the vesicle.

With respect to the organ of vision, we find in the class *Crustacea* a most extensive and interesting series of gradations, leading from the sessile median eye-speck to two distinct eyes, provided with all the essential optical apparatus and placed upon moveable peduncles. Ocelli or stemmata are combined with compound eyes in the same species in certain Entomostracans, as *Apus* and *Limulus*. A transparent speck of the integument forms the cornea of the ocellus, immediately behind which there is a spherical crystalline body in contact with a gelatinous or vitreous humour, upon which the extremity of the optic nerve expands: a layer of dark pigmentum covers all these parts with the exception of the cornea. In the compound eyes of *Daphnia*, the smooth undivided cornea protects and transmits the rays of light to an aggregation of small ocelli, each of which is lodged in a pigmental cell: the similarly constructed compound eye of the active little *Branchipus* is supported on a short moveable peduncle.

The large lateral compound eyes of the Limulus are sessile; the cornea is divided into a considerable number of small circular facets, each of which corresponds to an ocellus; and the optic nerve, after its long course as a simple chord, divides near the eye into a pencil of fine filaments, which severally receive the impressions from their respective ocelli, of the aggregate of which the large lateral eye is composed: the two small simple median eyes, which are almost in contact, command the space before the head, which is out of the range of the large compound eyes. Each simple eye receives its distinct nerve from the anterior apex of the corresponding cerebral lobe.

In the sessile eyes of the *Edriophthalma*, as, for example, in the *Serolis*, the inner layer only of the cornea is divided into hexagonal facets, corresponding with the number of the conical crystalline lenses of the compound eye. But in the Trilobites, the cornea presents the same subdivided surface as in the Limulus; and the position of the two eyes agrees with that of the corresponding compound pair in the large existing Entomostracan. The eyes are more elevated in the Trilobites. In the *Asaphus caudatus* the cornea is divided into at least 400 compartments, each supporting a circular prominence: its general form is that of the frustum of a cone incomplete towards the middle line of the head, but commanding so much of the horizon in other directions, that where the distinct vision of one eye ceases, that of the other begins. In the mandibulate Crustaceans, distinguished by having their compound eyes supported on moveable peduncles, the form of the corneal facets varies; they are square in the river craw-fish, hexagonal in the hermit and common crabs. There is a conical crystalline lens behind each facet imbedded in a small vitreous humour, upon which the optic filament expands, and each ocellus is lodged in a pigmental cell, which likewise covers the bulb of the optic nerve; the cavity containing the compound eye is closed behind by a membrane continuous with the inner layer of epiderm, and pierced for the passage of the optic nerve (*fig*. 90. *e*). In the Podophthalmous Crustacea there is generally a spacious furrow or cavity, in which the eye and its peduncle can be lodged and protected, and it is termed the orbit. In one or two species the eye-stalks project beyond the margins of the carapace.

One of the most valuable and interesting results of the study of the comparative anatomy of the eye in the Crustacea is the insight which the fossilised remains of similarly constructed organs of vision in the extinct Crustacea have given respecting the state of the world at the time when they existed; and I cannot better conclude the present discourse than in the eloquent language of the geologist who first taught the value of the evidence in question. The eyes of the Trilobites of the transition rocks, and those of their nearest congeners, the fossil Limuli from the Carboniferous series, " give information," says Dr. Buckland, " regarding the condition of the ancient sea and ancient atmosphere, and the relations of both these media to light, at the remote period when the earliest marine animals were furnished with instruments of vision in which the minute optical adaptations were the same that impart the perception of light to Crustaceans now living at the bottom of the sea.

" With respect to the waters wherein the Trilobites maintained their existence throughout the entire period of the transition formation, we conclude that they could not have been that imaginary turbid and compound chaotic fluid, from the precipitates of which some geologists have supposed the materials of the surface of the earth to be derived; because the structure of the eyes of these animals is such, that any kind of fluid in which they could have been sufficient at the bottom, must have been pure and transparent enough to allow the passage of light to organs of vision, the nature of which is so fully disclosed by the state of perfection in which they are preserved. With regard to the atmosphere, also, we infer that had it differed materially from its actual condition, it might have so far affected the rays of light, that a corresponding difference from the eyes of existing Crustaceans would have been found in the organs on which the impressions of such rays were then received.

"Regarding light itself, also, we learn, from the resemblance of these most ancient organisations to existing eyes, that the mutual relations of light to the eye, and of the eye to light, were the same at the time when Crustaceans, endowed with the faculty of vision, were first placed at the bottom of the primeval seas, as at the present moment.

"Thus we find among the earliest organic remains, an optical instrument of most curious construction, adapted to produce vision of a peculiar kind, in the then existing representatives of one great class in the articulated division of the Animal Kingdom. We do not find this instrument passing onwards, as it were, through a series of experimental changes from more simple into more complex forms; it was created at the very first, in the fulness of perfect adaptation to the uses and condition of the class of creatures to which this kind of eye has ever been, and is still, appropriate."

LECTURE XV.

CRUSTACEA.

The Limuli, which form the only genus of large Crustaceans represented by species which co-existed with the Trilobites, differ from all other living Crustacea in their organs of mastication, which are the modified basal joints of the five posterior pairs of legs: the first small pair serve to bring the objects of food to the mouth; they are supported on a rudimental labrum. In the *Asaphus platycephalus* Mr. Stokes has discovered a distinct subquadrate labrum deeply emarginate anteriorly; the nearest approach to this, the only known part of the trophi of the Trilobites, seems to be made by the entomostracous genus *Apus*, in which, however, the labrum is truncated. A few of the lowest organised *Crustacea*, as *Caligus*, *Nymphon*, and *Pycnogonon*, obtain their aliment, like the *Epizoa*, by suction.

In the Malacostracous Crustacea the mouth is closed by a small and simple membranous labrum above, by a bifid labium below, and by a pair of maxillæ and mandibles at the sides; the mandibles are the legs or jointed appendages of the fourth cephalic segment. In the common crab you will observe behind and exterior to the mandibles a second pair of jaws, which, like the first, have their principal part terminated by a cutting edge: the two following pairs of jaws are distinguished by their articulated feeler or palp, and by their flabelliform appendages, which penetrate into the interior of the branchial cavity; the maxillary plate is armed with teeth: the fifth and last pair of jaws has the maxillary plate so much expanded as to cover and protect the whole oral apparatus: it has likewise a palp and flagellum articulated to its base. All the foregoing maxillary organs are modifications of entire limbs, which are thereby translated from the locomotive series; the jointed legs so metamorphosed belong to the last four cephalic, and the first two thoracic, segments.

The alimentary canal is most simple in the suctorial Crustacea, in which it presents no noticeable difference from that in the Epizoa; the hepatic appendages are however more localised and better developed.

In the Limulus the mouth is situated nearly in the centre of the inferior surface of the great cephalo-thoracic segment; the œsophagus is continued from it in a very unusual course forwards, and expands into a stomach, which is situated at the anterior part of the head. This organ is abruptly bent upon itself upwards and backwards, and is continued by a gradual diminution of diameter, as appears upon an external view, into the intestine, which passes backwards with a slight vertical bend, to the base of the penultimate abdominal segment. When we examine the interior of the alimentary tract, the distinction between the stomach and intestine is effected, as Van der Hoeven has shown, by a conical valvular pylorus, which projects into the commencement of the intestine. The stomach is lined by a very dense and corrugated horny membrane. The hepatic mass, which, with the generative glands, fills the greater part of the cephalo-thoracic cavity, pours its secretion into the commencement of the intestine by two ducts on each side.*

In the Stomapods or Squillæ the stomach also bends forwards in advance of the cardiac orifice; a bi-articulate plate extends from that orifice backwards, through the pylorus into the intestine, and regulates the passage of the alimentary substances into that tube; they are previously subjected to the action of four lateral dentated pyloric processes.

In the higher Crustacea the stomach is of a globular form, more

* Prep. No. 477, A.

capacious than in the *Limulus*, and its walls are connected with a calcareous frame-work supporting dense tubercles, which project into the interior of the stomach around the pylorus, and are so situated and moved with relation to each other as to divide and bruise the alimentary matter before they pass into the intestine. In the common lobster these gastric teeth are three in number, the middle one serving as a kind of anvil upon which the two larger lateral pieces work.* This complex kind of gizzard is sometimes found to be everted and protruded from the mouth, the gastric teeth being then external, like those of the anterior muscular segment or proboscis of the alimentary canal in the Anellides.

The intestine in all the Crustacea is continued to the vent without convolutions; a terminal portion or rectum is sometimes, as in the lobster, indicated by a slight circular valve; the vent is situated beneath the terminal segment of the abdomen, anterior to its appended swimming plates in the Macroura, which would indicate that the long spinal appendage of the Xiphosura was not the analogue of the post-abdomen, but of its last joint in the Macroura.

The liver is a considerable organ in all the Crustacea; it makes its appearance in the inferior species as so many cæcal prolongations of the intestine, continued from many points, according to the primitive form which it presents in the Aphrodita. The biliary cæca extend even into the limbs in the Nymphons. In the Stomapods the biliary cæca, continued ten or eleven in number at equidistant points from each side of the intestine, are more ramified, and are confined to the thoracic-abdominal cavity, where they penetrate the interspaces of the muscles.†

In the Decapod Crustacea the liver consists of two symmetrical halves, communicating by distinct ducts with the intestine; each half consists of numerous lobes, which, in the larger Macroura and Brachyura, are leaf-shaped, and composed of straight tubular cæca, arranged obliquely to a median canal, which forms, as it were, the leaf stalk. In some species one or two pairs of long slender and simple tubuli likewise communicate with the intestine.

No other vessels are yet known to convey the chyle or nutrient fluid to the circulating system than the irregular venous receptacles which are in contact with the parietes of the intestine. Almost the whole venous system presents the form of wide flattened sinuses, and offers an intermediate condition between that in the Nereis and the generally diffused state of the venous blood through all the cellular interspaces of the body in the class of insects. Through these sinuses, however, the blood flows in a constant and definite course.

* Preps. Nos. 407, 408.

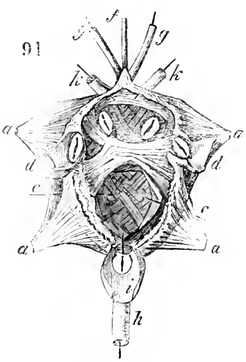
† Duvernoy, Annales des Sciences, vi.

The numerous experiments of Audouin and Milne Edwards * on the circulation of the Crustacea, and the apparently favourable circumstances under which they were made, have very generally been regarded as conclusive of the accuracy of their explanation of that important function in the present class. According to these physiologists no other than the two great branchial veins terminate in the heart, and, consequently, only pure aërated or arterial blood is propelled by it over the general system: the circulation is, in fact, the same as in the Gasteropodous Mollusca: the ventricle is exclusively systemic, and is provided with only two venous apertures. Four such apertures are described and figured by Dr. Lund on the dorsal surface of the heart, but these are regarded by Audouin and Edwards as depressions merely between the muscular fasciculi, having no communication with the ventricular cavity.

I have tested the conflicting evidence of these observers by dissection of the heart in the lobster; and you will perceive by this preparation † that it is more complicated than even the Danish Naturalist supposed, and fully bears out the opinion of Hunter in regard to the mixed nature of the circulation in the Crustacea.

Fig. 91. shows the heart laid open on the ventral aspect; by exposing its cavity from this side, it was readily determined whether the exterior depression on the dorsal surface did or did not lead into the cavity. On either side of the anterior depression from which the two antennal (*f*) and the ophthalmic (*g*) arteries arise, there is a large oblique fissure, guarded by a pair of semilunar valves. The vein, which terminates by each of these orifices, is an extended, irregular, and extremely flattened sinus, lying above the heart, and between it and the lining membrane of the shell, communicating anteriorly with a similar broad irregular flattened sinus, which occupies a similar situation above the stomach, and receiving posteriorly the blood from a series of flat and expanded sinuses which correspond to each segment of the tail. There are two similar openings at the sides of the ventricle, posterior to the preceding, which conduct the blood from lateral sinuses into the heart: these orifices, indicated by the bristles (*c*, *c*), have each a pair of semilunar valves. The arterial blood, returned from the branchiæ, enters the

91



Astacus marinus.

* Hist. Nat. des Crustacés. 1829

† No. 898. A.

heart by the large orifices on the sides of the ventral aspect (*d*, *d*), regurgitation being likewise prevented by two semilunar valves at each orifice.

The muscular fasciculi of the ventricle are so arranged as to leave tolerably distinct chambers for each series of arterial orifices. The strongest bands or columns are transverse, and dorsad of the branchial apertures: anterior to these is a chamber receiving the carbonized blood from the two anterior dorsal apertures; it is partially divided, the upper chamber giving off (*f*) the ophthalmic, and (*g*) the antennal arteries. The lower chamber sends off (*k*, *k*) the hepatic arteries. The larger posterior chamber receives the two lateral venous apertures, and gives off (*h*) the superior caudal artery, and (*i*) the sternal artery, the only one which has a pair of semilunar valves at its origin.

A portion only of the ordinary venous blood is returned directly by the four valvular orifices just described. The blood is returned from the maxillæ and legs to a series of inferior lateral sinuses at the bases of the branchiæ; from these sinuses it passes, by vessels performing the office of branchial arteries along the outer margin of the gill, and after being distributed over the branchial lamellæ, is collected into the vein along the inner margin of the gill, and by the union of the branchial veins into one trunk, on each side, is poured into the ventricle by the two orifices on its under surface (*d*, *d*).

We may trace in the heart of the Crustacea a gradational series of forms, from the elongated median dorsal vessel to the short, broad, and compact muscular ventricle in the lobster and the crab. In all the Crustacea, as in all the other articulate animals, the heart is situated immediately beneath the skin of the back, above the intestinal tube, and is retained *in situ* by lateral pyramidal muscles (*fig.* 91, *a*, *a*). In the lower, elongated, slender, many-jointed species of the Edriophthalmous Crustacea the heart presents its vasiform character: it is broadest and most compact in the crab.

In this series we may trace a general correspondence in the progressive development of the vascular as of the nervous system, concomitant with the concentration of the external segments, and the progressive compactness in the form of the entire body. But there is a remarkable exception to this concomitant progress in the Limulus, indicative, with the general condition of the instruments of locomotion and respiration, of the essentially inferior grade of organisation of that genus, which, as has already been observed, seems to be the last remnant of the once extensive group of Trilobitic Crustacea, which swarmed in the seas of the ancient secondary periods of the earth's history.

We have seen in the compact and broad existing representative of those extinct gigantic Entomostracans, that the nervous system exhibits a concentration of its principal central mass around the mouth, analogous to its condition in the common crab, but with a ganglionic double cord continuing from it. The heart, however, is far from presenting a corresponding degree of concentration: it remains an elongated, fusiform tube, extending parallel with the intestine from the pylorus to the rectum: it is contained in a pericardium with thin membranous walls, formed by the central sinus of the venous system, and it receives the blood from that sinus and from the branchial veins by a series of from seven to ten lateral vertical slits, defended by valves as in the higher Crustacea. * An aortic trunk proceeds from each extremity of this heart. The anterior aorta is the largest, and immediately divides into three branches. The middle and smallest branch passes forwards to the anterior edge of the cephalic shield, following the curve of its middle line, and supplying the small median ocelli in its course. The two larger lateral branches form arches which curve down the side of the stomach and the œsophagus, giving branches to both those parts and to the intestine, and becoming intimately united with the neurilemma of the œsophageal nervous collar. They unite at the posterior part of that collar, and form a single vessel, which accompanies the abdominal nervous ganglionic chord to its posterior bifurcation where the vessel again divides. Throughout all this course the arterial is so closely connected with the nervous system as to be scarcely separable or distinguishable from it. The branches of the arterial and nervous trunks which accompany each other may be defined and studied apart.

The posterior aorta is chiefly destined for the supply of the sword-like tail of the Limulus: the first part of its course is wavy, to adapt it to the strong inflections of that appendage. The aërated is mixed with the venous blood in the heart, and is propelled in that mixed condition throughout the body in the Limulus, as in the lobster.

The respiratory organs in the Crustacea are essentially appendages to the basal articulations of a certain number of the feet, and are originally developed from the flabelliform appendage, although they ultimately become entirely distinct from the extremities in the higher Crustacea.

The *Branchiopods* are so called because their fins or feet present the form of simple plates or flattened vesicles, which float in the surrounding fluid, and expose the blood to the oxygen which the water contains. The branchia are appended to the thoracic limbs, in the form of membranous plates, in the *Amphipoda ;* and to the ab-

* Van der Hoeven, loc. cit. pl. 2. fig. 9.

dominal limbs, as subdivided lamellæ, in the *Isopoda:* the branchial plates expand into vesicles attached to the thoracic feet in the *Læmodipoda.* In the *Stomapoda,* the respiratory plates are also external, and are appendages of distinct locomotive organs, and each plate is divided into a series of small filaments or tubes; so as to resemble a broad feather: their position is abdominal. Similarly formed external gills are appended to the thoracic segments in the *Thysanopoda.*

In the lobster and crab tribes, the branchiæ are protected by the carapace, and are lodged in lateral recesses formed by the apodemata of the thoracic segments. These branchial recesses are parts of a common cavity, lined by an internal fold of the tegumentary membrane, and having two apertures of communication with the surrounding medium. The posterior aperture lets in the water, which, traversing the branchial cavity, escapes by the one in front. In the crabs the entry is a cleft in front of the base of the chelæ or forceps-claw, and is so placed in reference to the prolonged base of that limb as to be closed or opened at the will of the animal. In the lobster and other Macroura, the entry to the branchial chamber is an extended fissure.

The dynamical part of the respiratory functions is performed by the lamelliform appendages of the second pair of jaws, which are so situated in regard to the outlets of the branchial chambers as to drive out a certain quantity of the water which has been admitted into the chamber. * The loss of the foul water necessitates the entry of fresh water by the inferent orifices; the respiratory cavity being neither capable of expansion nor contraction. The mode of breathing in the crypto-branchiate or decapod Crustacea is thus the reverse of that in the Batrachia, in which the dynamical mechanism serves only to draw in the respiratory medium in successive quantities. In the higher vertebrata the thorax is so constructed as to execute acts both of inspiration and expiration.

The branchiæ in the decapod Crustacea are in the form of long and slender quadrangular pyramids, and consist of either numerous thin plates, or minute cylinders closely arranged perpendicular to the axis of the pyramid. There are nine branchial pyramids on each side in the crabs, two being rudimental; but the number is more variable, and usually greater, in the Macroura, amounting to twenty-two in the lobster.

So far as the gills are attached to the bases of the ambulatory or natatory legs, they must be influenced by their movements; and the more active the progress of the Crustacean, the more briskly will its respi-

* Milne Edwards, Annales des Sciences Nat. tom. xi.

ration proceed; and since the muscular energy directly depends upon the amount of respiration, the two functions are brought into direct relation with each other by this simple connection of their respective instruments.

The land crabs have their branchiæ always supported by water through special modifications of the apertures of the branchial cavities, which enable them the better to retain fluid, and also by numerous folds or by a spongy structure of the lining membrane of the respiratory cavity by which the quantity of the contained fluid may be augmented. The moisture contained in the branchial chambers of the land-crabs (*Gecarcinus*) and tree-crabs (*Birgus*) is doubtless much more highly aërated than the water which bathes the branchiæ of the strictly aquatic species, and thus may explain the fact that the Crustacea which habitually live out of water are drowned by being long immersed in that fluid.

No other trace of distinct excretory organs has hitherto been detected in the present class than the simple, unbranched, long, and, slender tubes which open into the intestinal canal of some of the higher Crustaceans: these may be uriniferous tubes, like the corresponding parts in certain insects and spiders.

Tenacity of life in the Crustacea appears not to be enjoyed in any unusual degree: but some species, as the *Artemia salina*, can exist in hot and strong brine, which would quickly destroy most other animals.

Like other Articulata subject to periodical ecdysis, the Crustacea have the power of reproducing lost extremities. If a leg be fractured or severed across one of its segments, it is cast off by a violent muscular effort at the second articulation: if the Crustacean have not the power of thus ridding itself of the wounded member, it usually dies from the hæmorrhage; but this is immediately arrested by the contraction of the lacerated part of the joint where the limb is cast off with least difficulty and pain. A small cylindrical appendage first sprouts from the cicatrix, which soon after presents distinct articulations, and resembles in miniature the limb which it is destined to replace: its growth is slow until the period of the moult, when, if the animal be in vigorous health, the new member rapidly acquires its normal size.

There is no propagation by spontaneous fission or gemmation in the class *Crustacea:* every species is developed from ova formed by organs peculiar to one series of individuals, and impregnated by the fertilising product of organs as peculiar to another series. But although the male and female organs are never naturally combined in the same individual, accidental or monstrous hermaphrodites occasionally occur, in which the male organ is developed on one side, and the female organ on the other side of the same animal. This dimidiate hermaphroditism *, as it is termed, has been most commonly observed in the lobster, and is indicated by external characters. The generative orifices open on the last thoracic leg on the male side, in which the abdominal plates are smaller and more simple; whilst on the opposite side they are broader and more ciliated, and the generative aperture is situated on the middle or third ambulatory leg.

This singular kind of malformation seems to depend upon the very slight connection, or want of connection, between the right and left generative organs of the same individual, whether male or female. The external apertures are always distinct on each side; and when a combination of the right and left generative organs does occur, it is by a partial union of the two testes, or of the two ovaria.

In the male *Cymothoa* both the essential and efferent portions of the male apparatus are distinct on each side: the testis is here much simplified, and consists of three elongated pyriform vesicles forming a common tube by the union of the short vasa deferentia, which arise respectively from the great end of each vesicle.

In the *Astacus fluviatilis* the testes are blended together at the middle line along the posterior half of their extent, anterior to which they are separated and symmetrical: they consist of packets of minute contorted capillary secerning tubes. The vasa deferentia quit the gland at the junction of its three apparent lobes: they form many convolutions at the sides of the hinder part of the thoracic segment, where they may be distinguished by their opake white colour. They dilate into sperm receptacles in the last portion of their course, and terminate at the small prominent orifices at the basal joints of the last pair of thoracic legs.

In the *Maia* the testis consists of an elongated and convoluted mass of extremely minute vermicular tubuli, which mass is united by a slender transverse commissural process with the testis of the opposite side. The vas deferens is formed by the gradual enlargement of the tubuli, and is disposed in a number of close convolutions, and somewhat suddenly dilates into a spiral seminal receptacle, which terminates, as in the *Astacus*, on the basilar piece of the last pair of legs. In many crabs, however, as in the *Grapsus* and *Ocipoda*, the external opening of the male organ is found on the sternal part of the last thoracic ring. The terminal part of the duct can be everted by a kind of erection to form a temporary organ of intromission; and the Crustacea are singularly analogous to serpents in the double number

* See Brande's Dict. of Science, *Art.* HERMAPHRODITE.

as well as the structure of this part. Certain appendages of the first and second abdominal rings in the male crabs are probably connected as exciting organs with the sexual function.

The female organs present, like the male, a progressive complication of structure as the species ascend in the class. Most of the small Entomostraca carry the impregnated ova in appended ovisacs, like those of the Lerneæ. These sacs are not developed in the Limulus, which also differs from the smaller Entomostraca, inasmuch as the ovarian mass interblends its lobes and processes with those of the liver; the oviducts form more frequent communications with each other than in the higher Crustacea, but ultimately terminate, like the vasa deferentia, by two distinct but continuous orifices on the back part of the first abdominal lamelliform appendage.

The ovaria in the lobster are of great length on each side; the oviduct comes off from the outer part of nearly the middle of the gland, and descends to terminate at the basal joint of the third pair of ambulatory feet.*

In the Brachyura the female apparatus reaches its highest state of complication, and consists of an ovary, oviduct, and a copulatory pouch, or spermatheca, on each side. The ovaria are elongated cylindrical sacs in the *Maia*, and are divided into an anterior and a posterior part, the short oviduct being continued from the union of the two: the anterior parts of the ovaria are united together by a short transverse canal; the posterior divisions are very intimately united through half their extent: the spermatheca is developed a little above the termination of each oviduct.

The species of a genus of Macroura (*Mysis*) are called "Opossum shrimps," from carrying their ova during the process of development in abdominal recesses, analogous to the marsupial pouch; but this superadded complexity in the reproductive economy is common, under various modifications, to all the Crustacea.

The ova, after extrusion from the oviducts, are retained and protected in the *Cymothoa* and other sessile-eyed Malacostraca under their thorax by means of the flabelliform appendages of the extremities, which appendages are unusually expanded, and overlap each other, so as to form a marsupial cavity or temporary receptacle, in which the incubation of the ova is completed. In the Podophthalma, the lamelliform ciliated appendages of the abdominal segments include similar marsupial or incubatory recesses for the ova. The female lobster and other Macroura are distinguished from the male by the greater development of these appendages; and in the

* Prep. No. 3188.

Brachyura the shorter abdomen or tail is so much more expanded in the females as to cover the whole sternum, and render the sex distinguishable at a glance.

In certain parasitic species of *Cymothoa*, the males have eyes, the females, which are considerably larger, have no eyes: they have probably been effaced by age and lack of use, as in the parasitic females of the Epizoa.

The lower forms of Entomostracous Crustacea, and especially the suctorial species, have long been known to undergo remarkable changes of form in repeated moultings during their growth, analogous to the metamorphoses which have already been described in the Epizoa: differing, in fact, from these only in degree; the last or procreative stage being attained in most Entomostraca under a locomotive form, which differs less from that of the newly excluded young, than does the corresponding mature stage of the deformed parasitic Lernæa. There is a period when the young Limulus is destitute of the characteristic caudal spine: this fact was first observed by M. Edwards in the embryos on the point of exclusion from the egg, at which period the abdomen supports only three pairs of appendages.

With respect to the Malacostraca, in 1778, a Dutch naturalist, Slabber, described and figured a minute swimming Crustacean of the genus called *Zoea* by modern naturalists: it was provided with a pair of large and distinct eyes; its carapace was armed with a long frontal and a dorsal spine; and its abdomen was terminated by a forked tail. He preserved this little animal alive in sea water, which was daily renewed, and on the fourth day he found that the animal had changed its form; the feet, eyes, and antennæ were more developed, the frontal spine had become comparatively small, the dorsal one had disappeared, and the tail had changed from the bifurcate to the spatulate form, and was fringed by a row of short spines. Many years elapsed ere this observation was repeated, and it seems to have been forgotten, when Dr. Leach, the most accomplished Crustaceologist of his day, founded the principal character of the class Crustacea on the absence of metamorphosis.

During the spring of 1822, Mr. V. Thompson * captured an abundance of the singular Zoeas in the harbour of Cove; the largest of them was daily supplied with fresh sea-water from May 14th until the 15th of June, when it died in the act of changing its skin. The disengaged members, invested with the new integuments, were changed both in number and form, and corresponded with those of the decapod Crustacea, the anterior pair being furnished with large pincers. Here, therefore, was a strong indication that, under the form of a Zoea, was

* Zoological Researches, vol. i. Part I. p. 1.

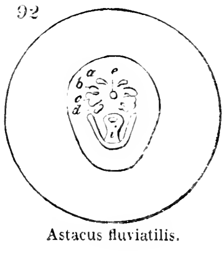
masked that of some one or other of the higher Crustacea; and, probably, one of the common species of the Irish coast. To the development of these, therefore, Dr. Thompson next turned his attention, and he succeeded in hatching the ova of the common crab during the month of June, and found that the young were excluded under the form of the *Zoea Taurus*, with the addition of lateral spines to the thorax; whereupon he concluded that the decapod Crustacea indisputably underwent a metamorphosis.

In the year 1829 Dr. Rathké published his Researches on the river craw-fish (*Astacus fluviatilis*). In this species the ovum first appears in the shape of a minute transparent vesicle, which afterwards becomes surrounded by a second, forming the membrana vitelli: the nature of the processes effecting this stage appears not to have been observed. The yolk increases in quantity, and is rendered opake by the presence of numerous granules, and changes from the lenticular to the spherical figure; then the internal minute transparent germinal vesicle quits the centre, and comes into contact with one part of the parietes of the ovum. The colour of the yolk successively changes to yellow, orange, and brown; the clear vesicle disappears, and the production of the embryo commences. Rathké failed to ascertain what became of the vesicle. The formation of the ovum in the ovary continues half a year. In the month of November the vesicle was visible; in the ensuing March it had disappeared.

The ovum escapes into the oviduct by bursting the inner lining of the ovary. It is surrounded by a layer of albuminous matter, and is enclosed within a coriaceous chorion and an irregular deposited nidamental tunic, by which the ovum, after exclusion, becomes attached to the ciliated plates beneath the tail of the mother.

The first appearance of the embryo is as a whitish cloud of indeterminate form, spreading over the vitellus, and assuming, as it extends, a reticulated appearance. A discoid portion of the layer is defined from the rest, and increases in thickness at its middle part: its longest diameter is about half the radius of the egg. A depression appears in the centre of this, which passes more and more deeply into the vitellus, and the embryonic spot expands at its margins. The patch next grows heart-shaped, and the antennæ, the labrum, mandibles, and abdomen become simultaneously recognisable. The antennæ (*fig.* 92, *b* and *c*), at first short and simple processes, increase in length, and their extremities become notched; the mandibles (*d*) also lengthen and enlarge, particularly in their basal portion; the labrum (*e*) recedes from between the anterior antennæ, and takes

92

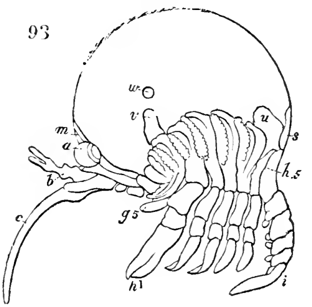


Astacus fluviatilis.

its station between the posterior: the eyes (a) now first make their appearance. A cavity is formed behind the labrum, which communicates with the commencement of the œsophagus; the tail or abdomen (i) elongates, and the depression in its surface is converted into the anus; the rest of the alimentary canal is a simple wide sac, which, by the extension of the mucous layer of the germinal membrane, now includes the vitelline mass.

The three anterior pairs of maxillæ begin to show themselves at a little distance behind the mandibles, and afterwards the fourth and fifth pairs; the last (*fig.* 93, g 5.) increasing in size more rapidly than the rest. Thus, including the eyes (a) and the two antennæ (b, c), nine pairs of appendages may now be recognised, of which the two last belong to the thorax: the five posterior pairs of thoracic members, which are not, like the first two, developed into jaws, are produced in regular succession from before backwards from that portion of the body which is turned upwards, or the epimeral elements of the rudimental segments. Each of the legs at its first appearance is exactly similar to the hindermost maxillæ; these, therefore, are retained in the service of manducation by an arrest of development. The ambulatory legs increase inversely with respect to the maxillæ, the anterior (*fig.* 93, h 1.) soon acquiring four times the length of the posterior (h 5). The rudiments of the future branchiæ next appear as small processes from the base of each leg. The seven segments of the third division of the body (i) may now be distinguished by six transverse furrows, and by the rudiments of foliaceous appendages.

93



Astacus fluviatilis.

The heart (s) appears at first in the shape of a small compressed vesicle, situated near the junction of the anterior and posterior segments of the body: blood-vessels seem to be prolonged from it, and its pulsation speedily becomes distinguishable.

The nervous system consists at first of eleven pairs of minute white spots, from the anterior of which a short and broad process passes forwards on either side of the œsophagus. The above described stages of development are in progress from the beginning of April to the middle of May.

The whole of the organs continue to approach more nearly to their mature form. The brain, liver (u), and salivary glands (v), next make their appearance. The outer integument of the body is developed from the ventral to the dorsal aspect, and the yolk-laden intestine is finally, with the heart, walled in by the confluence of the lateral lobes of the integument along the middle line of the back.

The integument is very soft when the animal quits the shell: it subsists, at first, on the remaining portion of the yolk, during which time its coat becomes sufficiently hardened to admit of its moving about in quest of food with more safety. The different appendages increase in length, and more especially the branchiæ, the growth of which is now remarkably rapid. The changes of the interior parts of the animal, with the exception of the development of the sexual organs, consist in a gradual adaptation of parts already formed to their proper functions.

The relative positions of embryo and vitellus are the same in the craw-fish as in the *Daphne pulex* and *Branchipus stagnalis.* The maxillæ present at an early period a considerable resemblance to those of the *Apus:* the legs at the period when they are devoid of branchial appendages typify the persistent condition of the Branchiopoda: after the branchiæ are developed, but before they are enclosed in the branchial chamber, the characteristic persistent condition of the respiratory system of the Edriophthalma and Stoma poda is sketched out. M. M. Audouin and Milne Edwards have shown that the successive changes of development of the nervous system of the craw-fish correspond in like manner with distinct types of formation observed by them in its permanent condition in lower species of the class; thus the double series of ganglions, which first indicate the subœsophageal central part of the nervous system in the embryo craw-fish, is analogous to the permanent state of the nervous system in the mature *Talitrus.* At a more advanced period the two series of ganglions in the fœtal craw-fish approach the median line and become united together as in the abdominal ganglionic chain in the adult *Cymothoa.* We have seen that in the brachyurous Crustacea a further concentration takes place by the longitudinal blending together of the whole series of the subœosophageal ganglia, which clearly indicates that the brachyurous Crustacea are more highly developed than the macrourous species; contrary, however, to the opinion of Dr. Rathké.

It is certain that the moult of the young craw-fish is not at any period accompanied by a marked change in the form of the body, or in the structure and functions of the locomotive members; this Crustacean, in short, undergoes no metamorphosis.

A series of less complete observations on the ova of a species of land crab (*Gecarcinus*), more recently published by Mr. Westwood, lead to the same inference in respect of that species. This accomplished entomologist coincides with Dr. Rathké in the general conclusion that the Crustacea undergo no metamorphosis, and that the contrary evidence adduced by Slabber and Mr. Thompson must depend on some erroneous observation.

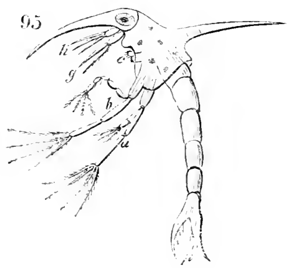
The opposite conclusions of both parties from the phenomena afforded them by the solitary species examined, may be compared with analogous generalisations which might have been drawn, in reference to the class of Insects, by the observer of the development of a cock-roach on the one hand, and by the observer of the metamorphoses of a butterfly on the other. As reasonably might the one, after detailing the progressive development of the orthopterous insect, broach the inference that insects underwent no other metamorphosis than the gradual acquisition of wings; and, with equal reason, might the other observer of the wonderful changes of the lepidopterous insect affirm them to be characteristic of all insects. It needs only that each theorist should question the reality of the other's observation to make the parallel complete. The failure of both to arrive by so short and easy a route at the entire truth, inculcates the necessity of acquiring a sufficient foundation, by careful and extensive induction of facts, before proceeding to erect the superstructure of general theory.

With regard to the metamorphosis of the common crab, valuable testimony in confirmation of Mr. Thompson's discovery has been contributed by Capt. Du Cane R. N.* This gentleman obtained crabs with ova under their tails in the month of December, from which the larvæ were produced in the months of March and April: the form of the larva at this period is shown at *fig.* 94. Soon after exclusion this larva casts off its envelope and assumes the appearance represented in *fig.* 95., which closely corresponds with that zoæiform Crustacean, whose further changes were witnessed by Mr. Thompson, and which he had assured himself was an early or larval state of a common crab. The last form which immediately precedes the assumption of the mature characters corresponds, according to Dr. Thompson, with that of the genus *Megalopa.*

94

Larva of Crab.

95



Larva of Crab.

The additional evidence afforded by Capt. Du Cane in proof of the

* Annals of Natural History, 1839, p. 438.

actual metamorphosis of the Crustacean in question, is most acceptable. He affirms a corresponding metamorphosis to occur in the ditchprawn (*Palemon variabilis*) and common shrimp (*Crangon vulgaris*). Dr. Thompson has witnessed similar metamorphoses in the genera *Palinurus, Squilla, Pagurus, Porcellana, Galatea,* and the marine species of *Astacus,* as well as in *Palemon* and *Crangon.*

Finally, the metamorphosis of another species of shrimp (*Caridina Desmarestii*) have been described with all the requisite care and detail by M. Joly, in the Annales des Sciences Naturelles for January 1843. The development of the ovum up to the period of exclusion and attachment to the maternal ciliated plates, closely corresponds with that described by Rathké in the *Astacus fluviatilis.* The first stages in the formation of the rudimental extremities, the first steps in the definition of the alimentary canal and circulating system, were likewise the same; the heart was observed to beat thirty-five times in a minute in the embryo *Caridina.*

But the formation of the abdomen is anterior to that of the antennæ, the labrum, and the maxillæ; and the ambulatory thoracic legs precede the masticatory pairs in their formation. The young *Caridina,* moreover, is born with only three pairs of jaws, and the representatives of the ambulatory feet are bifid, like those of the *Mysis,* and are at first likewise only in three pairs. The abdominal segments are without any vestige of lamelliform limbs.

The bifid feet of the larva are metamorphosed into auxiliary jaws, and the later bifid thoracic limbs are metamorphosed into the ordinary ambulatory legs. With respect to the branchiæ they are not at all developed when the young Caridina quits the ovum. The first moult takes place three days after exclusion from the egg; the subsequent ecdyses are numerous, and take place at long intervals. It is unquestionable that the Caridina, unlike the Craw-fish, is excluded neither under the form, nor with all the parts which it possesses in its mature shape. It wants, for example, the branchiæ, a certain number of maxillæ, the ambulatory thoracic, and the lamelliform abdominal feet; it possesses neither the squamous tail nor the complex stomach of the mature creature.

The cumulative evidence of the metamorphoses of *Crustacea* can no longer be rejected: but their modifications in different genera, and the number of the exceptions to the law, like that presented by the *Astacus fluviatilis,* are yet to be determined. Here, therefore, is an ample field open to the researches of the original observer, a field which must be diligently and extensively cultivated before it can yield the fruits of true generalisations as to the extent and nature and varieties of the metamorphoses in the class of articulate animals which support their bodies on jointed limbs and breathe by gills.

LECTURE XVI.

INSECTA.

Although spontaneous locomotion is the peculiar attribute of the Animal Kingdom, we have seen that the lowest members, the Zoophytes as they were termed, were, for the most part, fixed and motionless, like plants: we have seen that the first manifestations of locomotion were of the feeblest and simplest character, a rowing of the body through an element of equal density with itself, or a trailing of the body along the ground, which supported it at every point. As we advanced to the survey of the Articulate series of animals, we saw the integument progressively hardened, divided into segments which were united by flexible joints; at length supported upon moveable jointed limbs, consisting of hollow columns of integument hardened into a dense exterior crust, capable of serving the office of levers and fulcra, whereby the animal could raise its belly from the dust, and swiftly traverse the surface of the ground.

We now come to a class of *Articulata*, in which the highest problem of animal mechanics is solved, and the entire body and its appendages can be lifted from the ground and be propelled through the air. The species which enjoy this swiftest mode of traversing space, breathe the air directly: but their organs of respiration are peculiarly modified in relation to their powers of locomotion; they consist of innumerable tracheæ commencing from lateral pores called stigmata, or by anal tubes, which are ramified through and over every tissue and organ of the body. The nervous system is homogangliate; the organs of sense include two jointed antennæ and two compound eyes; the skeleton is principally external, and cut deeply into segments, whence the name of the class *Insecta*.

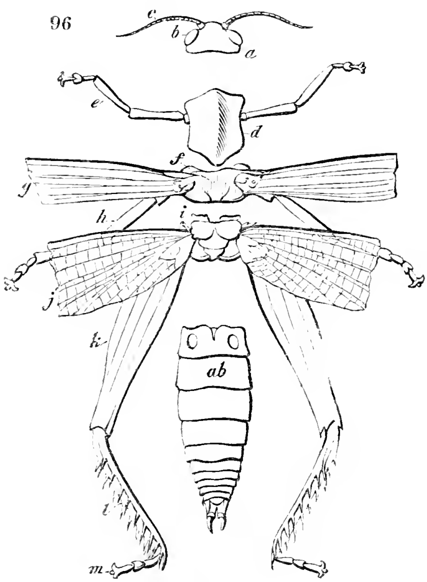
Not every Insect, however, has the power of flight, nor any Insect save in its last and most perfect state; many undergo most remarkable transformations before they acquire their wings, and although some Insects. which ultimately are so endowed, undergo a less amount of change, yet the metamorphoses are always least remarkable in the apterous species.

Of these lowest members of the class of Insects, many have more than three pairs of legs, have sometimes indeed eighty pairs and upwards in their mature state: metamorphic development exhausts itself, as in the Anellides, in the successive acquisition of new segments and legs in addition to those which previously or originally existed; these Insects are therefore termed *Myriapoda*.

True or hexapod Insects have thirteen rings, one for the head, three for the thorax, and nine for the abdomen. Certain flying Insects in their early or larval state present several pairs of rudimental feet, in addition to those attached to the first three segments, succeeding the head, but no true Insect in its mature state has more than the three pairs of articulated limbs just indicated.

Every Insect has a distinct head (*fig.* 96, *a*), provided with one pair of antennæ (*c*), and its trunk is divided into two regions called thorax and abdomen (*a b*).

96



Locusta.

The thorax is interposed between the head and the abdomen, and so far is analogous to that part in human anatomy; but it has neither the same relation to the contained viscera nor to the locomotive extremities which characterise the thorax in the vertebrate animals. To the Insect's thorax are attached all the locomotive members; both the first pair, which may be compared with the pectoral extremities of the vertebrate animal, and the last pair, which may correspond with the pelvic members, as well as the middle pair, to which there is no analogue in the vertebrate series. This centre of the locomotive powers is divided into three segments, which correspond with the three pairs of legs: the first segment is termed the "prothorax" (*d*), the second the "meso-thorax" (*f*), and the third, the "meta-thorax" (*i*). Each of these segments has a dorsal and a sternal piece: the dorsal half rings are called respectively "pronotum," "mesonotum," and "metanotum;" the ventral or sternal arcs bear the corresponding terms, "prosternum," "mesosternum," and "meta-sternum." From the inferior arches of the segments, the legs (*e*, *h*, *k*) are developed, or with them they are principally articulated, like the legs of the Crustacea and the ventral oars or setigerous prolegs of the Anellides. In the flying insects there are developed from the dorsal arches of the middle and third segments, locomotive appendages which constitute the wings (*g*, *j*).

It must not be supposed that the parts of the thorax which have just been described are naturally or uniformly separate, and moveably connected with one another; they are more commonly confluent, but in different degrees in different families; so as more or less to obscure the primitive traces of their original distinctness, which can only be demonstrated, as has been done by Macleay, Audouin, Burmeister, and others, by an extended comparison of the thorax in the whole class of Insects, or by tracing its development and modifications during the various stages of the metamorphoses When the composition of the thorax of an insect is thus studied, it is found to be made up of not less than fifty-two pieces, which have for the most part received, and necessarily, distinct names in Entomology, and many of them, very unnecessarily, more names than one.

The abdomen is usually formed of a greater number of segments, always nine in the larva, which retain a greater degree of mobility upon each other; but it supports no locomotive appendages in the hexapod insects.

The tissue of the external skeleton is of a dense, resisting, but light material; it looks and feels like horn, but it has for its base a peculiar substance called "chitine," which is insoluble in caustic, potash, and retains its form like charcoal when submitted to a red heat. The articulated appendages consist, like the segments of the trunk, of hollow cases or tubes of the same firm and slightly flexible substance; which tubes contain the muscles, nerves, and other soft parts in their interior. The integument is softer and more yielding in larvæ, flies, and most parasitic insects. It consists of three layers, epidermal, pigmental, and dermal, the derm and epiderm more closely resemble each other in physical properties than in other animals: they are separated and cemented together by sometimes two distinct coloured layers of rete mucosum. The hairs, spines and scales are processes of the epiderm, which often include a coloured substance.

I may now proceed to a more particular description of the jointed and aliform appendages of the skeleton. The first pair inserted into the front or upper part of the head, are the antennæ, which present a vast variety of shapes and sizes in different insects, but seem in all to have most intimate relation to the senses of touch and hearing. Their precise function has not, however, yet been well defined. The Entomologist avails himself of their various conformation to obtain characters for the distinction of families, of genera, or of species of insects; and a considerable section of the glossology of this extensive department of Natural History is devoted to the technical terms required to express the antennal characters. To the head likewise belong more or less complicated oral instruments, called "trophi," or "instrumenta cibaria," modified in some insects to serve for suction, in others, for mastication: they properly fall under the demonstration of the digestive system.

The jointed legs attached, as before stated, to the three thoracic segments, consist each of a hip, a thigh (*k*), a leg (*l*), and a foot (*m*), commonly called the tarsus; but which are not to be taken as rigorously answerable to the parts so termed in Human Anatomy. The hip, for example, consists of two joints, usually the shortest of the whole leg: the foot or tarsus includes from two to five joints, and is terminated by a pair of diverging hooks or claws. The peculiar powers of moving upon land or in water depend upon the modifications of the forms or proportions of these extremities. In water insects the tarsi are usually flattened, fringed with hair, and stretched out in the same plane with the trunk, like oars. In leaping insects the hinder limbs present as disproportionate a development as the legs of the kangaroo. In burrowing insects, the anterior limbs are distinguished by short, broad, and massive proportions, with a strong and flattened hand, like that of the mole, as in this best of insect burrowers *, which has been called the mole-cricket. Most insects are able to crawl up vertical walls, and some along glass and the ceilings of rooms, against gravity: the house-fly achieves this by virtue of the development of little suckers upon the under surface of certain expanded joints of the tarsus.

The wings of insects are essentially flattened vesicles, sustained by slender but firm hollow tubes called "nervures," along which branches of the tracheæ, and channels of the circulation, are continued. The wings never exceed two pairs, which are developed from the mesonotum and metanotum. Sometimes one or other of these pairs is wanting. The wings present many varieties in their shape, their consistence, and their teguments. When they subserve flight, they are thin and transparent; or if opake, are rendered so by an imbricated clothing of most delicate scales, which, when detached, resemble the pollen of flowers. In certain insects, especially those that burrow, the first pair of wings become thick, hard, and opake, forming a kind of shield to the back; they are called "elytra," and cover the posterior pair of membranous wings when these are not expanded for flight. Sometimes the anterior wings are membranous

* Prep. No. 463, A.

at their extremities, hard and opake at their base, when they are called "hemelytra." When the hinder pair of wings is wanting, it is replaced by a pair of rudimental appendages called balancers: other modifications of, or appendages to, the wings have been called "alulæ" and "patagia."

The muscular system is, as may be supposed, developed in relation to the several kinds and powers of locomotion indicated by the modifications of the extremities. As a necessary corollary of the cylindrical form and external position of the principal parts of the skeleton, the joints are for the most part ginglymoid, and restricted to movements in one plane. The muscles of the legs are consequently simply flexors and extensors. The coxæ have a round head inserted into cup, and the movements of the hip-joint are rotatory; the head is usually connected with the thorax by a similar joint, which, from the greater freedom of the movements, may be termed arthrodial. In insects of flight, the cavity of the thorax is almost entirely occupied by the muscles of the wings. The muscular fibre is transversely striated, and is also characterised by a second series of transverse indentations at regular but wider intervals.

The Orders of Insects are founded upon the modifications of the wings; those in which the first pair serve as sheaths, and the second alone are used for flight, and are folded transversely when at rest, constitute the order *Coleoptera:* they undergo complete metamorphosis, and are subdivided according to the number of joints of the tarsi. Beetles and most burrowing Insects belong to this order.

Those insects in which the anterior pair of wings are converted into elytra, of less density than in the *Coleoptera,* and in which the posterior wings are folded longitudinally when at rest, constitute the order *Orthoptera:* they are said to undergo a semi-metamorphosis, the chief change being the acquisition of wings. This order includes the most voracious and destructive Insects, as the Locust, Cockroach, &c.

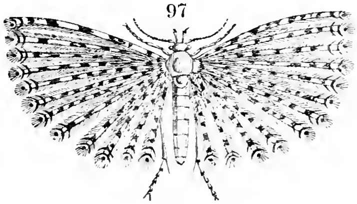
Those Insects which have both pair of wings membranous, transparent, strengthened by numerous nervures, and finely reticulated, form the order *Neuroptera,* which includes the highest organised insects, as the predatory dragon-flies.

The Insects which have four membranous wings simply veined, and crossing each other horizontally when at rest, form the order *Hymenoptera:* they undergo a complete metamorphosis, and include the most useful of insects, as the bee.

The Insects with four wings, more or less clothed with minute scales, are called *Lepidoptera:* they undergo complete metamorphosis, and include the most beautiful species of the class, as the butterflies: in one family of this order the wings are divided lengthwise into a number of feathered pieces, which radiate from the body like the stems of a fan. (*fig.* 97.)

The Insects which have the anterior pair of wings in the condition of the hemelytra, form the order *Hemiptera;* but certain genera have the dense part of the anterior wings reduced to so small a strip, that they are scarcely distinguishable, except by size, from the posterior pair, and these insects constitute a section of the order termed *Homoptera.*

97



Pterophora.

A few remarkable genera of insects have the anterior pair of wings reduced to small or rudimental elytra, and the posterior pair unusually large, and folded longitudinally, like a fan when at rest. The anterior wings being reduced to minute appendages twisted spirally, the Order has been hence termed *Strepsiptera.* The species, in their larval state, are parasitic on the bee tribe.

The order *Diptera* is characterised by the development of the anterior pair of wings into organs of flight, and the retention of the hinder pair in the condition of minute clavate appendages, usually called the "balancers." The prothorax and metathorax are rudimental whilst the mesothorax is disproportionately large to form the required space for the powerful muscles, which execute, through the two anterior wings, the function of flight.

In almost every Order of Insects there are species, or there are individuals, as the females of particular species, which are apterous; but since the time of Aristotle, who divided insects primarily into the "winged," *Ptilota,* and the "wingless," *Aptera,* most of the hexapod insects devoid of wings have been artificially grouped together. Cuvier and Latreille divide the Apterous Insects into three tribes, the *Suctoria* (fleas), the *Parasita* (lice, including the *Pediculus capitis* and *Pthirus inguinalis* of the human species), and the *Thysanoura,* including the *Lepisma* and *Podura* or skip-tails.

The grand and characteristic endowment of an insect is its wings; every part of the organisation is modified in subserviency to the full fruition of these instruments of motion. In no other part of the Animal Kingdom is the organisation for flight so perfect, so apt to that end, as in the class of insects. The swallow cannot match the dragon-fly in flight; this insect has been seen tc outstrip and elude its swift pursuer of the feathered class: nay, it can do more in the air than any bird, it can fly backwards and sidelong, to right or left, as well as forwards, and alter its course on the instant without turning. Now what are these "limber fans," that give the little articulate animals such command over aërial space? I do not mean their structure or composition; the anatomical question has been already answered. I do not ask for their analogy; that is rightly expressed by their common name; they have the same relation to the insect as instruments of motion, which the feathered wing bears to the bird. But what is their essential nature, or with what are the wings of the insect homologous? Are they modified anterior limbs, like the wings of bats and birds and flying-fishes? Not so, for they co-exist with and are superadded to the jointed anterior pair of legs. Are they such expansions as form the parachute of the little dragon (*Draco volans*)? These do, indeed, co-exist with arms and legs, but they consist of a fold of integument stretched out upon elongated and straightened ribs, which are appendages of a vertebral column. But an insect has no vertebral column, no true internal skeleton. The strong and numerous nervures which sustain the thin alar membranes of the Libellula are articulated processes of the external chitinous tegument.

A circulation can be traced through these membranes, at least in their early and softer state; air-vessels are abundantly spread over the supporting frame-work: the wings of the Lepidoptera appear after the third moult, as tegumentary flattened vesicles, soft, and permeated by tracheæ, and when fully expanded in the imago, they must still take their share in the business of respiration. Nay, it has been found that the rudimental wings of the pupæ of certain water insects are the gills of such; they perform the same function as the very similar membranous and vascular tegumentary expansions in certain Anellides (see *fig.* 68. p. 130.); which expansions are developed, as in the larvæ of the Ephemera, from the tergal arch of the segment, and co-exist with rudimental legs from the ventral arch of the same segment.

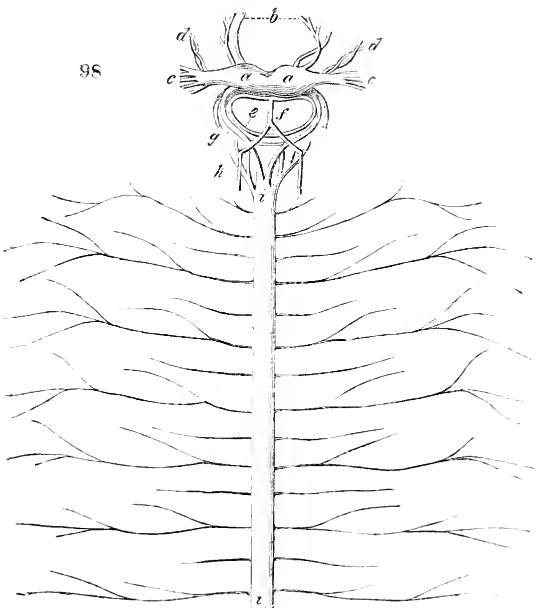
Well, therefore, has the deep-thinking Oken * called the wings of insects "aërial gills;" they are, in fact, the homologues of the tergal branchiæ of the vermiform Articulata, raised to a higher function in corellation with a generally transmuted state of the rest of the organisation, which is advanced to the utmost perfection of which the Articulate type of structure is susceptible. And have we not already seen the membranous aliform branchiæ of the beetle protected, like the gills of the lobster, by an elytral carapace developed from a more advanced segment? Have we not likewise found the metamorphosed branchial wings of the Pterophora subdivided lengthwise like the tufted tergal gills of the Nereis?

* Natur. Philosophie, 2d Ed. p. 418.

The air-breathing articulated animals with jointed legs offer a close correspondence with those that respire by gills in the progressive steps of complication of the nervous system and the order in which those steps succeed each other. The lowest insects, like the lowest Crustaceans, resemble the worms, in the great length and slenderness of their body, and in the uniform size, shape, and number of the constituent segments. In the Iulus, whose very short and numerous rings support each two pairs of rudimental legs, the corresponding ganglions of the abdominal chords are much less conspicuous than in the earth-worms, and the whole central axis of the nervous system, continued from the brain, is almost as devoid of partial swellings as the spinal chord of the apodal vertebrate. It lies, however, as in other Articulata, on the opposite side of the body to that in which the brain is situated.

The cephalic ganglion (*fig.* 98. *a*) of the Iulus is transversely elon-

98



Iulus.

gated, and obscurely divided by a slight median indentation into two side-lobes: its upper and latter extremities are prolonged outwards into the short and thick optic nerves (*c*, *c*), which resolve themselves half way towards the compound eye into a plexus of filaments for its several divisions. Two separate antennal nerves, conjectured by Straus to be motory and sensory (*d*, *d*), are sent off on each side below and in front of the optic nerves to the short seven-jointed antennæ. On each side also, but below the antennal nerves, arise the two nerves (*b*) united together by an anastomosing branch which supply the palpless mandibles.

The thick œsophageal chords (*g*) are continued from the posterior and inferior angles of the brain; and, though apparently simple, consist essentially of two chords, which become separate at the lower part of the pharynx: the anterior chord girts the pharynx by a transversely oval ring, formed by its confluence with its fellow; the posterior and normal columns converge, at an acute angle backwards, blend together, and expand into the commencement of the abdominal nervous trunk; thus inclosing the œsophagus by a second and looser collar. The closer anastomotic ring is analogous to that formed by the transverse commissural band of the œsophageal chords in the lobster and limulus; and probably also to the anterior nervous ring discovered by Lyonnet in the Cossus ligniperda. The stomato-gastric nerves (*f*), which arise from the posterior part of the brain, immediately form a third slender ring (*e*), about the œsophagus, from the middle of the upper part of which the trunk of the stomato-gastric system is continued a short way back upon the stomach, when it divides; the two divisions diverge at an angle of 45°, bend abruptly backwards, and run parallel with each other along the dorso-lateral parts of the wide and straight alimentary canal.

Two large nerves (*h*) are sent forwards from the beginning of the thick subœsophageal or ventral chord (*i, i*), to supply the confluent maxillæ, which form the under lip: the nerves of the two single pairs of feet, belonging to the thoracic segments, next arise, and afterwards the more numerous minute nerves to the little feet, which, by their articulation to the segments in double pairs, indicate such segments to be severally a confluence of two. The simplicity of the abdominal chords corresponds with the close approximation and great numbers of the organs from which they receive impressions and to which they transmit stimuli. The analogy of this exceptional condition of the abdominal chord or nervous axis in the Iulus to the dorsal spinal chord of the Vertebrata, is as instructive as is that of the equally exceptional ganglionic condition of the spinal chord in the Tetrodon amongst fishes to the normal abdominal knotted chords in the Articulata, in tracing their mutual relations to each other.

The segments of the Polydesmus are relatively fewer and larger than in the Iulus, and their lateral margins are produced: each, however, with the exception of the first three, which answer to the thorax in hexapod insects, supports two pairs of legs: but these are longer than in the Iulus. Accordingly we find the sub-abdominal nervous chords (*fig.* 99.), which show as little trace of their median separation as in the Iuli, swelling into two slight enlargements (*g*, *g*) opposite each of the abdominal segments: two nerves are sent off from either side of each enlargement, and the anterior of these four pairs of nerves is directed at an acute angle forwards and outwards to the stigmata: the remaining pairs supply the muscles of the segment and the legs, and are of equal size.

99

Polydesmus.

In the Centipede, a series of equal and equidistant ganglia is developed upon the ventral surface of the two abdominal chords. Only in the first and last of the abdominal ganglions can any modification of size be detected. The anterior, or sub-œsophageal ganglion, for example, is larger than the rest, having to supply the modified legs which perform the function of jaws and under lip; the chords, diverging as they escape on each side of the œsophagus, enclose it by uniting with the large bilobed ganglion, or brain above. The nerves from this part supply the large antennæ and the aggregated ocelli. In the structure of the abdominal columns a tract less closely connected with the ganglionic nerves may be traced along their dorsal aspect. This was first pointed out by Mr. Newport, who attributes to it the motor function. A large, vascular trunk, connected also with the dorsal aspect of the nervous system, has been regarded as part of the nervous system; by some as a motor, by others as a respiratory column: its true nature was detected by Mr. Lord.* With regard to the ganglionic and non-ganglionic portions of the true nervous axis, the same physiological reasonings will apply as have led to the conclusions already given respecting their office in the crustaceous animals.

Of the four nerves which come off from the sides of the ganglionic portions of the columns, the second, which is principally distributed to the muscles of the corresponding pair of legs, arises in a great proportion from the ganglion itself. The first and third nerves, which are smaller than the second, supply the muscles and integuments of the segment. The fourth pair of nerves passes to the breathing pore and to the integument. This, therefore, must be regarded as the respiratory nerve. The stomato-gastric nerve is a distinct system connected with the anterior ring or brain.

Thus in the Myriapodous insects we find that although the prin-

* Med. Gazette, March 3d, 1838.

ciple of irrelative repetition prevails in the nervous system as in the skeleton and locomotive instruments, yet it does not prevent the recognition of the leading physiological divisions of that system. We have, for example, the supra-œsophageal or cephalic portion, which is subservient to the functions of the special organs of the senses, and is the centre whence voluntary impulse may be directed along the non-ganglionic tracts of the nervous axis, and to which ordinary sensation may be transferred by similarly uninterrupted nervous filaments. We have, secondly, a large sub-œsophageal mass, which, originating the nerves analogous to the fifth pair, for the masticating organs and other parts of the head, may be regarded as analogous to the medulla oblongata. In the abdominal chords and ganglions we have the requisite machinery for the automatic reception and reflexion of stimuli, independently of sensation and the will; and to these are superadded internuntiate and uninterrupted chords, for bringing the body under the dominion of the will, and for producing harmony and consent of action throughout its extent. The special nerves to the respiratory system, and the stomato-gastric nerves, complete this already complicated nervous system.

In the hexapod insects the nervous system differs chiefly from that in the Myriapods in having its primary divisions more definitely developed, and in manifesting degrees of concentration corresponding with the increase of bulk and strength in particular parts of the trunk, and in the locomotive organs appended thereto. Most insects, however, commence their career as worms; the high form which they are ultimately destined to attain in the articulate series is at first masked by the guise of an Anellide or Entozoon. Some insects retain their larval or vermiform state much longer than others; and after passing a great proportion of their lives under this form, fall into the state of the pupa, or chrysalis, relapsing, as it were, a second time into the condition of an ovum, there and then undergoing that part of their development which before was left incomplete, and finally, emerge in their perfect state to enjoy for a brief period the highest faculties, animal and organic, which they are destined to acquire; fluttering in the air, it may be, for a single day, procreating their kind, and perishing. Now the development of the nervous system, like that of the muscular, digestive, and other systems, being completed at distinct and sometimes remote periods, requires to be studied in the first and last of the active states of the insect, and also in the intermediate period, when, owing to the rapidity and extent of the changes which it undergoes, the nervous system offers to the comparative anatomist and physiologist phenomena of the highest interest.

The apodal Entozoiform larvæ, in which the segments of the body are obscurely defined, as those of most Diptera, Hymenoptera, and of some Coleoptera with very rudimental feet, have a simple ventral nervous chord, almost as devoid of ganglionic enlargements as in the Nematoidea and Iulidæ: it is, however, usually relatively shorter, failing to reach the posterior extremity of the body, and the fine nerves pass off on each side and radiate from the extremity.

In the larva of *Stratiomys chamæleon* the ventral chord is divided by a series of constrictions into eleven consecutive and contiguous ganglia.

The larvæ, which present, like the Centipede, larger and more definite segments, most of which are provided with legs or prolegs, have a ganglionic centre for each segment, and intermediate chords.

This anellidous and chilopodiform type of the nervous system has been best described and figured by Lyonnet. The subject which this inimitable dissector and artist selected for his patient investigations was the caterpillar of the *Cossus ligniperda*. The nervous axis consists of thirteen ganglions, arranged along the median line of the body, and connected by two chords or columns. The first and largest ganglion, situated in the head above the mouth, and of a bilobed form, Lyonnet calls the brain; the remaining twelve ganglions (as in *fig.* 104, 1 to 12.) are situated below the alimentary canal; the eleventh and twelfth are so close together that their distinction might readily be overlooked; but it was pointed out by Lyonnet. The sub-abdominal ganglions and inter-communicating chords were called by Lyonnet the spinal marrow. Some anatomists who have applied the analogy of the ganglionic and non-ganglionic roots of the spinal nerves in the higher Vertebrata to the explanation of the functions of the ganglionic and non-ganglionic parts of the nervous axis in Insects, have thought that they found in the works of Lyonnet corroboration of this inconclusive physiological view. Lyonnet, however, expressly denies that the parts which he called brain and spinal marrow in the insect were similar in anatomical structure to those in the higher animals.

" The spinal marrow of the caterpillar, if one may say that it possesses such," observes Lyonnet, " sensibly differs from that of man. It is slender; it bifurcates at intervals, and enlarges from distance to distance to form its masses, which I have named ganglions." The intervening chords Lyonnet terms " conduits de la Moelle épinière." He particularly points out the difference in relative position, and in the means of protection assigned to the ganglionic columns in insects, and to the spinal chord in the higher animals. As to any views of distinct physiological properties in the ganglions or the non-ganglionic nervous tracts, none such appear in the works of Lyonnet; nor, indeed, did they form part of the do-main of physiology at that period; and it was a great advantage to Zootomy that Lyonnet looked at his subject with the eye of truth, and not through the prism of any pre-formed physiological notions.

The supra-œsophageal ganglion gives off ten nerves; eight in pairs, and two solitary or azygos nerves; one of these latter is the anterior œsophageal ring, which Mr. Newport has figured and described in the *Sphynx ligustri.* Its extremities are connected with the cephalic ganglion immediately anterior to the attachment of the principal columns which form the posterior œsophageal ring. The second solitary nerve is sent off from the middle of the posterior side of the cerebral ganglion, and proceeds backwards to the œsophagus. The cephalic nerves, sent off in pairs, supply the antennæ, the ocelli, the muscular and integumentary parts of the head, and communicate with branches of the maxillary nerves. The most remarkable pair, however, is that which arises anterior to the annular or œsophageal nerve, and which constitutes the cephalic roots, or connections of the stomato-gastric system. Each of these nerves passes forwards and divides; the external tract joins one of the maxillary nerves of the subœsophageal ganglion. The internal one converges towards its fellow, and terminates with it in the first of the median cephalic series of ganglions, which Lyonnet terms frontal ganglions. The longest nerve in the whole body of the caterpillar is given off from these ganglions as it passes along the œsophagus to the stomach and intestines: it was called by Swammerdam the recurrent nerve. There are two other small ganglions situate in the head of the caterpillar on each side of the large bilobed or cephalic ganglion. The largest nervous columns connected with the supra-œsophageal ganglion, are those which enclose the œsophagus by uniting with the first of the lower series of ganglions. From this ganglion nerves are distributed to the mandibles, the maxillæ, the lips, and their special organs of sensation or palpi. Two distinct diverging columns connect the first with the second ventral ganglion; and this is similarly connected with the third. The inter-communicating chords of the remaining ganglions appear single at their anterior part, and bifurcate as they are connected with the next ganglion in succession. They are of a greyish blue but transparent colour, and are very elastic. From each side of the abdominal ganglions are given off two principal branches; the anterior to the muscles chiefly, the posterior chiefly to the integuments, but communicating with the muscular branch of the succeeding ganglion. From the beginning of the separation of the bifurcated inter-ganglionic columns, or conduits, Lyonnet says, "there descends a nerve, the extremity of which is enlarged a little above the succeeding ganglion, which sends off from the enlargement a transverse nerve to the right and to the left, to which I give the name of spinal rein (bride épinière). Of these transverse nerves there are ten pairs; they terminate chiefly in the stigmata and tracheæ, but send off small branches to the skin and to the dorsal vessel. These are the respiratory ganglia and nerves, and have been erroneously considered as the motor column and nerves.

The nervous system in perfect insects approaches to its larval condition according as the segments of the body and their locomotive appendages are less concentrated and developed; thus, in the darkling beetle (*Meloë*) the abdominal nervous columns still manifest eight distinct ganglions, of which the last, perhaps including three ganglions of the larva, is now the largest, and radiates its branches to the generative organs. The first, or sub-œsophageal ganglion, sends forward four median branches to the under parts of the mouth, and is connected with the brain by the two lateral chords forming the post-œsophageal collar. The usual nerves are given off from the brain, those to the eyes having acquired an increase of bulk, corresponding with the great change in the size and complexity of the organs of vision. The stomato-gastric nerves arise close to the antennal branches, and form a median frontal ganglion, and are connected with a pair of lateral ganglions: from these the usual recurrent nerve is given off. In the thorax we distinguish the second ventral ganglion, which, as it distributes branches to the first pair of legs, I have called the brachial ganglion. The third ventral ganglion supplying, amongst other parts, the elytra, may be termed the elytral ganglion. The fourth ventral ganglion is distinct in the present species, and, supplying the nerves to the second or true wings, may be termed the alar ganglion. The fifth, sixth, and seventh, or first three ganglions in the abdomen, distribute nerves to as many large and moveable segments of that division of the trunk: the last ganglion is the largest, and its size is conformable with the bulk of the generative apparatus, upon which, on the rectum, and the modified terminal segments of the abdomen, its branches are expended.

In insects having the organs of flight better developed, the elytral and alar ganglia present a greater proportional size; but different degrees of concentration in the centres of the nervous system are met with in these higher forms of insects. In the Blattæ, for example, there are as many as ten distinct ventral, or inferior ganglions. The supra-œsophageal nervous centre or brain is a transversely oblong bilobed mass, sending its upper and largest pair of nerves to the eyes. Anterior and below the antennal nerves arise from small mamillary processes of the brain, reminding us of olfactive lobes. The stomato-gastric nerves are seen a little in advance of those in the deflected part of the head. The œsophageal chords are short, uniting in a maxillary ganglion, or first of the ventral series, which is situated in the head; the inter-communicating chords, which pass from this to the brachial ganglion, are long, straight, parallel, and juxtaposed. The brachial ganglion sends off two large and two small pairs of nerves, the anterior ones are distributed to the muscles of the arm, which are lodged within the anterior portion of the thoracic shield; the second nerve is continued to the terminal segment of the anterior extremities like the second nerve from the ganglions of the centipede. The elytral ganglion, or the third of the ventral series, is larger than the preceding one. Viewed from the dorsal aspect, it is seen to distribute three small nerves to the muscles of the wing-cover; the posterior branch, anastomosing with the nerve sent from the succeeding ganglion to the wing, thus serves to combine these organs of flight in action in the Orthopterous insects. In the Coleoptera, whose elytra do not move in flight, this anastomosis of the nerves does not take place. Four pairs of nerves come into view when the elytral ganglion is exposed from below: the anterior of these runs forward at an acute angle to the muscles of the first and second pairs of legs. The next two anastomose with an alar branch. The third pair enters the second pair of legs, and is distributed to their terminal segments. The posterior nerve passes to the alar plexus. The substance of the bilobed elytral ganglion seems to be superadded to the under or ventral part of the nervous chord. The alar ganglion, formed by a confluence of the fourth and fifth of the larval ganglions, is situated at the same distance from the elytral as this is from the brachial ganglion. It is not quite so broad as the elytral ganglion, the wings which it supplies being shorter than their covers. The anterior nerve enters into communication with the elytral branches, as does also the second nerve, with the addition of branches to the muscles of the legs. The third nerve is distributed to the third pair of legs; the fourth to the muscles of the wing. The remaining six ganglions of the ventral series are contained in the abdomen: they are smaller than the preceding, the distance between them progressively increasing after the third. The last, formed by the confluence of the eleventh and twelfth ventral ganglions of the larva, is of a triangular form, and the largest of the series. It sends off a pair of conspicuous nerves to the cercæ or anal antennæ. The two interganglionic columns are in contact lengthwise from the head to the anal ganglion. In the Meloë they are smaller, and separated by a marked interspace. The respiratory nerves may be seen on the dorsal aspect above the second, third, and fourth ventral ganglion. If the nervous system of the Blatta be compared with the stages of development of that system in an insect presenting a more concentrated type in the perfect state, as in the species of butterfly described by Heroldt, it will be found to correspond with the sixth stage figured by this author in the pupa of the *Papilio brassicæ*.

In the predatory leaf insect (*Mantis*) the progress of coalescence has reduced the number of abdominal ganglia to four, the three thoracic ganglions continuing distinct, so that the nervous system corresponds with the eighth stage figured by Heroldt in the Lepidopterous insect just mentioned. The supra-œsophageal mass consists of two triangular lobes having their bases rounded and anterior, and their apex prolonged into the œsophageal chords. Two small nerves are sent off from the anterior part to the ocelli, where they swell into a slight enlargement. Two short and thick optic nerves pass from the sides of the brain to form the ganglions supplying the large compound eyes.

The stomato-gastric nerves arise, one on each side, near the optic nerves. The œsophageal columns are short, and directly converge to the inferior cerebral ganglion, which gives two large and several small nerves to the jaws: it is situated in the head. Two long and parallel columns extend to the first thoracic ganglion, which transmits long and large nerves to the formidable prehensile anterior pair of legs. The second thoracic or elytral ganglion is at a great distance from the first, and much nearer the third or alar ganglion. Anastomosing branches connect the nerves which these ganglions respectively distribute to the elytra and wings. The Mantis is chiefly remarkable for the great length of the ventral chords connecting the brachial with the elytral ganglia, and which renders them favourable for minute analysis of their structure. Anterior and posterior columns, or divisions analogous to those in the spinal marrow of higher animals, cannot be distinguished. The so-called sensorial tract is confined to accumulations of nervous matter at the origin of the nerves to the locomotive organs.

The results of the experiments in which the body of the living Mantis has been so divided, that a segment with one of these ganglionic enlargements and the locomotive organs it supplies has been detached from the rest, illustrate the functions of the aggregated centres of nervous matter in relation to their power of receiving and transmitting impressions, so as to maintain the order of action o such detached organs upon the application of a stimulus, for a considerable period after the mutilation.

The jaws of the separated head of a Mantis bite forcibly the stick which is held to them. The formidably armed prehensile legs in like manner wound the finger that touches them, when the segment of the body supporting them is separated from the head and the rest of the trunk. And if decapitation or amputation of the prothorax be neatly performed on the living insect, while in its natural and ordinary position, perched by its middle and hinder pairs of legs upon a twig, the rest of the trunk does not fall to the ground, but is maintained for a certain period in that posture, which it even recovers by actions of the wings, when the balance is slightly and purposely disturbed.

The supra-œsophageal or cerebral mass in insects obtains its largest development in the dragon-fly, which from the size and perfection of its organs of vision, its great and enduring powers of flight and predatory habits, may be regarded as the eagle of insects. From the side of each of the superior lobes of the brain, the optic nerve is continued of equal breadth, so as to seem rather as a lobe of the brain. It expands, and, like the stalk of a mushroom, forms the stem of a very large reniform ganglion, the convexity of which is turned forwards and outwards, and the free concave projecting margin developed at the under part. Thousands of branches to the divisions of the compound eye are given off from the convex surface of this ganglion. The brain presents a single median inferior lobe; the œsophageal chords sent downwards to the maxillary ganglion are short and thick. This ganglion is succeeded by three large equidistant thoracic ganglia, of which the last two, corresponding with the elytral and alar ganglions of the preceding insect, are, as might be expected, from the development of the muscles of the wings (both of which are alike organised for flight), considerably the largest. Of the ganglia of the abdomen, the terminal one resulting from the confluence of two, and which supplies the organs of generation, is remarkable for its large size.

In the white butterfly (*Papilio brassicæ*) the brain is a thick transverse rounded mass, indented by a longitudinal furrow along the median line. From its sides proceed the large optic nerve, now greatly surpassing the other cerebral nerves in size. The œsophageal collar is triangular, leaving a very small interval for the passage of the alimentary gullet. The maxillary ganglion is relatively much smaller than in the dragon-fly, the blatta, and other mandibulate insects. The first two thoracic ganglions are blended into one, and the third thoracic and first abdominal ganglions have coalesced to form a similar mass in the thorax, connected with the preceding by short chords, separated by an interval to allow the passage between them of certain processes of the thorax giving attachment to the muscles of the legs. The ganglions of the thorax have been observed in some species (as the *Bombyx Neustria*) to present a reddish tint. They are succeeded in the Lepidoptera by four other ganglions in the abdomen, of which the last, as usual, is the largest.

The nervous system of the chaffer (*Melolontha*) has been dissected and delineated by Strauss with a minuteness and accuracy second only to those of Lyonnet. In these beautiful plates * are shown the bilobed brain with its auxiliary ganglia for the eyes and antennæ; the stomato-gastric nerves and their small lateral cephalic ganglia are also clearly exhibited. The sub-œsophageal or maxillary ganglion is of an oblong form; the brachial ganglion is triangular; the elytral ganglion is of a circular, and the alar ganglion of a pyriform, figure; these two latter being concentrated into almost a single mass, and radiating the nerves to the abdomen, like the termination of the spinal marrow called cauda equina. The two median nerves of this series chiefly supply the organs of generation.

The three thoracic ganglia are blended together into one mass in the Diptera; and only two ganglions are developed on the abdominal portion of the ventral chords.

The greatest degree of concentration of the nervous system is presented in the insects of the Hemipterous order. In the *Nepa* or water-scorpion, for example, only three ganglions are present in its nervous system. The first, or brain, consists of two pyriform lobes in contact by their base. The maxillary ganglion is square-shaped, receiving the œsophageal chords at its anterior angles, and sending back their continuations from its posterior angles; these continue parallel with each other to the thorax, there expanding into a large rounded ganglion, much more voluminous than the brain, and from which radiate the nerves supplying all the rest of the body.

In certain Coleoptera, Hymenoptera, and Diptera, the principal changes which the nervous system undergoes in the progress to the imago state, are the acquisition of ganglions not present in the larva.

The progressive changes which the nervous system of the Lepidopterous insect undergoes in its metamorphoses from the larval into the perfect state, have been beautifully and accurately illustrated by Heroldt in the cabbage butterfly, and by Mr. Newport in a species of sphynx: but Lyonnet had anticipated both these observers, in recognising as well the principle as the details of these changes, which he briefly describes at the termination of the monograph already quoted.

The twelve ventral ganglions of the larva (*fig.* 103.) are sub-equal and, except the two last, at regular distances; in the pupa the inter-ganglionic columns are shorter, but the body, becoming still more abbreviated and concentrated, throws those columns into curved lines. The eleventh and twelfth ganglions coalesce; the sixth and seventh

* Here the work, entitled, "Considerations générales sur l'Anatomie Comparée des Animaux Articulés," &c., 4to. 1828. was shown.

disappear; the fifth blends with the fourth, and the third with the second; thus leaving four ganglions in the abdomen and two in the thorax (*fig.* 104.). Corresponding changes take place in the cerebral portion of the nervous system. The maxillary ganglion decreases with the diminution and change in the maxillary apparatus. The œsophageal collar contracts, as does the canal which it surrounds. The brain enlarges, having to supply organs of sense, especially those of sight, which are perfected to correspond with the acquisition of new and improved locomotive forces. Analogous changes we may naturally conclude to take place in other orders of insects; and we find, indeed, in some of these that the nervous system continues stationary at stages of development which are progressive and transitory in the Lepidoptera, and that further concentration is discovered to have taken place in the Melolontha, Cicada, Nepa, &c., than that which constitutes the highest stage observed by Heroldt and Mr. Newport in the Lepidoptera. The marvel is, that these changes, due in part apparently to mere mechanical influences, should be so regular, so orderly, so admirably adapted in their final results to the general condition and exigencies of the perfect insect: one might have supposed that the particles of the soft and semi-fluid nervous matter, squeezed by the pressure of the surrounding parts, when the body seems to be, as it were, contracted by an universal spasm, would be irregularly dislocated or aggregated into one or more masses; but, on the contrary, we perceive the nervous particles moving forwards and re-arranging themselves in orderly groups, definite in their forms, in their proportions, and in their relative positions; these being apparently regulated by a law of prospective arrangement and arranged precisely in those situations where the greatest supply of nervous energy is required to radiate from them in the active and perfect insect.

An idea of the situation and degree in which the sense of touch is exercised in insects may be formed by observing the modifications of the different parts of the integument, the papillæ, or folds upon its surface, the hairs, plumes, or soft jointed organs developed from particular parts of the body. The soft balls on the feet of grasshoppers, the pulvilli and suckers on those of flies, the soft, setaceous, or plumed antennæ, and, above all, the palpi, often provided with a terminal vesicle, present the requisite physiological conditions of the organ of touch. Although another sense, and most probably that of hearing, may reside in the antennæ, yet no one can witness the use of these organs by bees and ants, the exploratory actions of those of the ichneumon and of many other insects, without recognising in them instruments of the tactile faculty.

All Mandibulate insects have a process from the labium, within the mouth, so analogous to a tongue as to have received that name. It is particularly well developed in the dragon-fly and grasshopper, in which its soft, finely ridged, upper surface receives a rich supply of nerves. It is not present in the suctorial insects, which, as Burmeister well observes, always subsist upon one and the same food, generally inhabit what they feed on, and consequently less require the sense of taste.

Although a few physiologists have suspected that some part or appendage of the head, and others that the membranous lining of the spiracles were the organs of smell, the precise seat of that sense, which unquestionably exists in insects, has not yet been experimentally determined. The application by the common house-fly of the sheath of its proboscis to particles of solid or liquid food before it imbibes them, is an action closely analogous to the scenting of food by the nose in higher animals: and as it is by the odorous qualities much more than by the form of the surface, that we judge of the fitness of substances for food, it is more reasonable to conclude that in this well-known action of our commonest insect, it is scenting, not feeling, the drop of milk or grain of sugar. But no one ever saw an insect present its spiracles to a nutritive substance before feeding.

The signs of attention and hearing are plainer in insects than those of smelling; yet the precise organ has not yet been more definitely recognised, unless the structure, peculiar, however, to moths, described by Treviranus, be the true seat of the auditory sense; it consists of a simple drum situated in front of the base of each antenna. It is strange, however, that the organ under so well marked a form should not exist in crickets, tree-hoppers (*Cicadæ*), and other insects which attract their females by peculiar notes. Only the soft capsular membrane of the joint of the antenna, which in some movements may be rendered tense, has been alluded to by Burmeister as a structural indication of the organ of hearing in the peculiar appendages in which he supposes, with most other entomologists, that the sense resides. The acoustic nerve quits the antennal nerve, in the Crustacea, as if it were a branch of that nerve. Two, at least, and often more numerous nervous filaments from a slight ganglionic enlargement, penetrate the antennæ in insects; and these may subserve the distinct offices of the appreciation of the vibrations of sound, of the characters of surface, and of the regulation of the movements of the antennæ.

Of all the organs of the special senses not only is that of sight manifest without ambiguity, but it is more complicated and relatively larger in insects than in any other class of animals.

What would be thought of a quadruped whose head, with the exception of the mouth and the place of juncture with the neck, was covered by two enormous convex masses of eyes, numbering upwards of 12,000 in each mass? Yet such is the condition of the organs of vision in the dragon-fly, which, besides the two great compound eyes, supports, in the narrow interspace on the vertex of the head, three simple eyes, called ocelli and stemmata.

In all insects the eyes are sessile, or, if supported, as in a few rare instances, on prolongations of the head, such peduncles are not moveable like those which support the compound eyes of the higher Crustacea.

The Centipede has many simple eyes, arranged in a cluster on each side of the head, and requiring only a little closer approximation to form a compound eye. The required approximation takes place in the Iulus, but the optic nerve, instead of swelling into a ganglionic mass, separates into a pencil of nerves at the base of the cluster, one for each ocellus. The transition to the large compound eye of the hexapod is made by the Iulus and Scutigera; but the interval is very wide between the Myriapods and Anellides in regard to both the number and structure of the organs of vision.

The lateral compound eyes of winged insects are generally circular, sometimes oval, or reniform; they occupy the sides of the head, and sometimes encroach upon the upper part so as to meet there. In some Capricorn beetles, as *Tetraopes*, the antennæ project from the middle of the ovate eyes and divide them into an upper and lower half: the compound eyes of certain beetles of the genera *Ateuchus* and *Geotrupes* are almost or quite divided into two on each side by the encroachment of the canthus; some *Ephemeræ* and the *Gyrinidæ* have two pairs of compound eyes: in the latter they are situated one on the upper, the other on the lower surface of the head, and must serve the aquatic whirligigs to discern at the same time objects beneath them in the water, and above them in the air.

The integument of the head, which passes uninterruptedly over the compound eye, then becomes transparent, and is subdivided into a number of hexagonal corneules, varying in number from 50 in the ant, to 4000 in the house-fly, to above 17,000 in the butterfly, and to more than 25,000 in the Mordella beetle. In general each corneule is thicker than it is broad, and thicker at its middle than at its circumference; a layer of pigment here insinuates itself into the interspaces between the corneules. In bees and flies fine hairs project from these interspaces, which must defend the eye or warn the insect against the approach of foreign bodies. Each division of the compound eye has its lens, which combines the characters of both crystalline and vitreous humours: it is always of a more or less elongated conical form, having its base applied to the corneule, and its apex to the optic nerve. The base is not immediately in contact with the cornea, but is separated by a minute aqueous chamber into which a process of the pigmental membrane penetrates, leaving a small pupil opposite the middle of the base of the lens. The pigment is continued along the crystalline vitreous cone to its apex, forming a sheath around it, and enveloping also the adhering filament of the optic nerve; at once separating and connecting together the component ocelli of the compound eye. Fine tracheal ramifications have been traced upon the pigment, which displays very various, and often brilliant or metallic, hues in its outer layer.

The larvæ of the *Coleoptera*, *Lepidoptera*, *Neuroptera*, some *Hymenoptera*, and *Diptera*, have merely simple eyes. Two or three of such ocelli are retained, with the superadded compound eyes, in all the preceding orders save *Coleoptera*, in which only compound eyes are present in the perfect state.

The high degree in which the power of discerning distant objects is enjoyed by the flying insects corresponds with their great power of traversing space.

The few exceptional cases of blind insects are all apterous, as the *Claviger*, and often peculiar to the female sex, as in the glow-worm and cochineal insect.

LECTURE XVII.

INSECTA.

The extraordinary powers of locomotion possessed by insects, the variety of elements which they can traverse, their aptitude to gain access to every situation where organised matter may be obtained, prepare us to expect that they should manifest all the modifications of the digestive system which may be required for the assimilation of the different kinds and conditions of the solids and fluids of plants and animals.

One insect preys upon another; pursues and attacks, like the falcon, on the wing; but, with better mastery over the air-element, it can tear to pieces and devour its prey without alighting. Another insect, sedentary and inactive, imbibes the juices of a plant; a third eats its way into the hard wood; a fourth burrows in the earth for roots or worms.

Some traverse the surface of the earth with a succession of steps too swift for definition; some by leaps so extraordinary, as to have excited the powers of the dynamical calculator from the earliest periods. The waters, also, have their insect population; some swiftly cleaving the clear element, some gyrating on the surface, whilst others creep along the bottom. Nor are the activities of the aquatic insect confined to that lower sphere. The Nepa, or the Dytiscus, at the same time, may possess its organs of reptation, of burrowing, and of flight; thus, like Milton's fiend, it is qualified for different elements, and

> "Through strait, rough, dense, or rare,
> With head, hands, wings, or feet, pursues its way,
> And swims, or sinks, or wades, or creeps, or flies."

With such diversified powers of attaining food, there are, in fact, associated, in Insects, equally, if not more varied, structures for imbibing, seizing, masticating, and digesting nutritious substances. The patience of the anatomist is taxed to the utmost to unfold these delicate structures; but his admiration is chiefly excited by the discovery that they are so clearly referable to a common type.

The most marked modifications of the digestive organs relate rather to the physical condition than the chemical constitution of the food; depend more upon its being solid or fluid, than upon its being of a vegetable or animal nature. Some entomologists have separated all the insects which suck the juices of plants and animals from those which operate upon the solids, and have made the *Haustellata* and *Mandibulata* the primary divisions of the class.

The composite parts of the proboscis or siphon are however fundamentally the same as those that form the strongest or most formidable apparatus for mastication; but as they are most conspicuous and most uniformly developed for the latter office, I shall commence the demonstration of those complex parts of the mouth,— the trophi or cibarial instruments, — as they exist in a Mandibulate insect. (*fig.* 100.)

Man has two jaws only, and no Vertebrate animal has more; they work up and down, or in the direction of the axis of the body. Insects have also their upper and lower jaws, horny edentulous plates, serving in many for little else than to close the mouth, and hence

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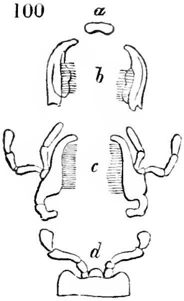


Trophi of a Mandibulate insect.

called lips; the upper one (*fig.* 100. *a*) the "labrum," the lower one (*d*) the "labium:" but they have likewise four more complex jaws, acting upon each other in pairs, from side to side, or transversely to the axis of the body. The upper pair of jaws (*b*) are called the "mandibles," the lower pair (*c*) the "maxillæ." The three lower instruments, viz. the two maxillæ and the labium, are provided with the jointed instruments of sensation, called "palpi," the maxillæ, in some insects, supporting each a pair of these appendages, which, besides their sensitive and selective offices, serve also to seize and hold steady the alimentary substances whilst these are divided by the mandibles and maxillæ. The lower lip has a basal joint, or "mentum," supporting a more flexible part (*ligula*, or labium proper), near to the base of which the palpi are articulated. The upper, or inner integument of the ligula, is usually developed into a kind of tongue, which is a distinct part (*lingua*) in the locusts and Libellulæ. The labrum, or upper lip, is generally a simple transverse flattened plate.

The mandibles are subject to most variety in relation to the habits and kind of food of the insect. In texture they vary from the hardest chitine to soft membrane. In the predatory tiger-beetles they terminate in sharp hooked points, like canine teeth, and are hard enough to pierce the firm integument of other insects. In the dragon-fly the inner margin of the mandibles is armed with three or four sharp laniariform processes. In some insects the upper dentations of the mandibles have a trenchant edge, like canine teeth; while the lower ones are broad and framed for bruising, like molar teeth, as in the cock-chaffer or the locust. The maxillæ usually correspond with the mandibles in their general characters; but the teeth, which may be developed from their inner edge, are more uniform and delicate: their terminal piercing hook in the tiger-beetles is movable. The maxillæ are often clothed with short hairs.

The mandibles of the bee-tribe are simple, but strong and trenchant; they are most important instruments in the economy of the different species, and are modified accordingly. The maxillæ and labium are lengthened out to form the proboscis, but especially the lingual appendage of the latter, which has two appendages, called "paraglossæ," developed from its base, and has its upper surface and sides beset with hairs.

In the Hemiptera both the mandibulæ and maxillæ are alike attenuated, and prolonged into stiff needle or lancet-shaped organs, which are protected by a sheath formed by the equally elongated labium, the upper groove of which at the same time serves to conduct the liquid food into the mouth: the maxillary and labial palpi have disappeared; the latter may have coalesced with, and transferred their properties to, the labial sheath. With such an instrument the Cicada perforates the bark of the trees on which it lives, and exhausts their sap; and with a similar modification of the trophi, the bug and flea pierce the skin and suck the juices of animals.

In the blood-thirsty *Diptera*, as the gnat and forest fly, the labrum, as well as the two lateral pairs of jaws, are prolonged into lancet-shaped organs, and are sheathed in a thickened lower lip, which is terminated by two fleshy suckers: the maxillary palpi are attached to the base of the maxillæ.

The singular spiral "antlia" of the butterfly and other Lepidoptera is formed by the elongated slender maxillæ, still characterised by the minute palpi at their base. The inner margins of the maxillæ are concave, and the edges of the channels are in close contact, or are confluent, so as to form a canal along which the juices of flowers can be pumped up into the mouth. Each maxilla is likewise hollow, and it is uncoiled or coiled by the varying tension of this canal. The labial palpi are of large size, and defend the antlia when it is retracted and coiled up. The labrum is a small triangular piece, which bends down towards the mouth, and the rudimental, conical, slightly bent mandibles are hidden by the labial palpi.

The large curved piercing jaws of the Centepede are hollow, and traversed by the duct of a poison-gland.

The alimentary canal is most simple in the larvæ of insects, in which, as in worms, it usually extends, without convolutions from one end of the body to the other; in a few larvæ, as that of the bee, it has only the anterior opening or mouth, and the opposite or anal orifice is not developed until the pupa-state. In all mature insects the alimentary tract presents the two distinct apertures; it is simplest in the carnivorous larviform Myriapods; presents more numerous and distinct constrictions and divisions in the Hexapods, and increases in complexity and length, as the food requires most preparation in order to its conversion into the animal nutrient fluid or chyle.

The œsophagus of the Centipede is long, and dilated posteriorly, where it communicates with the stomach; this is a small muscular cavity, bent upon itself, and lined by a longitudinally plicated horny membrane. The intestine is long, straight, and wide, slightly sacculated transversely; it contracts, and is longitudinally folded near its termination. In the Iulus a short and wide œsophagus expands into a shorter and wider muscular stomach. This is succeeded by a long and wide chylific stomach, with longitudinal folds, separated by a circular linear constriction, in the posterior third of the body, from the intestine: this is divided by a second constriction into two equal parts, the first longitudinally folded like the stomach, the last puckered into short transverse sacculi; until within a little distance of the anus, which is protected by a pair of horny valves.

In the *Polydesmus* the œsophagus gradually expands into the long chylific stomach, which is separated by a short contracted pyloric tube from the intestine. This suddenly swells out to equal width with the stomach, is puckered up in its posterior half by short transverse plicæ, where it first gradually, and then suddenly, contracts to terminate at the anus.

The accessory glands of the digestive tract are slender tubes in the Myriapod, as in the Hexapod tracheary Insects. In the Polydesmus and Iulus there are two such salivary glands at the sides of the œsophagus, converging anteriorly to open into the pharynx. The more compact and similarly situated poison glands, which terminate in the large perforated hooked mandibles, in the Centipede, are superadded to the simpler salivary glands of the *Chilognatha*.

Slender biliary tubes creep upon the intestinal tunics in the Centipede, and pour their secretion into the canal close to the gizzard. Excretory, probably urinary, tubes open into the terminal division of the intestine; and these are present in the Iulidæ.

The alimentary tract in Hexapod Insects is divided into pharynx, œsophagus, ingluvies or crop, gizzard, chylific stomach, small intestine, cæcum and rectum. All these parts rarely co-exist in the same insect. The œsophagus is directly continued from the sucking apparatus in Haustellate Insects without a pharyngeal dilatation.

In the carnivorous Dragon-fly * the alimentary tract is short and straight: there is neither crop nor gizzard, the chylific stomach is long, cylindrical, and is divided from the œsophagus by a slight constriction; the short intestine which succeeds is dilated at its commencement, and plicated longitudinally as far as the contracted rectum. In other insects a duodenal and iliac tract of intestine may be distinctly recognised. In the tiger-beetle (*Cicendela*) and the carnivorous *Carabidæ*, there is a small gizzard, preceded by the usual ingluvial dilatation of the œsophagus and followed by a long chylific stomach, the external surface of which is beset with secerning follicles. The small intestine makes a short turn before terminating in the dilated colon.

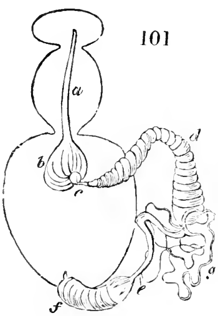
The alimentary canal of the browsing cockchafer is considerably

* Prep. No. 589.

longer, and is disposed in three or four coils. But in the Orthopterous vegetable-feeding insects, the canal is characterised by its superior width rather than by its length; and in them the complications requisite for animalizing the food are chiefly manifested by the gastric division. The œsophagus dilates into a wide glandular crop in the cockroaches * and locusts †, and has a similar receptacle appended to it in the mole-cricket.‡ The gizzard has a strong muscular coat, and a callous epithelium, the inner surface of which is beset with projecting teeth or hooks, as in the cock-roach, or with scale-like plates, as in the cricket, generally disposed in longitudinal rows. The tunics of the chylific stomach are produced at its commencement into cæcal appendages, which augment and complicate its cavity. There are two such cæca in the common and mole-crickets, four in *Locusta serrata,* six in the migratory locust, and eight in the cockroach. In the coleopterous *Buprestidæ* the stomach is prolonged into two cæcal appendages, themselves beset by smaller cæca.

The gizzard always coexists with the crop, but not always the crop with the gizzard, in insects. All the suctorial species have a crop, either appended to the œsophagus, or forming a preliminary dilatation to the chylific stomach. It is of small size in the bug (*Cimex lectularius*), and almost obsolete in other Hemiptera. In the bee, (*fig.* 101.) §, the œsophagus (*a*), having traversed the thorax as a slender tube, dilates in the abdomen into the large honey-bag (*b*). The valvular funnel-shaped orifice of the chylific stomach (*c*) projects into the side of the ingluvial reservoir, and must be withdrawn by a special action, in order to receive any portion of the nectar for the nourishment of the bee itself: it then returns by an antiperistaltic motion, and forms a kind of intussusception in the crop, converting it into the convenient, closed receptacle for the collected sweets until the bee reaches its hive; when the honey, having undergone a slight change, which renders it less susceptible of the acetous fermentation, is regurgitated into the waxen cell, and the crop collapses into longitudinal folds. The chylific stomach (*d*) is long, gradually widened to its termination, and transversely plicated. The ileum (*e*) is short and slender: the colon or rectum (*f*), wide and capable of great

101



Alimentary canal. Bee.

* Nos. 607, 608, 609.
† Nos. 443. 610.
‡ No. 611.
§ Nos. 476, 477.

distension. The bees on which Hunter experimented * endured a long confinement, but could not be compelled to foul their hive; as soon as liberated, they rose in the air and disburthened their overladen cloaca.

In the Lepidoptera (*fig.* 105.), the ingluvies projects, like a bag, from the side of the œsophagus (*j*); and in the *Zygænæ* it is divided, as in the pigeon, into two equal parts. The chylific stomach is very small, but is sacculated, and, according to Meckel, is shaggy in the death's-head moth. The small intestine (*l*) is longer and more convoluted than in the bee; the large gut (*m*) is short and wide.

In the Diptera the crop †, though situated upon the stomach in the abdomen, is appended by a long and slender neck to the beginning of the narrow œsophagus. The lower end of the œsophagus expands into the chylific stomach, the cardia being sometimes marked by a callous ring, which is the remnant of a small bladder existing there in the larva. The small intestine is convoluted; the rectum short and dilated, and provided with two lateral conical glandular bodies. ‡ Hunter made experiments to determine the function of the appendiculated crop. "I kept a fly," he says, "for twelve hours without food, and then gave it milk and killed it, and found no milk in the crop, but it had got through almost the whole tract of intestines: here the animal had immediate occasion for food, therefore the milk did not go into the crop. This experiment at the same time shows that every part of the intestine digests." Another time Hunter killed his flies after they had drunk their fill, and found the crop full, as well as the stomach and intestines: he suspects, therefore, that the crop serves as a reservoir, and "that when there is more food than what is immediately necessary, then it is thrown into the crop to be used in future." §

The result of Hunter's first experiment, and the absence of the crop in the flea and some other suctorial insects, negative the idea of Burmeister that the crop in *Hymenoptera*, *Lepidoptera*, and *Diptera* promotes the suction of food by a voluntary power of self-expansion, if even the structure of the part justified the idea; but, on the contrary, they prove it to be a receptacle of nutriment.

In the Cicadæ the chylific stomach is of great length, intestiniform, and its termination is connected, but does not communicate, with its commencement; the chymified fluids pass at once from its termination into the intestine.

The entire alimentary canal consists of three tunics, an external

* See Philos. Trans. 1792. p. 176.

† No. 596. ‡ No. 2123.

§ Physiol. Catalogue of Hunterian Collection, vol. i. p. 189.

fine membraneous, or peritoneal layer, a compact muscular membrane, and an internal mucous or epithelial coat. Between the last two there is a white spongy layer of cellular tissue, compared by Ramdohr to transuded chyle, and which is sometimes the seat of gastric glands.

The several divisions and convolutions of the alimentary canal are supported and attached to the adjoining parts by the air-vessels: there is no mesentery.

At least three kinds of glands add their secretions to those of the cæca and follicles of the alimentary canal. The first kind open in or near the commencement of the canal, and are regarded as salivary glands. They are classified by Professor Burmeister as follows: —

A. Salivary vessels which open into the mouth, generally beneath the tongue, sometimes at the base of the mandibles. They take the following forms: —

1. As simple, long, undivided, twisted tubes; thus in the majority of insects, viz. all butterflies, many beetles, and flies.

2. As a narrow vessel which empties itself into one or two bladders, whence the salivary duct originates (*Nepa, Cimex, Sarcophaga*).

3. As a ramose vessel with blind branches (*Blaps*).

4. As two long cylindrical pipes, which unite into one excretory duct (*Reduvius*).

5. As four small, round bladders, each pair of which has a common duct (*Pulex, Lygæus, Cimex*).

6. As a multitude of such vesicles (*Nepa*).

7. As capitate tubes, in the free ends of which many very fine vessels empty themselves (*Tabanus*).

8. As tubes which at intervals are surrounded by spiral cæca (*Cicada*).

9. As granulated glands, which on each side unite into a salivary duct, both of which join into a single excretory duct. Müller has observed this high form of conglomerate salivary glands in *Phasma;* Treviranus in *Apis;* and Burmeister in *Locusta, Gryllus,* and *Termes.*

The biliary secerning organs never attain this condition, but, in all insects, manifest the condition of long, slender, cylindrical tubes, which Cuvier, who seems not to have been aware of the conglomerate structure of certain salivary and seminal glands, describes as the character of all the secreting organs in insects.

In a few instances, as in *Chermes* and *Aphis*, the biliary tubes are wanting: in almost all insects they are four in number, never fewer; sometimes they are six or eight in number: in a few instances, as the mole-cricket and cockroach, they are very numerous. Dr. Burmeister has generalised the observations of different anatomists on the bile-tubes, as follows:—

1. Four.
   a. Free at the end; most *Diptera*, and the families *Termitina*, *Psocina*, and *Mallophaga*.
   b. Anastomosing; many *Coleoptera*, *Hemiptera*, and *Diptera*.
2. Six biliary vessels.
   a. Anastomosing; many *Coleoptera;* for example, *Cerambycina* and *Chrysomelina*.
   b. Free at the end; *Lepidoptera*.
3. Eight free biliary vessels; *Neuroptera*.
4. Many biliary vessels; *Hymenoptera*, *Orthoptera*, and the *Dictyotoptera subulicornia*.

Those biliary vessels are longest which are fewest in number: they lie in folds by the side of the stomach and intestine, and terminate in a circle at the commencement of the small intestine. In *Lygæus apterus* they terminate in a dilatation on one side of the gut.

The urinary glands are usually in the form of long and delicate tubes, but sometimes present the structure of groups of round vesicles, as in the *Carabus*, in which the common duct terminates in a small dilatation: the urinary bladder is likewise present in the water-beetles. The excretion is poured into the termination of the intestine, or evacuated contiguous to the anus.

No absorbent vessels have been detected in insects: the chyle, which is a clear or greenish fluid, with round or oval corpuscules, is supposed to transude through the tunics of the intestine into the free cavity of the abdomen: it passes, in reality, into the wide and irregular sinuses which seem to constitute the cavity of the abdomen, but which communicate with similarly ill-defined venous receptacles extending into other parts of the body and its appendages, resembling the general interspaces of the cellular tissue, and constituting the venous system, through which the blood moves in a definite and regular course to the heart. This organ (*fig.* 104. *s*) is an elongated muscular and valvular tube, situated along the middle of the back, and usually called the dorsal vessel: it is largest in the abdomen, and so diminishes anteriorly, that its continuation in the thorax may, in most insects, be regarded as the aorta. It is retained in its position by flattened triangular bands of muscular fibres. This character, its distinct transverse linear muscular fasciculi, its slight constriction at regular intervals, and the peculiar valvular loops at these constrictions, characterise the long and slender vasiform dorsal heart in the

Iulus and Scolopendra, and indicate its great advance beyond the condition of the dorsal artery in the Anellides.

In the perfect Hexapod Insect, the heart has the appearance of a series of slightly conical segments, partially sheathed one upon the other: lateral apertures exist at the sides of the intus-susceptions, where, in fact, valvular folds of the inner tunic do project into the interior of the heart, and partially divide its cavity into so many separate chambers. The whole of this part of the heart is included in a saccular venous sinus, from which the blood passes into the interior of the heart, and, by the disposition of the valves, it is at once prevented from returning into the sinus, or passing in any other direction in the heart than towards the head, or into the next chamber in advance of that by which the fluid was admitted. The number of venous orifices varies in different insects: — in most species there are eight pairs of apertures; in the stag-beetle there are six pairs; in the humble-bee five pairs; in the phasma there is, according to Müller, only a single pair at the posterior chamber of the heart, by which, in fact, in all Insects, the chief currents of the blood appear to enter the organ. As far as the head the blood is propelled from the heart along a tubular aorta of the usual form; but the branches from this would appear soon to lose themselves in the generally diffused sinuses. In the Myriapoda, however, the blood is continued in a vessel along the dorsal aspect of the ventral nervous chord; but the traces of the true tubular vascular system are scanty and obscure.

Cuvier, misled by the anomalous diffused condition of the venous system, supposed that there was no circulation of the blood in Insects; yet the dorsal vessel was too conspicuous a structure to be overlooked. Such, however, was the authority of the great anatomist, that the nature of the heart began to be doubted, and the strangest functions to be attributed to it. Hunter, however, who was prepared to appreciate the true state of the circulating system in insects, by his discovery of the approximatively diffused and irregular structure of the veins in the Crustacea, has described in his Work on the Blood * all the leading characters of the circulation in Insects as it is recognised by Comparative Physiologists of the present day. He says, that, "As the lungs of the flying Insect are placed through the whole body, the heart is more diffused, extending through the whole length of the animal;" that "where the veins near the heart are large, there is no auricle, as in the lobster and generally in insects;" that "in the winged Insects, which have but one heart, as, also, but one cir-

* Quarto, 1794. p. 220. et seq.

culation, there is this heart answering both purposes" (viz. the corporeal and pulmonary circulations); and again, "with respect to its use, it is, in the most simple kind of heart, to propel the blood through the body, immediately from the veins, which blood is to receive its purification in this passage, when the lungs are disposed throughout the body, as in the flying Insect." In the note at p. 221. he alludes to the animals in which the veins are entirely cellular; and expresses his idea more definitely in the following passage from his manuscript Observations on Insects:—"*Of the veins.* The veins of the Insect would appear to be simply the cellular membrane; but they are regularly formed canals, although not so distinctly cylindrical canals as in the quadruped, &c., nor branching with that regularity. They would appear to be, or to fill up, the interstices of the flakes of fat, air-cells, muscles, &c., and therefore might be called in some measure the cellular membrane of the parts."*

The chief merit of the rediscovery of the circulation of the blood in Insects is due to Carus; its phenomena have been witnessed in the appendages of Insects by other observers, as Ehrenberg, Wagner, Burmeister, Bowerbank, and Tyrrell. Hunter counted thirty-four pulsations in a minute in the heart of a silkworm. Herholt counted from thirty to forty pulsations of the heart in a minute in a full-grown caterpillar: Suckow observed thirty per minute in a full-grown caterpillar of the pine moth, and only eighteen in its pupa state.

The action of the heart is accelerated in Insects, as in other animals, by muscular exertion and excitement; and Mr. Newport has counted as many as 142 pulsations in a minute, in a species of wild bee so excited.

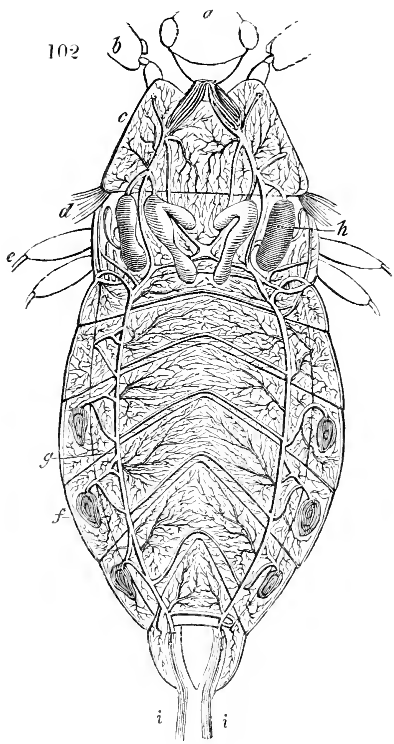
Although the anatomist searches in vain for that profusion of arterial and venous vessels which pervade the body of most animals, the insects are not without their systems of capillary tubes, which ramify as richly over all the organs and through every tissue, and which connect together the different parts of the body. These vessels, however, carry air instead of blood; the relations between the sanguiferous and respiratory systems are reversed, and the air is distributed by a vascular system over the reservoirs of blood, instead of the blood being distributed by a capillary net-work over a reservoir of air. The aëriferous tubes in insects are called "tracheæ," having their parietes strengthened by an elastic cartilaginous filament, not indeed disposed in a series of distinct rings, but in a continuous close spiral coil. By this structure the most delicate and invisible ramifications of the air-tubes may be easily recognised under the microscope. The

* Physiol. Catalogue, vol. ii. p. 31.

spiral filament is situated between the external cellular, and an internal delicate epithelial lining.

The tracheæ commence either from lateral apertures, called spiracles and stigmata (*fig.* 102. *f*), or from pneumatic tubes (*i*), generally continued from the anal segment; these latter are peculiar to insects which live in water, as the Nepa and Ranatra.

102



Respiratory system, Nepa.

The air is conducted from the spiracles or the pneumatic tubes, both which may coexist together, into a large longitudinal tracheal trunk (*g*), which runs near each side from one end of the body to the other; they are connected together by transverse tubes, which run across the posterior margin of each abdominal segment, and distribute an infinitude of smaller tracheal ramifications. Some of these branches dilate into air receptacles (*h*), the number and size of which, like the air-cells in birds, are in direct relation with the powers of flight. In the Nepa these reservoirs of air are confined to the thorax: in other insects, as the grasshopper, they are frequently developed also upon the transverse abdominal tracheæ: they are very capacious in the abdomen of the bee.

The spiracles differ in number and form in different insects. In the Coleoptera there is a spiracle at the interspace between every two segments; the Diptera have the fewest spiracles. In some insects the orifice is situated upon an entire oval horny ring. In many insects, especially those that burrow, the margins of the spiracles are defended by a fringe of hairs, which prevent the entry of extraneous particles. In the mole-cricket, the thickened margin of the spiracle is strengthened by two horny half rings, and can be closed by the action of the small sphincter muscle.

Most of the aquatic larvæ breathe by temporary gills; in the Phryganeæ these consist of vascular laminæ developed from each side of the upper part of each abdominal segment; in the Semblidæ plumose branchiæ are similarly situated.

The amount of respiration is directly as the degree of the activity of the insect; and its temperature is increased in an approximate degree. The extraordinary development of the breathing organs demonstrate their essential relations to the energies of the muscular system; and, by a minor modification, they are made subservient to the diminution of the weight of the insect. In the Apterous insects, and especially the Myriapoda, there is no trace of air vesicles, but both in the Centipede and Iulus the minute tracheæ ramify throughout the body.

LECTURE XVIII.

INSECTA.

The sexes are distinct in all Insects: in certain social species, as bees and ants, there is a third kind of individuals, commonly called neuters, but these are essentially females with the organs imperfectly developed and passive.

In the Centipede the testes are small, slender, fusiform bodies, placed one behind the other in the dorsal region of the posterior part of the body: four pairs and an odd one are on the left side, and three pairs on the right. A minute efferent tube is continued from both ends of each testis, which tubes unite with those of the adjoining organ, and ultimately form a single vas deferens, common to the two lateral series of testes, and situated along the middle of the body: it forms a kind of epididymis by its zig-zag convolutions, and, after having received the ducts of three pairs of small prostatic glands, it terminates in the cloaca.* In the Iulus the external openings of the male apparatus are situated upon a small protuberance behind the seventh pair of legs.

In the Hexapod Insects the testes usually present a more complicated structure, but are almost as diversified in the form, number, and disposition of their secerning follicles as the stamens of plants. They present their most simple condition in the Lepidoptera, in which they approximate during the metamorphosis, and unite into a single globular mass, the primitive separation of the two testes being indicated by a

* Prof. R. Jones and Straus Durckheim.

circular indentation and by the two distinct vasa deferentia. In certain moths, as the *Tinea*, the original condition is retained in the imago state. The vasa deferentia and tubular glands are extremely long and convoluted tubes.

In the male *Aphis* three, four, or five spherical testes communicate by short tubes with a common transverse duct, the two extremities of which bend down and complete the circle by uniting to form the short ductus ejaculatorius. A long pyriform vesicular gland is appended to each lateral vas deferens.

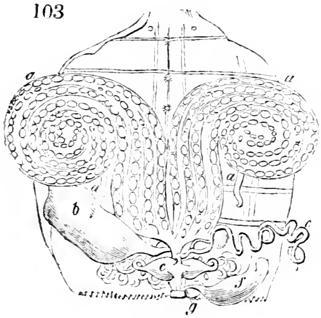
In all other insects the testes form a pair of white glandular bodies: in the dragon-fly they are elongated and fusiform, as in the Centipede. In the *Cercopis* each testis is a clavate gland, gradually contracting to the vas deferens. In the crane-fly (*Tipula*) the testis is a convoluted filamentary tube, dilating into a vesicle before it is continued into the vas deferens: in the *Ranatra* the tube is twisted spirally. In the *Dytiscus* the testis is a filiform tube, much longer than the abdomen, but convoluted into a round ball. In the *Hydrophilus*, a series of short blind processes are given off from one side of a common duct. In the *Buprestis* a fasciculus of longer cæcal tubes radiate from the end of the sperm duct. Sometimes the extremities of similar radiating tubes are dilated into saccular flattened glands, as in the rose-beetle (*Cetonia*), and numerous more composite forms have been detected; all, however, are referable to modifications of the primitive blind secerning sac. Their analogy to the sexual parts of plants has already been alluded to, and Entomologists have found it requisite or advantageous to borrow the neat and descriptive terms, with which Linnæus has enriched botanical science, in order to indicate the diversified forms of the male apparatus.

The vasa deferentia always receive the ducts of glands which are analogous to the vesiculæ seminales; these are generally formed of slender tubes, not exceeding the length of the abdomen in the *Lucanus*, *Locusta*, and *Libellula*, but five times longer than the body and much convoluted in *Dytiscus*, ten times as long as the body in *Blaps*, and thirty times as long in the *Cetonia aurata*. The sperm-duct is dilated where it receives the secretion of the accessory glands, as in the bee. In many insects, representatives of prostatic glands communicate with the ductus ejaculatorius.

The intromittent organ is a modification of the last or two last segments of the abdomen, and is usually retracted out of sight: it consists of a large exterior sheath and a delicate membranous tube: the sheath commonly consists of two lateral valves. Accessory prehensile organs are developed in some insects, of which the most remarkable are attached to the base of the abdomen in the male Libellula.

The female sexual organs (*fig.* 103.) consist of the ovaries (*a*, *a*), the oviducts, the uterus (*g*), the spermatheca (*b*), the mucous glands (*e*), and vagina; but these are not all present in all insects. The external organs are the vulva, the sting, the holders, and ovipositor, some of which are likewise peculiar to particular species.

103



Noctua Brassicæ.

The most constant and essential parts of generation of the female insect, viz. the ovaria, are subject to almost as many varieties as the testes in the male; their forms may be arranged into almost as many genera and species, which are very often analogous to those of the essential glands in the opposite sex. Teh ovaria in the Lepidoptera do not, however, coalesce into a single mass, like the testes in the male: they are either digitate or verticillate; that is to say, they consist of a few egg-tubes suspended to the end of the oviduct, becoming attenuated as they recede from it; or they consist of numerous very long egg-tubes, proceeding from a short oviduct and terminating in filiform extremities: they are usually disposed in spiral coils bending at the two sides in opposite directions, as in the *Noctua Brassicæ*. In the forest-fly each ovarium consists of two egg-tubes; in the flesh-fly it consists of a single tube, which is of great length, and twisted spirally. In the mantis a single series of short egg tubes are attached to one side of a common duct. In the gnats, crickets, and locusts, the numerous egg-tubes, which are somewhat compressed, lie upon one another like scales, or the tiles upon a roof. In the Ephemera and Stratiomys, the ovaries have the primitive form of simple elongated bags in which the eggs are contained linked together by delicate filaments.

In the plant-louse (*Aphis*) the ovaria consist of eight short and straight tubes continued from a very short and wide oviduct: the anterior capillary beginnings of the ovarian tubes are composed of a single file of nucleated cells. From these a distinct canal is continued for a short distance, which dilates into a sac filled with numerous other nucleated cells; a second constriction separates it from another dilatation containing a more definite group of nucleated cells forming a vitelline mass, presenting sometimes an elongated or larviform figure; the ovarian tube then dilates into an elongated wide receptacle in which the development of the larva is completed in the apterous and larviparous females, which produce their young during the spring and summer months. In the autumn the organs are somewhat changed in form; the terminal ovarian portion dilates into a clavate cœcal extremity filled with numerous ova: the rest of the straight canal is divided into two successive elongated elliptical chambers, the last being the largest, and generally containing an elongated ovum which is excluded as such.

The fertility of an Insect is indicated by the length and number of the egg-tubes. Seventeen ova have been counted in a single tube in the queen-bee, which has more than a hundred of such tubes. But her fertility is greatly surpassed by the queen of the Termite community, in which the abdomen expands to so enormous a bulk, in order to include the ovaria, that the thorax and head seem like mere appendages to its anterior part. She lays, according to Smeathman, sixty eggs in a minute, and this rate is continued, with, perhaps, intervals of repose, for several days.

However various may be the form and structure of the ovaria, their situation is nearly the same in all insects. They occupy the sides of the abdomen, and, when fully developed, distend that cavity, leaving space only for the intestine and the internal accessory parts of generation. They are connected together by the branches of the tracheæ, and, in many insects, are retained in their position more particularly by delicate but firm filaments continued from the anterior extremity of each ovarian tube, and ascending to become connected with the thoracic aorta. Professor Müller describes these filaments as opening into the dorsal vessel.

The oviduct varies in length and capacity: in the Hydrophilus four filamentary blind canals are attached to each side; but in most insects the accessory glands communicate with the common canal formed by the union of the two oviducts. The common canal has usually a dilatation at its middle part, beyond which it receives the tube of the spermatheca and the duct of the colleterium or mucous vesicle.

Experiment has proved the office of the spermatheca (*fig.* 103, *b.*) to be that which its name implies.* By the application of the fluid contained in it to the eggs of an unimpregnated female Hunter made them fruitful: he also found that the intromittent organ penetrated its canal, an observation which has since been confirmed by Andouin, and other observers.

The colleterium (*fig.* 103, *c.*) secretes the white gluten, with which the impregnated eggs, when not developed in the body, are covered, and by means of which they are cemented together and fastened to other objects. In some insects, as the *Tineæ*, the mucous organ has the

* See Hunter, Animal Economy, 8vo, 1837, p. 461.

simple tubular form; in the *Melöe* it is a vesicle furnished with a short neck; it is a large ovate bladder in most of the Lepidoptera, as in *fig.* 103. In the stag-beetle there are two mucous vesicles, the short ducts of which unite into a common tube. In the *Elater murinus* the colleterium bifurcates repeatedly, and the base of each fork distends into a triangular bag.

Accessory filamentary tubes are met with in several of the butterflies. Certain social Hymenoptera, which, as John Hunter quaintly observes, "have property to defend," possess a peculiar poison apparatus, which is essentially a modification of accessory parts of the female organs, and the only part which reaches its functional activity in the neuters of the Bee and Wasp. The poison is secreted by two long and slender ducts, which unite together and empty their secretion into an oblong bag, which discharges itself by a narrow duct between the valves of the sting. This is a long, slender, and sharp process, with a serrated edge, which generally prevents its retraction when thrust into the skin: the protecting valves are modifications of the last abdominal segment.

The corresponding parts are variously modified in other insects to insure a proper deposition of the eggs. In some insects, as the *Locusta viridissima*, the bivalve ovipositor is longer than the body, and by means of it, the ova are conveyed to the proper depth in the soil, the act of oviposition being precisely analogous to that of setting seeds in the earth. In the saw-flies, a third organ, analogous to the sting in bees, and similarly serrated, is superadded to the ovipositor: with this instrument the female saw-fly (*Tenthredo*) saws into the substance of leaves, and there insinuates her eggs. The Ichneumons have a similar apparatus, but extremely elongated and slender, by means of which they introduce their ova beneath the skin of other insects.

Insects, like Crustaceans, are occasionally subject to one-sided or dimidiate hermaphroditism. Numerous instances of this kind are given by Ochsenheimer. In fourteen of the above cited instances, the right side was male and the left female: in nine instances it was the reverse. Occasionally Hermaphrodites are found, where the characters of one sex, instead of extending over one half, are limited to particular parts of the body, which agrees in the main with the other sex. Thus an individual of the *Gastrophaga Quercus* has been observed, in which the body, the antennæ, and the left wings were those of the female, the right wings those of the male. The external sexual characters are very striking and various in the class of Insects, and readily lead to the detection of the hermaphroditical condition of the internal organs.

The development of an insect commences, as in all other animals, from a minute pellucid vesicle, having a central nucleus or spot.

Such vesicles make their appearance in the capillary beginnings of the ovarian tubes, where they are drawn out to microscopic tenuity. From these extremities the ova successively pass into the wider part of the tubes, and in this course increase in size by the multiplication of vitelline cells around the primitive vesicle: at first the ova are separated from each other by an amorphous granular substance of equal size, which is called a placentula, but lower down by mere constrictions of the egg-tube: here they acquire a distinct vitelline membrane, and then, still continuing to increase in bulk, by the progressive addition of that material which is afterwards to be expended in forming the tissues of the future insect, they reach the termination or converging point of the ovarian tubes, and enter the shorter and wider oviducal track: here they receive additions to their external surface from the collateral and accessory glandular organs, and admit into their interior the mysterious principle of the male fluid, which would seem to be assimilated into their substance.

In this state the ova are excluded in most insects; but there are some species, as the common flesh-fly (*Musca vomitoria*), in which development proceeds, prior to the exclusion of the ovum, to an extent equivalent to the acquisition by the embryo of the form and condition of the young of the viviparous entozoa; the formative processes closely according with those which have already been traced, at p. 77., in the *Ascaris acuminata*. The sub-divided and hyalinized cells of the yolk have arranged themselves into the form, and have been transmuted into the tissues, of a worm, — a worm which, coming from the egg of an insect, is termed a grub, maggot, or larva. In a few other insects, again, this stage of intra-uterine development is brief and transitory, a merely passive, embryonic stage, which is left for a second one, commencing by the formation of the head, by a slight excess in the growth of the first three segments of the trunk, and the budding forth from these of rudimental limbs; the head is then furnished with eyes, antennæ, and trophi, the wings are developed, and in this state, inclosed in the exuvial skin of the larva, and ready to issue from it as the perfect insect, the young of the forest-fly are brought forth. The process is termed pupiparous generation: the more premature production of the flesh-fly is called larviparous generation. By far the largest proportion of the class of insects, as I have already said, is oviparous; and the development of the embryo takes place out of the body of the parent.

There are many striking and beautiful manifestations of instinctive prescience in the modes of oviposition, and in the location and attachment of the ova. Many insects not only provide the germ with the nutritive vitelline mass, or the material for the first development of the embryo (if, indeed, the parent can be said to be concerned in that supply which is the result rather of a series of spontaneous fissions with an inherent power of assimilation of the primitive germ itself), but, in some cases, the parent, having selected a fit place for the deposition of her precious burthen, continues the maternal office by placing near the ovum the kind of food which the larva will necessarily require in order to complete its growth.

Some insects, as bees and ants, feed the larva; supply them with the required food from time to time, as nurses satisfy the cravings of a child; but these cares rarely devolve upon the mother in the insect class: they are performed by a distinct race of individuals, of the feminine sex, but incapable themselves of exercising the procreative faculty.

The forms of the eggs of insects are very variable; often beautiful and regular, like the seeds of plants; sometimes very singular; always perfectly adapted to the required conditions for the development of the future insect. The eggs are cylindrical in *Bombyx everia;* conical, with tuberculate ribs, in *Pontia napi;* hemispherical in *Bombyx dumeti;* lenticular in *Noctua psi;* cup-shaped in *Orgyia antiqua;* flask-shaped in *Culex pipiens;* petiolate in *Hemerobius perla;* provided with diverging processes like ears in *Scatophaga putris*, to prevent their sinking too deep in the soft dung; provided with a special adaptation for floating in some aquatic insects; with numerous other modifications.

When embryonic development begins, the vitellus becomes condensed, as in the Ascaris, receding a little from the vitelline membrane at its poles. The usual processes of subdivision take place, but in so much greater a degree at the peripheral layer that the subdivided vitelline mass becomes invested by a stratum of minute and nucleated cells. Kölliker, who has observed these early stages of insect development in the *Chironomus tricinctus* Schrank, gives the following account of the process. The primordial cells, at first round, and provided with one nucleolus, become afterwards elliptical, and generally two nucleoli can be discerned in them; afterwards two cells exist, of smaller size than the parent cell. He concludes that this fissiparous generation of cells, which accords with that observed by Siebold and Bagge in the Ascaris, is the general mode of their multiplication. "Hæc omnia, etsi nunquam cellulas in aliis inclusas offendi, ne ad sententiam adducunt, posteriores a prioribus gigni, ita semper binæ in unaquaque cellula matre oriantur." *

The vitelline mass becomes elongated and vermiform, and, by farther subdivision and coalescence of the peripheric stratum of cells

* Observationes de primâ Insectorum Genesi. 4to. Turici. 1842.

("cambium" of Herold), a smooth transparent integument is formed. like that in the Entozoon, first along the ventral aspect, then ascending up the sides to the dorsal aspect, which is likewise closed in by the reciprocally approximating folds which cover the cephalic and caudal extremities. The division of the integument into the thirteen segments commences at the ventral aspect, which is convex, the vermiform body of the embryo being, at first, bent upon the back.

In the capitate larvæ the entozoal type is quickly left by the cervical constriction, and the development of a distinct head, which commences by the formation of the part afterwards retained as the labrum. The mandibulæ and antennæ next appear behind the labrum as convex lobes; and the part of the head in the lower interspace of the mandibles forms the labium. The maxillæ next bud forth between the labium and the mandibles, and the median fissure, surrounded by the rudimental trophi, sinks deeper into the substance of the head, and, meeting a slender anterior production of the internal vitelline sac or cavity, establishes the mouth and œsophagus. Whilst these stages are in progress, the peripheral series of included vitelline cells have undergone a series of spontaneous fissions; whereby the remaining mass becomes included within a second stratum or cambium, which, by coalescence and further metamorphoses of the cells, is transformed into the tunics of the alimentary canal, the interspace between which and the outer integument forms the abdominal cavity. A certain proportion of the vitellus, not included in the ellipsoid alimentary canal, has undergone transformations, by which the foundations of the muscular system, the ventral nervous chord, and the dorsal vessel, are laid. An attenuated posterior prolongation of the ellipsoid vitelline or alimentary sac forms the rectum, and opens upon the thirteenth segment, while it is bent upon the dorsal aspect.

In such a condition, but without the cephalic and trophal development, the entozoiform larva of the flesh-fly is born or excluded from the parent: in a similar condition the larva of the bee quits the vermiform ovum, but without the external communication with the digestive or vitelline sac, having been established at the posterior extremity.

In some Coleoptera development proceeds to the formation of the appendages of the head, as above described, and a capitate but apodal larva is excluded, as in the nut-weevil.

In the other Coleoptera, as the *Donaciæ**, the ventral arcs of the second, third, and fourth segments, send out bulbous rudiments of the thoracic legs, before the tergal or notal elements of the segments are completed; the abdomen is closed above whilst the development of the

* Kolliker, loc. cit. p. 15.

extremities has proceeded to the formation of obscure joints and terminal hooks. The rudimental palpi begin to bud from the maxillæ and labium; the mandibles acquire their hard terminal hooks, and closely resemble the thoracic feet. In this state the larva is excluded.

At an earlier period the simple bulbous antennæ, mandibles, and maxillæ, indicate three cephalic segments, equal in size and distinctness to those of the thorax. The labrum and labium might perhaps be regarded as indicative of two other abortive segments, but with this concession not more than five cephalic segments can be defined by observation of the early development of the insect. The biliary and other tubular glands result from juxtaposition in a linear series of vitelline nucleated cells, which coalesce by liquefaction of the parts of the capsule in contact with each other, the nuclei remaining longer and indicating the primitive separation of the cells. The ovarian tubes have appeared to me, in the larva of the silkworm, to retain the primitive series of nucleated cells at their capillary beginnings without coalescence, which has taken place to form the lower part of the tube: such persistent, primitive, nucleated granules seem to form the basis for the formation, by the usual fissiparous multiplication, of the subsequent ova.

In the Aphides the corresponding vitelline cells retain their share of the fecundating principle (which was diffused through the parent egg by the alternating fissiparous, liquefactive and assimilative processes,) in so potent a degree, that a certain growth and nutritive vigour in the insect suffice to set on foot, in the ovarian nucleated cells, a repetition of the fissiparous and assimilative processes by which they transform themselves in their turn into productive insects; and the fecundating force is not exhausted by such successive subdivisions, until a seventh, ninth, or eleventh generation.

This procreation from a virgin mother, this transmission of the virtue of the ancestral coitus to the ninth generation, have hitherto ranked amongst the most marvellous and inexplicable phenomena in physiology. Reaumur eluded the difficulty by affirming the Aphides to be androgynous; but all subsequent entomologists deny the existence of any trace of male organs in the virgin larviparous Aphis; and all have recognized the distinct winged male insect. Leon Dufour referred the phenomena to spontaneous or equivocal generation, which is independent of any impregnation. But this kind of generation is purely hypothetical, and has been rendered less and less probable by every successive exact observation and experiment; and in the Aphides the male insects are unequivocal and numerous.

Professor Morren, the latest and most exact observer of the anatomy and habits of the Aphides, alludes to an opinion he had formerly held, viz. that the generation of the Aphides took place, as in some Entozoa, by the individualisation of a previously organised tissue.* No one, however, has observed a portion of mucous membrane, muscular or nervous fibre, or other organised tissue detach and transform itself into an Entozoon; such a process is as hypothetical and as little in accordance with observed phenomena as spontaneous generation. The fissiparous nucleated cells, once metamorphosed into a tissue, can produce nothing further; but those which retain their primitive state amidst the various tissues which the rest have constituted in building up the body of the new animal, may, by virtue of their fissiparous and assimilative forces, produce something further. They may give rise to a succession of similar cells which may float, as blood-discs, in the circulating stream, to be afterwards converted into the different tissues of the individual; they may, as in the Aphides, retain sufficient of the fecundative and organising forces to disseminate the like virtue through their multiplied subdivisions, and give rise to the different tissues and organs of a new individual, which in its turn may include some unmetamorphosed nucleated cells, with organising energies similar to those of the parent cell of which they were the fissiparous progeny.

The individual Aphides thus generated are all, until the last brood, females, which are brought forth as larva, and generate and perish under that form. The last brood includes both sexes, which acquire their full development and winged state, and the females exclude impregnated ova. The gemmiparous procreation by the larval polype of the Medusa of similar larvæ; the subsequent acquisition by both of a more concentrated form, generating the young discoid Medusæ by a series of spontaneous divisions; lastly, the acquisition of the distinct sexes and the procreation by impregnated ova by the perfect Medusæ, are phenomena essentially analogous to those of Aphidian generation.

The larvæ brought forth by the apterous and virgin Aphis have reached a more advanced state of development than the normally generated larvæ of the Coleoptera and Lepidoptera. The compound eyes are developed on the head, and the antennæ have acquired their mature form and proportions: the six thoracic legs have attained their due length, are divided into the normal number of joints, and gain the requisite firmness for use almost immediately

* "A dire vrai, je me refuse à émettre une opinion au milieu d'un tel dédale, et je tiens pour plus philosophique d'avouer son ignorance dans un phénomène où la nature nous refuse même l'apparence d'une explication. S'il fallait une explication à toute force, j'admettrais que la génération se fait ici, comme chez quelques Entozoaires, par individualisation d'un tissu précédemment organisé."

after birth. The only change which these fertile female larvæ afterwards undergo is increase of size and development of the reproductive organs. In the last generation, which is the seventh, the ninth, or the eleventh, according to the species of *Aphis*, the fertilising influence would seem to have expired, and developmental force exhausts itself in more frequent and numerous moultings, in the formation of wings, and in the modification of the female organs already described. Many males, which, like the females, acquire wings, form part of the produce of the last brood, which takes place in Autumn. They rise in the air, frequently migrate in incalculable numbers, unite, and the females then produce eggs, which are glued to twigs and leaf-stalks, retain their vitality throughout the winter, are hatched in the spring, and give birth to the apterous and larviparous females, which continue to produce successive generations of similar females until the close of summer.

But why, it may be asked, should there be this strange combination of viviparous generation at one season and of oviparous generation at another in the same insect? The viviparous or larviparous generation effects a multiplication of the plant-lice adequate to keep pace with the rapid growth and increase of the vegetable kingdom in the spring and summer. No sooner is the weather mild enough to effect the hatching of the ovum which may have retained its vitality through the winter, than the larva, without having to wait for the acquisition of its mature and winged form, as in other insects, forthwith begins to produce a brood, as hungry and insatiable, and as fertile as itself. The rate of increase may be conceived by the following calculation: —

The *Aphis lanigera* produces each year ten viviparous broods, and one which is oviparous, and each generation averages 100 individuals.

1st generation	1 aphis produces	
2d	100	hundred.
3d	10,000	ten thousand.
4th	1,000,000	one million.
5th	100,000,000	hundred millions.
6th	10,000,000,000	ten billions.
7th	1,000,000,000,000	one trillion.
8th	100,000,000,000,000	hundred trillions.
9th	10,000,000,000,000,000	ten quatrillions.
10th	1,000,000,000,000,000,000	one quintillion.

If the oviparous generation be added to this you will have a thirty times greater result.

The last change in the working of the procreative machinery of the Aphides is essential to the preservation of the race; the larvæ of these little delicate insects would be all destroyed by the winter frosts; but the cold is effectually resisted by the latent vital forces of the ova, which are defended by a compact case of mucus, and are instinctively glued by the parent to the sheltered nook or crevice of the plant, of the inherent temperature of which they have the benefit.

Other Hemiptera and all the Orthoptera produce eggs in which the development of the embryo proceeds in the order already described until it attains as advanced a state as that of the viviparous larva of the Aphis. The subsequent changes of these insects consist in the growth of all the parts, which takes place chiefly during the period of the moult and the gradual acquisition of the wings, which is not attended with any loss of activity or diminution of voracity.

The successive states of an apodal worm, of a worm with feet, and of one with feet and wings, being accompanied likewise with the acquisition and perfection of the antennal and visual organs of sense, and of the internal and external organs of generation, and often with great changes in the digestive, muscular, and nervous systems, in the development of one and the same insect have been emphatically termed metamorphoses. Entomologists have defined various kinds of metamorphoses under special heads, as the coarctate, obtected, incomplete, semi-complete, and complete metamorphosis.

The progress of the insect through these several stages being in many species interrupted, and active life enjoyed for a longer or shorter period under one or other of the immature forms, these have been sooner and more prominently brought under the notice of the naturalist, than if they had had to be sought for, as in the bird or mammal in the early periods of the development of the minute embryo. They have consequently had assigned to them a character of singularity and exception which they do not intrinsically deserve. The different stages of development have been likewise, for the most part, studied only in the instances in which they are manifested by insects after exclusion from the egg, and thus their minor modifications and differences have attracted more attention than their essential resemblances and relations to one and the same type and course of development.

As soon as the young insect breaks through the egg-shell it is called a *Larva*, whatever grade of development it may have attained *in ovo*. During the period when it acquires the wings it is called a *Pupa*.

From the importance which has been assigned in some entomological classifications to the developmental changes of insects, and the special denominations that have been multiplied to express them, you might suppose the "complete," the "semi-complete," the "incomplete," the "obtected," and "coarctate" metamorphoses, to be different degrees and distinct species of transformations. But the insects which are said to be subject to the semi-complete and incomplete metamorphosis pass through the same kind and amount of change as those characterised by the obtected or coarctate pupa. The differences resolve themselves essentially into the place where, and the time in which, they assume and quit the vermiform state.

The Orthopterous and Hemipterous insects, characterised in entomology by a semi-complete metamorphosis, are, at one stage of their development apodal and acephalous larvæ, like the maggot of the fly; but instead of quitting the egg in this stage, they are quickly transformed into another, in which the head and rudimental thoracic feet are developed, as in the hexapod larvæ of the *Carabi* and *Petalocera;* the thorax is next defined and the parts of the head acquired, at which stage of development the young Orthopteran corresponds with the hexapod antenniferous larva of the *Melöe;* but it differs from both these kinds of Coleopterous larvæ in being inactive and continuing in the egg almost until all the proportions and characters of the mature insect are acquired, save the wings.

Oddly enough that development is called "a complete metamorphosis," which is permanently arrested at the stage in which the orthopterous insect enters life, and the only hexapod insects, as the apterous *Cimex* and *Pediculus* in which the metamorphosis is never completed, are those in which it is said to be "complete." Burmeister, however, seems to be the only Entomologist who has pointed out the inaccuracy of the Fabrician definition;* but he failed to free himself from the thraldom of words when he supposed that, in the development of any insect there was, "properly speaking, no change of form, but merely a repeated casting off of the exterior skin." †

With regard to the terms incomplete, obtected and coarctate, they indicate, in fact, comparatively unimportant modifications of the last moulted skin of the larva of those insects which are torpid or quiescent at the period of the development of the wings. In the bee and beetle (*Hymenoptera* and *Coleoptera*), the legs, wings, and antennæ bud out and carry with them processes of the last larval integument, which thus forms in the pupa special sheaths for each growing organ

* Manual of Entomology, by Shuckard, p. 43.
† Ibid. pp. 33. 428.

of sense or locomotion in the perfect insect, and which organs are therefore comparatively free, although the pupa be quiescent. Lamark called such pupæ "Mumiæ."

In the obtected Lepidoptera the growing wings, antlia, antennæ, and thoracic legs are only partially covered by the pupal integument, being lodged in recesses on its inner surface, which make corresponding projections on its exterior, where their form and position may thus be recognised.

In the coarctate metamorphosis of the Diptera, the larva sheds its last skin before the growing legs and wings have impressed their forms upon it, and the exuvium constitutes an egg-shaped horny case, upon which there is not the least indication of the parts of the perfect insect.

Under whatever form the insect be excluded from the egg, if we trace its development further back, we shall find that the tendency of the mysterious multiplication, arrangement, and transformation of the hyaline and vitelline particles is vermiform. In all insects the embryo first manifests itself as an apodal smooth Entozoon; next as an anellide of thirteen rings: in all insects the first segment is quickly modified and the mouth established; and in this state the larva is excluded in some insects, as the bee and fly, without any appendages being developed.

The maggots of the order *Diptera* typify the Entozoa; they have no distinct scaly head, and no thoracic legs; hence they have been termed "vermilarves." They represent the parasitic worms not only in structure but in habits; the larvæ of the *Gasterophili* called "bots," pass that stage of their existence in the alimentary canal of higher animals. The larva of the *Anthorugia canicularis* may be in like manner considered as entozoa of the human subject. There is a breeze-fly (*Œstrus hominis*)* which deposits its egg beneath the integument of the living body, and its larva there grows and flourishes like the Filaria in the cellular tissue. The larva of a species of *Cuterebra* occasionally finds its way into the human frontal sinus. Other vermilarves, as those of the *Œstri Bovis* and *Tarandi*, are developed beneath the integument or in the nasal sinuses of the Ruminants indicated by their specific names. I know not to what other modes of animal life than that of the parasitic Entozoa we can compare the habits of the voracious maggots of the flesh-fly, the essential condition of whose existence is the putrid flesh of higher organised beings. Here, however, the development of helminthoid larva has been beneficently ordained in order to neutralise the noxious effects of the

* Howship, Proceedings of the Royal Society, March 21, 1833.

otherwise inevitable processes by which dead animal matter reverts to its primitive elements. Insignificant indeed do these larvæ seem to be in the scale of nature, yet Linnæus* used no exaggeration when he averred that three flesh-flies would devour the carcase of a horse as quickly as would a lion. The assimilative power is so great in the meat-maggot that it will increase its own weight two hundred times in twenty-four hours.

But the organising energies are not exhausted by the rapid growth of the larva; some remain to be exercised in the formation of the new and peculiar organs which entirely change the form and properties of the creature. For this exercise they require the suspension of all the ordinary actions of life. The larval skin is thrust off by the new integument of the new organs, and is converted into an opaque brown case: the inclosed insect shrinks partly by the loss of exhaled fluids, partly by the condensation of its former soft tissues into the new and firm substances constituting the legs and wings. A large and distinct head is now developed, with eyes, antennæ, and instrumenta cibaria; all which processes are carried on in the quiescent concealment of the opaque and dark exuvium, like the analogous processes in the egg of the Orthopterous, and within the womb of the pupiparous, insect. The active carnivorous vermilarve returns, in fact, a second time to the state of an ovum, when it becomes the coarctate pupe; and the perfect insect, splitting its cerement, issues forth as by a second birth.

The larvæ of the gnats (*Culex*) and crane-flies (*Tipulæ*) have a distinct corneous head with jaws: the former have a plumose anal coronet, by which they sustain themselves at the surface of the water: the orifices of the tracheæ are placed in the middle of this coronet. A pair of tracheal tubes extend through the long, slender, and extensile anal canal of the aquatic grub of the *Musca* (*Eristalis*) *tenax*. By this mechanism, which is analogous to the tube of the diving bell, the rat-tailed larva can derive its requisite supply of air from the surface while groping for food in the mud at the bottom of the pool.

The economy of the Hymenoptera and the various circumstances attending the development of their apodal larvæ form the subjects of a long chapter in the History of Insects.

I must be governed in the unavoidably brief selection from this rich storehouse of intereresting facts by the specimens which Hunter has left for our instruction. Here (exhibiting the preparation No. 3104.) we have a portion of the nest of a social hymenopterous

* Systema Naturæ, Musca carnaria.

insect of the wasp tribe (*Polistes major*), showing the larvæ and their cells in every stage of growth: the smallest larvæ and the shallowest cells are at the lower margins of the pendent nest; and observe how, in these beginnings of cells, the part of the incomplete circumference forms two, three or more sides of a complete hexagon, demonstrating that this is the form of cell originally and expressly made by the insect, and not the accidental and inevitable result of the reciprocal pressure of originally cylindrical cells, moulded upon the bodies of their simultaneously-working fabricators. The parent wasp of this colony began her labours in spring. A solitary mother and independent builder of the required shelter for her offspring, she herself nursed and fed her first brood, which, being non-breeding labourers, soon aided their parent in building the cells and rearing her larvæ. You will observe that the full-grown grubs are shut in by a transparent convex pellicle, which covers the mouth of the cell.

In the common wasp, the larva is hatched eight days after oviposition; it grows to its full size in twelve to fourteen days, then spins its delicate hood, casts its integument, which has grown with its growth from the time of quitting the egg, and, after a passive pupa state of ten days, emerges a perfect insect. The males and perfect females are reared at the beginning of autumn: the abundance of food yielded by the ripe fruit at that season may influence the higher development of the larvæ, which are fed by the regurgitated contents of the crop of the nursers.

The fertile females share with the non-breeders or neuters of the rapidly increasing community, the labour of rearing the young broods: the males, or drones, perform no kind of work. At the close of autumn, when provender is scanty, and hardly to be got, the neuters, by a strange, and, as it would seem, perverted instinct, save the later brood of grubs from the pangs of famine by killing and casting them out of the nest. The young females are impregnated previous to the setting in of winter: the males soon after die; the females then disperse, seeking winter quarters in sheltered situations; and those which survive the rigours of the frosty season commence, at the return of spring, the foundation of a new colony.

The higher instincts of the honey-bee (*Apis mellifica*) teach it to lay up a winter store of food, upon which, the males having been destroyed on the performance of their sole office, the queens, with a family of neuters, subsist till spring. The neuters alone now recommence their labours of housing, in waxen cells, the eggs of the fertile female, and feeding the larvæ. New colonies so raised successively emigrate from the parent hive, or swarm; they consist of a queen or fertile female, and perhaps a thousand attendant neuters. Thus the association, which is annually dissolved and recommenced by the wasps, is permanent in the honey-bee, and the fertile female, or queen, never shares with the neuters the labours of the hive.

The development of the bee is m re speedy than that of the wasp; the larva is hatched in three days after the exclusion of the egg; it feeds and grows five days; is then shut up by the workers, spins itself a cocoon in thirty-six hours, remaining a passive pupa eight days; then breaks through the lid and emerges in its perfect state. Thus the whole period of development from the exclusion of the ovum is twenty days; this, however, relates to the neuter. The male or drone larva spends only twenty-four hours in spinning its cocoon, and emerges on the sixteenth day after its deposition as an egg. A young queen is perfected on the twenty-fourth day.

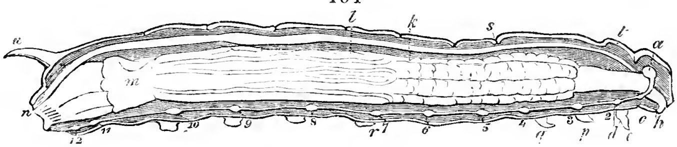
In these preparations (Nos. 3117. to 3123. inclusive) are shown the irregular subelliptical cells with the larvæ and perfect insects of the humble bees (*Bombi terrestris* and *lapidarius.*) The societies of this genus, which consist of about sixty, and occasionally of two hundred individuals, continue, as in the wasp-tribe, only until the beginning of winter, and the few impregnated females which survive the frosts, found fresh colonies at the commencement of the following spring. The fertile female shares in the labours of the community which she has originated, and she is provided, like the neuters, with the dense fringe of hair surrounding the pollen plate of the hind legs, which the queen of the hive-bee does not possess. The first progeny of the humble-bee are neuters; the males are not developed until autumn, and they are the produce of a smaller kind of fertile female. The whole economy of the humble-bee was very completely observed by Hunter, whose MS. notes on this subject have been published in the fifth volume of the Physiological Catalogue.

The larvæ of the Coleoptera are active, although some, as the nut-grub, are apodal, like the larvæ of the bee. In most of the herbivorous species the thoracic legs are represented by fleshy tubercles; but the larvæ of the carnivorous beetles have the thoracic legs more completely developed before quitting the ovum. The head is horny, and the trophi are well developed in all: the jaws frequently resemble those of the perfect insect, as in the *Carabidæ*, the larvæ of which likewise have antennæ.

The circumstance of most physiological interest in the development of the Coleopterous order of insects is the great length of time during which the species actively exist in the vermiform or larval stage of their development. The larvæ of the cockchafer typify the earth-worm in their habits, and continue for three years burrowing in the soil and devouring the roots of grass and other vegetables. The larva of the stag-beetle bores its way into the trunk of a tree, generally a willow or oak, and remains there six years. It is furnished with two powerful jaws, with which it gnaws the wood. It forms a cocoon of the minute chips or tan, to which it reduces the wood, and passes a considerable period in the pupa state; during which, the large horns of the male are folded upon the breast and abdomen, protecting the antennæ and legs.

The anatomy of an insect in its different stages of development, and the changes of both the external and internal parts in the progress from the larva to the imago state, have been most accurately and closely examined in Lepidopterous insects. Many of these changes are shown by Hunter, in his extensive series of preparations of the silkworm moth.* They were investigated by Lyonnet in the *Cossus ligniperda.* They have been described and illustrated with much accuracy and detail by Herold in the *Papilio Brassicæ,* and by Mr. Newport in the *Sphinx Ligustri.* The larvæ of the Lepidoptera quit the egg with a scaly head and jaws, with three pairs of thoracic legs, short, and with claws (*fig.* 104, *o, p, q*), and usually

104



Sphinx Ligustri. Larva.

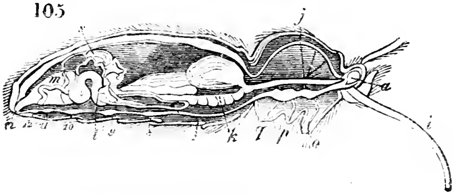
four pairs of tubercular prolegs (*r, r*), supported by the sixth, seventh, eighth, and ninth segments; sometimes there is also a fifth pair upon the anal segment. The prolegs, which entirely disappear in the pupa, are however less constant than the thoracic legs. The larvæ of the lepidoptera are commonly herbivorous, and devour considerable quantities of vegetable matter. The coarsely masticated leaves are conveyed by a short and wide œsophagus (*fig.* 104. *d*), to a much longer and wider chylific stomach (*k*). Six pairs of capillary bile-tubes (*l*) indicate by their insertion the commencement of the intestine (*m*), which terminates by a wide, short, and longitudinally plicated rectum at *n*, upon the last segment.

In its perfect state, the butterfly, or sphinx, subsists only on the fluids of vegetables: its maxillary apparatus is converted by the abrogation of the horny mandibles and the extreme prolongation of the maxillæ, into the antlia (*fig.* 105. *i*), already described. A

* See Nos. 2976. to 3036. inclusive.

long and slender œsophagus, *j*, conveys the fluids to the chylific stomach, and to a wide crop (*fig.* 105. *k*), which during the pupa state has been gradually expanded from one side of the end of the gullet. The chylific stomach (*q*) has shrunk into a comparatively short fusiform cavity, which is still characterised by the transverse sacculi and constrictions.

105



Sphinx Ligustri. Imago.

The small intestine (*l*) has diminished in width, but increased in length, and now lies in several convolutions between the chylific stomach and colon, the upper part of which has also been produced into a cæcum (*m*). The biliary vessels are diminished in length, but still communicate, by a short common duct on each side, with the commencement of the small intestine.

In the bee the metamorphosis of the digestive organs is still more striking than in the butterfly, inasmuch as the alimentary cavity consists, beyond the short and wide œsophagus, exclusively of a large transversely plicated chylific stomach without intestine or vent.

The larvæ of bees and wasps have from four to six biliary vessels, which shrink in diameter and contract in ength during the pupa state.

The gizzard is never present in the vermiform larvæ of the *Coleoptera*, although usually possessed by the perfect insect.

In the larvæ of the *Scarabæi*, *Melolontha*, and most herbivorous Coleoptera, the chylific stomach is shorter than in the imago; but it is furnished at both ends with cæcal appendages, which disappear during the metamorphosis, except in the genus *Hister*, in which some traces remain in the perfect insect.

The salivary vessels of the caterpillars of the Lepidoptera are of two kinds; one pair is short and broad, sometimes vesicular, as in the *Cossus ligniperda*, and their ducts terminate at the base of the maxillæ. Those of the second pair are very long and slender, occupying, with their longitudinal coils, the sides of the abdomen, and sending their slender ducts forwards to unite together and terminate upon a peculiar prominence upon the under lip, which is called the spinneret.* These tubular glands, though classed with the salivary apparatus, are peculiar, in their full development, to the larvæ, and are called "sericteria" or silk-tubes, because they prepare the glutinous material, or silk, which the larva spins to form its cocoon. In the perfect in-

* See preps. Nos. 2985. to 2988.

sect, the remains of the salivary apparatus are limited to the thorax, and the common duct opens beneath the tongue.

The epithelial lining of the alimentary canal of the larva is shed at each moult; that of the closed stomach in the bee-maggot is evacuated in the pupa state through the new formed anus.

The superabundant nutriment prepared by the voracious larva is stored up in the condition of masses of fat which surround the viscera and occupy their interspaces.

The parasitic Ichneumons introduce their ova beneath the skin of the larvæ of Lepidoptera. When hatched the Ichneumon larvæ subsist upon the fat of the caterpillars, which they infest. They avoid penetrating the alimentary canal, but evidently destroy many of the minute branches of the trachea which ramify in the adipose tissue. Such wounded tracheæ probably permit the escape of sufficient air for the respiration of the parasitic larvæ; for though the caterpillars so infested survive and go into the pupa state, they are uneasy, and evidently diseased; the loss of the adipose store of nutriment prevents the completion of the metamorphosis, and instead of a butterfly, a swarm of small Ichneumons emerges from the cocoon.

With respect to the outward form and integuments of the vermiform larva, these are contracted lengthwise, and partially dilated during the pupa state. The longitudinal muscles contract, and are permanently shortened by interstitial absorption: they shorten the body by sheathing the segments one within the other, the intussuscepted portions being afterwards modified or removed.

The dorsal vessel (*fig.* 104, *s*), which is developed above the intestine, and begins to pulsate before the larva quits the egg, undergoes a corresponding change with the common integument in the pupa state. It seems to be contracted by a series of intus-susceptions; the abdominal part is slightly expanded, more definitely divided into chambers, and better provided with valves: the thoracic portion is simplified, shrunk in diameter, and is more distinctly defined as an aorta sent off from the heart. (*fig.* 105.)

The respiratory system undergoes still more remarkable modifications. The branchiæ of the aquatic larvæ either disappear or are developed into wings: the long pneumatic tubes of those which, living in water, breath air, shrink and disappear. The partial dilatations of certain tracheæ to form reservoirs of air for diminishing the specific gravity of the body, begin to be formed in the pupa state of the flying insect.

Herold has shown that germs of the generative organs exist in the larvæ of the Lepidoptera: the testes appear on each side as four nucleated cells in a longitudinal series, which, by progressive coalescence longitudinally, and by approximating transversely, and ultimately uniting at the middle line, first form an eight-chambered, and afterwards a spherical, gland. (*fig.* 105. *s.*) The ovaria, retaining their primitive separate state, increase in length, and assume the spiral disposition in the pupa state.

I have already* described the chief changes which the nervous system undergoes during the transformation of the larva into the imago, and need only now observe that the general principle of those changes is like that which governs the modifications of the muscular system, viz. a localisation of special masses at particular parts for special purposes, the result of which is the departure from a common to a particular type of arrangement.

One of the most obvious and remarkable phenomena in the larval life of an insect is the successive sheddings of the skin. The number and frequency of the ecdyses varies in different species, and relates to two circumstances, viz. the rapidity of the growth of the body, and the susceptibility or otherwise of the skin to be distended or to grow with the increase of the body.

The soft-skinned maggots of many flies, which acquire a vast increase of size during their brief larval state, never moult until they change into pupæ, when the exuvium forms the pupa-case. In like manner the soft-skinned apodal larvæ of the Hymenoptera do not moult until they have acquired their full size. The caterpillars of the Lepidoptera moult at least three times, and some more frequently; the *Bombyx villica*, for example, from five to eight times, and the tiger-moth (*Arctia caja*) ten times.

With regard to the nature of the mutations and ecdyses which culminate in the perfect insect, I should hardly have felt justified, after what has been already detailed respecting the development of the larva in the egg, in referring to the hypothesis of Swammerdam, — that the imago was actually included in the larva, and that all new skins pre-existed beneath the old one, — if such opinion had not been adopted to explain the metamorphoses of insects in the admirable work of our countrymen, Kirby and Spence.* The accurate observations of Herold on the changes and development of the organs during the pupa state show these to be, like the original processes of the development of the larva itself, the results of a transmutation, increase, and coalescence of primitive elements of the different tissues.

The few instances of the reproduction of mutilated parts in insects have been observed to take place only at the period of the moult, and are never manifested by the imago. A young *Blatta*, in which

* p. 209.

† Introduction to Entomology, vol. ii., p. 61.

both the antennæ had been cut off, moulted a fortnight after the operation, and then acquired two new but shorter antennæ: the legs and prolegs of caterpillars are said to be reproduced in like manner after one or two moultings.

The passive and, as it were, embryonic condition to which most insects (Coleoptera, Lepidoptera, Hymenoptera, Diptera, many Neuroptera) return when, after an active larval life, the organising energies again superinduce the processes of development upon those of mere growth, is called the pupa state. The chief modifications of the pupa have already been explained in relation to the terms coarctate, obtected, incomplete, by which they were designated by Linnæus.

Some pupæ are protected only by the exuvial skin of the preceding stage, and have been termed "naked;" others repose in cases or "cocoons," artificially prepared by the larva. The valuable silken cocoons of the larva of the *Bombus mori*, called, par excellence, the "silkworm," are familiar examples of pupal chambers. In this cocoon * of a larger Lepidopterous insect (*Oiketicus Kirbyi*), the larva, by one of those marvellous prescient instincts which give so much interest to entomological enquiries, covers the close and thick web of fine and soft silk which it has prepared for its pupal repose with a strong outer defence of portions of twigs irregularly bound together by silken filaments: thus suspended to a branch of the tree, it deceives and escapes the attacks of predatory insectivorous birds. The pupæ whose cocoon remains partially open, as in *Saturnia* and *Phryganea*, are usually called "guarded" (*pupæ custodiatæ*).

All pupæ which are placed in dark situations are colourless, or of a yellowish white, and become darker when exposed to the light. The pupæ of most butterflies, which are suspended in open day, are of a green or yellowish brown colour: some are speckled with glittering spots of golden hue, either natural or produced by the attacks of parasitic insects; and such pupæ have obtained the name of "chrysalis" and "aurelia."

The active pupæ of Orthoptera and Hemiptera are called "nymphs." These insects, which are also said to have semicomplete pupæ, and to undergo an imperfect metamorphosis, are subjected, as I trust I have already proved, to the same law of repetition or analogy which is expressed so conspicuously in insects to which alone a perfect metamorphosis has usually been attributed: for, although moulting be no metamorphosis, even when accompanied, as it usually is in insects, with a certain change in the form of the body, yet the course of the development of those insects which, after exclusion

* No. 3073.

from the egg, are subject only to ecdysis and growth of wings during an active nymph-hood, manifests, prior to exclusion, the same analogies, which Oken expresses in the following words: — "Every fly creeps as a worm out of the egg; then, by changing into the pupa, it becomes a crab, and, lastly, a perfect fly."*

It is not, indeed, true that every flying insect creeps, as a worm, out of the egg: all the *Orthoptera* and *Hemiptera* are excluded under the type of the crab, *i. e.* with perfectly developed jointed legs, eyes, antennæ, and maxillary organs. The metamorphoses which the locust undergoes in its progress from the potential germ to the actual winged and procreative imago are nevertheless as numerous and extreme as those of the butterfly. The differences are relative, not essential; they relate to the place in and the time during which the metamorphoses occur, and to the powers associated with particular transitory forms of the insect. The legs of the worm-like embryo-locust were once unarticulated buds, like the prolegs of the caterpillar; but the creature was passive, and development is not superseded for a moment by mere growth; these organizing processes go on simultaneously, or, rather, change of form is more conspicuous than increase of bulk: the six rudimental feet are put to no use, but constitute mere stages in the rapid formation of the normal segments, which attain their mature proportions and their armature of claws and spines, before the egg is left. The first segment of the originally apodal and acephalous larva is as rapidly and uninterruptedly metamorphosed into the mandibulate and antennate head, with large compound eyes.

Thus developed, the young Orthopteran or Hemipteran issues forth into active life. It may at once begin the great business of its existence, the propagation of its kind, as in the *Aphis*, and feed and die without further change of form; but generally the active crab-like larvæ are subject to three moults. After the first the larva has merely increased in size; but the rudiments of the wings begin to bud forth beneath the second skin, and, after the second ecdysis, they present themselves externally as small leaves, which cover the sides of the first abdominal segment. When this active pupa or nymph again moults, the insect attains its perfect condition; the, at first, short, soft, and thick wings rapidly expand to their full size, then dry in the air, the circulation of the blood along the nervures is arrested, and the metamorphosis of the individual is complete. Here, then, we see that the pupa stage, which, in the butterfly, was passive and embryonic, in the locust is active and voracious, whilst their respective conditions in the larval state are reversed: the whole period

* Naturgeschichte für Schulen, p. 577.

of the life of the Orthopterous insect, from exclusion to flight, may, if its organisation during that period be contrasted with that of the Lepidopterous or Coleopterous insects, be called an active nymphhood.

Entomologists, overlooking that stage of the orthopterous and hemipterous insects in which they are masked by the vermiform or true larval condition, have arbitrarily applied the term "larva" to the more advanced stage in which these insects, with certain Neuroptera, quit the egg. Mr. Westwood, seeing that at this stage they are nearly similar in form to the perfect insect, though wingless, has proposed to call them "homomorphous," or "monomorphous;" and those insects in which the larva is generally wormlike, &c. "heteromorphous." It needs only an acquaintance with the embryonic changes of a cockroach or cricket to feel how inapplicable is the term monomorphous or uniform to such an insect or its development.

In the Coleoptera and Lepidoptera the general articulate type is longer retained, and the particular one later acquired: in the Hemiptera and Orthoptera, the morphological and histological changes more rapidly and uninterruptedly effect the ascent from the common to the special form. The insects with a so called imperfect metamorphosis, contrary to the statement of Burmeister*, do pass through the earlier forms of the articulate subkingdom, but more rapidly and uninterruptedly than those in which the metamorphosis has been deemed more complete. In these the worm-like insect or larva is active, and the crab-like insect or pupa passive; in those the larva is passive and the pupa active.

If the different stages in the development of man were not hidden in the dark recesses of the womb, but were manifested, as in insects, by premature birth and the enjoyment of active life, with a limitation of the developmental force to mere growth; if the progress of development was thus interrupted and completed at brief and remote periods, with great rapidity, and during a partial suspension of active life; — his metamorphoses would be scarcely less striking and extreme, as they are not less real, than those of the butterfly.

As the insect must pass through the earlier forms of the Articulate,

* Burmeister's statement is, " In insects with an imperfect metamorphosis there cannot consequently " (the consequence is a hypothetical necessity in Nature, for a difference among insects with respect to their metamorphosis) " be a passage through the earlier forms and grades of the animal kingdom." (Shuckard's Translation, p. 423.) But no insect ever passes through the forms and grades of the radiate subkingdom. Commencing as a Hydatid, it quits that subkingdom by the analogy of the Entozoa, and its subsequent grades are through the forms of the Articulata exclusively. No insect ever is or resembles the ciliated Infusory, the Polype, or the Acalephe.

so must man through those of the Vertebrate, subkingdom. The human embryo is first apodal and vermiform: not, however, at any period an articulated worm. The metamorphoses of the germ-cells in the spherical (hydatid-like) ovum have laid down the foundation of the nervous system coeval with the first assumption of a definite animal form ; and, by placing it along the back as a rudimental spinal chord, have stamped the vermiform human embryo with the characters of the apodal fish. When the four undivided compressed extremities bud out, the form of the abdominal-finned fish, or of the Enaliosaur, is indicated. The development of the heart, of the vascular arches, of the generative organs with their cloacal communication with the rectum, typify the oviparous reptile. But these stages are rapidly passed, and the special character acquired.

Let us suppose that man, or any mammiferous animal, quitted the ovum and the parent in the guise of the fish, passed a certain period in water, retaining the branchial structure, the undivided extremities and the cloaca, and acquired only increase of bulk under that guise ; let us suppose that then such larva, seeking some safe hiding place, returned to embryonic passivity and unconsciousness, and was rapidly transformed into the perfect state. Under this hypothetical modification of the course of human development, the changes of form would be plainly recognisable, and in the accessory circumstances, as well as the essentials, the mammalian metamorphoses would resemble those of the insect.

If, on the other hand, every insect had been developed like the *Diptera pupipara*, and the changes from egg to larva and from larva to pupa had been hidden in the oviduct of the mother, a long period might have elapsed before the recognition of these metamorphoses, and they could only at length have been discovered by a series of embryotomies, like those that have brought to light the corresponding metamorphoses of man and the mammalia generally.

By a premature exclusion and activity of the embryo, and by alternate periods of growth and development, one small group of vertebrate animals, the anourous Batrachia, do actually manifest the correspondence with the metamorphoses of insects, which I have illustrated by an instance of hypothetical possibility in man. Nay, do not the Marsupial mammalia offer an example of the premature exclusion ? It needed only that the young kangaroo, with its equal and rudimental limbs, should possess, like the tadpole or caterpillar, the power of self-subsistence, and have gone on feeding and growing, whilst the further and final changes of form were reserved for, and concentrated in, a future brief period, to render the parallel almost complete. The creeping or swimming larva of the Mammal would then have gained its instruments for leaping, as the caterpillar acquires its organs of flight, and the concomitant development and metamorphoses of the organs of sense, of digestion, and of generation would have been closely analogous in both animals.

LECTURE XIX.

ARACHNIDA.

There remains one class of articulate animals to be considered in our present ascending survey of the animal kingdom, and which, therefore, you will conclude to be the highest organised of the homogangliate Invertebrata. Yet the species which are grouped together under the name *Arachnida* never acquire wings: many are parasitic, many terrestrial, and a few are aquatic; there are some, however, that, notwithstanding their apterous condition, can rise and float through the air, which they effect in a manner analogous to our balloon aeronauts, by manufacturing and suspending themselves to a foreign substance light enough to be buoyed up and wafted along the atmospheric currents. The animals to which I allude, and whose anatomy and physiology I propose to make the subject of the present lecture, are those commonly known under the name of mites, scorpions, and spiders.

You will be disposed to ask why these Articulata are held superior to insects? They present a more concentrated form of the nervous system and of the heart: the larger species, likewise, present a higher condition of the respiratory system, which is less diffused than in insects, and in some consists only of air-sacs or lungs. Perhaps the most essential mark of the superiority of the Arachnida is the course of their development. The spider undergoes no metamorphoses comparable with those of insects. It is at no period of its development an apodal worm. The mature form is sketched out from the beginning, the divisions of the body characteristic of the perfect animal are established before the vitelline mass is included by the tegument; and, long before the characteristic palpi and legs are completed, the equally characteristic ocelli are developed upon the head. If you should still be disposed to think that the superior organs of vision and the wings of insects are essential signs of a higher organisation, by parity of reasoning, you must be prepared to place birds above mammals.

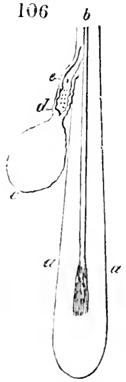
The Arachnida, like insects, are organised to live in air; but they are distinguished at first sight by the general form of the body and the number of their legs, and by some important modifications of their internal structure. The head is always, in the Arachnida, confounded with the thorax, and is deprived of antennæ, or at least of homologous parts exclusively employed in sensation. They have four pairs of legs. Some of the species respire by pulmonary sacs only, in others these are associated with ramified tracheæ, and the smaller Arachnidans breathe, like insects, by tracheæ exclusively. The dorsal vessel and a circulating system exist in all: the heart presents a more compact and muscular form in the pulmonary Arachnidans.

The integument is chitinous, as in insects, but presents the same variations in density, in different species, as in the winged Articulata. In the scorpions it is as dense and inextensible as in the Coleoptera: in the spiders and mites it is generally softer than in insects, especially that of the abdomen.

The body is divided into two principal parts, of which the anterior is called the "cephalothorax," because it answers to the two first segments of insects in a confluent state: the second and larger division is called the abdomen; it is generally larger and wider than the first, from which it is divided by a deep constriction; but in scorpions it forms, as in Crustaceans, a slender continuation of the thorax, a kind of caudal appendage divided into many joints. The organs of locomotion are all attached to the cephalothorax, and consist of eight legs, presenting different grades of development in the different forms of the class, but, in most, being very similar to those of insects, and almost always terminated by two hooks.

The microscopic parasite of the sebaceous sacs and hair-follicles of the human skin, lately discovered by Dr. Simon of Berlin, and described in Müller's Archiv. für Physiologie (1842, p. 218. pl. xi.), represents the lowest organised form of the class *Arachnida*, and, like the parasitic *Cymothoe* and *Bopyrus* of the Crustaceous class, makes a transition from the Anellides to the higher Articulata. In length, it ranges from $\frac{1}{50}$th to $\frac{1}{100}$th of an inch. *Fig.* 106. gives a magnified view of the human hair-follicle (a), containing the bulb of the hair (b), the appended sebaceous sac (c), and the duct (d) containing the parasitic Arachnidan in question (e). That this parasite ranks with the Arachnida, and not with the red-blooded or any of the lower organised worms, is evident from the division of the body into thorax and abdomen, from the structure of

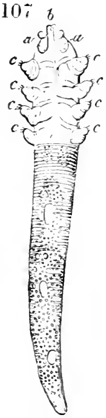
106



Demodex folliculorum in situ.

the head and mouth, which are confluent with the thorax, and from the undivided abdomen. The thoracic appendages (*fig.* 107. *c, c*), eight in number, as in the Arachnida, are however of the simplest and most rudimental kind, and are terminated by three short setæ; the Anellidous type of the locomotive appendages being still retained. The integument of the abdomen is very minutely annulated. The mouth is a suctorial one, or proboscidiform, consisting of two small spine-shaped maxillæ (*b*), and an extensile labium, capable of being elongated and retracted; it is provided on each side with a short and thick maxillary palp (*a, a*), consisting of two joints, and with a narrow triangular labrum above. Although the structure of the mouth, as described and figured by Dr. Simon, has much analogy with that of the *Acari*, like which, also, the follicular parasite in one of its stages of development is a hexapod, yet it differs from the *Acari*, and from all other *Holeteræ* of Dugés, in the articulations of the thorax; whilst it equally differs from the *Pseudo-scorpionidæ*, and the *Pycnogonidæ*, which have the thorax articulated, in the rudimental form of the feet, and the structure of the trophi.

107



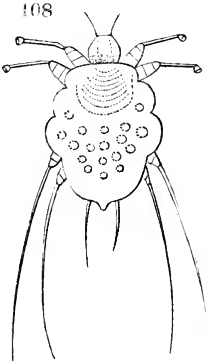
Demodex folliculorum. magnified.

It can hardly be supposed that the changes of form indicated by the figures 8, 1, and 2 of Dr. Simon's memoir can be acquired without ecdysis; but such a metamorphosis, with the natural divisions of the body and the structure of the oral and thoracic appendages, indubitably raise the parasite of the hair-follicle above the Entozoa, to which class Prof. Erichson, in Dr. Simon's memoir, has correctly stated that the present parasite cannot belong. For the reasons above given, I cannot assent to the place which that accomplished naturalist has assigned to the Arachnidan in question among the *Acaridæ*, much less to the genus *Acarus*. Of the generic distinction of the parasite there can be no doubt, and I therefore propose to call it *Demodex folliculorum*, from δημος, lard, and δηξ, the name of a boring worm, indicative of the habitat and vermiform figure of this parasitic arachnidan, which insinuates itself into the hair-follicles and the sebaceous glands that communicate therewith.

In some of the small and parasitic tracheary Arachnida, or mites, certain pairs of legs are terminated by adhesive suckers, and others are occasionally terminated by setæ, as in the itch-mite (*Sarcoptes Galei*, *fig.* 108.).

The mouth, in all Arachnidans, is situated on the anterior segment and is provided with instruments adapted either for suction or mastication. In the parasitic mites the rudiments of the jaws are more or less enveloped in a sheath formed by the lower lip: the maxillary palpi are usually the only parts which have free and independent movements, and their extremity is commonly armed either with a hook or with a pair of small nippers.

108



Sarcoptes Galei, or itch-insect, magnified.

In spiders the mandibles (*fig.* 114. *a*) are situated at the front of the head and are terminated by a moveable and very sharp hook, which is pierced at its extremity by a small fissure, serving to give issue to the poison secreted by a gland lodged in the preceding joint. The maxillæ (*fig.* 114. *b, b*) are two in number, and the labium (*fig.* 114. *e*) situated between these organs is composed of a single piece. The maxillary palpi (*fig.* 114. *c*), compared with those of insects, are of great length and size, and resemble the thoracic feet, which, in the Mygale, they nearly equal in length. In female spiders they are terminated by a single moveable claw: in the males the last joint (*fig.* 114. *d*) is dilated, and presents a more complicated structure. In the scorpion the mandibles are short and terminate in a pair of strong pincers: the maxillary palpi are proportionally more developed than in the spiders, and, like the mandibles, they terminate by pincers, which are so strong and large in the great scorpion (*Buthus Africanus*), as to resemble the chelæ of the Crustacea, and more especially as they are succeeded by four pairs of simple and smaller thoracic legs.

In the genus *Galeodes* the mandibles are chelate, but much longer and larger than in the scorpions. The maxillary palpi resemble small slender feet, but without the terminal hooks; and the succeeding pair of legs being similarly modified, only six ambulatory feet of the ordinary structure remain. Two rudiments of antennæ have been noticed attached to the mandibles in certain species of this genus. The head is likewise more distinct from the thorax, and it supports the first of the four pairs of legs usually ascribed to the Arachnidæ. These modifications, with the union of the ocelli into two groups, indicate the Galeodes to form the passage to the Hexapod insects.

The modification and the connections of the pair of legs which succeeds the maxillary palpi in the Galeodes, demonstrate that they are the analogues of the labial palpi in Hexapod insects. The position of the rudimental antennæ in the same interesting genus confirms the indication afforded by the nervous system in spiders and scorpions, that the antennæ are confluent with the mandibles, if these be not altogether modified antennæ, as Latreille supposed to be the case in the present class.

In the composition of the cephalothorax of spiders, M. Audouin has discovered that the tergal elements of the coalesced segments are wanting, and that the back of the thorax is protected by the elongation, convergence, and central confluence of the epimeral pieces; the sternal elements have coalesced into the broad plate (*fig.* 114. *h*), in the centre of the origins of the ambulatory legs, from which it is separated by the episternal elements. The traces of the original separation of the four epimeral pieces may be easily distinguished in some spiders, as the *Pholcus rivulatus*. The non-development of the tergal elements explains the absence of wings, which we have seen, in the *Articulata*, to be the appendages of those elements, and to be very frequently restricted to the branchial function. The tergal parts of the thoracic segments are equally absent in the decapod Crustacea; but the back of that division of the body is protected by the carapace, continued backwards from certain cephalic segments: when this is raised, the epimeral pieces are seen converging, as in spiders, but not meeting and coalescing.

The soft and flexible integument of the abdomen in mites and spiders gives no indication of the segments or their component parts, but it is favourable for the study of its intimate organisation. Beneath the epiderm and pigmental layer may be distinguished a thin muscular chorion, the fibres of which surround the abdomen in various directions. To the epiderm belong the hairy and spinous appendages: the large bird-spiders (*Mygale*) are clothed with a thick coat of hair: some of the smaller species, as the *Aranea domestica*, have complex hairs, like the down of birds, implanted by a stem. In other spiders similarly implanted stems support scales, analogous to those of the *Lepidoptera;* the bright colours of the *Salticæ* and *Oxyopes* are due to these scales.

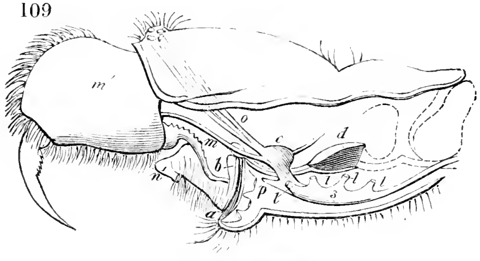
The muscular system is principally aggregated in the cephalothorax for working the organs of mastication and locomotion; there are, however, special muscles in the slender jointed abdomen of the scorpions for its inflection and extension, and more especially for the purpose of wielding the poisonous weapon with which it is terminated.

The principal masses or ganglions of the nervous system are concentrated around the œsophagus in the cephalothorax of the scorpion. From the small supra-œsophageal or cephalic bilobed mass are sent upwards the optic filaments, forwards the nerves of the forcipated mandibles or "chelicera," and, backwards, the stomato-gastric nerves; the sub-œsophageal ganglionic columns distribute nerves to the great maxillary cheliform palpi, and to the four pairs of thoracic legs: two slender continuations of the median columns are continued along the jointed abdomen or tail, and seven small ganglions are developed upon them, from which and from the interganglionic chords nervous filaments are distributed to the surrounding parts.

The ventral continuation of the anterior aorta, which lies loosely upon the dorsal aspect of the ganglionic chords, must be injected in order that its branches, which accompany the nervous filaments, may be distinguished from them. The vessel itself has been mistaken for a nerve, and has been regarded by some as the motor, by others as the respiratory tract.

In spiders the central masses of the nervous system are wholly, or in great part, concentrated in the cephalothorax. The brain (*fig.* 109. and 110. *c*) is a bilobed ganglion sending forwards and upwards the optic nerves (*o*) from its anterior angles, and below these, the two large nerves (*m*) to the mandibles: a short and thick collar encloses the narrow gullet, and expands into a second very considerable stellate or radiated ganglion (*s*), situated below the stomach upon the plastron: it sends off five principal nerves on each side; the first (*p*) to the pediform maxillary palpi; the second (*l*) to the more pediform labial palpi, which are usually longer than the rest of the legs and used by many spiders rather as instruments of exploration than of locomotion; the three posterior nerves supply the remaining legs, which answer to the thoracic legs of Hexapod insects. The nervous axis is prolonged beyond this great ganglion, as two distinct chords, into the beginning of the abdomen, where, in the Epeira diadema, it divides into a kind of cauda equina; but in the Mygale a third ganglion of very small size is formed, from which the nerves diverge to supply the teguments of the abdomen and its contents. The origin of the mandibular nerves close to the optic ones from the supra-œsophageal ganglion strongly indicates the antennal relations of the mandibles, whilst the analogues of the maxillary and labial palpi receive, as in insects, their nerves from the sub-œsophageal mass. The stomatogastric nerves are sent off from the posterior and lateral parts of the brain and form on each side a reticulate ganglion, which distributes filaments to the stomach.

109



Nervous system, *Mygale*.

Many of the lower parasitic species of arachnidans are blind: not any of this class have compound eyes, although the stemmata in some, as the *Galeodes* and the genus *Pholcus*, have their ocelli arranged in two lateral groups. The scorpions have eight ocelli, two of which are situated near the middle line, and three on each side, near the anterior angles of the cephalothorax.

In the spiders the ocelli are generally arranged in a group, upon an eminence at the middle of the anterior part of the cephalothorax; they are generally eight, never less than six in number. The position of the four median ones is the most constant; they generally indicate a square or a trapezium, and may be compared with the median ocelli in hexapod insects. The two, or the two pairs of lateral ocelli may be compared with the compound eyes of insects; the anterior of these has usually a downward aspect, whilst the posterior looks backwards; the variety in the arrangement of the ocelli of spiders always bears a constant relation to the general conformation and habits of the species. Dujés has observed, that those spiders which hide in tubes, or lurk in obscure retreats, either under-ground or in the holes and fissures of walls and rocks, from which they only emerge to seize a passing prey, have their eyes aggregated in a close group in the middle of the forehead, as in the bird-spider (*fig.* 109.), the clothos, &c. The spiders which inhabit short tubes, terminated by a large web exposed to the open air, have the eyes separated, and more spread upon the front of the cephalothorax.

Those spiders which rest in the centre of a free web, and along which they frequently traverse, have the eyes supported on slight prominences which permit a greater divergence of their axes; this structure is well marked in the genus *Thomisa*, the species of which lie in ambuscade in flowers. Lastly, the spiders called *Errantes*, or wanderers, have their eyes still more scattered, the lateral ones being placed at the margins of the cephalothorax. The structure of these simple eyes resembles that which has been so well described by Müller in the scorpion; Lyonnet had recognised the crystalline lens. The iris, or process of pigment which advances in front of the lens, is green, red, or brown in the diurnal spiders, and black at the back part of the eye. The nocturnal species, as *Mygale* and *Tarantula*, have a brilliant tapetum, but no dark pigment.

In the scorpion the transparent prominence which indicates each ocellus is a thick dermal cornea, not divided into facets; it is deeply excavated at the middle of its inner surface for the lodgment of the spherical lens: the back part of this body rests upon, without sinking into, the anterior surface of a hemispherical vitreous body. The interspace between this body and the lens forms a circular channel filled with aqueous humour and receiving a circular process of the thick pigmental chorion which defines the pupil and confines the lens to the anterior chamber. The pigment coats the retina, and covers part of the optic nerve.

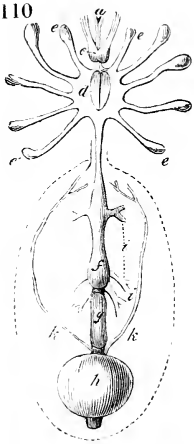
Spiders have the sense of hearing, but neither the organ nor its situation are known. The same may be said of the sense of smell. The membrane lining the mouth and pharynx may have the faculty of taste, and influence the Arachnidans in their choice of food. The soft and often hairy integument must be to a certain degree sensitive, but touch would appear to be exercised principally by the leg-like instruments into which the maxillary and labial palpi are converted.

The alimentary canal is short and straight in most Arachnidans: a slight convolution of the intestine takes place in some spiders: that of mites is straight and wide, but the stomach, in some, is produced into lateral sacculi. In scorpions, the alimentary canal extends, without any gastric dilatation or intestinal convolution, from the mouth to the anus. Five short and straight diverticula are sent off at equal distances from each side of the thoracic portion, and are lost in the granular and seemingly adipose masses, which have been regarded as a kind of epiploon by some, by others as an hepatic organ. Two delicate capillary secreting tubes unite on each side, close to the intestine, and open into that part of the canal which is in the anterior part of the tail-like abdomen.

The spiders are remarkable for the minuteness of the pharynx and œsophageal canal. Savigny believed that in some species there existed three pharyngeal apertures, through which the juices, expressed from the captured insect by the action of the maxillary plates (*fig.* 109. *n*) were filtered, as it were, into the narrow œsophagus. In the Mygale, however, there is certainly but one aperture: this is defended above by a horny plate, or rudimental labrum; below by the labium, which is soldered to the plastron in the Mygale, but jointed and movable in most of the smaller spiders.

The pharyngeal fissure (*fig.* 109. *b*) ascends between an anterior convex plate or palate and a posterior concave plate, both which are shed and renewed at each moult. The slender œsophagus passes backwards at a right angle to the pharynx, perforates the nervous ring, and expands into the stomach (*fig.* 109. *d*). In the house-spider (*Tegenaria domestica*), the gastric cavity is produced into four sacs, which are susceptible of great distension when a large prey is captured. In another species of spider, the œsophagus (*fig.* 110. *a*), having passed under the brain (*c*), suddenly expands into a stomach, almost as broad as the sternum, which sends off a long clavate cæcal

110

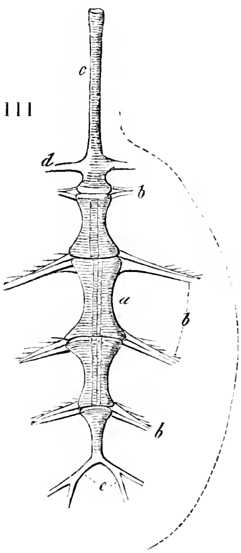


Alimentary canal, Spider.

process into the base of the maxillary palpi (*e*), and of each thoracic leg (*e′*). A shorter diverticulum (*d*) is continued from the upper part of the stomach. The intestine is contracted where it passes through the pedicle of the abdomen; it slightly expands in its straight course (*f*) along the anterior part of that cavity, then contracts and forms two short convolutions (*g*), and communicates with a large globular cæcum (*h*), from which the short rectum passes to the vent. Four biliary ducts (*i, i*) open into each side of the straight portion of the intestine. Two longer and more slender urinary tubes (*k, k*) communicate with the beginning of the cæcum, which seems to stand to them in the relation of an urinary bladder. Large masses of adipose epiploon occupy, in well-fed spiders, the sides of the abdomen, and cover and conceal the granular cæcal terminations of the hepatic organ.

The chyle is received immediately by the veins, and conveyed to the dorsal vasiform heart. This organ is confined to the six dilated anterior segments of the abdomen in the scorpions, where it is of uniform diameter, except at its two extremities: it receives the venous blood from the surrounding pericardial sinus by ten or eleven pairs of apertures, each guarded by a pair of valves. From the anterior and larger extremity the anterior aorta is continued, which is short, and soon divides into three branches: a longer and more slender vessel is continued along narrow terminal segments of the abdomen from the attenuated posterior end of the heart.

111



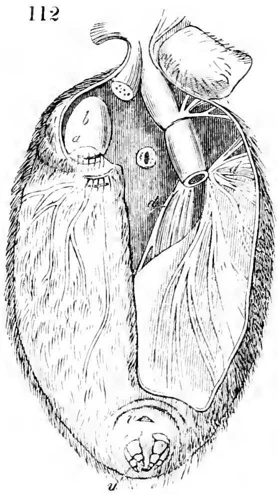
Heart of Spider.

In the spiders the heart (*fig.* 111. *a*) extends, as in flying insects, along nearly the whole of the abdomen, but is wider than in the scorpion or in insects. It is fusiform, with thick walls, composed chiefly of transverse muscular fibres, slightly decussating on the inner surface: a narrow strip of longitudinal fibres extends along the middle of the dorsal surface.

The blood is returned to the heart by three or four veins (*b, b*) on each side: it is propelled forwards by the contraction of the muscular walls, which action can frequently be discerned through the thin integument of the smaller spiders. M. Dugés, who succeeded in throwing a solution of carmine into the heart from behind forwards, found a plexus of vessels at the base of the pulmonary lamellæ, and these productions of the breathing sacs were coloured rose-red by the injection of their capillaries. Hence it would appear that the heart of the Arachnida served the purposes of both pulmonic and systemic circulations, as Hunter discovered to be the function of the heart in the flying insect. An artery is continued from both extremities of the heart; the anterior aorta (*c*) immediately gives off two transverse branches (*d*), which Dugés regards as pulmonary arteries: the posterior vessel soon divides into the genital arteries (*e*). The venous apertures are bivalvular, as in the heart of the scorpion. The heart is situated in all Arachnida, as in the other Articulata, beneath the dorsal integument and above the alimentary canal. The blood contains colourless round corpuscules, which have been seen to circulate in the limbs of young spiders; returning by a less regular channel than the arterial one: the veins of the great cavities of the body are doubtless irregular and wide sinuses.

All true Arachnidans breathe the air directly: the tracheary respiratory apparatus of the mites commences by a few orifices upon the abdomen: in the species, parasitic on the Hedgehog (*Ixodes Erinacei*), there are three stigmata; two near the sides, and one below, at the middle of the abdomen: the latter is described by Audouin as a spherical tubercle, pierced by a number of minute holes, by which the air penetrates the tracheæ. These air-tubes resemble in structure, ramification, and extensive diffusion, the corresponding parts in insects.

112



Respiratory organs, Segestria.

The spiders of the genera *Segestria* and *Dysdera* have four stigmata, situated on the under and anterior part of the abdomen: the anterior one on each side (*fig.* 112. *a*) is the aperture of the pulmonary sac (*b*); the lower orifice (*c*) leads to a short and wide cylinder, from which radiate numerous tracheæ (*d*) having the usual shining surface. These tubes are united together in bundles and diverge to the surrounding parts by dissociation, not by true ramification, like the tracheæ of mites and insects. One bundle is dispersed throughout the abdomen; another enters the cephalo-thorax, and resolves itself into groups corresponding in number with the limbs to the extremity of which the fine silvery tracheæ can be traced. The pulmonary sac (*figs.* 112, 113. *b*), which receives the air by the anterior respiratory orifice, is of an elliptical form; the vascular surface is augmented by a number of broad and close-set lamellæ, which project into its interior.

In the scorpion, the stigmata or pulmonary orifices are eight in number, four on each side of the under surface of the anterior broad segments of the abdomen. They have the form of oblique fissures, surrounded by a thickened margin, to which the name of "peritrema" has been given. The vascular lining membrane of the cavity adheres to this margin, and is at first simple, but afterwards gives attachment to a series of broad and close-set lamellæ, arranged, as in the spiders, like the leaves of a book.

The peculiar organs of secretion in the class *Arachnida* are those which prepare the material of the web, which is analogous to silk, and those which secrete the venomous liquid. The former are proper to spiders; the latter common to both spiders and scorpions. The modification of the abdominal segment of scorpions, by which its hinder half is converted into a slender, jointed, flexible, tail-like appendage, seems to have special reference to the wielding of the envenomed sting. The glands which supply this weapon with its poisonous fluid are lodged in that well-known pyriform dilatation formed by the last joint of the tail, and which is terminated by the slender sharp, recurved sting.* A minute slit may be observed near the point, which is the common outlet of two slender ducts, that gradually dilate into two secreting sacs, lodged in the cavity of the expanded part of the joint, and separated from each other by a double vertical partition.

The poison apparatus of spiders is placed at the opposite extremity of the body. The perforated sting or fang forms the second joint of the mandible or modified antenna, upon which it has a gynglimoid movement, and lies concealed and protected when not in use in a furrow with dentated margins upon the basal joint (*fig.* 109. *m*). The poison gland is an elongated ovoid vesicle, the exterior of which is characterised by spiral folds produced by the arrangement of the fibres of the contractile tunic. The duct traverses the basal joint of the mandible and the cavity of the fang, and terminates in a fissure on its convex surface near the point. In the true *Araneæ*, the *Clubiones*, and the *Lycozæ*, the poison glands extend into the cephalo-thorax; but in the bird-spiders (*Mygale*) they are limited to the mandibles. It is probable, therefore, that the effects of a wound occasioned by

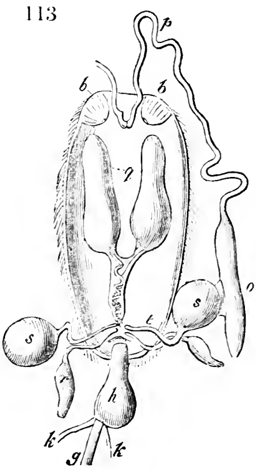
* See Prep. No. 2161.

these gigantic spiders may be exaggerated: those species of our native spider which are most formidably armed, are unable to inflict a wound on the human skin by any means so painful as the sting of a bee, but their poison rapidly takes fatal effect upon insects.

The organs which secrete the material of the web are lodged in the posterior part of the abdomen, and in the *Epeira fasciata*, which is remarkable for the large size of its web, they occupy, when in full activity, about one fourth of the abdominal cavity. They present the form either of slender and more or less branched tubes, or of dilated sacs, the excretory ducts of which terminate upon projecting jointed organs at the posterior extremity of the abdomen, called spinnarets. (*fig.* 112. *a.*)

In the *Clubione atrox*, the glands consist of four larger and numerous smaller tubes: two of the larger branched tubes are twice the size of the other pair. In the genus *Pholcus* (*fig.* 113.) the organ is reduced to a more simple condition; it consists of six vesicles of different shapes and sizes; two (*q*) are large and elongated; they occupy the middle of the under part of the abdomen, and their slender ducts are continued in a tortuous course to the spinnerets; two others (*r*) are also elongated, but are smaller than the preceding; the remaining two are spherical (*s*). The duct of each of these glands terminates upon its appropriate spinneret, and there are consequently six of these organs.

113



Pholcus.

The *Mygale avicularia* has only four spinnarets, and in the *Mygale cementaria* two of them are imperforate. Six, however, is the ordinary number of spinnarets in the spiders, two of which are longer than the others. The secretion does not issue by a simple outlet, but by a multitude of microscopic pores, which, in the shorter pairs of spinnerets, are prolonged from the terminal surface upon minute processes. If you throw a little dust upon the web of any of the orbitele spiders, of the *Epeira diadema* for example, you may observe that it adheres to the spiral, but not to the radiated, threads. Lyonnet supposed that the adhesive threads issued from tubes, and the others from sessile orifices. The secretion is a glutinous fluid, insoluble in water, and which quickly dries in air; some species, as the *Argyroneta aquatica*, spread their nets habitually under water.

The degree and mode in which spiders exercise this singular secreting faculty varies considerably in the different species. Some, as the *Clubiones*, line with silk a conical or cylindrical retreat, formed, perhaps, of a coiled-up leaf, and having an outlet at both extremities, from one of which may issue threads, to entrap their prey. Others, as the *Segestriæ*, fabricate a silken burrow of five or six inches in length, in the cleft of an old wall. The *Mygale cementaria* lines a subterraneous burrow with the same substance, and manufactures a close-fitting trap-door of cemented earth lined with silk, and so attached to the entry of the burrow as to fall down and cover it by its own weight, and which the inmate can keep close shut by means of strong attached threads.

The arrangement of spiders by M. Walcknaër into families, characterised by their habits, places the principal varieties of their webs in a very concise point of view.

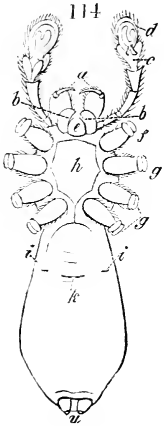
The *Cursores*, *Saltatores*, and *Laterigradæ*, make no webs; the first catch their prey by swift pursuit, the second spring upon their prey by insidious and agile leaps; the third run, crab-like, sideways or backwards, and occasionally throw out adhesive threads to entrap their prey. The *Latebricolæ* hide in burrows and fissures, which they line with a web. The *Tubicolæ* inclose themselves in a silken tube, strengthened externally by leaves or other foreign substances. The *Niditelæ* weave a nest, whence issue threads to entrap their prey. The *Filitelæ* are remarkable for the long threads of silk which they spread about in the places where they prowl in quest of prey. The *Tapitelæ* spin great webs of a close texture like hammocks, and wait for the insects that may be entangled therein. The *Orbitelæ* spread abroad webs of a regular and open texture, either circular or spiral, and remain in the middle or on one side, in readiness to spring upon an entangled insect. The *Retitelæ* spin webs of an open mesh-work and of an irregular form, and remain in the middle or on one side to seize their prey. Lastly, the *Aquitelæ* spread their silken filaments under water to entrap aquatic insects.

The silken secretion of spiders is not applied only to the formation of a warm and comfortable dwelling for themselves, or of a trap for their prey: it is often employed to master the struggles of a resisting insect, which is bound round by an extemporary filament, spun for the occasion, as by a strong cord. Lastly, a softer and more silken kind of web is prepared for the purpose of receiving the eggs, and to serve as a nest for the young.

All the Arachnidans are of distinct sexes. Among the spiders, the male may generally be distinguished from the female by his smaller size, longer limbs, and brighter colours. The essential and accessory organs of this sex are quite distinct and remote from each other: the principle of such separation, which is exemplified in the relation of the Fallopian tube to the ovarium in Mammalia, is carried to an extreme in regard to the vesicula seminalis and testis in the spiders. If the analogy of the female parts be here, as in other animals, a guide in the determination of the essential organs of the male, the testes ought to be the two long vermicular tubes, applied to the under wall of the abdomen, which commence posteriorly, either by a simple sac, as in the Mygale, or by an oblong vesicle, as in the genus *Pholcus,* the ducts of both of which terminate anteriorly by two approximate orifices, or else by a common opening, situated between the two pulmonary stigmata (*fig.* 114. *k*).

The second or copulatory part of the generative organs is confined to the two last joints of the maxillary palp (*fig.* 114. *c, d*): the dilatation of these joints is chiefly formed by a membranous tube or sac, commencing at the penultimate and reaching its greatest expansion at the last joint (*d*): this tube appears to line a cavity in the ordinary state; but it can be distended, everted, and erected; when it is seen to be terminated by a horny appendage.

114



Tegenaria domestica.

In the female spider the ovarium usually presents the form of a simple elongated fusiform vesicle (*fig.* 113. *o*), closed at one extremity, and communicating with a slender oviduct (*p*) at the other, which duct, after more or fewer convolutions, terminates at the corresponding angle of the simple transverse vulva. It is situated, like the outlets of the vasa deferentia, between the pulmonary stigmata. Each ovarium is divided in the Epeira, or diadem-spider, by a transverse septum, and the eggs are laid at two distinct periods.

The most careful observations, repeated by the most attentive and experienced entomologists, have led to the conviction that the ova are fertilised by the alternate introduction of the appendages of the two palpi of the male. Treviranus's supposition that these acts are merely preliminary stimuli, has received no confirmation, and is rejected by Dugés, Westwood, and Blackwall. At the same time, the most minute and careful research has failed to detect any continuation of the vas deferens into the terminal erectile sac of the palp, or any other termination than the abdominal opening above described. Dugés offers the very probable suggestion that the male himself may apply the dilated cavities of the palpi to the abdominal aperture, and receive from the vasa deferentia the fertilising fluid, preparatory to the union. Certain it is that an explanation of this singular condition of the male apparatus, in which the intromittent organ is transferred to the remote and outstretched palp, is afforded by the insatiable proneness to slay and devour in the females of these most predacious of articulated animals.

The young and inexperienced male, always the smallest and weakest of the sexes, has been known to fall a victim and pay the forfeit of his life for his too incautious approaches. The more experienced suiter advances with many precautions; carefully feels about with his long legs; his outstretched palpi being much agitated: the female indicates acquiescence by raising her fore-feet from the web, when the male rapidly advances; his palpi are extended to their utmost, and a drop of clear liquid ejected from the tip of each clavate end, where it remains attached, the tips themselves immediately coming in contact with a transverse fleshy kind of teat or tubercle protruded by the female from the base of the under side of the abdomen. After consummation, the male is sometimes obliged to save himself by a precipitate retreat; for the ordinary savage instincts of the female, " etiam in amoribus sæva," are apt to return, and she has been known to sacrifice and devour her too long tarrying or dallying spouse.

There is a redeeming feature in the psychical character of the female spider, in the devotion with which she fulfils all the duties of the mother. But before proceeding with the examples of the maternal instinct, I shall first point out the anatomical characters of the generative organs in the scorpion.

The palpi of the scorpion take no share in the formation of the generative system in either sex: both male and female are provided with a pair of peculiar comb-like appendages, attached directly behind the genital aperture, which is situated at the middle line of the under and posterior part of the abdomen. Müller has observed that the teeth in the comb of the male scorpion (*Buthus Africanus*) are much more numerous and smaller than those in the female; but the sexes are not otherwise distinguishable outwardly. The males appear to be fewer in number than the females.

The testis of the scorpion is a long and slender tubulus, which divides, and the divisions anastomose together to form three loops or meshes. A short blind sac (*Vesicula glandularis*) communicates with the termination of the tubulus, and the common duct terminates in an oblong receptacle, the outlet of which is situated close to the corresponding one on the opposite side of the body, at the middle of the under part of the last segment of the thorax.

The tubular oviduct of the female scorpion divides and unites with its fellow through the medium of a third shorter middle canal, forming three meshes on each side, and a seventh longer anterior loop by the terminal union of the oviducts before they open upon the bivalvular vulva.

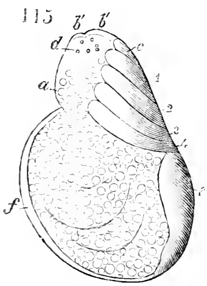
The ovaria consist of lateral appendages going off at right angles from the longitudinal canals, and expanding into elliptical sacculi before communicating with the canals: the ova are developed in the slender blind free extremities or beginnings of the ovaria, and the embryo is developed in the sacculus, the scorpion being viviparous. The course of its development, which would be a subject of great interest, has not yet been traced.

Spiders are oviparous. The mother prepares a soft and warm nest for the eggs, which she guards with great care. The *Lycosa vagabunda* carries her cocoon about with her: if it be removed and a ball of cotton substituted, she has been known to bestow upon it the same care; but when the cocoon was offered together with the cotton ball, she seldom failed to select her own fabrication. The *Saltica* selects an empty snail-shell for her cocoon, and spins a silken operculum across the mouth. The *Epeira fasciata* incloses her eggs, which are as big as millet-seed, in a papyraceous cell, surrounded by a cottony covering, which she then suspends by a dozen threads or pillars to a larger chamber of silk. The whole is attached to a branch of a high tree, and is guarded by the mother, who quits it only in extreme danger, and returns when this is past.

The ovum of the spider, at its exclusion, consists of a large and finely granular vitellus, invested by the membrana vitelli, which is separated from the chorion by a very thin structure of colourless liquid, analogous to the albumen or the white of the hen's egg. The yolk is generally of a yellow colour; but in some species of spider is grey, white, or yellowish brown. An opake white elliptical spot indicates, at this period, the metamorphosed and impregnated centre from which subsequent development radiates. The previous changes which have led to this condition of the excluded ovum have not hitherto been studied: the subsequent ones, up to the complete formation of the young spider, have been described and figured by the accurate and industrious Herold.

The germ-spot consists of minute opake whitish granules, of smaller diameter than those of the vitellus: in some species Herold observed several germ spots on different parts of the superficies of the yolk, which rapidly coalesced into one body. Development commences by expansion of the circumference of the germ-spot, which, as it expands, covers the yolk with a semitransparent thin layer, the basis of the future integument. Herold next describes the granules of the germ as being decomposed into almost imperceptible molecules, in which we may recognise the ordinary result of the fissiparous property of its constituent nucleated cells: their powers of assimilation are at the same time manifested by the changes which they effect in the albumen, at the expence of which they seem, in the first instance, to increase their numbers and diffuse themselves over the surface of the vitellus. This covering of the yolk Herold calls "colliquamentum;" he observes that the original position of the germ-spot is indicated by a clear transparent point (hyaline?); that this point becomes thickened and pearly; then opake, so as to conceal the subjacent vitelline cells. A similar change progressively extends over the colliquamentum; and when one fourth of the circumference of the yolk is thus covered, the opake layer has taken on a definite form, resembling the figure 8, the smaller and anterior division being the base of the future head, the posterior and larger one, of the thorax. A fissure is next observed to divide the cephalic from the thoracic portion, the two parts being distinct at this period, and determining the essential nature of the first great segment of the body in the mature spider. The margins of the thorax are next seen to be subdivided on each side by three parallel fissures into four segments: these are the bases of the epimeral pieces (*fig.* 115. 1, 2, 3, 4.). The part of the opake integument which connects the two series below is the rudimental sternum. A second constriction begins to divide the thorax from the abdomen; the mandibles or antennæ (*b b*) begin to bud forth as two convex processes from the anterior part of the head: the part intervening between these and the epimeral pieces forms the rudiment of the maxillæ (*c*). The intermediate labium also begins to be defined from the sternum. The opake peripheral layer (*e*), extending from the thorax to the opposite end of the ovum, lays the foundation of the ventral integument of the abdomen. Upon the opake integument, which is extending backwards over the dorsal part of the head, the characteristic group of simple eyes (*d*) begins at this time to be distinctly developed, and the rudiments of the maxillary palps and of the four pairs of thoracic legs become recognisable: now, also, the dorsal vessel (*f*) appears along the upper curvature of the abdomen, and thus all the chief characteristics of the future spider are manifested, whilst the great mass of the vitellus remains still visible through the transparent and incomplete lateral and dorsal parts of the integument.

115



Embryo Spider.

The constriction between the two divisions of the body increases; the legs and palpi next present slight traces of articulations; as they increase in length they cross the middle line of the sternum, and interlock with those of the opposite side. The mouth, the vent, and the wide alimentary canal are formed; the integument is completed, as in other *Articulata*, by a dorsal cicatrix, and in this state the young spider breaks through the attenuated chorion. The head, the mandibles, the thorax, and abdomen are first extricated, and afterwards, but with more difficulty, the palpi and legs are withdrawn. It very soon has to repeat a similar process in throwing off its fœtal integument, which becomes too small for its rapid growth. This moult always takes place in the silken nest of the parent; the young spider then issues forth, and is subject to repeated moults before acquiring the mature size.

We perceive, therefore, that throughout the whole process of the development of a spider, there is nothing worthy to be called a metamorphosis. The highest of the Articulata indicates in the feeblest manner, and can scarce at any period be recognised in the condition of, the apodal and acephalous worm; but, with the first rudiments of trophi and legs, the characteristic or special form is acquired.

The regeneration of the legs of the spider follows precisely the same law as that which regulates their reproduction in the Crustacea. If the limb be injured at the tarsus, tibia, or femur, it must first be cast off at the coxo-femoral joint before the process of reproduction can commence, and this must be preceded by a moulting of the integument; the new leg being at first of small size, but with all its joints and appendages, and acquiring the full proportions at the second moult.

LECTURE XX.

TUNICATA, BRACHIOPODA.

The Articulate series of animals leads the investigator of the ascending course of organic development from the vermiform Zoophytes to the higher organised worms which circulate red blood, and through the strange and changeable forms of Epizoa and Cirripeda to the Crustacea, the Insecta, and the Arachnida, in which three classes of articulated animals with jointed limbs, as many diverging branches from the common vermiform root, seem respectively to terminate.

Yet having attained these different summits of the articulate branch of organisation, the enquirer still finds himself at a great distance from any of the Vertebrate forms of animal life. How vast the hiatus which separates the worm from the apodal fish, the crab from the tortoise, and the flying insect from the bird or bat! He soon attains the conviction that there is no regular and uninterrupted ascent in the scale of organisation, as Bonnet fancied; no single and continuous chain of beings, as was sung by Pope.

Not even with the insight which we now command into the living forms that peopled this planet during past and remote epochs of its history, can we supply all the hiatuses which exist, and connect together in a linear series the existing and extinct members of the Animal Kingdom. But we can discern that many connecting links in partial series have perished; and we know that the broken hypothetical chain of being nevertheless continues to flourish and to adequately fulfil its appointed office in maintaining the balance of the conflicting influences of increase and decay, and the general well-being and progress of organic life upon the present surface of the earth.

If we would make a closer approach to the vertebrate type of organisation, we must retrace our steps, and, again returning to the Radiata, ascend by another and very different series of animals, from those which have last occupied our attention.

In the Articulata the advance is most conspicuous in the organs peculiar to animal life, and was manifested in the powers of locomotion, and in the instincts, which are so various and wonderful in the insect class.

In the Mollusca the organising energies seem to have been expended chiefly in the perfection of the vegetal series of organs, or those concerned in the immediate preservation of the individual and the species.

The Mollusca are so called on account of the soft unjointed nature of their external integument. The scattered centres, or Heterogangliate type of their nervous system, is often accompanied with an unsymmetrical form of the entire body; which, in compensation for the low condition of the perceptive energies, is protected in most of the species by one or more dense calcareous plates, called shells.

The nervous system, as has been explained in the introductory lecture, consists of a medullary collar, surrounding the œsophagus, and communicating with more or fewer ganglions near the œsophagus, or dispersed, usually below the alimentary canal, in other parts of the body.

In a large proportion of the lower organised Mollusca there is no head, and no nervous centre is needed above the gullet for the reception of the impressions received by special organs of sense. The mouth is simply a pharynx or beginning of the œsophagus without jaws, tongue, or mouth properly so called. Such Mollusca are termed *Acephala*. All other Mollusca are provided with a head, which generally supports feelers or soft tentacula, eyes, and a mouth armed with jaws.

The acephalous Mollusca are all aquatic, and are divided into classes according to the modifications of their integument or of their gills.

The *Tunicata* are those which are inclosed by an elastic gelatinous uncalcified integument; they breathe either by a vascular pharyngeal sac, or by a riband-shaped gill stretched across the common visceral cavity.

The *Brachiopoda* are defended by a bivalve shell, have two long spiral arms developed from the sides of the mouth, and respire by means of their vascular integument or mantle.

The *Lamellibranchia* are bivalve conchiferous Mollusca, which respire by gills in the form of vascular plates of membrane attached to the mantle. The common oyster and mussel are examples of this best known class of Acephalous Mollusca.

The Encephalous Mollusca are divided into classes according to the modifications of the locomotive organs.

The *Pteropoda* swim by two wing-like muscular expansions extended outwards from the sides of the head.

The *Gasteropoda* creep by means of an undivided muscular disc attached to a greater or less extent of the under part of the body.

The *Cephalopoda* have all or part of their locomotive organs attached to the head, generally in the form of muscular arms or tentacula: in this class only do we find, in the present series of animals, an internal skeleton. In the rest of the Mollusca the hard parts are external; but the integument is sometimes uncalcified and flexible, as in the low organised class which will occupy our attention to-day and which in this condition of their exo-skeleton afford the parallel to the cartilaginous state of the endo-skeleton in some of the lowest of the vertebrate series.

To connect the Tunicata with any of the classes of animals which we have previously considered, it is necessary to revert to the Polypi, for it is in this group of the Radiata that we shall find the animals which have the closest natural alliance with the present class of Mollusca.

Suppose a Bryozoon to have its ciliated oral tentacula reduced to mere rudiments, and to have the pharynx enormously expanded, with its vascular internal surface richly beset with vibratile cilia; it would then be converted into an Ascidian, and the transition from the

Radiated to the Molluscous series would be effected. But the Bryozoa, after their larval locomotive stage of existence, became rooted, like plants, and were aggregated together, forming compound animals; and you may be disposed to ask whether any Molluscous animal can present these Zoophytic conditions. Such do in fact prevail among the Ascidian Tunicaries. All these low-organised Mollusca, after a brief period of natation, become adherent to foreign bodies, and many form groups of individuals united together by a common organised external integument; the present order of *Tunicata* consists, in fact, of compound and simple Ascidians. I shall first demonstrate the organisation of this group by these large examples of the simple or solitary Ascidians *, which do not essentially differ in anatomical structure from the compound species, whose small size renders this a subject for microscopic investigation.

The exterior tunic of the solitary Ascidian is a thick gelatinous or coriaceous elastic substance adhering by its base, or by a long flexible peduncle to some foreign body, and perforated at the opposite end or at the side by two apertures. The exterior of this tunic is sometimes rough and warty, the inner surface always smooth and lubricous.

The second tunic is muscular; it adheres to the outer tunic at the circumference of the two orifices, and is connected to it by blood-vessels at a few other points; elsewhere it is quite free, and the opposed surfaces of the intervening space between the muscular and elastic tunics has the aspect of a serous cavity. Its fine fasciculi of fibres are remarkably distinct, and are arranged in two layers, the external circular, the internal longitudinal. The fibres or fasciculi of the outer layer are smaller than those of the inner one, and less regularly disposed. They describe regular circles around the processes leading to the orifices of the shell. Other fibres of the outer layer pass transversely from one tube to the other. The longitudinal fasciculi radiate from the two orifices, and decussate each other, winding round the bottom of the sac. Deeper, again, than this layer there is a sphincter surrounding the base of each tube, or orifice, from which a third more delicate layer of longitudinal fibres are given off.

Of the two more or less protuberant and stellate apertures in the outer tunic, one leads directly into the muscular sac, the other into a wide vascular sac contained in the muscular one. The entry to the vascular sac is defended by a circle of short tentacles. The inner surface of the sac is marked by parallel and equidistant transverse lines, the interspaces of which are divided into a series of narrow vertical compartments: the surface is beset with vibratile cilia. An

* Preps. Nos. 614, 615, 616. 785. 898. B. 998. 1303. C.

orifice at the bottom of this cavity conducts by a short œsophageal canal to the stomach, an oblong dilated sac, with longitudinal folds. The intestine is disposed in a sigmoid flexure, adheres to the branchial and muscular sac, and terminates by an anal aperture near the base of the second orifice of the tunic.

A simple follicular liver is developed from the stomach. In the *Cynthia tuberculata* it communicates with the stomach by a single aperture, from which a groove is continued towards the cardia.

A generative gland, generally dendritic in shape, occupies the concavity of the intestinal fold, and sends a short and simple duct to terminate near the anus. In the female *Cynthia tuberculata* there are two ramified ovaria; the ovisacs being appended to the branches of a central stem, passing up by the side of the rectum, and extending over one side of the branchial sac.

The heart is a simple, elongated, vasiform muscle, inclosed in a pericardium, attached to the branchial sac; continued at either end into a vessel; the ramification of one being expended chiefly upon the respiratory organ; those of the other upon the viscera and tunics of the body. According to the direction of the circulating currents the one will be an artery, the other a vein, and the circulation itself will be pulmonic and systemic.

The nervous system must be first sought for in the interspace between the two openings of the muscular tunic; there you will find a ganglion from which it is not difficult to trace filaments diverging to each aperture of the sac where the circular disposition of the muscular fibres prevails; other branches accompany the longitudinal fibres, and supply the respiratory sac; two contiguous filaments are continued to the œsophageal orifice.

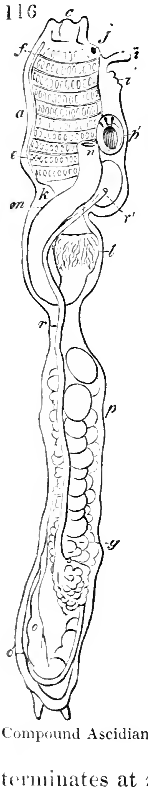
In the animal manifesting this organisation, which is much richer unquestionably than the amorphous and rugged exterior would seem to promise, the only vital actions obvious to ordinary vision are an occasional ejection of water from the orifices of the tunic by a sudden contraction, succeeded by a slow and gradual expansion. Such contractions and expansions, aided by the ciliary currents, which the microscope has detected, and the peristaltic movements of the alimentary, circulating, and secerning tubes, are all the actions which the organic machinery has to perform in the living ascidian.

The respiratory currents of sea water with the nutrient molecules in suspension are introduced by the ciliary action through the branchial orifice into the pharyngeal respiratory sac, from which the œsophagus selects the appropriate food. The alimentary excretions and the generative products are expelled through the anal outlet by the contraction of the muscular tunic.

In consequence of the space between this and the outer tunic being closed, that tunic accompanies the muscular tunic in its contraction, through the influence of the surrounding pressure; when the muscle ceases to act, the elasticity of the outer coat begins to restore the fibrous sac to its former capacity, and the surrounding water flows into its cavity, either directly or by distending the branchial sac. We shall find other instances of the economising of muscular force by the substitution of elasticity as we ascend in the survey of the molluscous organisation.

In the small compound Ascidians the organisation is essentially like that of the solitary species, but the viscera are somewhat differently disposed: the cavity is longer and narrower, the entire animal viewed singly being more vermiform.

116



Compound Ascidian.

In *fig.* 116., from Dr. M. Edwards' elaborate memoir, the anatomy of one of the individuals of the species which he has called *Amaroucium proliferum*, extracted from the common investing tunic, is displayed. *a* is the proper or muscular tunic, in which most of the fibres are longitudinal; it is much more feeble than in the solitary Ascidians: *c* is the oral or branchial orifice: *e*, the branchial sac: *i*, the anal or cloacal outlet; it is protected by the overhanging valve *ï*, which is required by the compound Ascidians on account of the excretory outlet in the muscular tunic communicating with a common cloacal cavity in the external tunic, around which the individuals of the composite series are grouped: *j* is the ganglion of the nervous system: *k*, the short and wide œsophagus: *l*, the stomach, the exterior of which is rendered shaggy by the appended biliary follicles; *m*, is the intestine: *n*, the anus: *o*, is the heart, which, by its remoteness from the branchial sac, differs more in relative position from its analogue in the simple Ascidians than any other viscus; it is provided with a pericardium *o′*: *p* is the ovarium, *p″* an ovum about to escape through the cloacal outlet, with the embryo ripe for exclusion. The most important structural difference between the aggregate and solitary Ascidians is the combination in the former of a male apparatus with the ovarium. In *fig.* 115. *g* is the testis: *r*, the vas deferens, which terminates at *r′*, in the common cavity of the muscular tunic.

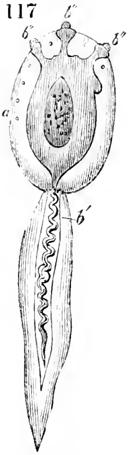
Some of the compound Ascidians are ramified, and their tunics so transparent as to permit the movements of the internal organs to be studied in the living animal. A very singular condition of the circulating system has thus been detected. The blood actually moves backwards and forwards, to and from the heart in the same vessels, as it was supposed to ebb and flow in the human veins before Harvey's great discovery. The oscillation of the currents is not constant and regular; the blood is received from the vessel at one end of the heart, and propelled by a contractile wave into the vessel at the opposite end: after a true circulation has gone on in this course for a certain period, a change is observed in the course of the peristaltic contractions of the heart; the blood for an instant stagnates in the vessels, and then the wave travels in the opposite direction; the heart drives the blood into the vessel from which it had before received it, and the course of the circulation is reversed. In the compound Ascidians the vascular systems of the different individuals anastomose freely with each other.

At first sight it is difficult to conceive how the fixed and compound Ascidians can multiply their race in situations at a distance from that which they themselves occupy. This difficulty has been removed by M. M. Audouin and Milne Edwards, who observed that the young of the compound Ascidians were not only at their origin solitary and free, but possessed the power of swimming rapidly by the aid of the undulatory movements of a long tail. They were seen occasionally to attach themselves to the side of the vessel of sea-water containing them, and then to recommence their course, as if to seek a more suitable point of attachment. After two days of free and locomotive life, they finally fixed themselves; and, when detached, remained motionless.

These phenomena are now known to be common to the embryo of many of the lower sedentary animals. In regard to the Ascidians, it has been confirmed by M. Sars in the *Botrylli* of the coast of Norway, and has been more recently observed by Sir John Graham Dalyell, in a solitary Ascidian of the Frith of Forth.

In the genera *Polyclinum* and *Amaroucium*, Dr. Edwards has observed that the ovum, whilst still included in the ovarian mass, consists of the small central germinal vesicle, of a granular vitellus and a vitelline membrane. In the progress of the ovum to the cloacal cavity, the yolk acquires a deep yellow colour, the germinal vesicle disappears, and in its place there is a nebulous speck upon the surface of the yolk. This is doubtless the remains of the germinal vesicle, which has come to the surface of the yolk to meet the impregnating influence, and has undergone the changes by fissiparous multiplication, to which I have so often had occasion to allude. Dr. Edwards has observed the contact of the spermatic animalcule with the ova in the cloaca.

117



Larva of Amaroucium proliferum.

The next stage which he records, viz. the granular or mulberry structure of the vitellus, is the result of the spontaneous divisions and assimilative powers of the yoke-cells. The subdivided mass through which the properties of the hyaline and fertilising principle have been diffused, is next covered by the expansion of the germ-spot, forming the basis of the integument. A process of this integument then begins to extend from a particular point, and, rapidly elongating, wraps itself like a cord about the vitellus. This body with its integument then becomes condensed, and separates from the chord, which, retaining only its basal attachment to the pellucid integument, forms the caudal appendage. The integument (*fig.* 117. *a*) increases in thickness. The extremity of the yolk opposite the caudal attachment developes a series of cylindrical productions, which reminds one of the arms of a polype, but they are few in number. Three of them have expanded extremities (*b''*, *b''*), which increase in length; whilst the other processes diminish, and finally disappear. A spiral filament is continued from the membrane of the vitellus down the centre of the tail (*b'*).

In this state the embryo escapes from the ovum, generally while in the cloaca of the parent, but sometimes after the egg has been expelled from the common central outlet. The young animal immediately unfolds its tail, and begins to swim like the tadpole of the frog, which it so much resembles in form. The three clavate cephalic processes are the organs by which it effects its final adhesion and settlement. When this has taken place, the tail shrinks, and is usually detached by progressively increasing contraction at its base; — a kind of spontaneous fission.

The sessile and adherent trunk now becomes the seat of an active development: the integument is thickened; the yolk becomes elongated and divided by a circular constriction into two unequal parts, in each of which a clear spot can be recognised. One of these spots, by subsequent development, becomes the heart; the other the respiratory sac. The subdivided vitelline mass, which now begins to be rapidly metamorphosed into the special tissues, also acquires a distinct tunic, which soon separates itself from the thick and gelatinous external integument. The quadrifid orifice of the branchial sac is first formed upon the internal tunic. The contour of the great respiratory pharynx can next be discerned, and the constriction of the sac opposite to the mouth, which indicates the œsophagus. About the same time may be seen the outline of the anal orifice upon the internal integument: then the opaque yellow tunics of the dilated stomach, and the reflected intestine appear; and below these parts the pulsations of the large transparent vasiform heart render that organ conspicuous.

The whole of the viscera included by the smooth integument have been observed to rotate in the cavity formed by the thick gelatinous tunic, to which the visceral mass again becomes attached by the adhesion of the muscular tunic at the branchial and anal orifices, and by the establishment of corresponding orifices in the integument.

Savigny was of opinion that the ovum of the compound Ascidian contained the germs of all the individuals composing the characteristic groups in the mature aggregate animal, and that their development was simultaneous; but the observations of Dr. Edwards have proved that a second mode of reproduction, namely that by gemmation, is superinduced upon the young Ascidian, after the foregoing development from the impregnated ovum, which offers an interesting analogy to the phenomena presented by the polype-larva of the Medusa The individuals formed by the gemmation of the primary bud of the young Ascidian, instead of being detached, are retained; the process of gemmation being regulated so as to produce the characteristic pattern in which the different individuals are grouped in the mature compound animal.

The gemmation commences by the development of a small tubercle from the abdominal portion of the internal tunic of the young Ascidian. This is prolonged, retaining an active circulation in its interior, and is accompanied by a corresponding growth of the outer gelatinous integument, which becomes clavate. The process then bifurcates; the divisions, in like manner. becoming elongated, expanded and bifurcated at their extremities. Soon the outline of an Ascidian is sketched in each of these extremities. The primitive connection with the parent is obliterated; but the young individuals remain united together by their primitive peduncle, according to the law which determines their mode of grouping into systems. By the progressive increase of their outer gelatinous integument, they finally coalesce and form the compound mass.

The second order of the class *Tunicata* includes the Salpians, which float in the open sea, and are characterised by their transparent elastic outer tunic, which is elongated, compressed, and open at both extremities. The muscular fibres of the mantle, or membrane lining the cartilaginous tunic, are arranged in flattened bands. The mouth and stomach, the liver and the heart, are aggregated in a small mass or nucleus, near the anterior aperture of the tunic; the intestine extends towards the opposite aperture, and terminates freely in the common cavity of the mantle. A single narrow plicated ribband-shaped branchia extends obliquely lengthwise across the pallial cavity. The heart is elongated, and in some species slightly curved and sacculated ; it communicates with a large vessel at each extremity, one of which is ramified principally upon the visceral mass ; the other upon the branchia and the muscular tunics.

From recent observations made by Dr. Edwards on young *Pyrosomata* (a compound genus of Salpians), it appears that the circulating currents change their direction periodically, by virtue of peristaltic and antiperistaltic vermicular contractions of the heart, as in the Ascidians.

The sexes are distinct in the Salpians, as in the solitary Ascidians. The ovarium or testis is usually of an oblong form, sometimes single, sometimes double, adherent to the inner surface of the mantle ; where, likewise, the embryo is developed.

The only conspicuous vital action in the Salpians is the rythmical contraction and expansion of the mantle ; in which the elasticity of the outer tunic antagonises the contraction of the inner one. During expansion the sea-water enters by the posterior aperture, and is expelled, in contraction, by the anterior one ; its exit by the opposite end being prevented by a valve. The reaction of the jet, which is commonly forced out of a contracted tube, occasions a retrograde movement of the animal. The currents which successively traverse the interior of the animal, renew the oxygenated medium upon the surface of the respiratory organ, bring the nutrient molecules within the reach of the prehensile subspiral labial membrane of the mouth, and expel the excrements and the generative products. Thus a single act of muscular contraction is made subservient by the admirable co-adjustment of the different organs to the performance of the functions of locomotion, nutrition, respiration, excretion, and generation.

Certain genera of Salpians, as the phosphorescent *Pyrosoma*, are permanently aggregated into a compound organic whole having a definite form. All Salpians quit their viviparous parent associated together in long chains ; after floating for a certain time under this form the society is dissolved, and each individual, according to Dr. Chamisso, propagates a solitary young one like itself. This grows to the size of the grand-parent, and then brings forth a social chain of young Salpæ, which, by the exercise of their uniparous generation, again give origin to the solitary and multiparous individuals. Thus, observes Chamisso, only the alternate generations resemble each other.

The case is strictly analogous to the generation of the compound

Ascidians, of which the solitary young gives origin, by gemmation, to a compound group, which again procreates, by impregnated ova, solitary individuals.

Class Brachiopoda.

These Acephalous Mollusca are deprived, like the Ascidians, of the power of locomotion, and are attached by a longer or shorter peduncle to foreign bodies. Their muscular tunic or mantle is, as it were, slit open, and consists of two broad membranous expansions, called lobes, which are covered by two calcareous plates, adapted to inclose and defend all the soft parts of the animal.

The Brachiopoda flourished during the ancient secondary periods, and are most abundant in the fossil state. Of the few existing genera, the *Lingula* is characterised by its long peduncle, and the equality of the valves of its shell, neither of which are perforated: the *Orbicula* is sessile, and adheres by one end of a short transverse muscle, which perforates one of the valves of the shell: the *Terebratula* is attached by a short peduncle, which projects through a hole in a beak-shaped prolongation of one of the valves.

The viscera are situated at the part of the shell next the hinge or peduncle, and are confined to a very small space in the *Terebratula*. The rest of the interspace of the lobes of the mantle is almost entirely occupied by two long ciliated arms, continued from the sides of the mouth, and disposed in folds and spiral curves. The bases of the arms are confluent, and form a transverse fringed band above the mouth: a narrow parallel fold of membrane passes below the mouth, which opens upon the mantle-lobe attached to the perforated valve.

In the *Terebratula australis* each arm extends outwards, advances forwards, curves slightly inwards, and bends abruptly back upon itself, the two parts of the bend being connected together: then the stem again curves forward, and becomes united to the corresponding bend of the opposite arm, the conjoined extremities describing spiral convolutions turned towards the dorsal valve: the bent portions of the fringed arms are supported by slender and elastic calcareous processes. Remains of more complicated internal calcareous appendages are presented by certain extinct Brachiopods, as the *Spirifer*. In some species of existing *Terebratula*, as *Ter. psittacea*, the arms are disposed in a series of spiral folds; but they have only short and simple calcareous processes at their base. The spiral arms of the *Orbiculæ* and *Linguloæ* have no internal calcareous support. In all the Brachiopods the stem which supports the brachial fringe is hollow. In the *Terebratulæ* and *Orbiculæ* the spiral terminations of the arms have their central canal surrounded by a double oblique series of muscular fibres: the canal is filled with fluid, and, by the contraction of the muscular fibres, the extremities are extended by the pressure of the contained fluid which is injected into them.

The alimentary canal is very short and simple: in the Terebratula it soon expands into a gastric cavity, surrounded by groups of the minute hepatic follicles, included in the peritoneal membrane behind the base of the arms. The stomach bends, and is continued in a short and straight intestine, which terminates between the lobes of the mantle, on the right side. A small transversely plicated membranous process is continued from each side of the beginning of the intestine.

The principal centres of the vascular system are two dilated sinuses or ventricles, situated on each side of the visceral mass, and communicating by one extremity with the vessels which ramify over the lobes of the mantle, and by the opposite extremity with those which supply the viscera. In the *Terebratula* and *Orbicula*, the respiratory function would seem to be performed chiefly by the pallial vessels; and in this conclusion we are supported by observing the prolongation of vascular loops from the pallial vessels in the *Lingula*, which affords the only indication of distinct branchial organs in the class *Brachiopoda*. The margin of the mantle is fringed with cilia, which are very long in the *Lingula* and *Orbicula*. In the latter Brachiopod I found them beset with smaller cilia: these, with the brachial fringes, and the microscopic vibratile cilia, which, doubtless, beset the whole surface of the vascular mantle, must be the chief agents in introducing the currents of sea water within the cavity of the mantle for nutrition, respiration, and excretion.

A nervous collar, with small ganglionic enlargements, surrounds the œsophagus in the *Terebratula*, as in the *Lingula* and *Orbicula*. Nervous filaments are continued from this centre to the adductor muscles, and to the vascular lobes of the mantle.

In the *Terebratula*, two pairs of muscles arise from each valve, some of which are attached to the opposite valve, and others lost in the pedicle. The pedicle is surrounded by an elastic yellow horny layer and a tubular prolongation of the mantle. In the *Orbicula* there are eight distinct muscles adapted for closing the shell, sliding the valves upon each other, and attaching them to foreign bodies.

In the *Terebratula* and *Orbicula* the ovaria are dendritic, and attached to the mantle, four on the lower and two on the upper lobe: the ova appear to be developed from the inner surface of the large and wide pallial veins, to the parietes of which they adhere. The testes in the male have the same form and disposition: they differ from the ovaria in their closer texture and their whiter colour.

On comparing together the three existing genera of Brachiopoda which have been selected for anatomical demonstration in the present Lecture, we may perceive that the modifications which are traceable in their respective organisations bear relation to the different situations which they occupy in the sea.

The *Lingula*, living usually near the surface, and sometimes where it would be left exposed by the retreating tide, if it were not buried in the sand of the shore, must meet with a greater variety and abundance of animal nutriment than can be found in the deeper waters, where the *Terebratula* usually resides. Hence its powers of prehension are greater; and Cuvier suspects that it may even enjoy a species of locomotion from the superior length of its peduncle. The organisation of its mouth and stomach indicates the molecular character of its food; but its convoluted intestine shows a capacity for extracting a quantity of nutriment proportioned to its superior activity and to the greater extent of its soft parts. The more obvious and complex respiratory apparatus is in exact harmony with the above conditions of structure and habits.

With regard to the *Orbicula*, and more especially the deep sea species of *Terebratula*, both the respiration and nutrition of such animals which exist beneath a pressure of from sixty to ninety fathoms of sea water, are subjects suggestive of interesting reflections, and lead one to contemplate with less surprise the great strength and complexity of some of the minutest parts of the frame of these diminutive creatures. In the unbroken stillness which must pervade those abysses, their existence must depend upon their power of exciting a perpetual current around them, in order to dissipate the water already laden with their effete particles, and to bring within the reach of their prehensile organs the animalcules adapted for their sustenance. The actions of the *Terebratula* and *Orbicula*, from their attachment to foreign bodies, are confined to the movements of their brachial and branchial filaments, and to a slight divarication and sliding motion of their protecting valves; the simplicity of their digestive apparatus, the still greater simplicity of their branchiæ, and the diminished proportion of their soft to their hard parts, are in harmony with such limited powers. The soft parts, in both genera, are, however, remarkable for the strong and unyielding manner in which they are connected together. The muscular system is much more complex than in ordinary bivalves, and is remarkable for the compactness of its fibre and the density of the glistening tendons. Here is obviously an apparatus of sufficient power to effect the requisite motions of the valves at the depths at which they may be destined to live. The *Terebratula,* in this respect the most remarkable of Bivalves, has an internal skeleton superadded to its outward defence, by means of which additional support is afforded to the shell, a stronger defence to the viscera, and a firmer basis of attachment to the spiral arms.

LECTURE XXI.

LAMELLIBRANCHIATA.

The relation of the contained soft parts to the bivalve shell of the Brachiopoda is such that, in the *Terebratula,* the perforated valve must be regarded as the inferior or ventral one, and the imperforate or shorter valve the dorsal one. In the *Lamellibranchiata* one valve is applied to the right, and the other to the left, side of the animal. In the common oyster and the Anomia, which are fixed and motionless, as in the Brachiopoda, the two lobes of the mantle are as little united with each other, and there is as little evidence of any locomotive organ or foot. The spiral brachia would seem to be reduced to two shorter and more simple processes, and the inferior labial fold to be produced on each side to the same length, so that there is a pair of labial processes on each side the mouth. These appendages have no internal calcareous support, which, by being bent, could open the valves ; nor are they long enough, save in some species of *Anomia,* to be protruded from the shell. In other Lamellibranchiate Bivalves the labial processes are short and simple. In all the present class the divarication of the valves is provided for by the insertion of an elastic substance at their hinge; and the valves are closed by the contraction of short and thick subcircular muscles, thence called the adductors. In the common oyster, and some other allied Bivalves, there is but one adductor muscle. The visceral mass occupies about half the cavity of the shell next the hinge. The rest of the interspace of the pallial lobes being almost wholly occupied by the branchial laminæ, which are four in number, of a crescentic figure, placed two on each side of the visceral mass. This is the characteristic condition of the respiratory organs in the present class of Acephalous Mollusca, and from which it derives its name.

In the oyster the mouth is continued by a short œsophagus to an expanded stomach, from which numerous ramified hepatic follicles are developed. The intestine, after describing a few convolutions, is continued along the interspace of the branchiæ towards their extremities which are furthest from the mouth. The ovarium or the testis surrounds the intestinal convolutions, and forms with the liver the chief part of the visceral mass.

The veins of the oyster terminate in a single auricle, which transmits the blood to a pyriform ventricle; the two divisions of the heart being contained in a distinct pericardium, situated between the visceral mass and the concave margin of the adductor muscle.

The principal centre of the nervous system lies upon the opposite convex margin of the same muscle, supplies it with nervous influence, distributes branches to the mantle, to the gills, and sends forwards two long filaments, parallel with each other, one on each side of the visceral mass, to the sides of the mouth, where they form small ganglions, communicating with each other by a transverse branch above the mouth, supplying the labial processes, and forming a second feeble communicating arch beneath the mouth, from which the gastric nerves are continued.

Most of the Lamellibranchiate Bivalves are free and locomotive. The instrument by which they move from place to place is a single symmetrical muscular organ developed from the ventral surface of the visceral mass. The body and protecting shell is longer in proportion to its depth in these locomotive bivalves; and there are two muscles provided for closing the valves. The superadded one is anterior to the mouth; the analogue of that which exists in the oyster being the posterior adductor.

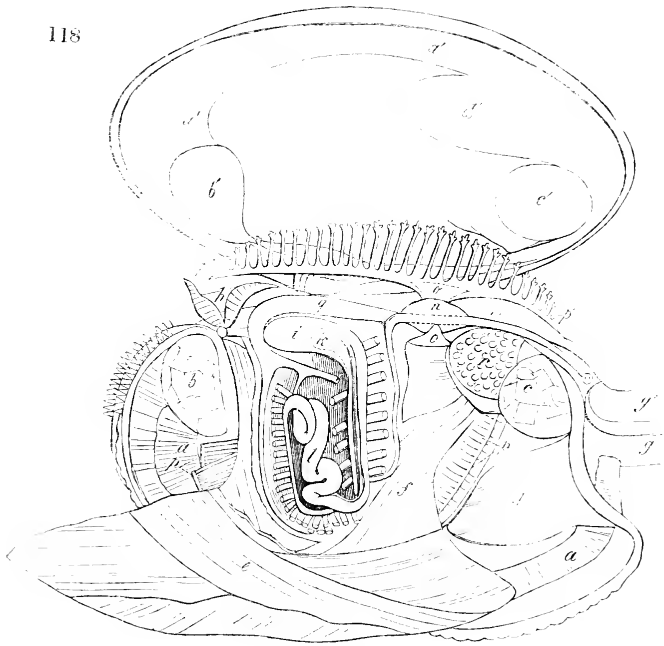
The bivalves with one adductor muscle are termed "monomyaries;" those with two adductors "dimyaries." The dimyary bivalves have always a foot; in its least developed condition it is subservient to the function of a gland which secretes a glutinous material analogous to silk, the filaments of which serve to attach certain bivalves, as the Pinna and the common mussel, to rocks; these filaments are termed the "byssus."

In most dimyary bivalves the foot is a true organ of locomotion. To some which rise to the surface of the water, it acts, by its expansion, as a float; to others it serves, by its bent form, as an instrument to drag them along the sands; to a third family it is a burrowing organ; to many it aids in the execution of short leaps.

We may generally observe in relation with the greater development and more active functions of the foot, a corresponding complexity of the respiratory system. This is generally effected by the superaddition of accessory organs in the form of tubular prolongations of certain parts of the margin of the mantle, which are provided with a special development of muscular fibres forming tubes called "siphons," which require for their retraction special muscles attached to the valves of the shell: in the *Pholas crispata* there is a third small accessory gill on each side.

In the *Venus chione* (*fig.* 118.) we have an example of one of

118



Venus chione.

these highest organised of the acephalous Mollusca, in which the characters of its grade of structure are indelibly impressed upon the valves of the shell. The muscular fibres (*a*, *a*) which retract the margins of the mantle have their fixed point within the margin of the shell, and leave there a linear impression at *a′*: the adductor muscles leave deeper impressions: *b* is the anterior adductor, and *b′* its corresponding impression: *c* is the posterior adductor, and *c′* its corresponding impression: *d* is the retractor of the siphons, and *d′* its corresponding impression: *e* shows the transverse fibres of the foot, which, by thin contraction, lengthen the organ, and cause it to protrude: *f* marks the longitudinal fibres or retractors of the foot. When the siphons are present, they are always two in number, corresponding with the oral and anal apertures in the tunic of the Ascidian: in *fig.* 118., *g* is the inhalent, and *g′* the exhalent, siphon. The labial processes are shown at *h*: the stomach at *i*. A remarkable elongated amber-coloured body, called the crystalline style, is indicated at *k*: it is contained in a special cyst, with its free extremity protruding into the stomach; it is peculiar to certain species of dimyary bivalves, and its use is unknown. The intestine (*l*) forms a few convolutions, and terminates in the rectum (*m*), which perforates the ventricle of the heart (*n*). The blood is received from the veins of the gills (*p*) in this, as in all other dimyary bivalves, by two auricles (*o*, *o*), which transmit their contents to the single fusiform ventricle, perforated in the remarkable manner just shown. In the genus *Arca*, which is remarkable for its great breadth, the ventricle itself is divided into two cavities, having the rectum in the interspace. An artery is continued from each extremity of the ventricle, which distributes the oxygenated blood over the viscera, the muscular system, and the mantle.

The branchial plates are essentially internal folds of the pallial membrane, and are strengthened by series of delicate jointed filaments, which support as many series of curved vibratile cilia. The respiratory currents are occasioned by the ceaseless action of these cilia, and are not dependant upon any opening or closing of the valves of the shell. The ciliary action is that likewise which brings the nutrient molecules to the mouth.

The two branchial lamellæ of one side are usually connected with those of the opposite side by their posterior extremities only; but sometimes the union is more extensive. In a few genera, as *Anatina* and *Pholadomya* the two lamellæ of the same side are so united as to appear like a single gill. In the *Pholadomya* it forms a thick oblong mass, finely plicated transversely, attenuated at both extremities, slightly bifid at the posterior one. A line traverses longitudinally the middle of the external surface, which has no other trace of division. The branchiæ on each side adhere to the mantle by the whole of their dorsal margin, and are united together where they extend beyond the visceral mass, being separated, by the interposition of that mass, along their anterior two-thirds. A narrow groove extends along the free anterior margins of each gill. When the inner side of this apparently simple gill is examined it is seen to be divided into three longitudinal channels, by two ridges, containing the vascular trunks and nerves of the gills. A style passed from the excretory siphon, behind the conjoined extremities of the branchiæ, enters the dorsal channel, from which the excretory respiratory currents are discharged: the middle channel is characterised by an orifice which conducts into the cavity of the gill, where the ova are hatched: the third channel forms the inner or mesial surface of the gill, which is not otherwise divided.

The returning veins of the body form a remarkable plexus at the base of the gills, near the pericardium, which assumes the form of a distinct glandular organ in the higher bivalves. The secretion of this venous body abounds with calcareous particles, and the gland was called by Poli the secreting organ of the shell: it is shown at *fig.* 118. *r.* Modern analysis has detected a large proportion of uric acid in the peritoneal compartment enclosing this venous plexus, and has thus determined it to be the renal organ.

The nervous system advances in a regularly proportional degree with the complexity of the general organisation, and especially with the muscular system: the ganglion upon the posterior adductor, which is most conspicuous in the oyster, is the largest and most constant in all other bivalves: it supplies the branchiæ with their nerves, and when these are approximated on each side, it is single; when they are wider apart, it is double. It is called, therefore, the branchial ganglion, but it distributes an equal share of nerves to the posterior and dorsal parts of the mantle.

In the common mussel the labial ganglions may be distinguished by their yellow colour at the base of the labial processes. They are connected by a short transverse nervous chord, passing above or in front of the mouth. From each of the ganglions two principal nerves are given off, one passing forwards to the anterior adductor, the other backwards along the base of the foot and the visceral mass to the posterior adductor. At a short distance from the labial ganglion, this latter nervous chord sends off a branch, which communicates with its fellow by means of a bilobed ganglion, situated at the anterior part of the base of the foot. This pedial ganglion and the labial and branchial ganglions just described, constitute the principal centres of the nervous system in the common bivalve here dissected with so much elaborate minuteness by Mr. Goadby. The pedal ganglion distributes nerves in one direction to the retractors; in another to the substance of the foot. The branchial ganglions send off nerves which are distributed principally to the posterior pair of the breathing organs, and two large nerves which diverge as they pass over the adductor muscles to proceed to the base of the tentacular processes guarding the posterior lobes of the mantle: these continue along the margin of each lobe of the mantle until they meet and anastomose with corresponding branches, which are continued over the anterior adductor muscles from the labial ganglions. Cuvier accurately describes this important feature in the nervous system of the bivalves. The marginal pallial nerve is not, however, simple, but consists rather of a series of elongated loops.*

* Many other particulars of the nervous system of the Mytilus, demonstrated in

The nerves of this and other bivalves present the soft and pellucid structure which is so common in the aquatic invertebrata. The modification of the nervous system, in other bivalve mollusca, have been ably compared and reduced to their analogues by Mr. Garner. In the oyster the subœsophageal loop is slender and contracted, and unconnected with any other ganglion excepting the labial ones in the pedate bivalves; the subœsophageal loop is more or less lengthened, having the form of a Roman arch in the Pecten, and that of the Gothic or pointed arch in the Cardium and Mya; it has for its key-stone, if we may pursue this analogy, the pedial ganglion. In some species this ganglion is more distinctly bilobed than in others; sometimes, as in the Pholas, it is situated more superficially near the tip of the foot; in all it seems to be the centre from which the viscera derive their nerves. The largest and most constant ganglions are those situated upon the posterior adductor muscle, following this muscle in all its varieties of position, and manifesting likewise differences in relation to the branchiæ, but always brought into direct communication with the oral or labial ganglions.

In these bivalves, as the *Ostrea*, *Cardium*, *Unio*, *Anomia*, *Venus*, *Pholas*, *Teredo*, *Solen*, *Mya*, and *Mactra*, in which the gills of one side are united to those of the opposite, the branchial ganglia are conjoined. But in those, as the *Mytilus*, *Modiola*, *Pecten*, in which the branchia are separate, and at a distance from one another the two ganglia are distinct, and joined by a transverse chord of greater or less extent.

A small siphonic ganglion is developed at the point of confluence of the muscular respiratory tubes in the bivalves which possess those accessory organs of respiration.

Dr. Siebold has recently described a small sacculus in the *Cyclas cornea*, attached to the anterior part of the labial ganglion, and containing a cretaceous nucleus of a crystalline structure, performing remarkable oscillatory movements: this sac he regards, with much probability, as a rudimental organ of hearing. The Pecten has a number of small ocelli arranged around the inner margin of the mantle, and which have been regarded from the period of Poli, who called the Pecten *Argus*, as rudimental organs of vision. Oysters appear sensible of light, and close their valves when the shadow of an approaching boat is thrown forward, so as to cover them before

the beautiful dissections and drawings exhibited, were detailed by the Professor, under the names of the "pre-pallial," and "post-pallial nerves;" the "circumpallial plexus," the "dorso-pallial plexus," the "visceral nerves," "branchial plexus," &c., the special description of which, with figures, would, he stated, shortly appear in a monograph directed to be published by the Council of the College. W. W. C.

any undulation of the water can have reached them. The labial palpi seem well adapted, both by structure and position, to exercise the sense of smell; but of the existence of this sense, or of taste, we have no proof. The mantle is highly susceptible of impressions by contact.

Between the freely open state of the mantle in the oyster and similar monomyary bivalves (*Ostracea*), and its condition in the dimyary bivalve (*Venus*) selected for the demonstration of the general organisation of the *Lamellibranchiata*, there are intermediate modifications. The common mussel is the type of a family (*Mytilacea*) in which the mantle is widely open anteriorly, the margins of the lobes being united together posteriorly, except for a small space forming an outlet for the excrements. In the *Chamacea* the margins of the pallial lobes coalesce, leaving a small anterior aperture for the foot, a second smaller one for inhaling the respiratory and nutrient currents, and a third posterior orifice for excretion. The family typified by the *Venus* has the two latter orifices produced into a siphonic tube, and the anterior or pedial aperture corresponds in width with the superior size of the foot. The modifications of the mantle are essentially the same in the family called *Inclusa;* but the narrower and longer figure of the body occasions a greater proportion of the confluent margins of the mantle between the anterior pedial and the posterior siphonic apertures, whereby the mollusc, especially when the foot is small, becomes inclosed in a membranous tube or sheath. The most essential difference is presented by the *Pholadomya*, which has, besides the pedial and two siphonic apertures, a fourth orifice at the under part of the base of the siphon, leading by a valvular protuberance into the interior of the pallial cavity. This additional aperture co-exists with a second small muscular process or foot, which is bifurcate at the extremity.

The bivalve shell of the *Palliobranchiata* offers, as might be expected, many modifications corresponding with those of the mantle. The shell consists essentially of an organised extravascular combination of gelatinous membrane and calcareous earth, chiefly carbonate of lime, arranged in successive layers, the innermost being the largest and latest formed; and each layer presenting a cellular or fibrous texture, which presents characteristic variations in different families.* The distinction between the internal or nacreous layers,

* The microscopic structure of shells has formed the subject of the investigations of a committee of the Microscopical Society of London, and of the independent and original observations of Dr. Carpenter. The results of these inquiries will form a valuable addition to the anatomical history of the Mollusca, and to the physiology of the extravascular tissues in general. R. O.

and the external or fibrous layers, has long been recognised, and has been forced, as it were, upon the notice of the palæontologist by the circumstance of the two being often separated from each other in fossil shells, and sometimes from one having perished whilst the other remained. As the nacreous layer alone forms the characteristic hinge uniting the two valves of the shell, and alone receives the impressions of the soft parts, the true characters of fossil shells, as those of the genera *Podopsis* and *Spherulites*, which, in consequence of their position in porous chalky beds, have lost all the nacreous layer, cease to be determinable. When the inner layer is preserved, its impressions reveal the organisation of the ancient fabricator of the shell as clearly as do the forms and processes of fossil bones that of the extinct vertebrate animal.

The siphon in some of the elongated *Inclusa* cannot be retracted into the shell; they are consequently exposed, as in the *Pholadomya* and *Pholades:* such species derive extrinsic shelter by burrowing in sand or stone. The Pholades have supplemental calcareous pieces in the hinge of the shell. The *Clavagellæ* and *Aspergilla* line their burrows with a calcareous layer, which forms in the latter a distinct tube, closed at the larger extremity by a perforated calcareous plate. One of the valves of the normal shell adheres to the tube in the *Clavagella*, and both are cemented to its inner surface in the *Aspergillum*.

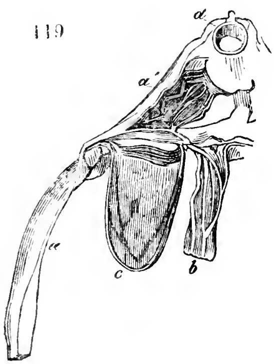
In the Teredo, or Ship-borer, the most vermiform of molluscous animals, the valves are reduced to mere appendages of the foot, at one extremity of the animal, and are restricted in their function to the operation of boring. As the ship-worm advances in the wood it lines its burrow with a thin layer of calcareous matter. The length of the body is chiefly due to the prolongation of the respiratory tubes, each of which is provided with a small elongated calcareous triangular plate. In the *Teredo gigantea* the tube, which sometimes surpasses six feet in length, has parietes of from four to six lines in thickness, the texture of which is crystalline or spathose.

The valuable pearls of commerce are a more compact and finer kind of nacre, often developed in the substance of the mantle, or around a particle of sand or other foreign body which has gained admission to the pallial cavity. The *Meleagrina* or *Avicula margaritifera* of the Indian seas is most famous for these productions.

The latest and best observations of naturalists and physiologists on the sexual characters and generation of the Lamellibranchiata have established the correctness of Leuwenhoek's conclusion that these mollusca are of distinct sexes, some individuals being male and others female. In the small species of *Anomia* parasitic upon fuci on the south coast of England, I have found the males and females nearly equal in number, the males being distinguished by their opake white testis abounding in spermatozoa, the females by their yellow or orange-coloured ovarium. There appears indeed to be only one observed exception to the diœcious condition, namely in the *Cyclas*, in which Wagner found, in addition to the ovaria, an isolated pair of testes. In the males the testes are double and have a somewhat more circumscribed form than the ovaria, but sometimes appear to be blended together at the median line: in the oyster they are situated on each side of the liver, and extend in the form of a triangular process between the adductor muscle and the gills. The testes extend at the breeding season in certain genera, as Mytilus and Modiola, into the substance of the lobes of the mantle; but in those bivalves which have a large foot, the testes are confined to the base of that organ. The ultimate texture of the testes is a congeries of vesicles containing a milky fluid, which seems to consist almost wholly of spermatozoa in the breeding season. The vasa deferentia are short and wide, and they open behind the mouth in the oyster, and terminate upon papillæ at the posterior part of the foot in most dimyary mollusca, as the Cardium, Pholas, Venus, &c.

The ovaria have a similar form and position in the female bivalves, but are usually more extensively ramified. At all seasons of the year some ova may be discerned in the ovarian cells, characterised by the germinal vesicle and spot. Towards the breeding season they are developed in immense numbers; and the addition of the coloured vitellus to the essential part of the ovum gives the characteristic colour to the ovaria. They are generally distended with the ova in the winter months. The fertilising filaments retain their influence after being discharged from the males; are drawn in with the respiratory currents, and at the breeding season the ovaries and oviducts contain a milky fluid abounding with the moving filaments. The ova then escape by the short oviducts, which terminate in positions analogous to those of the vasa deferentia. They are conveyed along the basal margin of the internal branchiæ, enveloped in mucus, from the oviducts to the posterior terminations of the inter-branchial space, where they enter the canal which traverses the base of the external gill, and pass into the receptacles formed by the interspaces of the transverse lamellæ, connecting the outer

119

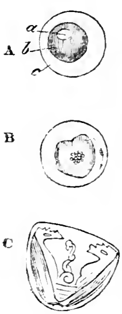


Anodon.

with the inner wall of this gill. In *fig.* 119. is shown a transverse section of the right lobe of the mantle (*a*), and of the right pair of gills in a fresh-water muscle (*Anodon*), at the period when the external gill is performing its marsupial function, and is laden with the ova: *b* is the inner gill, *c* the outer gill, showing the basal canal and the free margins of the partitions of the branchial cells in which the ova are incubated.

The development of the ovum takes place in this temporary marsupium: it has been studied by Carus in the *Unio* and by Quatrefages in the *Anodon*. *Fig.* 120. A shows the ovarian ovum of the *Unio litoralis* before impregnation: the germinal vesicle is seen at *a*, the coloured vitellus with the membrana vitelli at *b*, the albumen at *c*, covered by the chorion. Before the ovum reaches the branchial marsupium, the germinal vesicle has undergone the ordinary changes which lead to its apparent destruction: the albumen increases in quantity: pentagonal and hexagonal epithelial cells are developed upon the surface of the vitellus, as shown in *fig.* B.; vibratile cilia are developed upon them. Movements in the albumen are then observed in the vicinity of these cells. They extend over the yolk; the currents in the albumen increase in strength, and, finally, the yolk itself begins to revolve in the surrounding fluid. This singular phenomenon was observed by Leuwenhoek in 1695.

120



Ovum and Embryo: Anodon.

Two parallel fissures next make their appearance, which, sinking deeper into the yolk, divide that part, which is now included in the rudimentary digestive sac, from the lobes of the mantle. Calcification commences on the outer surface of these lobes, and the first layer of the future shell forms a small triangular valve on each side. When the rotation of the embryo is most active, seven or eight revolutions may be observed in the minute. The gills make their appearance as minute processes from the inner surface of the mantle, near the angle between the pallial lobes and the visceral mass. The development of the adductor muscle, single at the beginning and near the hinge, is indicated by feeble actions of opening and shutting the valves. The albumen during this development is absorbed and assimilated; and the embryo now distends the chorion. In the young *Anodon*, long filamentary processes, twisted together like a byssus, are developed from the visceral mass, which mass seems to shrink in size as the lobes of the mantle and valves of the shell increase. The thick, short, fleshy foot is subsequently developed in place of the byssiform filaments.

The young *Uniones* and *Anodontes* escape from the chorion before they quit the marsupium, and may be observed swimming freely about in the cavity of the external gill. They were mistaken for parasitical animals by Rathké, and described by him under the name *Glochidium;* and the difference of form between the young and the old *Anodontes* was such, that Professor Jacobson adopted the same opinion, considering it to be improbable that they could be the offspring of the animal in which they were found. In fact, besides the byssiform appendage which characterises the young *Anodon,* the valves are, at first, triangular, with one side short and straight, where they are united by the ligament, and the other two sides meet, and terminate in a point, beyond which a process of the mantle is continued, which is dentated on its outer surface: two pointed processes project from the inner surfaces of the valves. The entire amount of change effected in the progressive acquisition of the mature form merits the name of a metamorphosis.

The course of the intrabranchial development of the young Anodon extends over two, three, or four months: the young sometimes escape from the parent as late as in September. The young animal, after exclusion, uses the prehensile or adhesive filament to anchor itself to the shell of the parent, or to some foreign body.

In the genus *Cyclas,* Mr. Garner * has observed from ten to twenty of the young fry, situated in the internal branchiæ: they are discharged one by one when they attain about the sixth of an inch in diameter. The oviducts in the *Cyclas* open over these internal branchiæ, and are only accessible to the water from behind, as are the external branchiæ of the *Unio.* The young *Cyclades* are sometimes found adhering by a byssus to different parts of the body of the parent. The young of the genus *Naias* have been observed to anchor themselves after exclusion from the parent, by a byssus, which is usually wanting in the large and full-grown animals.

This temporary means of attachment must prevent many of the young and feeble bivalves from being carried away by the stream at a period when their shell has not attained sufficient hardness to protect them from the numerous predatory aquatic animals to whose attacks they would be exposed; and we may thus discern, in the deciduous byssus, an evidence of prospective design for the well-being of the weak and defenceless.

* Zoological Transactions, vol. ii. p. 97.

LECTURE XXII.

PTEROPODA AND GASTEROPODA.

Although the Acephalous Mollusca are for the most part deprived of the power of locomotion, or have it granted to them in a very low degree, yet some species of Lamellibranchians can swim, and the pectens, from their lively movements in the water, and the vigorous flappings of their brightly tinted valves, have obtained the name of sea-butterflies. Amongst the Mollusca provided with a distinct head, locomotion is the rule not the exception. The *Lithedaphus* is fettered by its calcareous operculum to the rock on which it grows, and the *Magilus* becomes immoveably sunk in its coral bed. Certain extinct genera of the family *Rudistes*, allied to the *Calyptreidæ*, were also sedentary; but all the other encephalous Mollusca are free and locomotive: some creep, some climb, some swim: a few combine these different powers; whilst certain small species have no other mode of progression than by floating or swimming on the surface of the ocean. These are provided with two fin-like muscular expansions, attached to the sides of the neck, which, from their resemblance to wings, suggested to Cuvier the name *Pteropoda* for this small and lowest organised class of the encephalous Mollusca.

Some Pteropods are provided with a light and delicate semitransparent shell. In the *Hyalæa*, it resembles a bivalve shell, of which the two valves had been cemented together at the hinge; leaving a narrow fissure in front and at the sides. In the *Cleodora*, the two plates of the shell are united together along the sides as well as at the base, leaving an opening only in front. The shell of the *Limacina* is a cone twisted spirally in one turn and a half. The shell of the *Cymbulia* is symmetrical, like a boat or slipper, but is cartilaginous. The *Clio* and *Pneumodermon* are naked, or without shells.

All the species of Pteropoda are of small size; they float in the open sea, often at great distances from any shore, and serve, with the Acalephæ, to people the remote tracts of the ocean. In the latitudes suitable to their well-being, the little Pteropoda swarm in incredible numbers, so as to discolour the surface of the sea for leagues; and the *Clio* and *Limacina* constitute, in the northern seas, the principal article of food of the great whale.

Those Pteropoda which have symmetrical shells composed of two plates have one applied to the dorsal, and the other to the ventral, surface of the body, as in the Brachiopoda; and the two muscular cephalic expansions may be regarded as analogous to the large arms of those Acalephæ: but the Pteropods manifest a much higher grade of development in having a distinct head, with tentacula and jaws anterior to the attachment of the wing-like expansions. In the Hyalæa, the head and fins form together a large division of the body, which has been compared to a cephalo-thorax; the part containing the viscera and which is lodged in the shell forming the abdomen.

In this species the upper or dorsal valve is nearly flat, and is prolonged anteriorly beyond the ventral plate, which is convex. Thin lobes of the mantle correspond with the divisions of the shell, but are united together at the sides; from which long membranous processes are continued in some species. The principal part of the muscular system arises by a narrow tendon from the posterior point of the shell, passes forward through the abdomen between the ovary and branchia, expanding as it approaches the head, where the fibres decussate, and diverge in the substance of the fins: other strata of muscular fibres decussate the preceding obliquely.

The mouth is a small longitudinal fissure, at the apex of two diverging labial eminences: it contains a lingual prominence, covered by a thin uncinated horny plate. In the *Clio* the tongue is more prominent, and is beset with transverse rows of recurved hooks; and the mouth is provided with two small lateral jaws, supporting a row of unequal horny teeth.* Salivary glands coexist with the maxillary organs in the *Clio;* they are wanting in the *Hyalæa.* In both Pteropods the stomach is large and globular, the intestine disposed in three or four coils, and terminating at the right side, and towards the anterior part of the mantle. The liver is voluminous, in part concealing the stomach, but transmitting the bile by a single duct to the beginning of the intestine. In the Pneumodermon the biliary secretion is said to be poured into the stomach by many pores; as, in the acephalous bivalves.

The cephalic expansions of the *Clio* are muscular, like those of the *Hyalæa,* subserving locomotion, not respiration, as Cuvier believed. The true branchial vascular network is developed in both Pteropods upon the inner surface of the mantle. A heart, consisting of an auricle and ventricle, is lodged in a pericardium, and situated on the left side in front of the branchia, from which it receives the blood by a large vein, and propels it by two aortæ to the locomotive appendages and other parts of the head, and to the abdomen and its viscera. The Hyalæa and Cleodora have no cephalic tentacles. The Cymbulia has two small tentacula with an ocellus at the base of each.

* Eschricht, Anat. Unters. uber die Clione borealis. 4to. 1838.

The head of the Pneumodermon is characterised by two groups of numerous tentacula, each terminated by a sucker; and the recent researches of Eschricht* have brought to light an analogous structure in the Clio, whose cephalic organs of prehension are much more complex than Cuvier supposed. Each of the six conical retractile processes of the head are perforated by numerous cavities, recognisable to the naked eye as red points, but containing about twenty microscopic pedunculated discs, the total number of which in the head of the *Clio*, Eschricht estimates at 360,000! There are two slender and simple tentacula which seem to exercise only the tactile faculty. Two supra-œsophageal or cerebral ganglia are developed upon the upper part of the nervous collar which incloses the beginning of the alimentary canal; the two pedial and the two branchial ganglia are closely approximated and connected with the inferior and lateral parts of the nervous collar. From these centres the nerves are distributed to all the viscera and parts of the body.

The male and female sexual organs are combined in the same individual. The duct of the voluminous testis communicates with a spherical vesicula seminalis, and is then continued to the base of an intromittent organ, which projects from an orifice on the right side of the head; this organ Cuvier compares in the *Cymbulia* to a small proboscis; in the Clio it is almost as long as the body, and proves impregnation to take place by reciprocal coitus, as in many of the inferior Gasteropods.

The ovarium is also a voluminous organ; and the oviduct is wide, and provided with glandular parietes through a great part of its course; it terminates close to the base of the intermittent organ.

The development of the ova of the Pteropoda has not yet been observed.

Class Gasteropoda.

The transition from the *Pteropoda* to the present class is obviously made by the *Philliroë*, the *Glaucus*, the *Carinaria*, and the *Firola*, all floating pelagic genera remarkable for the delicacy of their tissues, and the rudimental character of their gastric foot: these aberrant Gasteropods manifest the same affinity to the preceding group by the presence, in some, of lateral, symmetrical, more or less aliform expansions, and, in others, of a shell characterised by its elegant symmetry, lightness, and transparency; that of the *Carinaria* much resembles the shell of the *Cymbulia* in form, but is of a calcareous texture.

* Loc. cit.

The typical Gasteropods, characterised by the greater development, especially the breadth of their ventral muscular locomotive disc, constitute a very extensive, and widely distributed class of Molluscous animals, many of which appear to have superseded the extinct inhabitants of the chambered shells in the organic economy of the existing shores. Most of the species are marine; many inhabit fresh waters; a few are terrestrial. They offer corresponding conditions of the respiratory organs in relation to these media, with minor modifications, of which systematic naturalists, and especially Cuvier, have availed themselves, in distributing the numerous and diversified members of the class into orders.

In the lower organised Gasteropods the respiratory organs are exposed; those genera which support them on the back, or the sides of the back, as the *Glaucus, Eolida, Tritonia,* form the order *Nudibranchiata,* in which all the species are without shells, in the mature state; those genera which carry the gills at the lower part of the sides of the body, between the foot and mantle, as the *Phyllidia,* constitute the order *Inferobranchiata:* they are likewise naked or shell-less. The genera in which the gills have a similar position, but extend around the body, as the *Patella* and *Chiton,* form the order *Cyclobranchiata:* they are defended by a conical shell composed of one or many pieces.

In the rest of the class the respiratory organs are concealed. Those genera, as the *Aplysia* and *Bulla,* which have the gills protected by a fold of the mantle containing a rudimental shell, or by a reflected process of the foot, form the order *Tectibranchiata.* Those genera, as *Limax* or *Helix,* which have a vascular air-sac or lung, protected by a rudimental, or fully developed shell, form the order *Pulmonata.* A small order of marine Gasteropods, including the *Fissurella* and *Haliotis,* which have their pectinated branchiæ protected by a wide shield-shaped shell, is called *Scutibranchiata.* Another small order, in which similar branchiæ are protected, with the entire body, by a tubular shell, is called *Tubulibranchiata.*

In all the foregoing orders of Gasteropods the male and female organs of generation are associated in the same individual; in the last and highest organised order, called *Pectinibranchiata,* the sexes are distinct.

The soft parts of the Gasteropods are immediately invested by a soft inarticulated lubricous integument called the mantle, in which may be recognised an epidermal, a pigmental, and a dermal layer, the latter being highly contractile. The shell results from the metamorphosis and calcification of cells deposited in layers beneath the epidermis, in the situation of the rete-mucosum in the human integument. Its formation in the univalve Gasteropods commences in the embryo, and the first-formed part is called the nucleus of the shell; the succeeding layers are not, however, formed around this, but are added to the inner surface of the circumference of the previously formed parts; and the proportions in which the new formed layers extend beyond their predecessors determine the figure of the future shell. In some Gasteropods, at certain seasons, the margin of the mantle in which the shell-forming processes have greatest activity extends outwards at an obtuse or right angle to the last-formed margin of the shell, and after having formed a calcareous plate in this position, the mantle extends in the ordinary direction, increasing the length of the shell, and is again similarly extended at a right angle with the last formed part: it is to this periodical growth of the mantle and plethoric condition of the calcifying vessels that the ridges on the exterior of the shell in the wentletrap (*Scalaria pretiosa*) are due. Should the margin of the mantle, instead of being uniformly extended, send outwards a number of detached tentaculiform calcifying processes, these will form a row of spines corresponding in length and thickness to the soft parts on which they are moulded; and, as the calcification of the processes proceeds, the spines, which were at first hollow, become solidified, and finally soldered to the margin of the shell. This development of pallial calcifying processes or filaments and of the resulting spines, likewise alternates with periods of the ordinary increase of the shell; and thus its exterior surface may become bristled with rows of spines, as in the *Murex crassispina*.

The most simple form of univalve shell is the cone, which may be much depressed, as in the genus *Umbrella*, or extremely elevated and contracted, as in the *Dentalium*, or of more ordinary proportions, as in the Limpets. The apex of the cone is always oblique and excentric; directed in the Limpets towards the head, but in other Gastropods towards the opposite extremity of the body. The conical univalve shell is generally spirally convoluted, sometimes in the same plane, as the *Planorbis*, but more usually in an oblique direction.

As a general rule the spiral univalve, if viewed in the position in which its inhabitant would carry it if it were moving forwards from the observer, is twisted from the apex downwards from left to right, the spire being directed obliquely towards the right; but in a few genera, as in *Clausilia*, *Physa*, the shell is twisted in the opposite direction, when it is called 'perverse' or 'sinistral.' Some species of *Bulinus*, *Partula*, and *Pupa*, and a few marine shells, as *Fusus sinistrorsus*, are sinistral. The part around which the spiral cone is wound is termed the 'columella:' this is sometimes simple, sometimes plicated: in some shells it is solid; in some hollow; in the latter case its aperture is termed the 'umbilicus.'

The aperture which forms the base of the spiral univalve is bounded by an 'outer lip' and an 'inner lip,' which offers a smooth convex surface, over which the foot of the Gastropod glides to reach the ground. In many univalves the aperture of the shell is entire; in others, the margin is broken by a notch, or perforated by one or more holes, or a portion of it is produced into a canal or siphon. These modifications are important on account of the constancy of their relation to certain conditions of the respiratory organs. Thus the Pectinibranchiate Gastropods, in which the water is conducted to the shell by a muscular tube or siphon, have the margin of the aperture of the shell either notched or produced into a canal.

In some of the Gastropods the shell consists of one piece, when it is termed an 'inopercular univalve;' but the aperture of the shell is in the majority of the species closed by a plate, attached to the back of the foot, and called the 'operculum.' It is sometimes calcareous, forming a second shelly plate; but it more frequently consists of albuminous membrane only, or is horny; thus presenting the condition which the univalve shell itself manifests in certain genera, as *Limax* and *Aplysia*. Some opercula increase by the addition of matter to their entire circumference, and these are either concentric, as in *Paludina*, or excentric, as in *Ampullaria* and most of the Pectinibranchiate Mollusks. Other opercula grow by the addition of matter to part of their circumference; and these are either spiral or imbricated; in the latter the layers of growth succeed each other in a linear series. No operculum presents an annular form. As the operculum sometimes varies in structure in species of the same genus, as it is present in some volutes, cones, mitres, and olives, and absent in other species of those genera, and as some genera in a natural family, as *Harpæ* and *Dolium* among the Buccinoids, are without an operculum, whilst the other genera of the same family possess that appendage, it obviously affords characters of very secondary importance. In *Lithedaphus* (*Calyptræa*) *equestris* the whole base of the foot secretes a calcareous plate which is cemented to the rock, and the shell appears to consist of two valves. In the Chiton the shell is divided into many pieces arranged like scales upon the back.

Most univalve shells are composed of three strata, which differ in the arrangement of the calcareous particles. Hunter* discovered that the molluscous inhabitant of a shell had the power of absorbing part of its dwelling. This property, which is now generally recog-

* Philos. Trans. 1785, p. 343.

nised, is well illustrated by the thinning of the parietes of the internal whorls of the *Cones* and *Olives*, from which two out of the three layers of which they were originally composed may be observed to have been removed. The absorption of shell is also illustrated by the removal or smoothing down of the spines of the *Murices;* by the flattening of the inner lip of the mouth of the *Purpuræ;* by the widening of the fœcal aperture of the *Fissurellæ;* and it gives rise to various other modifications in the form and structure of shell in the progress of growth. Another change of form is due to the physical decomposition or destruction of a part of a shell during the lifetime of the inhabitant. This occurs to the apex of certain Univalves after the shell has been evacuated by the original occupant in the widening and lengthening the shell to accommodate it to an increase of bulk. Such shells are said to be "decollated," as, for example, the *Helix decollata.*

The inhabitants of univalve shells dispose in different ways of that part of their calcareous abode which they evacuate in the progress of growth; in the decollated shells the vacated spire is portioned off, prior to its abrasion, by the formation of a thin nacreous plate. In the *Vermetus gigas* the vacated portions of the tube are retained, and successively portioned off, a series of concave plates or septa being thus developed; a similar structure is indicated in the remains of the large elongated fossil shells, called *Icthyosarcolites.* In the *Magilus antiquus* the posterior part of the shell, as the soft parts move forwards, is progressively filled up with a dense, solid, subtransparent, crystalline deposit of carbonate of lime.

The part of the mantle which invests the viscera in the conchiferous Gasteropods is smooth, thin, and sub-transparent, resembling the sac of a hernia, which, with the viscera themselves, appears to have escaped from the common muscular integument of the body. This visceral mass, as it is termed, is lodged in the upper part of the cone of the shell, the spiral turns of which it follows. The head and foot of the animal can be protruded from the mouth of the shell, and be retracted within its last whorl, by the action of a muscle, which has its fixed point in the columella of the shell. The form and size of this compartment of the shell, and of its aperture, correspond with, and indicate the size of, the foot.

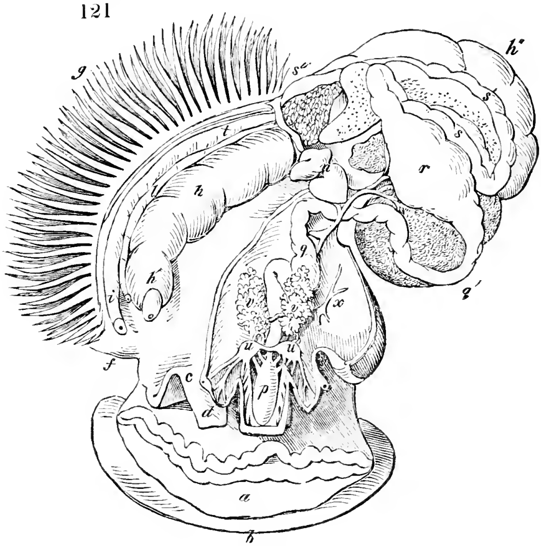
In the Pectinibranchiate Mollusca, which are the chief fabricators of the beautiful turbinated shells of the conchological cabinet, the foot is attached to the anterior part of the body by a narrow base; whence they have been termed by Lamarck *Trachelipods.*

These with the true Gasteropods are organised to subsist on a great variety of food: they select both animal and vegetable matter in both their living and decomposing states. The damage which the common snail produces, by devouring the produce of the garden, is too well known; and, on the other hand, the common whelk preys upon its congeners, nor do their strong shells defend them from its attacks.

The mouth is bounded by fleshy contractile lips in most of the Gasteropods, and these are developed, in the Haliotis, into a pair of labial processes: it is likewise generally armed with horny plates, trenchant or spiny, disposed either as jaws, or covering the tongue. The upper lip in the snail is armed with a crescentic dentated horny jaw, which is opposed by the bifid soft lip below. In the Tritonia, a curved trenchant horny plate works vertically upon another of similar form, and with these, as with a pair of curved scissors, this molluscous animal crops the tough sea-weed which constitutes its food. Certain fresh-water Gasteropods, as *Limnæus* and *Planorbis*, combine two lateral horny jaws with a superior dentated labial plate. The Limpet rasps marine plants with a narrow horny plate or ribband beset with numerous rows of minute recurved hooks, which armature extends beyond the mouth, and is longer than the entire body. The whelk is provided with a more complicated instrument in the shape of a proboscis, susceptible of considerable elongation, or of being entirely concealed within the interior of the body. Its extremity is vertically cleft, the divisions or lips having their inner surface beset with recurved spines. In the interior of the muscular cylinder, there is a tongue armed by a horny uncinated plate, as in the Limpets, but of much less length: it is stretched upon two elongated cartilages, which can recede from or approximate each other, or be moved together to and fro, by special muscles: by these movements the spines can be made to scrape with force against any opposed surface; and it is by the repetition of such movements, aided, as Cuvier conjectures, by a solvent property of the saliva, that the whelk effects the perforations in the hard shells of other mollusca, upon the soft parts of which it preys.

The salivary glands present different forms and degrees of development in different Gasteropods, bearing the ordinary relations to the construction of the mouth and the nature of the food. In the *Calyptræa* I found the salivary glands represented by two simple elongated secreting tubes. In the whelk they present a conglomerate structure, are situated on each side the œsophagus, at the base of the proboscis, along which they transmit their slender ducts to terminate on each side the anterior spines of the tongue. In the *Paludina vivipara* (*fig.* 121.), here selected for the illustration of the Gasteropodous type of the molluscous organisation, the salivary glands are shown at *v*. The proboscis, or muscular parietes of the mouth, is seen at *p* in its retracted state. The œsophagus *q* is long and slightly convoluted; *q′* is the last bend which the tube makes before expanding into the

121



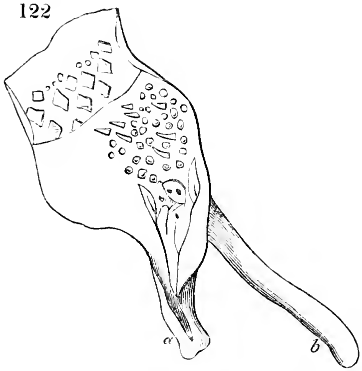
Paludina vivipara.

stomach, *r*: *s*, *s′* show the folds of the intestine in the substance of the liver and ovary; it penetrates the branchial chamber at *s″*, in which the rectum, *t*, is seen passing along the base of the pectinated gills, *g*, to terminate at *i*, close to the margin of the mantle *f*, which forms the branchial aperture. The letter *a* indicates the foot in its state of contraction, when its inferior or ambulatory surface is bent transversely upon itself: *b* shows the operculum attached to the posterior part of the foot: *c* are the tentacula, with the attached ocelli: *d* is the small siphon which projects below the right tentacle: *n* is the heart, which consists, as in almost all Gasteropods, of a single auricle and ventricle: *h* is the long and wide oviduct, which performs the office of the uterus in this ovoviviparous species of Gasteropod: *l* is the duct of a mucous or renal organ attached to the walls of the branchial cavity.

The disposition of the viscera of other Gasteropods offers few important deviations from that in the *Paludina vivipara*; but some of the peculiarities in the structure of certain organs deserve special mention.

In a few Gasteropods, the whelk, for example, the œsophagus presents a small ingluvial dilatation: the crop is wider in the *Aplysiæ*, in which the coats of the second stomach, or gizzard (*fig.* 122.), are

122



Stomach of Aplysia.

thickened, and the interior callous lining is beset with firm horny processes, some in the form of hooks or canine teeth, others in that of rhomboidal plates or molar teeth. These complexities relate to the low organised character of the food of the *Aplysiæ:* the sea-weed on which these Mollusca subsist, after coarse mastication and commixture with the salivary secretions, is macerated in the crop, conveyed to the stomach, there pierced by the gastric spines, percolated by the solvent juices, and pounded by the horny plates. The chyme is then mixed in the duodenum (*a*) with the hepatic secretion, and with the fluid, probably analogous to pancreatic juice, which is secreted by a single long blind glandular sac (*b*), communicating with the beginning of the intestine. A similar simple form of pancreas is present in some species of *Doris,* and other fucivorous genera of Gastropods, as *Tritonia* and *Scyllæa,* which likewise have horny gastric teeth. In the *Bullæa aperta* * the stomach is surrounded with three large horny plates, concave externally and convex towards the cavity. In the *Bulla lignaria* † the gastric triturating plates are calcareous: two of these plates present an irregular triangular form, with the angles rounded off, slightly concave externally, and convex towards the gastric cavity: they are united together by strong transverse muscular fibres attached to their circumference, except at the upper part of the gizzard, where a third valve of an oblong form is interposed between the two lateral ones. The imposition of the name *Gioenia* upon the large gastric plates of the *Bulla,* as the valves of a new bivalve shell, will not soon be forgotten by conchologists.

In regard to the number of cavities, the most complex stomach in the *Gastropoda* is that of the Onchidium, which has three longitudinally plicated gastric compartments.

The intestine, after performing a few convolutions in the substance of the liver and generative gland, always more numerous, and of greater width in the herbivorous than in the carnivorous Gasteropods, terminates, with a few exceptions, at or near the entry of the respiratory cavity on the right side of the body. The anus has a median

* Preps. Nos. 493, 494. † Prep. No. 492.

position in the *Doris* and *Testacella*, and terminates on the left side of the body in the Planorbis.

The liver is a bulky gland, and is subdivided into numerous lobules in all the Gasteropods: its secretion is derived from arterial blood, and is usually poured by one or two ducts into the commencement of the intestine. It is carried, however, into the stomach, and even into the œsophagus, in the Onchidium: and the *Haliotis* not only resembles the Palliobranchiata in the perforation of the stomach by the bile-ducts, but likewise in the perforation of the ventricle of the heart by the rectum, and in the division of the auricle into two cavities.

The auricle is divided in the Fissurella and in the Chiton as in the Haliotis. Both auricles, however, equally receive the oxygenated blood from the respiratory organ, as does the single auricle in all the other Gasteropods. The ventricle propels the blood to the viscera and muscular system of the body, and the heart is thus systemic, co-ordinately with the condition of the muscular system and the general endowments of the animal, as has been already explained in the Introductory Lecture. * The aorta, continued from the apex of the ventricle, divides into two principal branches in most of the Gasteropods. The auriculo-ventricular aperture is usually defended by two semilunar folds. The aorta, at its commencement, is frequently strengthened and enlarged by a muscular layer, similar to the *bulbus arteriosus* in fishes, and which, in the Aplysia, is continued beyond the origins of the primary branches of the aorta. The large venæ cavæ of the Aplysia are perforated by minute apertures, communicating with the cavity of the abdomen; and the exterior of the veins is provided with decussating muscular fibres, which probably regulate the diameter of their peritoneal communications. Cuvier supposes that this structure has relation to an absorption or passage of fluid from the abdomen into the veins. The vessels conveying the venous blood to the branchiæ are continued from these veins without the interposition of any muscular ventricle.

The general modifications of the respiratory organs are indicated by the characters of the orders of the present class already defined. In the terrestrial Gasteropods the breathing organ has the form of the simple undivided vascular sac, like the lung in the lowest air-breathing Vertebrate animals. The forms of the aquatic breathing organ are as various as its position.

In most of the Nudibranchiate species the gills are tufted and ramified, as in the higher Anellides; they are penniform in the Haliotis,

* Page 6.

and pectinated in all the diœcious Gasteropods, as the name of their order indicates: in these they never exceed two in number, which are of unequal size. In a few genera of amphibious Gasteropods a pulmonary sac is combined with branchial organs. The branchial surface is ciliated in all the Gasteropods, as is also the exterior surface of the body in the small fresh-water species.

Besides the large and well developed hepatic and salivary glands which are associated with the alimentary canal, we have seen that certain fucivorous Gasteropods present the simplest rudimental condition of the pancreas. The situation of the follicular urinary gland and of its excretory duct has already been pointed out in the *Paludina vivipara:* in some species the duct dilates to form a small receptacle. A group of follicular glands, sometimes imbedded in a distinct glandular sac, is present in many species for the elimination of some peculiar and characteristic colour; the yellow liquid of the *Bullæ*, and the famous purple secretion of the *Purpura*, are products of saccular modifications of this follicular gland. Numerous simple and scattered follicular glands lubricate the mantle with its characteristic mucus in all the Gasteropods.

At the grade of the Molluscous organisation which the Gasteropods have reached, their capabilities and spheres of action become more extended and diversified than in the Pteropods and Acephala; some are terrestrial, some arboreal, whilst the more numerous aquatic species are endowed with power to attain, subdue, and devour organised matter, dead and living. The nervous system of the Gasteropods is accordingly not only more complex and concentrated, not only subordinated to better developed masses in connection with organs of special sense and exploration, but it offers greater variety in its general arrangement and especially in the position of its ganglions, than in the Lamellibranchiate class; and with these modifications considerable differences in the outward configuration of the body are associated.

Some Gasteropods, for example, are symmetrical, more or less flat or depressed; others are compressed; the majority are contorted and lose their symmetrical form in an oblique twist: there are other diversities of organic structure which more immediately affect the condition of the nervous system, for some species possess both eyes and tentacles, whilst others are blind and akerous.

In the limpet (*Patella*), and in the *Bulla*, we find that the cerebral ganglions, as in the bivalves, are still distant from each other, and situated at the sides of the œsophagus, connected together by a nervous chord or commissure which arches over that tube: from these ganglions two filaments proceed backward on either side; the median and superior pair passes along the sides of the œsophagus, converges and meets below to form a pair of ganglions in close contact with one another which supply the foot and viscera: these are evidently analogous to the bilobed pedial ganglion of the *Mytilus*. The lateral and inferior filaments pass downwards to join two widely separated branchial ganglions, analogous to those situated on the posterior adductor in the *Mytilus*. We observe, however, a considerable difference in the relative positions of the pedial and branchial ganglions in the limpet; the latter have advanced into close contiguity with the pedial ganglions, and are connected with them by the same transverse chords, which in the Pecten and Mytilus serve merely to bring the branchial ganglions themselves into mutual communication.

We thus observe in the lowest and least locomotive Gasteropods a tendency in the nervous system to be aggregated at the fore-part of the body, the cerebral ganglions rising more to the upper surface of the now well-developed head, and the branchial and pedial ganglions beginning to concentrate themselves about the mouth. But this march of development does not prevent the homologies of the different ganglia from being satisfactorily traced. In the limpet there is a distinct head and mouth, with organs of special sense; and besides the large antennal and small ophthalmic branches given off from the cephalic ganglia, we find also superadded ganglia, having evident relation to the muscular mouth and pharynx and to the complex tongue, which are so many accessory parts appended to the simple opening of the gullet, with which the alimentary canal commences in the bivalves. The additional ganglia in question are placed below the pharynx, and are brought into communication with the sentient centres by a filament continued downwards and forwards from each of these ganglia: they also inter-communicate by a loop which forms a third azygos rudimentary ganglion beneath the œsophagus completing an anterior ring corresponding to that which is formed by the means of the pedial ganglion posteriorly.

The ganglions corresponding to the pedial pair in the *Bullæa* appear not to be joined together by a transverse band, but to be connected only with the branchial ganglion, and through them with the cerebral ones. The three are placed so close together, that Cuvier describes them as forming one mass. There are two pharyngeal ganglia formed upon filaments descending from the cerebral ganglions. The labial ganglions, which are devoloped in addition to the pedial ganglions, originate from the latter in the *Bulla lignaria*, and are connected with the cerebral ring only through them.

In the *Haliotis*, the superior or œsophageal part of the œsophageal circle is still a simple commissural chord. The sides of the circle are formed by a double chord, which unite below in a single branchio pedial ganglion; from which the visceral, as well as the branchial and muscular, nerves radiate.

In the *Doris* and *Onchidium* the cerebral, pedial, and branchial ganglions have coalesced into one annular mass, which, however, is chiefly supra-œsophageal in its position, united below by a slender chord passing across the under parts of the œsophagus. Two small nerves are given off, which descend and form two small pharyngeal ganglia, which, according to Cuvier, are united together. In the *Doris Solea* the quadripartite character of this large mass is however obvious.

In the *Paludina vivipara* the supra-œsophageal ganglions (*fig.* 121. *u*, *u*) are distinct, and connected together by a transverse commissural filament. The sub-œsophageal mass sends its principal branches to the foot; but one nerve comes off from the right side, crosses the œsophagus, and expands into a small ganglion *x*, which distributes its filaments to the retractor muscle that attaches the animal to its shell.

In the slug and snail the principal centres of the nervous system are a supra-œsophageal and a sub-œsophageal mass; but the complex character of the latter and larger mass is indicated by the triple nervous chord, which completes on each side the collar round the alimentary tube. From the inferior mass the nerves radiate to the muscular foot, the soft and susceptible integument, and the circulating and respiratory organs. The upper ganglion receives the large nerves of the tentacles and ocelli; it also communicates on each side by two minute filaments, proceeding from its posterior and outer angles, with a small pair of stomato-gastric ganglions situated on the side of the œsophagus.

The sub-œsophageal mass in the *Limnæus stagnalis* is of an orange-colour, and consists of seven ganglions united together by a loose cellular tissue.

In the *Aplysia* the sub-œsophageal ganglionic mass is divided into two parts, which are joined together by a sub-œsophageal chord, and brought into communication with the cerebral ganglions by ascending and converging chords. The cerebral ganglions are also joined together above the œsophagus, and assume the position of a true brain. They supply nerves to the tentacula, and give off anteriorly two chords, which turn forwards to join below the mouth, where they form a second œsophageal collar upon which the pharyngeal ganglions are developed. The branchial ganglion is situated towards the posterior part of the body; the connecting chords of this ganglion join those of the pedial ganglia, but may be traced directly to the brain.

The position of the cerebral ganglions varies according to the degree of extensibility of the mouth and œsophagus. Thus, in the *Helix*, they are placed above the mouth; in *Carocolla*, at the commencement of the œsophagus; in the *Buccinum* or Whelk, low down on the tube; in the *Purpura*, beneath the stomach.

As a general rule, we find that the superior ganglions give off tentacular, ocular, and oral nerves, whilst the inferior masses are the centres of the muscular, respiratory, and visceral internuntiate chords. In the spiral pectinibranchiate univalves, where the branchiæ and their nerves are twisted to the left side, it is the left branchia which is atrophied, while the right one is of large size. The nerves are similarly affected, the left one being filamentary; whilst the right is a large chord, and has the accessory branchial ganglion developed upon it.

The principal œsophageal ganglionic circle is surrounded by a thick membrane, which, in the large Tritons, assumes almost a cartilaginous hardness. A coloured pigment is not unfrequently found occupying a position analogous to that of the arachnoid, between the dense outer membrane and the ganglions. In the *Limnæus* and in the *Planorbis* this pigment gives to the ganglions their orange or roseate hue.

Amongst all this diversity in the number, size, and position of the nervous masses, certain ganglia are obviously analogous to those which have received determinate names in the lamellibranchiate Mollusca. The branchial ganglions receive impressions from, and transmit them to, the gills: they communicate also with the brain, and through that centre associate the gills with all other parts of the body. The pedial ganglion is more commonly divided than in the bivalves, and the two divisions are wider apart, in consequence of the great breadth of the foot. In those Gasteropods which possess a naked muscular mantle, we find a pallial ganglion associated with a pedial one, as in the *Aplysia*. The cephalic ganglions assume the character of optic lobes concurrently with the constancy and better development of the eyes; even when the organs of vision are more than usually minute or wanting, the cephalic ganglions are always larger than in the Acephala, and more decidedly superior in position. When separate, they are united by a thicker communicating chord, and are larger in proportion to the nerves given off from them. With the cephalic ganglions, likewise, we find connected the labial and pharyngeal ganglions, in which, perhaps, may reside the olfactory sense; there is good evidence, at least, that snails scent their food. The anterior of the aggregated ganglions, which form the subœsophageal mass in most Gasteropods, are in immediate connection with the acoustic vesicles. The functions of the other ganglions of the body seem to be limited to the automatic reception and reflection of stimuli.

Soft and lubricated and sensitive as the skin of the naked Mollusks seems to be, there are not wanting reasons for supposing it to be possessed of a very low degree of true sensibility. Baron Férussac, for example, states that he has seen the terrestrial Gasteropods, or slugs, allow their skins to be eaten by others, and, in spite of large wounds thus produced, show no sign of pain.

The vascular inferior surface of the foot can, doubtless, take cognisance of the character of the surface over which it glides; but the special organs of the tactile sense are the tentacula or horns which project from the lateral and upper parts of the head. These are wanting in a few Gasteropods, hence called *Akera:* they are sometimes two, and never exceed four, in number in the present class In the snails and slugs they can be retracted by an act of inversion. The anterior is the normal or constant pair; the posterior pair, which supports the eyes in the snail, is reduced to two short processes, which extend from behind the basis of the anterior tentacula in the *Turbo;* and which form slight projections from the outer side of the base of those tentacula themselves in the *Paludina* (*fig.* 122.), and in most Pectinibranchiata. In the Aplysia, however, which has four tentacula, the ocelli are sessile, and situated in advance of the bases of the posterior pair.

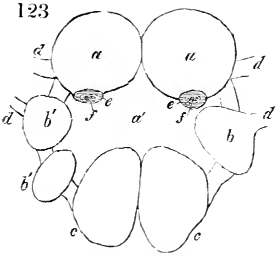
The eyes never exceed two in number in the Encephalous Mollusca: in the Gasteropods they present their largest relative size in the Pectinibranchiata. In this preparation * from a large species of Murex, you may readily discern the sclerotic tunic with its anterior orifice, the expansion of the optic nerve posteriorly between the fibrous and the pigmental tunic, and the large spherical crystalline lens, covered anteriorly by the transparent corneal integument; between which and the lens, there is a very small interspace for the aqueous humour and the pupillary circular opening left by the pigmental layer or choroid.

The existence of the sense of hearing in the Gasteropods was inferred by Dr. Grant, long before the organ was detected: he justly concluded that the sounds emitted by the *Tritonia arborescens* under water, were doubtless intended to be heard by others of the same species. The very general existence of an acoustic apparatus under its most simple conditions, in the lower Mollusca, has been established by the discoveries of Siebold. It consists of two round vesicles, containing fluid and crystalline or elliptical calcareous particles, or otolithes, remarkable for their oscillatory action in the living

* No. 1628.

or recently killed animals. In the *Limnæus* (*fig.* 123.), the acoustic cells adhere to the posterior part of the anterior ganglions of the great sub-œsophageal mass (*a, a*): *e* is the capsule; *f* the otolithes. They hold a similar position in the snail and slug, in which the number of otolithes ranges from eighty to above a hundred. The acoustic sacs are easily recognised by submitting the head of the smaller species of Gasteropod, or of the young of the larger species, to a gentle compression under the microscope.

123



Limnæus stagnalis.

From the analogy of the soft mucous skin of the Gasteropods to the pituitary membrane of the nose, Cuvier was led to conjecture that it might be the seat of the sense of smell; but the analogy seems to be too vague to render so general a diffusion of the nerves of a special sense very probable. That the sense is possessed by these Mollusca, is determined by the evidence which snails afford of scenting their food.

The tongue is, in almost all the Gasteropods, a mechanical organ for the attrition of the food: its complex horny uncinated armature seems to unfit it for the delicate office of appreciating the sapid qualities of nutritive substances; but some sense of taste may be exercised by the soft membranes of the pharynx.

Gasteropods have the power of repairing injuries and of reproducing lost parts to a considerable extent. New tentacula soon grow to replace those which may have been amputated. When they support eyes, as in the snail, the organs of vision are also reproduced: the mouth, with the horny jaw, has grown again in this Gasteropod; and when the snail has been decapitated, but with the œsophageal ganglions left behind, the head has been restored.

The general conditions of the sexual system have been already briefly defined. The complexity and bulk of the combined organs in the common slug and snail are truly extraordinary. The testis is the small, compact, minutely follicular gland, imbedded in the substance of the liver, and occupying, in the snail, the apex of the shell. The vas deferens becomes closely attached to the oviduct in its course towards the right side of the head, where it is joined by the short and simple duct of a small prostatic sac in the slug, the corresponding sac in the snail having a longer duct, from the middle of which a cæcal tube is developed. The vas deferens terminates near the base of a very long and slender intromittent organ, usually retracted and concealed within the visceral cavity, but which can be everted like the finger of a glove and protruded externally.

The ovarium is a larger, more elongated, and less minutely granular body than the testis, to which it is inferior or anterior in position. The oviduct is long and wide, with thick glandular tunics, and, near its termination, it communicates with the short and wide ducts of two ramified tubular glands, called the 'multifid vesicles.' But the complexity of the generative apparatus does not end here: the snail is provided with a pyriform muscular sac, the aperture of which terminates close to the generative outlet. The expanded base or head of a slender conical calcareous style or dart is attached to the fundus of the sac: its sharp apex extends close to the orifice, and by the contraction of the sac it can be protruded outwards. With it the snails pierce each other's skin, and the function of this curious organ would seem to be to cause a preliminary excitement to the reciprocal union of the two androgynous individuals.

In the diœcious Gasteropods the intromittent organ is usually of extraordinary length: it is grooved in most, perforated in a few; capable of retraction in the *Paludina*, but doubled back upon the outside of the mantle when drawn into the shell by the *Buccinum* and *Strombus*. In the *Carinaria* it is bifid.

The ova of the marine Gasteropods are enveloped, before exclusion, in mucous capsules, prepared by a special gland situated near the termination of the oviduct. The secretion in some species is soft, flexible, and transparent; in most it hardens by contact with the sea water, and assumes various definite and characteristic forms: the nidus is sometimes simple, sometimes compound, but each compartment contains many ova; and the development of the embryo proceeds in the nidamental chamber until its own little defensive shell is acquired.

In the terrestrial Gasteropods the ova are usually spherical and opake, and separately extruded. Snails and slugs oviposit in the earth. The tropical *Bulini* * cement leaves of trees together to form an artificial nest for their large eggs.

The ova of the sea-slug (*Tritonia*) are expelled together in the form of a long thread, and are arranged in a spiral manner in the tenacious transparent covering of the thread. In the *Doris muricata* the ova are aggregated in a flattened spirally disposed albuminous band when excluded from the oviduct. The harder albuminous capsules which defend the ova of other marine Gasteropods offer a great variety of forms, some of which are remarkable for their complexity,

* Prep. 2943. B.

others for their symmetry and beauty. Here are displayed the nidamental sacs of the frail *Janthina**; they are of a flattened pyriform shape, composed of a delicate reticulate film of albumen, and are attached by one extremity to a float, formed likewise by a secretion of albuminous matter, dilated into a group of cells filled with air. To this float the parent Janthina commits her little progeny, and having securely fastened their several cradles or nursery cells, she detaches the float, which bears the ova to the surface, and sustains them where they may best receive the full influence of solar light and heat. These nidamental capsules of the *Pyrula rapa*† are attached in regular linear series to portions of decayed wood; they are of a flattened sub-conical figure, adhere by their apex, and have their base emarginate. The nidamental capsules of the whelk ‡ are common objects on our sea-shore; they are aggregated in large irregular masses, often attached to portions of oyster-shell; each capsule presents a depressed ovoid figure, with one side convex, the other flat or concave. The small nidamental cells of the Cowrey (*Cyprea*) are aggregated in a flattened group. In the *Turbinella* § the cells are of a flattened sub-pentagonal form, and adhere together, superimposed one upon the other, forming what is termed a camerated nidus. Each chamber contains between twenty and thirty embryos. In this preparation you may observe that the rudimental shell is completely calcified and fitted to defend the little Gasteropod before it emerges from the temporary shelter provided for it by the parent. Numerous other modifications of these secreted nests of the Gasteropodous Mollusca might be enumerated.

The general course of development of the Mollusca of the present class has been observed in the *Planorbis* by M. Jacquemin, and in the *Limnæus* by M. Dumortièr. The transparency of the mucous capsules of the ova and of the ova themselves in these fresh-water Gasteropods renders them favourable subjects for such observations. The development of marine Gasteropods has been traced by M. Sars in the *Tritonia*, *Doris*, and *Aplysia*, and has been likewise studied in the latter genus, by Dr. Van Beneden.

In all these Mollusca the first steps in the formation of the embryo, after the disappearance or metamorphosis of the germinal vesicle, are the multiplication of the cells of the vitellus producing the twofold, fourfold, and more numerous subdivisions, like those which have been observed in the ova of so many of the foregoing classes. The leading differences in the Gasteropods at this stage of develop-

* See Preps. 2945, 2946.
† See Prep. 2947. A.
‡ Preps. 2948, 2949.
§ Prep. 2950.

ment depend upon the aggregation of the fissiparous cellules around one or around several centres; whereby, since all subsequent development radiates from such centres, one or many embryos may be matured in the same ovum. Thus the ovum of the *Tritonia* may give issue to seven or eight embryos; whilst that of the *Planorbis* and of most other Gasteropods is the seat of development of a single young one.

In the *Planorbis* the single centre of the ovum, or the germinal vesicle with its nucleus, is very evident in the ovarian ovum. The metamorphoses, which lead to the disappearance of the vesicle, take place in the oviducal pouch called the 'matrix.' The transparent nidamentum in which the ova are excluded is shield-shaped and striated; it is not attached to any foreign body but falls to the bottom. After the usual subdivisions of the yolk, a group of less opake cells makes its appearance in a particular part of the periphery of the granular mass; and an epithelial membrane begins to spread over its surface, from which cilia are soon developed. Their action begins about the third day to affect the surrounding albumen, and afterwards to rotate the yolk itself. The aggregation of stronger and more numerous cilia on a particular part of the surface of the yolk indicates the seat of the development of the respiratory organs. Two groups of extremely minute and compact cells, covered by a thicker epithelium, project from two other parts of the surface, and constitute the rudiments of the head and foot. The centre of the yolk presents the form of larger and less regular globules, which indicate the position of the wide digestive sac. The rudiments of the head and foot are sufficiently obvious on the fifth or sixth day; the respiratory organs are formed on the sixth or eighth day, according to the warmth of the weather. On the eighth day the characteristic tentacles begin to sprout from the rudimental head. On the tenth day all that part of the vitellus or embryo which is not occupied by the head, the foot, and the breathing organ, is covered by a thin and transparent pellicle, which is the rudiment of the shell. On the eleventh day one of the large central globules of the yolk begins to distinguish itself from the alimentary mass by feeble contractions and dilatations, of which about sixty may be counted in a minute: this is the heart. The mouth can now be discerned, and the small eyespecks appear like black granules at the base of the tentacula. On the twelfth day the embryo moves by its own contractions independently of the rotation produced by the cilia. On the thirteenth day acts of deglutition are discernible; the embryo swallows the remaining albumen, the anus is completed, and the genital organs begin to be formed. On the fourteenth day the young *Planorbis* ruptures by more violent contractions the chorion, and escapes into the water, protected by its own flexible shell.

In the *Physa*, the nidamental mass is short and ovate: in the *Limnæus* it is oblong, and not striated, as in the *Planorbis.* The double movement of the embryo is more conspicuous in the *Limnæus* than in the *Planorbis.* The first movement of the yolk is one of rotation upon its axis; but, as development proceeds and the ciliary vibrations are strengthened, the embryo begins to travel in an elliptical course around the interior of the egg; its two movements (to compare small things with great) resembling those of the planets in the solar system.

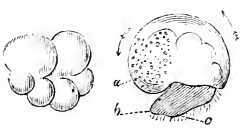
The ova of the *Aplysia* are excluded in a long string, enveloped by a transparent flexible mucus, the ova being aggregated in several irregular series in its centre. When examined at this period, the yolk has apparently divided itself into six, seven, or more numerous globules; or, in other words, as many germinal vesicles included in the same mass of albumen and in a common chorionic coat, have given origin to as many aggregations of vitelline cells; these, therefore, may be regarded as so many independent yolks, in each of which the same progressive fissiparous multiplications have been observed, as in the single vitellus of the ovum of the Planorbis, and of animals in general. *Fig.* 124. exhibits one of these yolklets prior to the commencement of the fissiparous action, by which subdivision of the mass is produced. *Fig.* 125. shows the quadrifid product of that action and of the assimilative powers of the resulting divisions A small clear vesicle, probably the seat of further subdivisions, is specially indicated by M. Van Beneden at *a.*

124 125

Aplysia.

In *fig.* 126. the multiplication of the globules has increased, and two of them, of larger size than the rest, indicate, one, the seat of the future branchial organs, the other that of the muscular mass. The ciliated epithelium, with which the vitellus is now almost entirely covered, occasions the usual rotations of that body. The progress of transformation of this monad-like embryo to the Gasteropodous form, resembles closely that which has been described in the Planorbis. The remains of the vitelline mass (*fig.* 127. *a*), not yet metamorphosed into special organs, indicates the expanded alimentary sac; *b* is the apex of the rudimental foot, and *c* the coarsely ciliated surface, which constitutes the now external branchia. These parts protrude from a rudimental, thin, pellucid and flexible shell, which covers all the rest of the surface of the body. The arrows indicate the direction of the rotatory movements of the embryo, which now likewise describes its elliptical revolutions in the chorionic

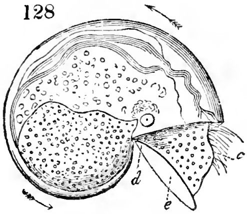
126 127



Aplysia.

cavity. As development proceeds and the embryo increases in size, the shell acquires a more distinctly turbinated form, and is slightly bent out of its vertical plane (*fig.* 128.). An operculum (*e*) is now observed to be formed upon the protruded surface of the foot; the œsophageal ganglion is visible at *d*. The ciliated branchial surface (*c*) begins to be withdrawn more into the interior; and, in this state, protected completely by an external shell, the young Aplysia is launched into the ocean.

128



Aplysia.

Truly may the subsequent growth, which effects an entirely internal position of the shell, with such a mutation of its form that the primitive nucleus can scarcely be detected upon the almost flattened plate now destined to protect the equally internal respiratory organs of the mature animal, justify us in applying to it the term metamorphosis. This term is still more applicable to the developmental phenomena in the Tritonia and Doris; since these Gasteropods, which are not only naked, like the Aplysia, but devoid of any internal rudiment of a shell, are provided with a delicate little nautiloid horny external shell in their young state.

LECTURE XXIII.

CEPHALOPODA.

We trace the progressive diminution of the existing species of Gasteropodous Mollusca by their fossil shells through the descending strata of the tertiary periods of geology, beyond which such indications become very doubtful and obscure.* In the oldest tertiary deposits, not more than $3\frac{1}{2}$ per cent. of the remains of any class of Mollusca have been identified with species now living. From this striking fact, which Mr. Lyell looks upon as indicating the dawn of the existing state of the testaceous fanna, he has proposed the term 'eocene' for these strata. In the next, or 'miocene' tertiary period, there are about 17 per cent. of fossil shells, identical with

* The supposed recent species of *Trochus* observed by Defrance in chalk, and the *Paludina* and *Cyclas*, described by Dr. Fitton from the Wealden, are not considered to be identical with existing species by Deshayes and Lyell.

recent species; in the deposits of a third or newer era (pliocene), from 35 to 40 per cent., and, in still more modern formations (pleistocene), the primitive forms have almost disappeared, and the number of species identical with those now living is from 90 to 95 per cent.

Amongst the shells which characterise the eocene strata, there appear four or five of symmetrical figure, divided into chambers, which are perforated by a tube or siphon, like this large Nautilus and this little Spirula, but belong to species which are unknown in modern seas. In the secondary formations, which succeed the eocene in depth and order of antiquity, the chambered siphoniferous shells become more numerous and diversified; they depart further from the two remaining recent types, and manifest a rich variety of form and structure. From these modifications of the shells we not only infer corresponding differences in the habits of their extinct occupants, but we can trace, in some instances, the nature of the associated differences in the organisation of the perishable soft parts.

The vast number of the complex shells known by the names of Ammonites, Orthoceratites, Hamites, Baculites, Turrilites, Belemnites, &c.; and the constancy which particular genera and species manifest in their relations to particular strata, indicate that the functions which their molluscous fabricators performed in the organic economy of the ancient world must have been equal and closely analogous to those which have since been assigned to the Pectinibranchiate Gasteropods, that have superseded them in the seas of the tertiary and existing epochs.

What, then, were the nature and affinities of the extinct constructors of those ancient chambered siphoniferous shells? Earnestly and repeatedly had this question been pressed upon the attention of zoologists and comparative anatomists, and long was it before any satisfactory reply could be returned. The *Nautilus Pompilius* and *Spirula australis*, which represent in the existing seas that vast assemblage of siphoniferous Mollusca which peopled the ocean during the secondary epochs, could alone yield the requisite data for its determination, and for a long period comparative anatomists were disappointed in their demands for these most rare and coveted subjects. In fact, until the year 1832, geologists could be supplied only with conclusions based upon more or less probable analogies and conjectures. Before this period, only one account of the *Nautilus Pompilius* was extant, in the work of Rumphius, a Dutch naturalist of the 17th century, whose figure of the animal was pronounced by Cuvier, the profoundest malacologist of his age, to be 'indechiffrable.' The little light that it might have thrown upon the interesting question of the affinities of the Nautilus was obscured by the grotesque, and, as they have since proved to be, fictitious figures of the animal, subsequently published by De Montfort and Dr. Shaw, and the evidence of Rumphius seems to have been rejected by the naturalists of the French circumnavigatory expedition under Captain Freycinet, who, on their return in 1831, published a description and figures of part of an unknown molluscous animal, presumed to be that of the *Nautilus Pompilius;* and which, had their conjecture been verified, would have indicated the chambered shell of the Nautilus to have been an appendage to some huge Gasteropod, allied to the Carinaria.

If the claims of the Ammonite and its extinct congeners to take rank in a higher class of Mollusca, had appeared to some zoologists to be established by the figure of the animal of the *Spirula*, published by Peron, it might, at the period to which I allude, have been objected that this evidence, likewise, had been invalidated by Fremenville's assertion to Brongniart, cited by De Blainville *, that the animal of the Spirula was wholly different from Peron's description of it.

If an appeal had been made from the unsatisfactory and conflicting evidence derivable from the existing chambered siphoniferous shells to the simple univalve of the *Argonauta*, which resembles them in its symmetrical figure, it might, on the one hand, have been objected that the correspondence of outward form alone, without the camerated and siphonated structure, was insufficient to support the conclusion of the cephalopodic nature of the *Nautilus* or *Spirula*, since the shell of the *Carinaria* might have been adduced as much more closely resembling that of the Argonauta; and, on the other hand, the scepticism of the majority of conchologists as to the Argonaut shell being actually fabricated by the Cephalopod usually found in it, might, until a very recent period, have been adduced to show how little value could be attached to the superficial resemblance between the Argonaut shell, and that of the Nautilus, in the determination of the Cephalopodic character of the constructor of the latter; and, by inference, of those of the allied extinct chambered shells. Most acceptable, therefore, at this conjuncture, was the arrival of the molluscous inhabitant of the *Nautilus Pompilius*, and a just subject of congratulation to us when we reflect on the share which this College has had in supplying the much wanted information.

The long-sought-for animal was captured in the South Seas by Mr. George Bennett, a member of the College, and by him presented

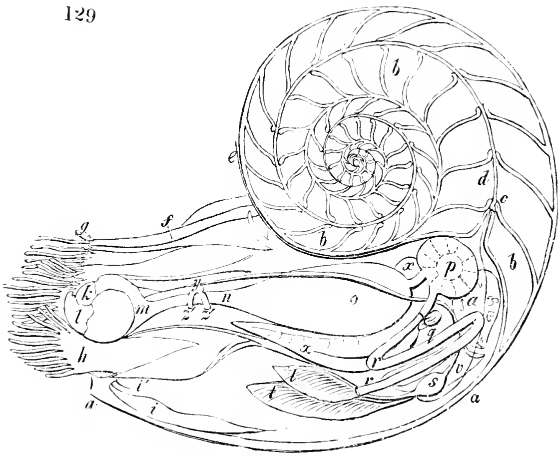
* Malacologie, t. i. p. 381., 8vo. 1825. Nouvelles Annales du Muséum, t. iii. p. 20. 4to 1834.

to the museum: here it was anatomised, and the description with copious and beautful illustrations published by the Council.*

The dissection of this unique specimen established the claims of the *Nautilus Pompilius* to rank in the highest class of Mollusca, and at the same time brought to light so many important modifications in the cephalopodic type of structure as to necessitate the establishment of a new order for its reception. I propose to devote the present Lecture to the demonstration of the principal organic characters of this order, which I have called *Tetrabranchiata*, and to a brief review of the extinct chambered siphoniferous shells, and of their relations to the existing Cephalopoda.

The soft parts of the pearly Nautilus (*fig.* 129.) form an oblong

129



Nautilus Pompilius.

mass divided by an irregular transverse constriction into two nearly equal segments; the posterior is smoothly rounded, soft, and membranous, containing the viscera, and adapted to the last chamber of the shell; the anterior is densely muscular, and includes the organs of sense and locomotion.

The mantle is very thin upon the posterior part of the body; it is continued backwards in the form of a slender tube, which penetrates the calcareous siphon (*c*), in the septum closing the occupied chamber behind, and is thence continued, as the membranous siphon (*d*), through all the other divisions of the shell to the central nucleus. As the mantle advances towards the anterior part of the abdomen, it increases in thickness, becomes more muscular, and extends freely out-

* Memoir on the Pearly Nautilus, 4to. 1832.

wards, forming a wide concave fold in the dorsal aspect (*e*), which is reflected over the black-stained involuted convexity of the shell. The margin or collar of the mantle is continued downwards and forwards on each side with a sinuous outline, and is perforated below for the passage of the muscular expiratory and excretory tube called the funnel (*i*). Besides the muscularity of the free border of the mantle, which indicates its power of extension and contraction, its surface is studded with the orifices of many minute glandular crypts; and it is the organ by which the growth of the shell is principally effected. The nidamental glands form two circular convexities on the ventral surface of the abdomen, behind which the mantle is encircled by a thin layer of brown matter, like the periostracum, which is very narrow above and below, but expands on each side into a broad plate, corresponding in size and form with the surfaces of attachment of the two great muscles for adhesion to the shell.

The anterior or muscular division of the Nautilus, which may be termed the head, forms a strong and wide sheath, containing the mouth and its more immediate appendages; its inner surface is for the most part smooth, the outer one divided and extended into many parts or processes. The chief of these forms a broad triangular muscular plate or hood (*f*), covering the upper part of the head, and presenting a middle and two lateral superficies; the former being traversed by a median longitudinal furrow, indicating the place of confluence of the two large hollow tentaculiferous processes of which it is composed. The back part of the hood is excavated for the lodgement of the involuted convexity of the shell, and the above-described fold of the mantle covering it. Each side of the head supports a group of perforated processes or digitations, the largest of which is next the hood, and the rest decrease in size as they descend in position. Exclusive of the short subocular, perforated process *, the digitations are eighteen in number on each side disposed irregularly, but all directed forwards, some not reaching as far as the anterior margin of the head, others projecting a few lines beyond it. They are of a conical, subtriedral form: the large one next the confluent pair which forms the hood, has, like that part, a papillose outer surface. Each process contains a long and finely annulated tentacle (*g*), of a subtriedral form, with the inner surface incised, as it were, by deeper and fewer cuts (*fig.* 132. *e*), so as to present the appearance of a number of close set transverse plates, slightly indented by a median longitudinal impression (*fig.* 132. *f*). This modification must increase the prehensile and sentient properties of the inner surface of the tentacle, and it is

* Particularly described and shown not to be tentaculiferous by M. Valenciennes, Nouvelles Recherches sur le Nautile Flambé, Archives du Muséum, 4to. 1839.

on the corresponding part of the larger and fewer tentacles of the dibranchiate cephalopods that the acetabula are developed. The angle between the two outer finely annulated surfaces subsides near the end of the tentacle, which thus becomes flattened.

To the nineteen tentacula which are supported by the confluent and free digitations on each side of the head, two others must be added, which project from very short sheaths, one before, the other behind, the eye; the lateral transverse incisions are deeper in these than in the digital tentacles. The eyes are about the size of hazel nuts, and are attached each by a short peduncle to the side of the head, behind the digitations, and a little below the margin of the hood. The inferior surface of the oral sheath is excavated for the lodgement of the infundibulum.

The mouth is armed with two mandibles, shaped, as in other cephalopods, like the beak of a parrot reversed, the lower mandible (*fig.* 129, *l*) overlapping and curving upwards beyond the upper one (*k*). Both mandibles are horny, with their tips encased by dense calcareous matter, and their base implanted in the thick muscular parietes of the mouth.

They are immediately surrounded by a circular fleshy lip with a plicated anterior border, external to which there are four broad flattened processes continued forwards from the inner surface of the oral sheath, two of which are superior, posterior, and external, the other two (*h*) are inferior, anterior, and more immediately embracing the mouth: the latter are connected together along their inferior margins by a middle lobe, the inner surface of which supports a series of longitudinal lamellæ. On the inner surface of the oral sheath beneath these processes there are two clusters of soft conical papillæ, and on each side of these a group of lamellæ. Each of the four processes, which I have called 'labial,' is pierced by twelve canals, the orifices of which project in the form of short tubular processes from the anterior margin, and each canal contains a tentacle similar to, but somewhat smaller than those of, the digitations. Thus the number of tentacula with which the pearly Nautilus is provided, amounts to not less than ninety, of which thirty-eight may be termed digital, four ophthalmic, and forty-eight labial. In the second specimen of this rare molluscous animal, presented to the college by Captain Sir Edward Belcher, there was a slight difference in number in the digital tentacula of the two sides, nineteen being on the right, and seventeen on the left side. The labial processes in the specimen of Nautilus described by M. Valenciennes contained thirteen tentacles instead of twelve; and some slight variation is not surprising in the number of prehensile organs developed in such unwonted profusion in the Nautilus.

The skeleton of the Nautilus consists of two parts, equally distinct in their position, texture, and organic properties: the one is the external chambered shell; the other is a rudimental cartilaginous cranium, which sends out processes for the attachment of the principal muscular masses. The shell of the Nautilus consists of an elongated sub-compressed cone, convoluted in close spiral whorls, upon the same plane, so as to be perfectly symmetrical. In the full-grown mollusk, three fourths of the shell from the commencement no longer serve to lodge the animal, but have been partitioned off, as they have been progressively evacuated, into a number of chambers (*fig.* 129. *b*, *b*), increasing regularly and gradually in size from the first to the last, or to the last but one. The open chamber (*a*, *a*), which contains the animal, is much larger than the rest, slightly curved, rounded behind and on the ventral aspect, and divided into two concavities on the dorsal aspect, by the projecting involuted spire. On the anterior surface may be observed two slight impressions of the large lateral muscles, and that of the connecting narrow cincture, and, posteriorly, the infundibular aperture of the calcareous siphon is seen at the middle of the last septum. This calcareous tube extends about one fourth of the way towards the succeeding septum, which, with all the others, is similarly perforated and prolonged backwards near their middle part. The septa, about thirty-five in number, are concave towards the aperture of the shell, except below, where they are convex transversely; for their circumference does not follow precisely the internal surface of the spiral cone, but describes a slightly sinuous outline. The shell consists of two layers; the outer one opake, white, or stained with the characteristic red-brown stripes; the internal layer is twice as thick as the former, and of a nacreous structure and aspect: the external surface of the shell is naturally covered with a reddish brown or greenish epiderm or periostracum; and upon the involuted convexity of the shell, the dorsal fold of the mantle deposits a thin plate of a vitreous texture, stained externally of a deep black colour, which can be traced as an extremely thin additional layer along the interior whorls of the shell. In the *Nautilus Pompilius* the hole or umbilicus, at the extremities of the imaginary axis round which the involutions of the shell have been made, is filled up by the deposition of the semi-vitreous material: but in the species or variety termed *Nautilus umbilicatus*, the margins of the dorsal fold of the mantle are not developed to the same extent, and the umbilicus continues open. The septa consist exclusively of the nacreous substance: they are thinnest at their margins, which, from their oblique applications to the wall of the shell, increase its thickness at the line of contact. The chambers are lined by a thin membranous pellicle, thrown off by the mantle when the animal was in the act of advancing forwards to enlarge its shell and form a new septum.

The internal cartilaginous skeleton of the Nautilus is confined to the inferior surface of the head: no part of it extends above the œsophagus. Viewed sideways, it presents a triangular form; a portion of the annular brain is protected by a groove on the upper surface of the cartilage: two strong processes are continued from its anterior and superior angles into the crura of the infundibulum, giving origin to the chief muscles of that part. Two other thinner processes are continued backwards, and curve inwards and downwards: they give origin to the two great muscles which pass from the internal to the external skeleton, or, in other words, attach the animal to the shell.

The muscular fibres of the head or oral sheath arise from the whole of the anterior or outer part of the internal skeleton. The muscular structure of the funnel presents a much greater development than in the naked Cephalopods; and, from its relation to those masses which, on the one hand, attach the soft parts to the shell, and, on the other, connect the head to the body, we may conclude that the funnel is the principal organ of natation, and that the Nautilus is propelled, like the Octopus, by a succession of jerks occasioned by the reaction of the respiratory currents upon the surrounding water. The orifice of the funnel is guarded by a valve (*fig.* 129. *i′*).

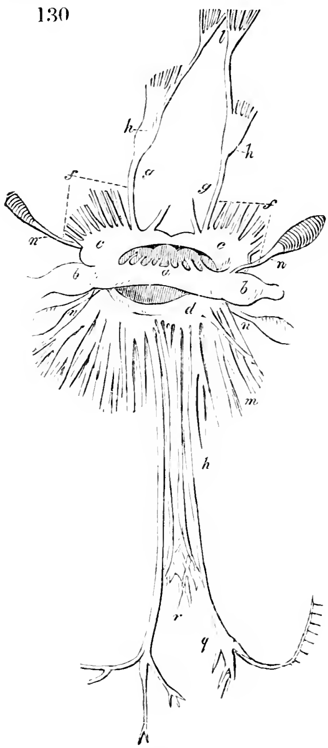
The retraction of the tentacula is done by longitudinal fibres, the elongation by transverse ones. These are not, however, disposed in circular or spiral series, so as to attenuate and lengthen the tentacle by a general compression, but present a more complex and beautiful disposition by which they diminish the transverse diameter without compressing the central nerve. The transverse fibres (*fig.* 132. *a*) arise in numerous and distinct fasciculi from the dense cellular tissue (*fig.* 132. *b*), surrounding the nerve in the centre of the tentacle (*fig.* 132. *d*), and radiate at equal distances to the circumference; they divide and subdivide as they diverge, and also send off lateral fibres, which form a delicate network in the interspaces of the rays, especially at the angles: the meshes include the longitudinal fasciculi, the cut ends of which are shown at *c*, *fig.* 132.

The mechanical arrangement of the contractile fibres is very similar to that of the complex muscles described by Cuvier in the proboscis of the elephant. The attenuation and elongation of this brobdignagian tentacle must be effected without compressing the central breathing tubes, and transverse fibres accordingly radiate from the dense ligamentous tissue which surrounds them: the same prospective contrivance is manifested to prevent the compression of the nerves and vessels in the muscular system of the ninety proboscides of the Nautilus.

For the special account of the myology of the Nautilus, which includes the muscles of the oral sheath and its digitations, those of the labial processes and mouth, those of the infundibulum, those for adhesion to the shell, those of the mantle, those of the tongue, the fibres of the tunic inclosing the liver and stomach, and the muscles of the organic system, I must refer to the published monographs on the anatomy of this animal.*

The principal masses of the nervous system of the Pearly Nautilus (*fig.* 130.) are concentrated in the head. The supra-œsophageal part, or brain (*a*), presents the form of a short, thick, transverse, round chord or commissure, connected at each extremity with three ganglionic masses. The middle and superior of these (*b*) supplies the eye and the inferior hollow tentaculiform organ: the anterior and inferior ganglion (*c*) meets its fellow below the œsophagus: the posterior ganglion (*d*), in like manner, joins that of the opposite side and forms a second and posterior œsophageal ring. The nerves given off immediately from the supra-œsophageal mass supply the muscular and other parts of the mouth, and have small pharyngeal ganglions developed upon them. The anterior œsophageal ring gives off principally the nerves to the tentacula (*f*, *f*), and the two median ones (*g*) are connected with a ganglion (*h*), which supplies the tentacula of the inferior labial processes and the lamellated organs on that part of the oral sheath. The tentacular nerves are continued, like those of the arms in the higher Cephalopods, along the middle of the tentacle, at-

130



Nervous System. Nautilus.

* Memoir on the Pearly Nautilus. 4to. 1832. Valenciennes, Archives du Muséum d'Histoire Naturelle. 1839.

tached by loose cellular tissue to the vessels of the part. The posterior collar gives off numerous nerves (*m*) of a flattened form, which supply the muscles of the shell. The respiratory nerves form a small ganglion (*q*) at the base of each pair of gills, from which branches are sent to those organs, to the heart, and to the appendages of the veins. A plexus of more delicate visceral nerves (*r*) is continued backward along the interspace of the branchial nerves, and the chief branches are connected with a small ganglion situated between the cardiac and pyloric orifices of the stomach. The posterior subœsophageal nervous mass combines the analogues of both the branchial and pedial ganglions in the inferior Mollusca: the anterior ring answers to the ganglia in the higher Cephalopods, called 'pes anserinus' by Cuvier: the ophthalmic tentacula, which derive their nerves (*n*, *n*) close to the origin of the optic ganglion, may be considered as analogous to the four tentacula in the Aplysia. The hollow plicated process beneath the eye, which Valenciennes regards as the olfactory organ, likewise receives its nerves from the extremity of the supra-œsophageal chord. Three small nervous filaments, described by the same author as passing from the extremity of the supra-œsophageal chord to the adjoining part of the cephalic cartilage, he considers as acoustic nerves; but these nerves are given off from the sub-œsophageal ganglion in the higher Cephalopods, and in all the Gasteropods, in which the organ of hearing has been observed.

The eyes, as before stated, are attached each by a short pedicle to the side of the head, over-arched by the projecting margin of the hood. The form of the ball is sub-hemispherical, being flattened anteriorly along its inferior border, there is a slightly elevated ridge, from which a smaller ridge is continued to the middle of the anterior surface of the eye, which is perforated by a round pupillary aperture, about a line in diameter. The sclerotic tunic, which is a tough, ligamentous membrane, is thickest posteriorly, and becomes gradually thinner to the margin of the pupil. The optic filaments form a pulpy mass at the floor of the eye, from which the retinal expansion is continued as far forwards as the semidiameter of the globe: it is lined, like the rest of the interior of the eye, by a thick black pigment, which is doubtless perforated by the retinal papillæ, or otherwise a perception of light must take place in a manner incompatible with our knowledge of the ordinary mode in which the retina is effected by luminous rays. The crystalline lens would seem to be small, if it exists independently of the vitreous humour: it was not present in the specimen dissected by me, and M. Valenciennes states that he was unable to observe any of the humours of the eye.*

* Loc. cit., p. 289.

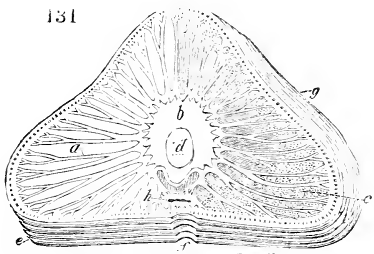
The cavity in the cephalic cartilage, apparently that described in my Memoir * as containing a sinus of the cephalic veins, but which M. Valenciennes regards as the organ of hearing, is defective in the structures which the uniform analogy of that organ in the molluscous subkingdom leads us to conclude are essential to it: there were no traces, for example, of otolithes.† This militates more strongly against the idea of the French anatomist than even the place of origin and anomalous number of the minute nervous filaments which he describes as penetrating the cavity in question.

With respect to the organ of smell, most physiologists will, I think, admit that the structure and position of the soft close-set membranous lamellæ at the lower and inner part of the oral sheath immediately in front of the mouth, manifest the conditions of the olfactory organ more fully and naturally than do those short hollow tentacles which project from the outside of the head beneath the eyes.

The complex and well developed tongue of the pearly Nautilus exhibits in the papillæ of its anterior lobes and in the soft ridges of its root, the requisite structure for appreciating the quality of taste.

The papillæ upon the exterior surface of the two large confluent digital processes forming the hood and of the two digitations next in size immediately beneath them, form a remarkable character in the Nautilus, on account of their obvious similarity to tactile papillæ; but the sense of touch must be specially exercised by the numerous cephalic tentacles, which, from their softness of texture, and especially their laminated inner surface (*fig.* 131. *f*), are to be regarded as organs of exploration not less than as instruments of prehension.

131



Section of tentacle, Nautilus.

The calcareous extremity of the upper mandible is sharp-pointed and solid to the extent of five lines. The lower mandible is sheathed with a thinner layer of the hard white substance, which forms a dentated margin. The fossils termed 'rhyncholites,' are the analogues of these calcareous extremities of the beak in cognate extinct cephalopods. The muscular subspherical mass, which supports and moves the mandibles, is provided with four retractors, and can be protruded by a strong semicircular muscle, which is continued from the margin of one of the inferior labial

* On the Pearly Nautilus, 4to, 1832, p. 16.

† "Elle était remplie d'une pulpe homogène" (coagulated blood?), "et ne contenait aucune sorte de concrétions." — Loc. cit., p. 291.

processes over the mandibles and their retractor muscles to the labial process of the opposite side.

The tongue is supported by a horny, slightly curved, and transversely striated plate. The fleshy substance of the tongue forms three distinct papillose caruncles anteriorly, into which the retractor muscles are inserted. The dorsum of the tongue is incased by a thin layer of horny matter, supporting four longitudinal rows of recurved spines; behind which the surface is again soft and papillose. Two broad duplicatures of mucous membrane project forwards from the sides of the pharynx; they each include a simple layer of salivary follicles, the secretion of which escapes by a single perforation in the middle of the process.

The lining membrane of the pharynx is disposed in numerous longitudinal folds, where it begins to contract into the œsophagus. This tube, having passed through the nervous collar, dilates into a capacious crop, from the bottom of which a contracted canal, half an inch in length, is continued to an oval gizzard. The intestine commences near the cardiac orifice, and soon communicates with a small round laminated pouch, through which the biliary secretion passes to the intestine. This tube forms two abrupt inflections, and terminates in the branchial cavity near the base of the funnel close to the proboscidian end of the oviduct.

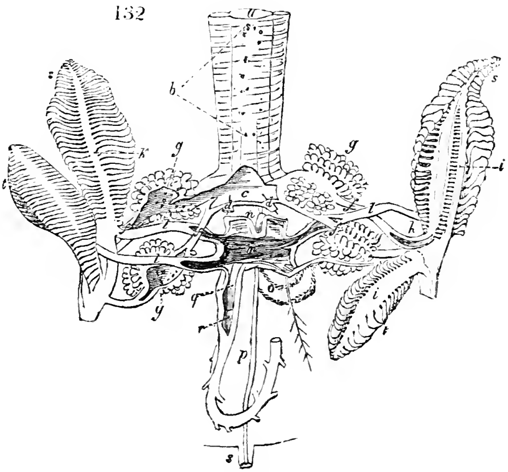
The epithelium of the œsophagus and ingluvies is developed into a thick cuticular membrane, with minute ridges in the gizzard. In the specimen dissected by me the crop and gizzard were laden with the fragments of a small crab, the pieces being more comminuted in the gizzard.

The liver is a bulky gland, extending on each side of the crop as low down as the gizzard; it is divided into four lobes, connected posteriorly by a fifth transverse portion: the lobes are subdivided into numerous lobules of an angular form. The secretion of the bile is derived, as in other mollusks, from arterial blood; it is conveyed from the liver by two main trunks, which unite into one duct, about two lines from the laminated sac. The bile, having entered the sac, is diverted by a peculiar development and disposition of one of the laminæ from flowing towards the gizzard. The follicular structure of this and the other folds of membrane indicate their glandular character; and the entire laminated pouch may be considered as a more developed form of pancreas than the simple cæcum which represents that gland in some of the Gasteropods. No other foreign secretion enters the alimentary canal, as there is not any ink-gland in the Pearly Nautilus.

The heart and large vessels, with their follicular appendages, are contained in a large cavity, subdivided into several compartments, which I have termed pericardium; it is separated from the branchial cavity by a strong membranous partition, in which the following orifices are observable. In the middle the termination of the rectum, to the right of this the orifice of the oviduct, and on each side at the roots of the anterior branchiæ there is a small mamillary eminence with a transverse slit, which conducts from the branchial cavity to one of the compartments of the pericardium containing two clusters of venous glands. There are also two similar, but smaller, slits contiguous to one another, near the root of the posterior branchia on each side. These, which seem to have been overlooked in my first dissection, were detected by M. Valenciennes in the specimen of the *Nautilus Pompilius* which he has recently described*; and I have observed them in that subsequently presented to the College by Capt. Sir E. Belcher. They lead to the compartments which I formerly described and figured†, containing the posterior clusters of the venous follicles. These compartments M. Valenciennes regards as shut sacs, communicating only by the above-mentioned apertures with the branchial cavity.

The venous branches, from the labial and digital tentacles, and adjacent parts of the head and mouth, terminate with those from the funnel in the sinus, partly excavated in the body of the cartilaginous skeleton, and in part continued round the œsophagus. From this sinus, the great vena cava (*fig.* 132. *a*) is continued, running in the interspace of the shell-muscles on the ventral aspect of the abdominal cavity, and terminating within the pericardium by a slight dilatation (*c*), which receives by two veins (*d*) the blood from the different viscera. The vena cava is separated by a layer of decussating muscular fibres from the abdominal cavity, which closely adheres to the parietes of the vein.

132



Nautilus Pompilius.

* Archives du Muséum, p. 257. 4to. 1839.
† Memoir on the Nautilus, p. 32. 1832. Plate 5. *u*, *u*.

There are several small intervals left between the muscular fibres and corresponding round apertures (*b*) in the membrane of the vein and peritoneum. This communication, with the general abdominal cavity, is similar to that already noticed in the Aplysia *: M. Valenciennes detected the same structure in the specimen of the Nautilus dissected by him.†

The branchial circulation may be considered to commence, when the blood again begins to move from trunk to branches, four of which are continued from the terminal venous sinus to convey the carbonized blood to the four gills, of which there is a larger (and a smaller one) on each side. Each pair of gills is connected by a common peduncle to the inner surface of the mantle; the larger branchia consists of a central stem supporting forty-eight vascular plicated lamellæ on each side; the smaller branchia has thirty-six similar lamellæ on each side.

The four vessels (*f, f*) continued from the venous sinus have attached to them, in their course to the gills, clusters of glandular follicles (*g, g*) of a simple pyriform figure: each vessel has three clusters of such glands contained in the membranous receptacles above mentioned. The walls of these receptacles exhibit in some parts a fibrous texture, apparently for the purpose of compressing the follicles, and discharging the contents of the membranous receptacles into the branchial cavity, by the apertures above mentioned at the base of the gills. Doubtless, therefore, the glands are emunctories, and eliminate from the venous blood an excretion, most probably analogous to urine. Their analogues exist in the higher Cephalopoda, in which they are considered to act as kidneys by Mayer; and it is more philosophical to conclude that the organs of so important an excretion should be present in all the class, than that they should be represented by the ink-gland and bag, which are peculiar to one order.

The veins (*f, f*) extend beyond the follicles each to the root of its respective gill, where it receives a small vein. At this part there is a valve (*h*) which opposes the retrogression of the blood; the vessel, which may now be termed branchial artery, penetrates the root of the gill (*i*), and dilates into a wider canal, which is continued through the soft white substance forming the branchial stem. A double series of branches are sent off from the lateral lamellæ, which ramify and subdivide to form the capillary plexus, from which the returning vessels terminate in the branchial vein. These veins (*l, l*) quit the roots of the gills, and return to terminate at the four corners of a subquadrate transversely elongated ventricle (*m*). From this ventricle two arteries

* P. 301. † Loc. cit. p. 287.

arise, one superior and small (*n*), the other inferior (*r*), and strengthened by a muscular bulb (*q*) to the extent of nearly half an inch. An elongated pyriform sac (*o*) is attached by a contracted origin near the root of a large aorta, and dilates to a width of two lines; then, again contracting, becomes connected by its other extremity to the venous sinus: it contained a firm coagulated substance. M. Valenciennes does not appear to have noticed this peculiar organ. The anterior aorta supplies the nidamental gland, and adjoining part of the mantle, and the rectum; then bends back to form the small artery (*p*), continued along the membranous siphon (*s*). The large aorta supplies the gizzard and ovary, winds round the bottom of the abdominal sac, sends off large branches to the liver, and regains the dorsal aspect of the crop along which it passes to the œsophagus, distributing branches on either side to the great shell-muscles. It bifurcates near the beginning of the œsophagus, and terminates by furnishing branches to the mouth, the surrounding parts of the head and funnel.

The female organs of the Nautilus consist of an ovary, an oviduct, and, as in the Pectinibranchiate Gasteropods, of an accessory glandular nidamental apparatus. The ovary (*fig.* 129. *u*) is situated at the bottom of the sac on the right side of the gizzard in a peritoneal cavity peculiar to itself. It is an oblong compressed body, one inch and a half in length, and an inch in breadth; convex towards the lateral aspect, and on the opposite side having two surfaces sloping away from a middle longitudinal elevation. At the anterior and dorsal angle there is an orifice about three lines in diameter, with a puckered margin, which conducts into the interior of the ovary. It is filled with numerous oval ovisacs of different sizes, which are attached by one extremity to the ovarian capsule, but are free and perforated at the opposite end; are smooth exteriorly, but rugose and apparently granular on the inner surface, owing to numerous minute wavy plicæ adhering thereto. The largest of the ovisacs were four or five lines in length; they were principally attached along the line of the exterior ridge, at which part the nutrient vessels penetrated the ovary.

The oviduct (*fig.* 129. *v*) is a flattened tube of about an inch in length, and from four to five lines in breadth; it extends forward by the side of the intestine, and terminates at the base of the funnel close to the anus. It becomes enlarged towards the extremity, and is deeply furrowed in the transverse direction both within and without; the parietes are also here thick and pulpy, and apparently glandular. It is probable, however, that the ova derive an additional exterior covering and connecting substance from the secretion of a large glandular apparatus, which is situated immediately below the terminal orifice of the oviduct. This apparatus is attached to the mantle, and gives rise to the two rounded convexities observable on the ventral aspect of the body behind the funnel. It is a transversely oblong mass, composed of numerous close-set pectinated membranous laminæ, which are about a quarter of an inch in depth, and are disposed in three groups; those of the larger group extend transversely across the mesial line of the body, and are unprotected by a membrane; but the two smaller divisions are symmetrically disposed, and have the unattached edges of the laminæ covered by a thin membrane, which is reflected over them from the anterior margin of the glandular body. These divisions form the sides and anterior part of the gland; and as the secreted matter must pass backwards to escape from beneath the margin of the protecting membrane, this membrane may serve both to conduct the secretion nearer the orifice of the oviduct, and also to prevent its being drawn within the respiratory currents of water, and so washed away as soon as formed.

In contrasting the organisation of the Nautilus with that of the inferior Mollusca treated of in the two preceding lectures, we find the main advance to have been made in the organs of animal life.

A true internal skeleton is established in the Nautilus, and thus the lowest Cephalopod offers an approximation to the Vertebrate type, which not even the highest of the Articulate series had attained. Perfect symmetry now reigns throughout the animal and vital organs. The muscular system forms a larger proportion of the body, with various arrangements and complications unknown in the lower Encephalous mollusks. The respiratory tube, though still completed by the overlapping, not by the coalescence, of its side-walls, has received an enormous development as contrasted with the siphonated Trachelipods; and, by its powerful muscles and their firm cartilaginous basis of attachment, it is evidently endowed with a new function, in relation to propelling the Cephalopod with its testaceous dwelling through the sea.

The nervous centres concentrated in the head have received a marked increase of bulk, which, nevertheless, is still manifested more strongly in the inferior masses, and especially the anterior subœsophageal ring than in the superior or cerebral part. Here, however, we find for the first time in the Molluscous series, especial ganglions subordinated to the greatly enlarged organs of vision.

The organs of reptation, which had progressively advanced (as Lamarck's denomination of the higher Gasteropods indicates) towards the head, are exclusively attached to that part in the Nautilus, and project from before the eyes and mouth. The mouth, besides its jaws and spiny tongue, is now served by organs of prehension; and it is most interesting to observe that these cephalic tentacula, at their first appearance, manifest the vegetative character in their multiplied repetition and comparative simplicity, compared with their analogues in the superior Cephalopods.

Some of the Gasteropods have a pair of jaws working upon each other, but in the horizontal plane, as in insects: in the Nautilus they are opposed to each other vertically, as in the Vertebrate series, and they present a form which is repeated amongst fishes by the Scari, amongst reptiles in the Chelonia, and almost universally in the class of Birds. The close resemblance to the latter class which the Nautilus offers in the modifications of the alimentary canal is sufficiently striking, but hardly more so than that the radiated animalcules presented, in which we discerned the germs, as it were, of the great molluscous branch of the Animal Kingdom.

In the very few conchiferous Gasteropods that are able to swim, the shell is of diminutive size, of a simple form and structure, and of an extremely light and delicate texture. The strong and muscular occupant of the Pearly Nautilus-shell would not have been able, notwithstanding its higher organization, to have risen and swam on the surface of the ocean unless it had been relieved from the impediment of its large and dense abode by the introduction of some special modification in the testaceous structure.

This is effected by the adoption, in the Nautilus, on a more definite plan and larger scale, of the second mode of dealing with the part of the shell successively vacated during the rapid growth of the animal, which has been defined in the general account of the structure and formation of univalve shells given in the foregoing lecture.* The abdominal part of the mantle of the Nautilus is attached to the inner surface of the shell by the intervention of a horny or epithelial cincture, the expanded lateral portions of which serve as the medium of insertion of the adherent muscles of the shell: the cavity of the shell posterior to this attachment is thus hermetically closed. A third point of attachment is to the bottom of the shell by the posterior extremity of the mantle, which probably presents a conical form in the embryo Nautilus. The line of attachment of both the muscles and the cincture progressively advances with the growth of the animal. A certain portion of the fundus of the shell thus becomes vacated, and the Nautilus commences the formation of a new plate for the support of the part of the body which has been withdrawn from the vacated shell. The formation of the plate proceeds from the circumference to the centre, and there meeting the conical process of the mantle, which retains its primitive attachment, the calcification is continued backwards for a short distance around that pro-

* P. 297.

cess, which now forms the commencement of the membranous siphon, and acquires the partial protection of the calcareous tube. An air-tight chamber is thus formed, traversed by the siphon, which perforates its anterior wall or septum; by a repetition of the same processes, a second chamber is formed, included within two perforated septa; and similar, but wider partitions continue to be added, concurrently with the formation of the new layers which extend and expand the mouth of the shell, until the animal acquires its full growth, which is indicated by the body having receded for a less distance from the penultimate septum before the formation of the last septum is begun.

The periodical formation of these septa in the progress of growth is analogous to that of the projecting external plates in the Wendletrap, and of the rows of spines in the Murex; but these external processes consist of the opake calcareous layer of the shell, whilst the internal processes in the Nautilus consist of the nacreous layer like the septa in the Turritella. Thus the embryo Nautilus at first inhabits a simple shell like that of most univalve Mollusca, and manifests, according to the usual law, the most general type at the early stage of its existence; although it soon begins, and apparently before having quitted the ovum, to take on the special form.

In acquiring the camerated structure of the shell, the Nautilus gains the power of rising from the bottom and the requisite condition for swimming; by the exhalation of some light gas into the deserted chambers, it attaches to its otherwise too heavy body a contrivance for ascending in its atmosphere, as we ascend in ours by the aid of a balloon. But the Nautilus, superior to the human aeronaut, combines with the power of elevating and suspending itself in the aqueous medium, that of opposing its currents and propelling itself at will in any direction. It possesses the latter essential adjunct to the utility of the balloon as a locomotive organ, by virtue of the muscular funnel, through which it ejects into the surrounding water, doubtless with considerable force, the respiratory currents.

It appears that the proportion of the air chambers to the dwelling chamber of the Nautilus and its contents, is such, as to render it of nearly the same specific gravity as the surrounding water. The siphon, which traverses the air chambers, communicates with the pericardium, and is most probably filled with fluid from that cavity.

Dr. Buckland conjectures that the Nautilus may possess the power of ejecting such fluid into the siphon, and thereby of compressing the gas of the chambers and increasing the specific gravity of the shell. Such, indeed, were the siphon dilatable, would be the natural effect of the contraction of the animal within its shell. The consequent pressure of the dense anterior muscular segment upon the soft and yielding visceral cavity, resisted at the same time by the unyielding posterior plate at every point, save that from which the siphon was continued, would propel into that tube as much fluid as it might be capable of receiving. These consequences would follow the instinctive retraction of the animal when alarmed; and if they should take place while it was floating on the surface, it would immediately begin to descend. If, desiring to rise again from the bottom, the Nautilus should protrude its body from the mouth of the shell, extend the folds of its mantle, and spread abroad its tentacula, it would withdraw the pressure from the abdomen, and, by the act of advancing, create a tendency to a vacuum in the posterior part of the shell. The fluid in the siphon would then, if that tube were contractile, return into the pericardial cavity, the gas in the chambers would expand, and the specific gravity of the animal be sufficiently diminished to cause the commencement of its ascent, which would doubtless be accelerated by the reaction of the respiratory currents upon the water below.

Neither the contents, nor the vital properties of the siphon are however yet known: an artery and vein are assigned for its life and nutrition: but the structure of the membranous siphon, in the specimens from which I have had the opportunity of examining it in a recent state, presents, beyond the first chamber, an inextensible and almost friable texture, apparently unsusceptible of dilatation and contraction: it is also coated beyond the extremity of the short testaceous siphon with a thin calcareous deposit. A graver objection to the hydrostatic action of the siphon is founded upon its structure in certain extinct species of Nautilus, as the *N. Sipho*, in which it is provided through its whole extent with an inflexible outer calcareous tube, rendering it physically impossible that the gas of the chambers could be affected by any difference in the quantity of fluid contained in the siphon. In the *Nautilus striatus*, also, the calcareous siphon is a continuous tube, slightly dilated in each chamber.

From these facts I incline rather to the conclusion, that the sole function of the air-chambers is that of the balloon, and that the power which the animal enjoys of altering at will its specific gravity, must be analogous to that possessed by the fresh-water testaceous Gasteropods, and that it depends chiefly upon changes in the extent of the surface which the soft parts expose to the water, according as they may be expanded to the utmost, and spread abroad beyond the aperture of the shell, or be contracted into a dense mass within its cavity. The Nautilus would likewise possess the additional advantage of producing a slight vacuum in the posterior parts of the chamber of occupation which is shut out by the horny cincture, and muscles of adhesion from the rest of that cavity.

Whatever additional advantage the existing Nautilus might derive, by the continuation of a vascular organised membranous siphon through the air-chambers, in relation to the maintenance of vital harmony between the soft and testaceous parts, such likewise must have been enjoyed by the numerous extinct species of the tetrabranchiate Cephalopods, which, like the Nautilus, were lodged in chambered and siphoniferous shells.

If the Nautilus extended itself in a straight line during its growth, instead of revolving round an imaginary axis, a straight conical shell would be produced, with the chambered part divided by simple septa concave next the outlet. Such are, in fact, the characters of the fossil shells called *Orthoceratites*. The siphon is usually central, but sometimes marginal; it is testaceous throughout, and generally moniliform or dilated at each chamber; this structure Dr. Buckland remarks, would admit of the distension of a membranous siphon. Mr. Stokes has discovered in a species of Orthoceratite from Lake Huron, a second calcareous siphon included within the moniliform siphon, which shows no corresponding partial dilatations, but is connected to the external siphon by successive series of radiating tubuli; the inner siphon was probably produced by a calcification of the membranous siphon, and of processes continued from it at regular intervals. The complex siphons of these *Orthoceræ* are of great relative capacity, and the species so characterised have been separated from the simple Orthoceratites under the subgeneric name *Actinoceras*.

I have already alluded to the slightly undulating contour of the margins of the septa in the Nautilus, which makes the surface next the aperture of the shell convex at one part and concave at another. In an extensive genus of extinct chambered shells called 'Ammonites,' the sinuosity of the margins of the septa is much greater, and most of the surface next the outlet is convex: the siphon perforates the septa at their centre in extremely few species, and in the rest is situated at that margin which is next the outer curve or circumference of the shell. Certain chambered shells thus characterised are straight, like the Orthoceratites, but generally compressed, with their numerous septa joining the outer shell by foliated dentations: they are termed *Baculites*. In the true *Ammonites* the shell is discoid and coiled upon itself as in the Nautilus; but it is strengthened by arched ribs and dome-shaped elevations on the convex surface, and by the tortuous windings of the foliated margin of the transverse partitions. Separate casts of the interior of the chambers are not unfrequently obtained, which have become detached by the solution of the calcareous walls and septa of the shell, or are held together by the dove-tailed lobes of the margins of the chambers. The last chamber of the Ammonite was of large size, as in the Nautilus, and doubtless contained all the soft parts of the animal save the small proportion which was prolonged into the siphon. Certain species, recently described by Mr. Pratt from the Oxford clay, were characterised by the production of a long and narrow process from each side of the mouth of the shell, indicating a corresponding modification in the lobes of the mantle, analogous to that which produces the auricular appendages of the mouth of the shell in certain Argonautæ. The same gentleman has likewise recently shown me a small Ammonite in which the mouth of the shell is arched over transversely by a convex plate of calcareous matter continued from the lateral margins of the outlet, and dividing this into two apertures, one corresponding with that above the hood of the Nautilus, which gives passage to the dorsal fold of the mantle ; the other with that below the hood, whence issue the tentacles, mouth, and funnel : such a modification, we may presume, could not take place before the termination of the growth of the individual.

The *Turrilite* is essentially an Ammonite disposed in spiral coils. The Hamites and Scaphites are other modifications of the outward form of similarly-constructed chambered shells : in the former the small extremity of the shell is curved, the rest being straight ; in the latter both ends are curved towards each other like those of a canoe.

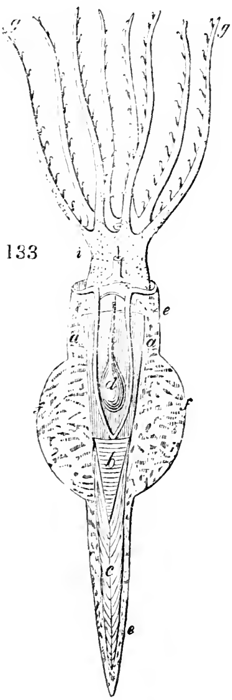
With none of these species has there ever been found a trace of the ink-bag ; a part, indeed, of so delicate a texture that some surprise may be excited in such of my hearers as are not conversant with the wonders of geology, that any evidence of its existence could be expected to be met with in a fossil state.

I shall, however, conclude this Lecture by bringing before you examples in which not only the ink-bag but the muscular mantle, the fins, the eyes, and the tentacles and their horny hooks, of extinct Cephalopods have been preserved from the remote periods of the oolitic deposits to the present time. Independently of these and many other examples of the durability of the inky secretion of the gland which is peculiar to the naked Cephalopods, the absence of the organ in the shell-clad Nautilus, too well protected to need such means of temporary concealment, would lead to the inference that the ink-bag must have been absent in the other low-organised Cephalopods covered by chambered siphoniferous shells.

A more complicated fossil shell than any of the preceding, but allied to them by the camerated and siphoniferous structure of one of its constituent parts, has occasioned much perplexity amongst Palæontologists ; the evidence of its nature has however for some years been in the main sufficient, in my opinion, to determine its affinities: but as the value of this evidence could only be appreciated by those who had studied the laws of correlation of the cephalopodic structures, it failed to produce general conviction; and the additional facts which I am able to-day to bring before you will not, therefore, be unacceptable. The shell to which I allude is that called the 'Belemnite,' which is associated with the more obvious congeners of the Nautilus through a considerable range of the secondary rocks.

The chambered part of the shell of this extinct Cephalopod has the form of a straight cone (*fig.* 133. *b*), the septa being numerous, with a slight and equable concavity directed towards the outlet or base of the cone. The intervening chambers are so shallow that the septa have been compared to a pile of watch-glasses. The septa are chiefly composed of nacreous substance, with a thin layer of opakĕ and friable calcareous matter on both surfaces, and the entire cone is enveloped in a sheath of opake calcareous matter lined with nacreous substance, and having on the outer surface, or there degenerating into, a pellicle or thin layer of a horny substance. This latter horny or albuminous tissue is continued forwards beyond the base of the chambered cone*, and forms the parietes of a cavity (*a*) containing some of the viscera of the animal.

133



Belemnite restored.

The chambered cone itself, with its sheath, is lodged in a conical cavity or alveolus † excavated in the base of a long conical or fusiform, sometimes compressed, spathose body (*c*), resembling the head of a dart or javelin, whence the name 'Belemnite,' applied to this genus of extinct Cephalopods. This spathose sheath or guard of the chambered cone is most commonly found detached from the rest of the shell, with its thin aveolar portion fractured, especially when fusiform and in the younger Belemnites, when it is pointed at both ends. In this state it has been mistaken for the spine of an Echinoderm. This opinion of Klein has been reproduced in later times by

* 'Phragmocone.'

† The term alveolus has been given improperly to the contents of the socket, viz. to the 'phragmocone.'

M. Raspail; but the instances of discovery of the guard associated with the chambered cone left no room for doubting its relationship with the Orthoceratites, although the precise degree of that relationship required much additional evidence for its determination.

The spathose guard consists of successive layers, of which the exterior ones run parallel with the outer surface, and progressively increase in length as they approach it, thus forming the conical cavity for the lodgemen of the chambered shell. The innermost or first-formed layers of the guard are not parallel with the outer ones, but recede from them at their upper extremity, where they form a point, and sometimes a dilated nucleus, in contact with the apex of the chambered cone. The interspace thus left between the early and the later strata of the guard is occupied by the coarse calcareous matter continued from the sheath of the chambered cone, and a filamentary process of apparently the same matter is continued down the centre of the guard to its apex.

The structure of the spathose layers of the guard is fibrous; the fibres being directed at right angles to the plane of the strata: viewed in thin sections by transmitted light it bears a close resemblance to that of the teeth of Pycnodont fishes, but certain proportions of the transverse fibres are apt so to intercept the light as to cause the appearance of elongated triangular dark specks, with their apices directed sometimes to the periphery, and sometimes to the centre of the guard. The microscopic structure proves this heavy spathose aggregation of subtransparent calcareous matter to be the effect of original formation, and not, as Walsh, Parkinson, and Lamarck supposed, of infiltration of mineral substance into an originally light and porous texture. Here is a section of a Belemnite *, in which the chambers of the cone have been filled with crystalline matter infiltrated from the water of the stratum in which the dead shell was imbedded; and you have a favourable opportunity of contrasting the crystalline condition of this infiltrated matter with the organised texture of the solid guard.

The exterior surface of this guard always exhibits, when perfect or entire, traces of vascular impressions: it is sometimes granular, and presents other modifications, which prove that it was covered by an organised membrane in the living Cephalopod. I have occasionally seen the remains of a more immediate investment by a thin friable layer of calcareous matter analogous to that of the outer layer of the sheath of the chambered cone, with which layer it becomes continuous. The exterior of the spathose guard is generally impressed with a longitudinal groove extending from the apex upwards.

* No. 1056. A.

The septa of the chambered cone are perforated by a marginal siphon, situated in most Belemnites on the side which is nearest the before-mentioned line or groove; but in certain species of Belemnites, characterised by the flattened form of the spathose guard, the siphon is on the opposite side. These Belemnites, which at first sight look like distorted or accidentally compressed specimens, are peculiar to certain members of the green sand formation, called the 'older Neocomian.' In some species the exterior of the guard is impressed with two opposite longitudinal channels in addition to the primitive and constant one.

Specimens of Belemnites have been discovered in which the spathose guard has been fractured during the lifetime of the animal; but the broken portions have been held together by the investing organised integuments, and have been reunited by the disposition of new layers of the fibrous structure peculiar to the guard. *

The existence of a camerated and siphoniferous structure on this complex and remarkable shell, induced most Zoologists to class it with the Ammonites and other more simple chambered shells. Mr. Miller having detected evidence of the internal position of the Belemnite in the exterior characters of the guard, first ventured upon a conjectural restoration of the entire animal †; and as only the dibranchiate type of Cephalopods was then known, he placed it in the body of a Calamary (*Loligo*), assigning to the terminal fins the office of clasping the guard and retaining it in its proper position.

The first evidence that bore directly upon the position of the Belemnite in the Cephalopodic class was detected by Drs. Buckland and Agassiz in specimens of Belemnite from Lyme Regis, in which the fossil ink-bag and duct was preserved in the basal chamber of the phragmocone. We must connect with this fortunate discovery the important fact, that remains of an ink-bag have never been met with in connection with any of the more simple or typical forms of chambered shells: we know that the ink-bag does not exist in the recent Nautilus; and it will be shown in the following Lecture that it is present in all the existing Cephalopods which possess more or less rudimental internal shells. I ought here, perhaps, to anticipate, or recapitulate the relations of co-existence of the ink-bag with the organization of the naked Cephalopods, which I pointed out, in 1832, in my description of the Nautilus Pompilius. The highly organized naked Cephalopods enjoy active powers of locomotion, which would be incompatible with the incumbrance of a large external protecting shell; but, to compensate for the want of this defence, nature has provided them with the power of secreting an inky fluid, which, when alarmed, they

* Duval-Jouve, Mémoire sur les Bélemnites. 4to. 1841. pl. x.

† Geological Transactions, N.S. vol. ii. p. 45. pl. ix. 1823.

eject into the surrounding water, and are concealed by the obscurity which they thus occasion. The branchial character of the naked Order of Cephalopods is an essential condition of their muscular powers. The presence of an ink-bladder, therefore, in the extinct Belemnites, would have implied the internal position of the shell, even if other proof had been wanting; and, by the laws of correlation, it implies likewise the presence of the muscular forces for rapid swimming, and the concomitant conditions of the respiratory, the vascular, and the nervous systems. Connecting, therefore, all these considerations with the detection of the ink-bag in the shell of the Belemnite, I could not hesitate in refering the Belemnites, and likewise the Spirula, on account of the ascertained internal position of its shell, to the Dibranchiate order, and I, therefore, separated these chambered and siphoniferous shells from the Nautilus and the Ammonites in the Classification of the *Cephalopoda* submitted to the Zoological Society in February 1836.

But the true grounds of this separation seem not to have been understood by some Palæontologists. Professor Phillips, for example, in his excellent Article on Turrilites in the part of the Penny Cyclopædia, published in January of the present year, has observed, "The relations of Turrilites, Scaphites, Baculites, and Hamites to Ammonites is very obvious; and, as through Goniatites, this great extinct group is certainly connected to the living and extinct Nautili, Mr. Owen has ventured to include them all in the Tetrabranchiate Cephalopoda (*Cephalopoda*), leaving Spirula and the Belemnites with Sepia and the Dibranchiate types. However this may be, the determination of the relative affinities among the numerous fossil Cephalopods, a point of great importance, must be worked out with the help of other considerations than the respiratory system." I have said enough to show that many other considerations than those of the respiratory system, and of equal importance with them, influenced me in the determination of the natural affinities of the Belemnites. Leopold Von Buch, who believed that he could trace in certain slabs containing Belemnites the impressions of the Cephalopods to which they belonged, concluded "that the body of the animal enveloped the greater part of the shell, and exceeded its length by eight or ten times." * Other considerations, taken from the shell itself, prove, as has already been shown, that it was wholly internal.

M. Duval, the latest and most accurate author on fossil Belemnites, reproduces the figure which M. D'Orbigny has published, and which is essentially the same as that given by Dr. Buckland in his Bridge-

* Oken's Isis, Bd. xxi. p. 438.

water Treatise; and, like it, differs from Mr. Miller's restoration, only in the position of the ink-bag and in the extended state of the terminal fins. With respect to these parts, M. Duval, from his discovery of the united fractures of the spathose guard, objects, with much acumen, that, if the fins of the Belemnite had been placed at the side of the guard, they must have been rendered useless by its fracture, and the creature, thus deprived of its power of swimming, would soon have fallen a prey to its numerous enemies, and would not have survived to exemplify the reparative powers of those ancient Cephalopods. M. Duval, however, modestly concludes by confessing that he should not have dared himself to figure from the known analogies, the animal to which the Belemnite ought to have belonged; for "I have not," he says, "a sufficiently exact knowledge of the organic laws of the Cephalopoda." * It seemed vain to hope that the soundness of the principles on which the classification of the Belemnites with the dibranchiate Cephalopods had been definitely proposed, should ever be vindicated by an example of parts apparently so perishable as the mantle, the fleshy arms and fins of these Mollusca. I have however the gratification to be enabled, by the kind permission of the Marquis of Northampton, to place before you a specimen of a Belemnite, in which not only the ink-bag but the muscular mantle, the head, and its crown of arms, are all preserved in connection with the Belemnitic shell. It appears to have been the peculiar property of the matrix, in which this and many similar valuable and instructive specimens were entombed, to favour the conversion of the muscular tissue into adipocire, and its subsequent preservation to the present time. Yet this matrix is a member of the Oxford-clay-formation, belonging to the middle oolite system; older, therefore, than the Portland stone, the Wealden and the Cretaceous group. The Cephalopod, in which we may now study the microscopic character of the muscular fibre, must therefore have existed at a period antecedent to the gradual deposition of these enormous masses of the secondary strata, which themselves preceded the formation of the entire tertiary series, and the overspreading unstratified masses called diluvial. The attempt to conceive or calculate the period of time which must have elapsed since the Belemnites were thus embalmed, baffles and awes the imagination.

A second, less complete, but highly instructive, specimen of the Belemnite, from the collection of Mr. Pratt, to whom I am indebted for the first knowledge and inspection of the soft parts of these extinct Cephalopods, exhibits the contour of the large sessile eyes, the funnel,

* Loc. cit. p. 20.

a great proportion of the muscular parts of the mantle, and the remains of two lateral fins, the ink-bladder and duct, and a considerable portion of the chambered cone. The two fins (*fig.* 133. *f, f*) present the form of flattened transversely striated fibrous masses with their free border entire and rounded. They are situated on each side of the visceral cavity, and demonstrate the accuracy of M. Duval's objection to their position in the previous conjectural restorations. A large tract of the grey fibrous substance, running parallel with and to one side of the remains of the head, indicates the position of the infundibulum, and is terminated by a concave truncation. At the middle of the visceral mass at the interval of the two lateral fins, there lies a compressed body of a horny texture and somewhat bilobed form, on which may be clearly distinguished striæ passing outwards in opposite directions from a middle line, and diverging from each other in their course, which resembles that of the fibres of the digastric muscle in the gizzards of the Cephalopods: this apparent remnant of the stomach lies anterior to the ink-bladder. There is a strong negative evidence that the Belemnite possessed horny mandibles like the other naked Cephalopods, since no calcareous ones or Rhyncholites have been discovered associated with these remains. The cephalic arms, which are preserved, belong to the normal series, and were eight in number: they were provided, not with simple acetabula, but with a double alternate series of slender elongated horny hooks, as in the genus of existing Calamaries, called *Onychoteuthis*. Each arm seems to have been provided with from twelve to twenty pairs of these hooks. They were doubtless developments of the horny hoop which encircles the central process of the acetabulum, as in the modern *Onychoteuthides;* but in the position of the pallial fins, the Belemnite resembled the *Sepiola*. The traces of the superadded pair of tentacula are somewhat doubtful.

The modern decapodous Cephalopod, which most nearly resembles the Belemnite in the structure of its internal shell, is the *Sepia*, or common cuttle-fish: the lateral fins of this species extend from the apex to near the base of the mantle. The nucleus, or terminal spine of the cuttlebone corresponds with the spathose guard of the Belemnite: the convex posterior broad layer of friable calcareous and horny matter is analogous to the enveloping cone; but its margins, instead of being approximated and soldered together, are free and lateral in position: the successive plates, embedded in its concavity, answer to the camerated cone of the Belemnite; but, instead of being perforated by one or many siphons, they are connected with each other by a series of minute undulating lamellæ.

Thus we have at length been furnished with the proof of the dibranchiate nature of the Belemnite, and we learn from the same ocular evidence that it combined characters at present divided between three distinct genera of the order; namely, first the calcareous internal chambered shell, to which the *Sepia* offers the nearest approach; secondly, the formidable hooks of the arms, which characterise the modern genus *Onychoteuthis;* and, thirdly, the limited attachment of the lateral fins to a position a little in advance of the middle of the body, as in the *Sepiola.*

The Belemnite, having the advantage of its dense but well-balanced internal shell, must have exercised its power of swimming backwards and forwards, which it possessed in common with the modern Decapod Dibranchiata, with greater vigour and precision. Its position was probably more commonly vertical than in its recent congeners. It would rise swiftly and stealthily to infix its claws in the belly of a supernatant fish, and then, perhaps, as swiftly dart down and drag its prey to the bottom and devour it. We cannot doubt at least but that, like the hooked Calamaries of the present seas, the ancient Belemnites were the most formidable and predacious of their class.

LECTURE XXIV.

CEPHALOPODA.

The deductions which were founded on the modifications of the chambered siphoniferous shell and other enduring remains of the very remarkable extinct genus which occupied our attention at the close of the last lecture, obliged me frequently to refer to the type of structure which characterises the *Dibranchiate* order of Cephalopods, and which places these Mollusca not only at the head of that division of the Animal Kingdom, but, in respect of its closer proximity to the Vertebrate type, unquestionably at the head of the whole Invertebrate series.

The body of the Dibranchiate Cephalopod is divided, as in the Nautilus, into two parts; a head, containing the organs of sense, mastication, and deglutition, and supporting the prehensile and principal organs of locomotion, and a trunk or abdomen, consisting of a muscular sac or mantle, with a transverse anterior aperture, and containing the respiratory, generative, and digestive viscera. With one exception the mantle is naked, and includes a more or less rudimental shell; and it supports, in most of the species, a pair of fins. In a single genus it is contained in a light and symmetrical monothalamous shell. Compared with the Nautilus, the cephalic tentacula are much reduced in number, the external ones, continued from the oral sheath, not exceeding eight, to which, in most of the genera, is added a pair of internal and much longer tentacula. The arms are much increased in size and of a more complicated structure, supporting on their internal surface numerous suckers, and sometimes connected together by powerful muscular web. The eyes are much larger and more complex, are no longer pedunculated, but lodged in orbits. The mouth is armed with two piercing and trenchant horny jaws, resembling in shape and in their vertical movements those of the Nautilus. The gills are two in number, each with a ventricle expressly appropriated to the branchial circulation; the systemic circulation having a single muscular ventricle, as in the Nautilus. The infundibulum is a complete muscular tube, shaped like an inverted funnel. They possess a gland and membranous receptacle for secreting and expelling an inky fluid. The sexual organs are in distinct individuals, as in the Tetrabranchiate order. All the species of both orders of Cephalopods are aquatic and marine.

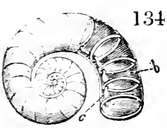
The Dibranchiate order may be subdivided into two tribes; the one provided with the eight ordinary arms and the two longer tentacles, hence called *Decapoda;* the other tribe without the tentacles, and called *Octopoda*.

The various forms of the extinct *Belemnitidæ* constituted one family in the Decapod tribe. The little *Spirula*, characterised by a less complex, but internal chambered shell, is the type of a second family. The cuttle-fish, characterised by its internal calcareous shell, which feebly represents that of the Belemnite, exemplifies a third family of Decapods called *Sepiadæ*. The common calamary (*Loligo*), in which the internal shell is reduced to a horny quill-shaped plate, represents the fourth and most extensive family of the present tribe, which I have called *Teuthidæ;* and in which one genus (*Onychoteuthis*) had the caruncle of more or fewer of its acetabula produced into horny claws. In all the Decapods the mantle supports a pair of fins, and the siphon is generally provided with a valve.

In the tribe *Octopoda*, fins are rarely developed from the mantle; but the eight ordinary arms are longer, thicker, and are united together by a broader web, which forms a powerful organ for swimming in a retrograde direction. One family in this tribe (*Testacea*) is represented by the genus *Argonauta*, in which, at least in the female sex, the first or dorsal pair of arms is dilated at its extremity into a broad thin membrane, like the mantle in the testaceous mollusks; by means of these membranes the animal, in fact, forms for itself an extremely light, slightly flexible, and elastic, but calcareous, symmetrical shell, which is simple, and not divided into chambers; the vacated portion communicating with the rest, and being used by the inhabitant as the receptacle for the eggs. The siphon is without a valve, but is articulated at its base on each side to the inner surface of the mantle. The second family of the Octopods I have termed *Nuda*, the species not being provided with an external shell. The first pair of arms is elongated, and contracts to a point: the funnel or siphon is without an internal valve or external joints. The rudimental shell is represented by two short styles, encysted in the substance of the mantle. The typical genus of this family is termed *Octopus*, in which the arms are provided with a double alternate series of sessile acetabula. In a second genus *Eledone*, the arms are provided with a single series of acetabula. In the *Cirroteuthis* a pair of filaments project between each of the suckers.

The shell or dermal skeleton, which has been progressively reduced in the present highly organised class, attains its lowest or most rudimental condition in the *Octopus* and *Eledone*. The genus in which the shell most nearly resembles that of the tetrabranchiate Cephalopods, belongs to the *Spirula*. A few mutilated specimens which had reached this country during this present century, had demonstrated it to be an internal shell, and the more perfect specimen dissected by M. de Blainville in 1839, proved it to have the characteristic organisation of the Dibranchiate order, and to possess, as Péron had indicated, the eight short arms and the two long tentacula of the Decapodous tribe. The shell of the *Spirula* (*fig.* 134.) is perfectly symmetrical, convoluted in a vertical plane with the whorls contiguous, but not touching. The shell commences by a small oval cell, followed by a series of chambers (b), which rapidly increase in size. The septa (a) are concave towards the outlet, and are perforated by a siphon at the internal or concave margin of the shell. A small funnel-shaped tube (c) is continued backwards from each perforation; and its apex penetrates the mouth of the succeeding tube. The circumference of the siphonic aperture is impressed, as Mr. Stokes first observed, by a circle of minute pits. The shell seems to be exclusively composed of a fine white nacreous substance; it is imbedded in the posterior part of the mantle, with a small part of its surface exposed on both the upper and lower sides of the animal's body: the exposed parts of the shell are invested by a granular straw-coloured epidermis.

134



Spirula australis.

The principal characters of the internal shell of the cuttle-fish have already been pointed out in the illustration of its analogies with that of the Belemnite. The preparations, Nos. 106, 107, 108, demonstrate the great proportion of animal membrane which enters into the composition of this light friable laminated shell.

In the rest of the *Decapoda*, the rudimental shell consists exclusively of animal matter, of the consistency of horn, and presents either the form of a pen, as in the Calamary, or that of a straight three-edged sword, as in the *Onychoteuthis*. This body was called 'xiphos' by Aristotle, and 'gladius' by Pliny. In the *Sepioteuthis* it is as broad in proportion to its length as the cuttle bone. In the *Onychoteuthis*, *Loligo*, and *Loligopsis*, it is much narrower, but is as long as the mantle. In *Sepiola* and *Rossia*, the gladius, commencing at the anterior margin of the mantle, ends before it has reached half way down the back. In the *Octopus* and *Eledone*, the last traces of a shell exist in the form of two small amber-coloured styliform bodies, contained loosely in capsules in the substance of the mantle.

The skin of the naked Cephalopod is generally thin and lubricous, and can be more easily detached from the subjacent muscles than in the inferior Mollusks. In some of the smaller Cephalopods it is semitransparent; it is densest in the Calamaries, in which the epidermal system is most developed, as is exemplified in the horny rings or hooks upon the acetabula. In the Octopods the epidermis is reflected over the interior of the acetabula without being condensed into horn. Upon the body the epiderm may generally be detached in the form of a thick white elastic semitransparent layer. The second, or pigmental layer of the skin, analogous to the rete mucosum, consists of numerous cells of a flattened oval or circular form, containing coloured particles suspended in a fluid. The colour is rarely the same in all the cells; the most constant kind generally corresponds more or less closely with the tint of the inky secretion. In the *Sepia* there is a second series of vesicles containing a deep yellow or brownish pigment: in the *Loligo vulgaris* there are three kinds of coloured vesicles, yellow, rose-red, and brown: in the *Octopus vulgaris* there are four kinds of vesicles, red, yellow, blue, and black. In the skin of the Argonauta all the colours which have been observed in other Cephalopods are present, and contained in their appropriate cells. These cells possess the power of rapid alternate contractions and expansions, by which the pigment can be driven into the deeper parts of the corium or brought into contact with the semitransparent epiderm. If the skin of an *Octopus* be slightly touched, the colour will be accumulated, gradually or rapidly, like a cloud or a blush upon the irritated surface. If a portion of the skin be removed from the body and placed in sea-water under the microscope, the contractions of the vesicle may be watched for some time: their margins are well defined, and they pass, during their dilatations or contractions, over or under one another. The power which the Cephalopods possess of changing their colour and of harmonizing it with that of the surface on which they rest, is at least as striking and extensive as in the Chameleon, in which, it seems, from the latest observations, to be produced by a similar property and arrangement of pigmental cells.

The internal organised skeleton of the dibranchiate Cephalopod is cartilaginous, as in the Nautilus, but consists of a greater number of pieces, and enters into a larger proportion of the organisation of the animal. The cranial cartilage is no longer limited in its position to the under side of the œsophagus, but completely surrounds that tube, which, together with the inferior salivary ducts and the cephalic branches of the aorta, traverses a narrow canal in its centre. The cartilage expands above into the cavity containing the brain, while below it is excavated to form the organ of hearing, and at the sides expands into the broad and thick orbital cavities. There is also a thin and long cartilage which supports the eyeball, and seems to be analogous to the ophthalmic peduncle of the Rays and Sharks. A process continued from the anterior part of the cranial cartilage expands into a broad transverse plate, and gives attachment to the muscles of the arms. The infundibular cartilage, which is a process of the cranial one in the Nautilus, is a distinct piece in the *Dibranchiata*. It is of a large size, and of a flattened triangular figure in the cuttle-fish, in which it is situated above the base of the funnel. It consists of three distinct portions in the Calamary. On each side the base of the funnel there is a smooth oblong articular cavity, formed by a distinct piece of cartilage, which is articulated with a corresponding cartilaginous prominence from the inner surface of the side of the mantle. These cartilaginous joints of the funnel vary in shape in the different genera: they are wanting in the *Octopus*. The lateral fins of the *Decapoda* are each supported by a narrow flattened elongated cartilaginous plate, which forms the medium of attachment of the powerful muscles of those fins. These appear to be analogous to the pectoral fins of fishes; but as they are not fixed to a vertebral column, their position is variable; in the *Rossia*, for example, they are situated near the anterior part of the body; in the *Loligo*, they are placed at the posterior extremity: in the *Sepia* they extend, like the great pectoral fins of the Rays, along the whole side of the body. In the Octopods the mantle-fins and their cartilages are wanting, except in the anomalous genus *Cirroteuthis*, in which they are attached to the anterior part of the sides of the mantle.

The sole locomotive organs in the ordinary Octopods, and the sole prehensile organs in all the Dibranchiata are the appendages developed from the head, termed 'arms,' 'feet,' 'tentacles,' and 'proboscides.' They have no true homology with the locomotive members of the Vertebrata, but are analogous to them, inasmuch as they relate to the locomotive and prehensile faculties of the animal.*

The eight arms of the *Octopus* commence by a hollow cone of muscular fibres attached by a truncated apex to the anterior part of the cephalic cartilage. The fibres are for the most part oblique, and interlace with one another in a close and compact manner, as the cone advances and expands to form the cavity containing the mandibulate mouth, at the anterior extremity of which they are continued forward, and separate into eight distinct portions which form the arms. The development of the eight external arms bears an inverse proportion to that of the body: they are longest in the short round-bodied *Octopi*, and shortest in the lengthened Calamaries and Cuttle-fishes, in which the two elongated retractile tentacles are superadded by way of compensation. These latter organs are not continued from the muscular cone, which correspond with the cephalic sheath in the Nautilus, but arise, like the internal labial processes in that Cephalopod, close together from the cephalic cartilage, internal to the origins of the ventral pair of arms. They proceed at first outwards to a large membranous cavity situated anterior to the eyes, and emerge between the third and fourth arms on either side.

In most Octopods the two dorsal arms are the longest: they are ten times the length of the body in *Oct. Aranea*. But besides their superior length, the dorsal arms present other peculiarities in this family of Cephalopods: in the genus *Argonauta* they are provided, as before stated, with the expanded calcifying membranes, which are usually spread over the exterior of the delicate shell, meeting and overlapping each other along its slender keel. The fabled office of these membranes, as sails to waft the argonaut along the surface of the ocean, and that of the attenuated arms as oars extending over the sides of the boat, have afforded a beautiful subject for poetic and pictorial imagery and philosophic analogy in all ages: and the little hypothetical navigator of nature's ship has been the subject of the disquisitions of naturalists from Aristotle to Cuvier, and of the song of the poet from Callimachus to Byron.

* Geoffroy St. Hilaire regards the cuttle-fish as a vertebrate animal bent double, with the approximated arms and legs extending forwards: a similar comparison may be found in Aristotle.

In the *Octopus velifer* both the first and second pairs of arms support broad and thin membranous appendages at their extremities. In the common Octopus the eight arms are connected together for some distance beyond the head by membranes and muscles, which form a circular fin; this constitutes its sole locomotive organ when swimming, and, by its powerful contraction, aided, however, by the ejection of the currents from the funnel, the animal is propelled through the water by a quick retrograde motion. In the *Oct. semipalmatus* the fin is extended along the basal interspaces of only the four dorsal arms. In the *Cirroteuthis* it extends between all the arms, and as far as their attenuated extremities.* There are two layers of transverse fibres in this web, the external of which arises from a white line along the back part of the base of each arm, the internal from the sides of the same arms between the attachments of the suckers. They decussate one another as they pass from arm to arm in the middle of the webs, and are included between two thin layers of radiating or longitudinal fibres.

The internal surface of the arms is that which is specially modified in the Dibranchiate Cephalopods, as in the Nautilus, for the prehensile and tactile faculties; but the structure is much more complicated in the higher order. On this surface each arm supports a single or double series or more numerous rows of acetabula or circular sucking cups: in the elongated pair of superadded tentacles of the Decapods, the suckers are limited to the expanded extremities, where they are generally aggregated in more numerous and irregular rows. These tentacles serve to seize a prey which may be beyond the reach of the ordinary arms, and also act as anchors to moor the Cephalopod in some safe harbour during the agitations of a stormy sea.

Each muscular arm is perforated near the centre of its axis for the lodgement of its nerve and artery, which are surrounded by a layer of cellular tissue; from the dense outer sheath of this cellular canal the transverse fibres of the arm radiate to the periphery, intercepting spaces containing the longitudinal fibres of the arm, the whole being surrounded by two thin and distinct strata of fibres, of which the external is longitudinal, and the internal transverse.

The mechanical structure of the acetabulum may be favourably studied in the *Octopus*, in which those organs are of large size, and sessile. The circumference of the disc of the sucker is raised by a tumid margin; a series of slender folds of membrane, covering corresponding fasciculi of muscular fibres, converge from the circumference towards the centre of the sucker, where a circular aperture leads to a

* Eschricht, Acta Acad. Nat. Cur. vol. xviii. p. 627.

cavity which widens as it descends, and contains a soft caruncle, rising from the bottom of the cavity like the piston of a syringe. When the sucker is applied to any surface for the purpose of adhesion, the piston, which previously filled the cavity, is retracted, and a vacuum produced.

The complex irritable mechanism of all these suckers is under the most complete control of the predatory Cephalopod. My friend Mr. Broderip informs me, that he has attempted, with a hand-net to catch an Octopus that was floating within sight with its long and flexible arms entwined round a fish which it was tearing to pieces with its sharp hawk's bill; the Cephalopod allowed the net to approach within a short distance of it, before it relinquished its prey, when in an instant it relaxed its thousand suckers, exploded its inky ammunition, and rapidly retreated under cover of the cloud which it had occasioned, by rapid and vigorous strokes of its circular web.

The Cephalopods which frequent the more open seas, and which have to contend with more agile and powerful fishes, have still more complicated organs of prehension. In the Calamary the base of the piston is enclosed in a horny hoop with a dentated margin. In the Onychoteuthis the margin is produced into a long, curved, sharp-pointed claw. These formidable weapons are sometimes clustered at the expanded terminations of the tentacles, and in a few species are arranged in a double alternate series along the whole internal surface of the eight ordinary arms, as they were in the extinct Belemnite.

In connection with the uncinated acetabula at the extremities of the long tentacula of this Onychoteuthis *, you may observe also a cluster of small simple unarmed suckers at the base of the expanded part. When these parts in each tentacle are applied to one another, they become locked together, and the united strength of both the peduncles is thereby more effectually brought to bear upon any resisting object which may have been grappled by the terminal hooks. This is a very striking mechanical contrivance: human art has remotely imitated it in the fabrication of the obstetrical forceps in which either blade can be used separately, or by the interlocking of a temporary joint be made to act in combination.

In the diminished number, increased size and progressive complication of the cephalic muscular appendages, and in their final modification for combining with one another to produce a determinate action, we trace the common order which regulates the development of other parts of the animal organisation. In our past review of the Invertebrata, we have witnessed this order in the appearance of the more essential organs, as the stomach, the heart, the gills, the generative

* Prep. No. 166, D.

organs; we find it equally regulating the development of the peculiar prehensile instruments of the Cephalopodic class.

At first very numerous, comparatively small and feeble, essentially alike, the cephalic tentacles of the Nautilus strikingly illustrate the law of vegetative or irrelative repetition. Their primary import is however plainly indicated by the direct derivation of their central nerve from the cephalic ganglion; and they present the same complex plan of arrangement of their muscular fibres which characterises the arms and tentacles of the dibranchiate Cephalopods. The prehensile surface of the tentacula of the Nautilus is made adhesive after the type of the simple laminated sucker of the Remora; the median longitudinal impression which partially divides the lamella, may represent the complete interspace which separates into two series, in the arms of most of the Dibranchiates, the more complex suctorial appendages which are developed on their internal surface: but at all events, the reduction of these arms in number, their augmentation in size, and perfection as prehensile instruments by the superadded complications, are phenomena which ordinarily attend the march of development. The order of this progress would be anomalously reversed if the tentacles of the Nautilus represented, as M. Valenciennes supposes, the caruncles of the acetabula, and the hollow processes of the oral sheath the cavities of those appendages of the arms of the Dibranchiata. According to the French Malacologist, the anterior circumference of the head or oral sheath in the Nautilus represents four of the eight arms developed therefrom in the *Dibranchiata*, and the two dorsal arms consist each of two enormous acetabula, whose cavities are deepened into tubes, and whose caruncles are produced into tentacula as highly organised in regard to their nerves and muscles, as are the acetabuliferous arms themselves in the higher orders. The four other arms of the Octopus are represented, according to M. Valenciennes, by the four groups of tentacula which are included within the oral sheath in the Nautilus. Such is not, however, the place of origin of any of the eight arms in the Dibranchiata; nor is it conformable with the general law of development, that a prehensile organ consisting of two large and highly complicated acetabula in a low organised Cephalopod should support two hundred smaller and more simple suckers in the higher organised species.

Fasciculi of muscular fibres are continued from the ventral pair of feet and the back part of the cranium to the muscular partition which divides longitudinally the branchial cavity: other fibres descend to join the muscular tunic enveloping the liver and œsophagus. In the cuttle-fishes and calamaries the branchial septum is not developed.

The respiratory tube or funnel is a complete muscular cylinder, formed by an external longitudinal, and an internal transverse, layer of fibres, with which are blended the insertions of the accessory retractor muscles.

The analogues of the great muscles which attach the Nautilus to its shell may be traced in the different genera of *Dibranchiata*, diminishing in size as the internal shell becomes more and more rudimentary. They arise in conjunction with the fibres of the fleshy tunic of the liver from the posterior part of the cephalic cartilage; but, soon quitting these fibres, they extend downwards and outwards, being perforated in their course by the great lateral nerve, and are inserted into the epidermic capsule of the internal shell.

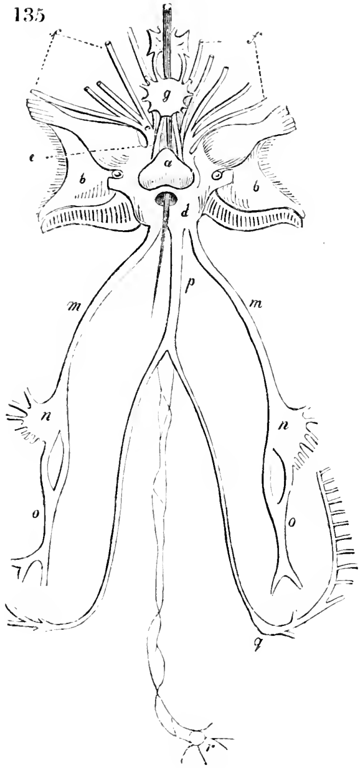
The thin shell of the Argonauta, which is external in regard to the true mantle, but internal in relation to the brachial membranes which formed it, is retained in its position chiefly by these membranes; and when they are, as they are capable of being, retracted into the cavity of the shell, it adheres to the surface of the body by the adhesion of contact only and its own elasticity, not by its attachment to any muscular fibres: hence the animal commonly drops out of the shell when dead.

The principal muscular fibres of the pallial fins extend, transversely to the axis of the body, to the margins of the fins: they present the same direction in the fossilised fins of the animal of the Belemnite. The action of the powerful muscles in the terminal fins of the calamaries must be aided in its effect upon the body by the elasticity of the internal pen or gladius. By these means they are enabled not only to propel themselves forward in the sea, but they can strike the surface of the water with such force as to raise themselves above it, and dart like the flying fish for a short distance through the air. This is the highest act of locomotion, the nearest approach to flight, which any of the molluscous animals have presented.

We find associated with the varied and active powers of locomotion just described, visual organs of large size and singular complexity of structure. The whole surface of the body is highly sensitive, with a concomitant development of the nervous centres, which exhibit the highest conditions observable in the Invertebrate series of animals.

The brain is inclosed in a cartilaginous cranium, together with a portion of the œsophagus, from which it is separated by the membrane analogous to the dura mater. Between that part of the fibrous membrane which lines the cerebral cavity and the pia mater covering the brain, there is an intervening space filled with a gelatinous arachnoid tissue. In the cuttle-fish, the supra-œsophageal cerebral

135



Nervous system, Sepia officinalis.

mass (*fig.* 135. *a*) consists principally of a cordiform body, superficially divided into two lateral lobes by a median longitudinal furrow. From the lower and lateral parts of this body proceed the short and broad optic nerves, which constitute the peduncles of the large reniform optic ganglions (*b*), and upon each peduncle there is placed a small spherical medullary tubercle: these tubercles exist also in the Calamaries, but appear not to be present in the Octopods.

From the inferior and anterior parts of the supra-œsophageal mass, a thick cord descends on each side of the œsophagus, unites with its fellow, and dilates below that tube to form the anterior sub-œsophageal ganglion, from which the nerves of the feet and tentacles arise. Two broader bands descend from the supra-œsophageal mass behind the preceding, and form, by a like enlargement and union, the posterior œsophageal body, which blends laterally with the anterior one, and forms with it a large mass with a central perforation. Four short and slender chords, two of which (*e*) are continued from the anterior apices of the optic lobes, and two from the anterior sub-œsophageal lobes, converge forwards and unite to form a round flattened ganglion (*g*), which is closely applied to the back part of the fleshy mass of the mouth above the pharynx, from which are sent off the nerves to the different parts of the mouth. Two filaments from the pharyngeal ganglion descend to join a pair of ganglions below the mouth, analogous to the labial ganglions of the Nautilus. The nerves of the arm (*f, f*) proceed from the anterior and inferior sub-œsophageal ganglion, and correspond in number to the organs which they supply, being eight in the *Octopoda*, and ten in the *Decapoda:* the corresponding nerves are much more numerous in the

Nautilus. In the Octopus, the brachial nerves pass along the inner surface of the base of the arms before they penetrate them. As soon as the acetabula begin to be developed, a series of closely approximated ganglions are formed upon the brachial nerves, of which some of the longitudinal fibres have been observed by Dr. Sharpey to pass over the ganglions. Before the ganglionic enlargements commence, each brachial nerve in the Octopus gives off two large branches, which traverse the fleshy substance of the base of the arms to join the two corresponding branches of the contiguous nerves which are thus associated together for consent of action by a nervous circle.

The infundibular nerves arise behind the origin of the brachial ones. Posterior to these the small acoustic nerves are given off from the sub-œsophageal mass. The delicate motores oculi arise from the upper part of the lateral connecting bands of the infra- and supra-œsophageal masses, which may be compared with the crura cerebri, as the nerves in question obviously answer to the third pair in the Vertebrata. The nerves which correspond to those of the shell-muscles of the Nautilus, form a single large pair (*m*, *m*), which arises from the posterior and lateral angles of the sub-œsophageal mass, extend outwards and backwards, perforate the shell-muscles, and form the large stellated ganglions (*n*, *n*), from which the nerves of the mantle are principally derived. In the *Octopoda* this may be described as the termination of the nerve; but in the *Decapoda*, in which lateral fins are superadded to the trunk, the great nerve previously divides into two branches, of which the outer one expands into the ganglion, whilst the inner branch, having been joined by one of the rays of the ganglion (*o*, *o*), pierces the fleshy substance of the mantle, and ends in a diverging series of twigs appropriated to the muscles of the fin.

In proportion as the trunk of the Cephalopod is attenuated and elongated, the pallial nerves become more parallel in their course, more dorsal in their position, and more similar to a rudimental spinal chord, of which the two lateral columns have retained their primitive embryonic separation.

The two large visceral nerves (*p*) arise from the interspace of the origin of the pallial pair; after distributing filaments to the muscles of the neck they descend parallel and close to one another behind the vena cava, give off the small filaments which constitute the plexus upon that vein and around the œsophagus, then diverge from each other towards the root of each gill, where they divide into three principal branches: one of these dilates into an elongated ganglion (*q*) and penetrates the fleshy stem of the branchia; the second descends to the generative organs; the third passes to the middle or systemic heart. The œsophageal plexus unites into a ganglion (*r*), attached to the parietes of the gizzard in the interspace between the pyloric and cardiac orifices.

With respect to the parts of the brain in the *Vertebrata*, which are represented by the cephalic nervous masses in the Dibranchiate Cephalopods, we may regard the cordiform superior mass, which is principally in communication and coexists with the large and complex eyes, as the homologue of the optic lobes; it cannot be the cerebellum, as Cuvier supposed, for that body never gives origin to any nerve; the cerebellum is also less constant than the optic lobes of the Vertebrate brain, and is posterior to them in both position and order of development.

The smaller supra-œsophageal mass, anterior to the optic lobes in the *Octopus* and some other cephalopods, may represent an olfactory lobe, or the rudiment of a true cerebrum. I have already indicated the parts which seem to represent the crura of the cerebrum; they unite with that large subœsophageal nervous mass, which, since it gives origin to the brachial nerves or the analogue of the fifth pair, to the acoustic and respiratory nerves, and to those two large moto-sensory columns which so obviously represent, by their structure, position and distribution, the spinal chord of the *Vertebrata*, must be regarded as the representative of the medulla oblongata: it is obviously the part of the nervous centre which is most intimately connected with the vitality of the animal, and which is therefore here, as in the higher animals, the deepest seated and best protected part of the nervous system.

The integument is remarkable in several of the naked Cephalopods for its irregular surface, which seems designed to increase its natural sensibility; in some, it is provided with flattened processes with denticulated margins; in others, it is beset with branched papillæ; in a third with simple obtuse papillæ; in a fourth with pointed tubercles; all which projections may serve to warn the animal of the nature of the surfaces with which it may come into contact. The margins of the acetabula and the attenuated flexile extremities of the arms which support them doubtless possess a delicate sense of touch. The fringed circular lip presents another example of the dermal covering modified to be the seat of this sensation.

The tongue is as highly developed for the exercise of the sense of taste in the dibranchiate Cephalopods as in the Nautilus.

The external circular lip may probably be the seat of the sense of smell; it is the part which is most analogous in position and structure to the olfactory laminæ in the Nautilus. This sense has been attributed to the Cephalopods by all naturalists who have observed their habits from Aristotle to Cuvier. It appears that the ancient

Greek fishermen were in the habit of attaching strong-scented herbs to their baits to deter the cuttle-fishes from coming to devour them.

The organ of hearing consists of two vestibular cavities, excavated in the thick and dense part of the cartilaginous cranium which supports the subœsophageal ganglions. In the cuttle-fish several obtuse elastic processes project from the inner surface of the cavity, which contains a delicate sacculus and otolithe. The acoustic nerve is spread over the sacculus, and is impressed by the movements of the otolithes, which respond to sonorous vibrations, which may be strong enough to affect the body generally. In the Octopus the vestibules are nearly spherical with a smooth internal surface; the otolithe is hemispherical; in the Eledone it is shaped like the shell of a limpet, with the apex rounded and curved backward. In all the Cephalopods the otolithes consist of carbonate of lime.

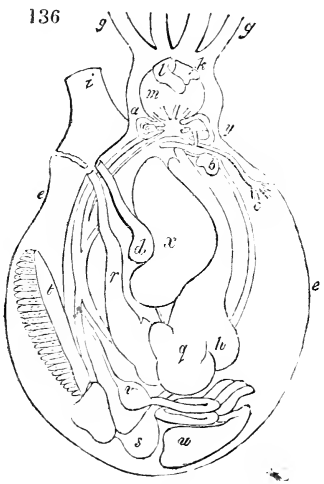
The orbit in the cuttle-fish is formed posteriorly by a thick cartilaginous cup, and is completed anteriorly by a dense white fibrous dermal membrane, which becomes transparent at the anterior part of the globe, and forms the cornea. The cornea and the fibrous tunic are lined by a thin serous membrane, which is reflected over the anterior part of the sclerotica, and through its anterior aperture (to which the cornea does not adhere), like the membrane of the aqueous humour, and is finally continued into the groove of the crystalline lens.

The space between the eyeball and its capsule, thus circumscribed, is filled with an aqueous humour, by which the cornea is separated from the eyeball, and kept tense. The outer tunic of the proper eyeball is a fibrous membrane covered by the aponeurotic expansion of the muscles of the eye, and with an anterior aperture which is closed by the crystalline lens. Within the fibrous tunic there is a thin cartilaginous coat perforated posteriorly by the numerous fibrils from the optic ganglion. The layer of fibrous membrane is continued from the anterior margin along with the outer fibrous layer to form the pupillary aperture, which is encroached upon by a bilobed process analogous to the curtain, which depends from the iris of the ray. The cartilaginous sclerotic is lined by a thick expansion of the nervous fibres given off from the optic ganglion. These fibres are sent off from the outer surface of the ganglion, which presents a pulpy texture in its centre. They are grouped into flattened bundles, which decussate each other, as observed by Dr. Power, before perforating the cartilaginous sclerotica, and, after expanding into the retina, extend towards the groove of the crystalline lens, and, being joined by a thin membrane from the anterior margin of the cartilaginous sclerotic, it forms a ciliary plicated zone, which penetrates the groove of the crystalline lens.

The inner surface of the retina is covered by a layer of dark pigment, which is penetrated by the papillæ of the retina. The vitreous humour has a distinct and strong hyaloid coat. The crystalline lens is of large size, and consists of two distinct parts; the anterior or smaller moiety being the segment of a larger sphere, and the posterior that of a smaller sphere: they are separated by delicate transparent membranes continued from the ciliary body. The lens presents the same denticulated fibrous structure arranged in concentric laminæ, as in the higher animals.

The large optic ganglion is imbedded in a white lobular substance, which defends it from the pressure of the muscles of the eyeball. These consist of three straight muscles and one oblique, which take their origin from the orbital cartilages, and expand upon the sclerotic tunic of the eyeball. The cornea of the cuttle-fish is perforated by a minute hole near the inner or anterior margin. In the Octopus the corresponding aperture is somewhat larger, and situate more in the axis of vision. In the Calamaries the corneal aperture is still larger, of a vertically oblong form, and the capsule of the crystalline lens, which projects through the sclerotic aperture, is immediately exposed to the sea water.

136



Octopus.

The dibranchiate Cephalopods are, without exception, predatory and carnivorous animals. We have seen that they are endowed with formidable organs for seizing and overcoming the struggles of a living prey, and their strong sharp hooked jaws are well adapted for destroying and lacerating them when caught. The jaws (*fig.* 136. *k*, *l*) are sheathed upon a firm fleshy substance, the fibres of which are so attached to the base of the mandibles as to open them; their closure is effected by fasciculi of muscular fibres which surround them externally.

The tongue is partially covered with a horny plate beset with recurved spines, which must assist in the further comminution and deglutition of the food. The fauces are also provided with spinigerous folds of membrane. In some of the Calamaries, in which the superior salivary glands penetrate the folds, the ducts open upon the inner surface, as in the Nautilus. In the Octopus the anterior or upper salivary glands are on the outside of the buccal mass. In most of the Dibranchiata a second and larger pair of salivary glands is situated on each side of the œsophagus, at the commencement of the abdominal or hepatic cavity; their ducts unite to terminate below the tongue in the concavity of the lower mandible.

The peritoneal membrane is divided and disposed as in the Nautilus, in order to form special receptacles for the different viscera. The œsophagus is narrower than in the Nautilus, and provided with longitudinal plicæ: it dilates soon after having passed through the cranium into a long ingluvies, forming a large cul-de-sac at its commencement in both the Octopus and Argonaut; but in the Decapods it continues narrow and of uniform breadth to the stomach. This cavity (*h*) is an elongated sac, presenting, in the disposition of its muscular fibres, in the proximity of the cardiac and pyloric orifices, and in the thickness of the epithelial lining, the usual characters of the gizzard. The intestine, at a short distance from the pylorus, communicates with a glandular and laminated sac (*q*) analogous to that in the Nautilus, and presenting a similar globular form in the Rossia and Loligopsis; but elongated and spirally convoluted in the Sepia and Loligo. It receives the biliary secretion between two broad lamellæ, as in the Nautilus. The intestine is very short in all the Dibranchiata. In the Octopus it is bent upon itself (*r*), as in the Nautilus; but in the Sepia and Loligo it is continued forwards in a straight line, from the stomach to the vent. Its internal membrane is longitudinally folded, but is smooth at the short tract beyond the entry of the duct of the ink-bag; its termination is constricted either by the muscular fibres of the branchial septum, or by those which connect together the pillars of the funnel. In the Decapods provided with fins for swimming forwards, the anus can be closed by triangular fleshy valves; and in some species these are modified into the form of antennal filaments.

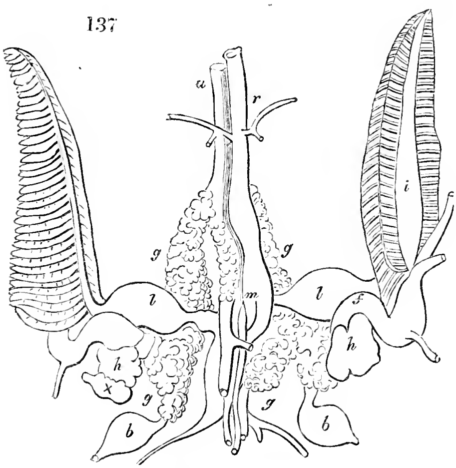
The liver (*x*) is of large size in the Dibranchiata, but of more simple form than in the Nautilus. In the Sepia it is divided into two lateral lobes, which are notched at the upper extremity; in the Onychoteuthis it is a simple, elongated, compressed lobe with undivided extremities: in the Octopus it forms a single oval mass, flattened anteriorly: in the Eledone it is spherical, corresponding with the ventricose visceral sac. In the two latter genera the ink-bag (*d*) is enclosed within the capsule of the liver, and was naturally mistaken for the gall-bladder by some of the early anatomists of these Mollusca; but in the Argonaut and in all the Decapoda, it manifests its distinct function by its separate position. The liver is surrounded by a smooth capsule, and is not subdivided externally into lobules, as in the Nautilus and lower Mollusca. The biliary ducts in the Octopoda are simple canals, which unite and terminate by a common orifice, in the pancreatic sac. In the Decapoda they receive the ducts of numerous clusters of cæcal appendages beyond the smooth part of the liver.

The ink-bag consists of tough white fibrous texture, the outer surface of which is coated by a thin silvery or nacreous layer: its inner surface presents a fine spongy glandular texture. It presents a trilobate form in the Sepiola, and an oblong pyriform shape in the Sepia and Loligo. It is a very active organ, and its inky secretion can be reproduced with great activity. The tint of the secretion varies in different species, as is exemplified by the Italian pigment called 'sepia,' and the Chinese one, called 'indian ink.' It is of a very indestructible nature, as is exemplified by its frequent preservation in a fossil state in both the extinct Calamaries and the Belemnites. It is affirmed by some chemists to contain a peculiar animal principle, which Vizio has termed 'melanine.'

Many of the Cephalopods possess the power of emitting a luminous secretion. All of them are nocturnal and social animals, and are readily attracted by bright metallic substances.

Prior to the dissection of the Pearly Nautilus, the Cephalopods were regarded as having three distinct hearts; but two of these, which are appropriated to the branchial circulation, are peculiar to the higher order, and are perhaps the main-spring of their superior muscular energies.

137



Sepia officinalis.

In the Dibranchiata the venous blood returns from each arm along its lateral and posterior parts by two veins, which severally unite at the base of the arm with the opposite vein of the adjoining arm, the whole being ultimately conveyed to an irregular circular sinus, which is continued between the head and the funnel into the great anterior cava (*fig.* 137. *a*). In the Octopus this vessel is provided with two semilunar valves at its commencement. At its entrance into the pericardium it usually receives two large visceral veins, and it divides into two branches (*g, g*), continued downwards and outwards to the branchial hearts at the base of each lateral gill: previously to communicating with these it dilates into asinus, which also receives the venous blood from the sides of the mantle. The two divisions of the vena cava, and also the visceral veins (*b, b*), after having entered the pericardium, are furnished with clusters of spongy or glandular follicles, which open into these veins by conspicuous foramina. The follicles vary in form in different genera; in the *Eledone* they are elongated and pyriform: in the *Argonauta* and *Octopus* they are shorter, and arranged in distinct clusters: in the *Loligo* they are represented by a spongy thickening of the tunics of the veins: in the *Sepia* the secerning appendages are more elongated, but are very numerous, close-set, and of an irregular form, giving a floccular character both to the great divisions of the vena cava and to those parts of the visceral veins which are contained in the pericardial or great venous cavity. The special compartments, into which these glandular appendages to the veins are lodged, communicate with the respiratory cavity by two papillary orifices, situated near the base of the gills. As the kidneys derive their peculiar excretion from venous blood in the lower vertebrated animal, Prof. Mayer's supposition * that the venous follicles of the Cephalopods are analogous organs, is by no means an improbable one. They may serve in a secondary degree as temporary reservoirs of the venous blood when it is impeded in its course through the gills; and, as the venous follicles are endowed with a peristaltic motion, they may regulate the quantity of blood transmitted to the gills.

The branchial circulation is, however, expressly provided with a muscular ventricle (*fig.* 136. *s*) in the Dibranchiate Cephalopods, one of these ventricles (*fig.* 137. *h*) being situated at the base of each gill. The regurgitation of the blood into the glandular veins is provided against by the interposition of the two semilunar valves at the entry of the ventricle. In the Decapoda and in the Argonaut, each branchial ventricle has a fleshy appendage (*k*) attached to its lowest surface.

A single branchial vein which dilates into a small sinus (*fig.* 137. *l*) returns the blood to a single median systemic heart, which is rounded in the Octopods, lozenge-shaped in the Calamaries, and fusiform, but bent upon itself, in the *Sepia* (*fig.* 137. *m*) *Sepioteuthis*, and

* Analekten fur Vergleichenden Anatomie, 4to. 1835.

Sepiola. It sends off two aortæ, as in the Nautilus, the larger or posterior aorta being provided with a muscular bulb, and with two semicircular valves at its origin. The distribution of the large aorta very closely resembles that of the Nautilus. The vascular ring which encircles the œsophagus typifies the branchial arches in the Vertebrate animal; but it supplies the head and all its complex radiating appendages.

The branchiæ (*fig.* 136. *t. fig.* 137. *i*) are two in number, as the name of the order indicates. They are concealed, as in the Nautilus, by the mantle, which extends in front of the other viscera to form the branchial chamber: a distinct muscular tube projects from its outlet. The rectum and the generative organs open into the branchial chamber at the base of the funnel, manifesting the same relation of the breathing organs to the termination of the alimentary canal, which characterises the lower orders of the Mollusca. Each gill consists, as in the Nautilus, of a number of triangular vascular laminæ, extending transversely from either side of the fleshy stem, and decreasing in size to the extremity of the gill; each plate is composed of smaller transverse laminæ, which are themselves similarly subdivided, the entire gill presenting the tripinnate structure, which affords the most extensive surface for the minute subdivision of the blood-vessels. In the *Loligopsis* each gill has twenty-four pairs of plates: in the *Sepia*, thirty-six pairs; in the *Loligo sagittata*, sixty pairs. The stem of the gill is not only attached by its base, but by a thin fibrous membrane through nearly its whole length to the mantle.

The mechanical part of the respiratory act is performed by the muscular actions of the mantle and funnel, the gills not being provided with vibratile cilia, as in many of the inferior Mollusca. The water is admitted into the branchial cavity at the anterior aperture of the mantle, outside the base of the funnel. Two large valvular folds of fibrous membrane, which are concave towards the respiratory cavity, prevent the currents from escaping by this entry: they are, therefore, propelled by the whole force of the contraction of the muscular mouth through the cavity of the funnel, the base of which is articulated, in most of the Cephalopods, by lateral joints, with the sides of the anterior aperture of the mantle.

At first sight it might seem that the Cephalopods which had but two gills were less efficiently provided with the means of respiration than those which have four; but increased number, irrespective of correlative structure in an organ of the animal body, is ever a mark of its inferiority; and the four branchiæ of the Nautilus forcibly illustrate the true character of vegetative repetition, when contrasted with the two gills of the cuttle-fish in connection with their superadded ventricles. With this mechanism for the vigorous propulsion of the venous blood through the oxygenating organs, they acquire, in the Dibranchiate Cephalopods, a perfection of structure unknown in the rest of the Invertebrata, but always present in the Vertebrated classes.

The male *Dibranchiata* are always fewer, and generally smaller, than the females; the latter sex alone has hitherto been recognised in the genus *Argonauta,* and some suspect the brachial membranes and the shell to be sexual distinctions. In the common *Loligo,* the gladius of the male is one fourth shorter, but is broader than that of the female.

The male organs consist of a testis, a vas deferens, a vesicula seminalis, a prostate, the sac of the spermatophora, and the penis.

The testis is situated in a particular compartment of the peritoneum at the bottom of the visceral cavity: it consists of a membranous pouch, to one part of the inner surface of which are attached a number of slender branched tubuli, diverging, dichotomising, and terminating in blind extremities: the tubuli swell at the breeding season, burst, and discharge an opaque white fluid, crowded with spermatozoa, into the cavity of the sac, whence it escapes by a contracted orifice into the slender and convoluted vas deferens, where the fluid is moulded, by the addition of a mucous secretion, into a cylindrical coherent mass. In this state it is transmitted to a wider glandular canal, with fibrous parietes and a cellular cavity in the Octopus, and encroached upon, in the Sepia, by a plicated production of the lining membrane: this division of the efferent part of the male apparatus is analogous to the glandular part of the oviduct in the female: here the spermatozoa are enclosed in filamentary sheaths of albuminous matter, of a definite form, according to the species of Cephalopod. The anterior extremity of this contractile vesicula communicates, in the *Octopus,* with a wide, bent, cæcal tube (prostate), with thick glandular parietes, and having the form of a simple pouch in the *Sepia,* from which a short and wide duct leads to a longer and larger pyriform pouch, with thinner walls, containing the moving filaments of Needham, and from which the short muscular penis is continued. The prostate, in the *Sepiola,* communicates by a long and slender duct with the vesicula seminalis.

The moving filaments in the terminal pouch are packets or capsules of spermatozoa and sperm-fluid, with a peculiar associated mechanism. They form one of the most remarkable peculiarities of the Cephalopoda, and have been regarded as parasitic worms, under the names of *Echinorhynchus, Scolex dibothrius, Needhamia expulsatoria,* &c., by different comparative physiologists: they have been aptly denominated 'spermatophora' by Dr. Milne Edwards.

In the Octopus they are from six to eight lines in length, slightly enlarged at one extremity. Their outer tunic or capsule is elastic and transparent: this contains an elongated sac, occupying the larger extremity of the sheath, and filled with the minute clavate spermatozoa. This sperm-sac communicates by a short narrow canal or isthmus, with a second narrower or elongated sac, with highly elastic parietes. From this sound sac a spiral filament is continued to the small extremity of the outer sheath. In the Cuttle-fish, the isthmus connecting the sperm-sac with the ejaculatory sac is longer, and the coils of the spiral membrane are closer and more numerous. The spermatophora, or Needhamian filaments of the Calamary are remarkable for the superior size and length of the internal sac containing the spermatozoa.

Under every modification, the analogy of the apparatus which forms the receptacle of the essential particles of the fertilising fluid, with the nidamental sacs containing the ova in the opposite sex, is very obvious, and this explanation of the nature of the moving filaments, which has been illustrated with much accurate detail by Drs. Peters and Edwards, is, without doubt, the correct view. The movements of the spermatophora, when liberated from the sac, are truly remarkable; the smaller extremity of the outer capsule, to which the spiral spring is attached, protrudes by a kind of inversion, and the inner spermatic sac is drawn forwards; the action is repeated until the ejaculatory sac is extended from the sheath, when there is a slight cessation of movement. It then recommences; the sperm-sac is compressed and protruded farther; the isthmus gives way, and the spermatozoa are violently expelled, both outwards and into the cavity of the external sheath. The efficient cause of the movements appears to be a combination of the contractility of the external sheath and sperm receptacle, the elasticity of the spiral membrane, and the phenomena of endosmosis. The final intention of the superaddition of protecting sheaths for the semen, like those for the ova, appears to relate to the safe conveyance of the spermatozoa to the ova of the female, there being apparently no true intromission in the Cephalopoda; the peculiar mechanism of the sperm-receptacles insures their rupture and the dispersion of their contents after their brief transit through the sea water.

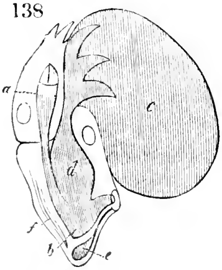
The female organs consist in the Dibranchiate Cephalopods, as in the Nautilus, of ovarium, oviduct, and superadded nidamental glands, but with several modifications in the efferent part of the apparatus. The ovary is always single, and the ovisacs, characterised by their elliptical form and reticulate parietes, are attached to one part of its cavity, as in the Nautilus. In the Cuttle-fish there is a single oviduct, with a glandular laminated outlet; and there are two distinct laminated nidamental glands on each side of its termination. In the Octopoda there are two oviducts, which in the Octopus and Eledone are each provided with a special glandular enlargement about the middle of their course: but there are no detached nidamental glands. In the Loligo there are two distinct convoluted oviducts, and two separate nidamental glands. These glands in the Cuttle-fish rest upon a soft parenchymatous body, of a bright orange colour: the corresponding part is rose-coloured in the Sepiola: it is double in the Rossia and the Calamaries: these bodies have no ducts, and appear to be the analogues of the suprarenal bodies in the vertebrate animals.

The ova when received in the membranous part of the oviduct, consist of a deep yellow vitellus, enclosed in a delicate vitelline membrane, and protected by a thin smooth shining chorion: they receive additional layers of a thick albuminous matter from the gland of the oviduct, which may be compared to the shell-secreting cavity in the oviduct of the fowl. The ova are connected together in characteristic clusters by the secretion of the superadded nidamental glands when these are present.

In the Argonaut the minute ova are appended by long filamentary stalks to the cavity of the involuted spire of the shell where they are hatched. The ova of the Calamary are enclosed in long gelatinous cylindrical sheaths, and offer a close analogy to the spermatophora in the male. The ova of the Sepioteuthis are likewise enclosed in cylindrical sheaths; but these are shorter, and contain fewer ova, than in the Loligo. The eggs of the Cuttle-fish are of comparatively large size, of an oval form, attenuated at the extremities, and each enveloped in its proper horny covering, which is prolonged into a pedicle at one extremity, and attached by it to some foreign body: numbers of these ova are generally found clustered together, and they have commonly received the name of sea-grapes.

The early stages in the development of the Cephalopodous Mollusk appear not to have been hitherto observed. The head can very soon be distinguished by the pigment of the rudimental eyes: the branchiæ at their first appearance project on each side of the pedicle of the large yolk-bag, from the anterior and lateral part of the unclosed abdomen, and the embryo Cuttle-fish at this period manifests the infero-branchiate type. The visceral sac is progressively enclosed by the advancement of the pallial walls from behind forwards; the pedicle of the yolk-bag (*fig.* 138. *c*) pro-

138



Embryo Sepia.

gressively contracting, and being pushed, as it were, towards the head; the short intestine is developed from the bottom of the stomach (*b*), and passes straight forward to the base of the projecting funnel. The arms grow around the mouth (*a*) and the vitelline duct, which is continued anterior to the mouth, parallel to the œsophagus, and gradually dilates (*d*) as it descends into the stomach. The original connection of the yolk-bag is in part retained or indicated in the Octopus by the anterior cæcal production of the crop. At the later periods of development the respiratory movements are vigorously performed by the alternate dilatation and contraction of the mantle and by a corresponding erection and depression of the funnel: the ink-bag (*e*) is now conspicuous by the colour of its contents, which are sufficient to blacken a considerable quantity of water, and the little Cephalopod is thus provided with the means of concealing itself from any enemy that might be prepared to devour it upon its emergence from the defensive covering of the ovum. At the period of exclusion five of the layers of the dorsal shell (*f*) of the young cuttle-fish have been formed; but, except the nucleus, which is calcified, they are horny and transparent. The lateral fins are not merely developed, but are broader than in the mature animal; and the cephalic arms are furnished with a web; so that the young Sepia is enabled to swim either forwards or backwards, and its eyes have acquired the requisite development to warn it of an approaching enemy, or direct its course to its appropriate food.

And now, Mr. President, I perceive that the hour of lecture has drawn to its close, and with it the period allotted for the annual exposition in this theatre of the physiological treasures of the Hunterian Museum. I should do injustice to my feelings were I, Gentlemen, to suppress the expression of the great gratification which your untiring attendance at these lectures has afforded me. This encouragement, knowing that the lectures would commence with the lowest and most minute forms of animal life, and be exclusively devoted to the Invertebrated classes, I had not ventured to anticipate from an audience, including many members who are actively engaged and eminent in the practice of an arduous profession.

For there is so small a part of the multifarious and diversified details of the anatomy and physiology of the Invertebrata, from which the practical Surgeon can directly profit: they seem so remotely connected with human physiology: the animals themselves are so different in form, in powers, in modes of life, from those which more obviously attract the interest of the anatomical Teacher.

We learn, indeed, with little surprise, that the import of the dissections of the Invertebrate animals, by the busy care-worn Surgeon who, in the last century, prepared the most instructive illustrations of our present lectures, were not understood, and that these occupations of Hunter were regarded by some of his contemporaries as a kind of laborious trifling. But the question of "cui bono?" which might then be pardonable, is surely inexcusable at the present day, when the relations of Surgery as a science to Physiology, and the dependence of Physiology upon Comparative Anatomy ought to be better understood. I would not, however, desire a more satisfactory answer to any remaining scepticism as to the necessity or importance of the dissections of the lower organised animals, than your reception of the present course of lectures; and I trust that a very brief retrospect of some of the deductions that have been obtained from the details to which you have patiently listened, will suffice to demonstrate their value to all who are interested in the progress of physiological science.

The Invertebrated classes include the most numerous and diversified forms of the Animal Kingdom. At the very beginning of our inquiries into their physiology we are impressed with their important relations to the maintenance of life and organisation on this planet, and their influence in altering and augmenting the crust of the earth itself, relations of which the physiologist conversant only with the Vertebrated animals must have remained ignorant. At our first entrance, and by the lowest portal, into the vast and intricate repositories of the animal mechanisms, we are at once introduced to the phenomena of spontaneous fission and ciliary motion, of the generality and importance of which in the animal economy each day seems to bring fresh proof, but which are most conspicuously manifested in the Monads.

The physiologist must have remained in ignorance of the most instructive modifications and combinations of the principal organs of the animal frame, if the researches of the Comparative Anatomist had been confined to the Vertebrated animals, or to those which are constructed on the same general type as ourselves. Without a much deeper investigation, we never could have understood the relative importance of the different organs, or have become acquainted with their most striking analogies.

Only in the Invertebrated classes do we find examples in which the lungs, like the liver, are supplied by the ramifications of the trunk of a vein without the interposition of a heart. Only in the lowest of the Invertebrate animals could we have found the office of the lung performed by a vascular portion of the integument; and the Invertebrata alone could have furnished us with examples of the progressive modifications of this portion of the vascular skin, by which the breathing organ is at length definitely developed.

But why do I cite the respiratory system? The earliest and most instructive forms of almost every organ, as it is permanently arrested in its development and adapted to the exigencies of the mature animal, must be sought for amongst the Invertebrata.

These animals alone furnish us examples of the circulation of the blood without a heart, and of a circulation aided by the hundred-fold repetition of the propelling reservoir in the same individual. In these alone we meet with the singular condition of the circulating fluid meandering back to the heart through diffused venous lakes, instead of cylindrical canals. Only the low organised Invertebrate animal could have revealed to us the actual existence in nature of a condition of the blood's motion, once erroneously held to be universal, viz. its flux and reflux in the same vessels, from trunks to branches and from branches to trunks, to and from the heart.* Could this remarkable exceptional case of the minute Ascidian have been shown to the antagonist of Harvey, how triumphantly he might have appealed to the evidence of the senses as demonstrative of the doctrine which Aristotle had taught and illustrated by the analogy of the tides of Euripus!

In the Invertebrate series we can contemplate the most simple and essential condition of the nervous system, — a ganglion with radiated internuntiate chords, a centre for the reception and transmission of stimuli. In this series we see such centres multiplied and set apart for different segments, or for different organs of the body. Of such arrangements, the anatomist of the Vertebrata exclusively could have formed no adequate conception. And not only are the conditions for the performance of the most essential function of the nervous system,—viz. the working of the muscular machinery agreeably with impressions received from external objects, independently of any consciousness of such changes, or of any choice and volition in the mode of remedying or avoiding them, — most plainly set forth in the Invertebrate types of the nervous system; but they afford the best subjects for illustrating that primary function by experiment. No vertebrate animal, for example, could have yielded such striking results as have been detailed in the experiments on the Mantis.†

The Invertebrate animals reveal the constant relation of the brain to a position above or behind the alimentary tract, and demonstrate that organs of special sense govern the existence of the supra-œsophageal nervous mass, and that its increase of bulk is in the direct ratio of their increase in number or complexity.

The relation of the physical defence of an animal by shells or

* Lecture XX. Tunicata, p. 273. † Lecture XVI. Insecta, p. 207.

crusts to the low condition of the sentient system, is most strikingly manifested in the Invertebrate series, and could be but feebly discerned in the higher animals, none of which exhibit the external or dermal skeleton modified to encase the limbs and form the levers and fulcra of the moving powers. The defence of the crab and oyster, by dense and impenetrable armour as a compensation for their lack of intelligence and defective powers of action, reminds one of the condition of the soldier in the early and ruder states of the art of war.

If the structure and functions of the human mechanism had been illustrated only by comparison with those of other Vertebrata, the physiologist would have been acquainted with only one leading modification of the generative system in the Animal Kingdom, namely, the diœcious or bisexual. The analogy between animals and plants in the modes of continuing the species is fully illustrated only by the Invertebrata. Here the anatomist finds the self-sufficing combination of fertilising and productive organs in the same individual, as in most flowers. Other Invertebrata present the still more remarkable combination of male and female parts arranged for reciprocal union. The closer and more remarkable analogy with the vegetable kingdom offered by that peculiar modification of the generative system, in which we found the oviduct and vulva exclusively destined for the transmission of the moving particles of the fertilising fluid, the fertilised ova escaping into the abdomen by dehiscence of the ovarium, so that extra-uterine gestation was a natural and constant phenomenon, was demonstrated by dissection of the earthworm.

But the diversified structures of the Invertebrate animals not only teach us the most remarkable and instructive modifications and correllations of individual organs and systems, but lead to an insight into, and can alone furnish the demonstrations of, the most important generalisations in zootomical science.

Of that which I have termed 'the law of vegetative or irrelative repetition,' by which is meant the multiplication of organs performing the same function, and not related to each other by combination of powers for the performance of a higher function, the Invertebrata afford the most numerous and striking illustrations.

Almost every organ of the body illustrates this vegetative condition at its first appearance in the Animal Kingdom. A stomach or assimilative sac is the most general characteristic of an animal. Such sacs are developed in great numbers in the body of the Polygastrian, but each sac performs the same share of the digestive function, irrespective of the rest. The case is very different in the ruminant animal, in which each of the four stomachs has its appropriate office, and all combine together to produce a more efficient act of digestion.

The organs of generation, the next essential parts of the mere animal, when first definitely introduced with their characteristic complications in the low organised Entozoa, illustrate more forcibly the law of irrelative repetition.

We trace the definite development of the heart and gills in the Anellida, in some species of which both organs are irrelatively repeated above a hundred times. And when these, like most of the vegetative organs assume a more concentrated form in the Molluscous series, we perceive in the structure and relations of the two auricles of the bivalve as compared with the single auricle of the univalve, and of the twenty tufted gills of the Phyllidia, or of the four gills of the Nautilus, as compared with the two branchiæ with their perfect circulation in the Sepia, that plurality is but a sign of inferiority of condition.

When locomotive and prehensile appendages first make their appearance in free animals, they are simple, soft, and unjointed, but they are developed by hundreds, as in the Asterias and Echinus: they manifest the principle of vegetative repetition to a remarkable extent when they are developed into symmetrical pairs of setigerous tubercles in the Anellides, and even when they first appear as jointed limbs in the Myriapoda: but as they become progressively perfected, varied, and specialised, they are reduced to ten in Crustacea, to eight in Arachnida, and to six in Insecta. We have just seen that the same law prevails in the introduction of the analogous cephalic organs of locomotion and prehension in the Mollusca. It is beautifully illustrated in the introduction of the organ of vision into the animal kingdom.

The numerous ganglions, nerves, and muscles, which the vegetative succession of the segments of the body and their locomotive appendages in the Articulata calls forth, have sometimes been adduced as invalidating the claims of the Vertebrata to be regarded as of higher or more complex organisation; but when the law of irrelative repetition is rightly understood, the multiplication of similar parts for the repetition of the same actions is at once appreciated as essentially the more simple, as well as the inferior condition to the assemblage of less numerous parts in the same body with different offices, and with prospective arrangements that enable them to combine their different powers for definite ends.

The lowest Invertebrata resemble locomotive cells: they propagate by spontaneous fission and grow by assimilation; sometimes they exhibit their geometrically multiplied divisions to a certain extent within a common capsule. The earliest phenomena in the development of the Mammiferous ovum most closely resemble these in the Gonium and Volvox. Like phenomena have been observed in the vitelline germ of the frog and the fish. But the universality of the phenomena of spontaneous division, of the fissiparous procreation of nucleated cells, and of their growth by assimilation and coalescence round definite centres, as the properties of the primordial germ in all animals which produce the most conspicuous changes in the yolk, has been mainly established by collecting the observations that have been made upon the development of the embryo in the different classes of Invertebrata, and by the comparison of these with the analogous phenomena observed in the development of the Vertebrate Animal, and which we may conclude to characterise the first steps in the formation of the human embryo.

And since later observations have established what I first observed, and suggested to be a general property of the blood-corpuscle,—viz. its power of spontaneous subdivision into smaller vesicles*, it is highly probable that the preliminary steps to its conversion into a tissue are the same as those of the nucleated cell which constitutes the germ of the entire animal; and the proposition that the phenomena of spontaneous fission, of which the Monads offer the most conspicuous examples, are the most universal and important in the operations of the living animal, ceases to wear the aspect of exaggeration.

It is however certain that the most extraordinary consequences of the fissiparous property of the nucleated cell are manifested in the Invertebrate series of animals, of which generation without fecundation of the procreating individual is an example. This phenomenon, which has so much astonished and perplexed physiologists, as manifested in the Aphides, becomes perfectly intelligible and reducible to the general law.

The Monad divides itself before our eyes, constituting two, then four, next eight individuals, and so on. The impregnated germinal vesicle, which the Monad permanently represents in nature, propagates, in like manner, by spontaneous fission and assimilation, a number of impregnated cells like itself. Most of these cells are metamorphosed into the tissues of the growing embryo, but not necessarily all. Certain nucleated cells, the progeny of the primordial one, and inheriting its powers, may become, without further stimulus, the centres of development of processes like those which have built up the body that contains them: they may bud forth from the stem of the Hydra, and form new individuals by the process of gemmation; they may bud forth, in like manner, from the larval polype of the Medusa, which

* Medical Gazette, November 13. 1839. Dr. Martin Barry's Paper in Philos. Transactions, 1840.

thereby procreates in its immature, and, as it seems, virgin state, like the wingless larvæ of the summer Aphides; they may enter the unimpregnated oviducts of these insects, and be there developed in the manner which has already been described.*

Did time permit, I might easily multiply the instances from the Invertebrate organisations, which bear directly on the establishment of the most important general laws in physiology. I shall conclude by adverting to one which is alike interesting to the anatomist and naturalist, and which has exercised the powers of the most exalted intellects of the present age. To the disquisitions and discussions in which Goëthe, Oken, Cuvier, and Geoffroy have taken part, the doctrines of Morphology and Unity of Organisation owe their existence.

Some of the medical acquaintances of John Hunter, who, we are told, complacently apostrophised his pursuits, in the language of pity, when they found him dissecting a snail, a bee, or a worm, little dreamt of the expanded views of the animal organisation at which he was obtaining glimpses through those narrow casements. It would seem that Hunter himself was oppressed with the grandeur of the prospect, with the extent of the generalisations which his investigations of the lower animals, and of the embryonic forms of the higher ones, were forcing upon his reflective mind, if we may judge from his struggles to express ideas, at that period so novel and so vast, and to which he could but give imperfect utterance. "If we were capable," he says, "of following the progress of increase of the number of the parts of the most perfect animal, as they first formed in succession, from the very first, to its state of full perfection, we should probably be able to compare it with some one of the incomplete animals themselves, of every order of animals in the creation, being at no stage different from some of those inferior orders; or, in other words, if we were to take a series of animals from the more imperfect to the perfect, we should probably find an imperfect animal corresponding with some stage of the most perfect."†

With the great accession of facts with which Comparative Anatomy has since been enriched, particularly from monographs detailing dissections of the Invertebrate animals, we may now attempt a more exact enunciation of the resemblance which a higher organised animal presents to those of a lower order in its progress to maturity: and the consequent extent to which the law of 'Unity of Organisation' may be justly, and without perversion of terms, be predicated of animal structures. We shall see some grounds for the statement that the

* Lecture XVIII. Insecta, p. 235.

† Hunterian MS. quoted in Physiological Catalogue, vol. i. p. 4.

more perfect animal is at no stage of its development different from some of the inferior species; but we shall obtain proof that such correspondence does not extend to every order of animals in the creation.

The extent to which the resemblance, expressed by the term 'Unity of Organisation,' may be traced between the higher and lower organised animals, bears an inverse ratio to their approximation to maturity.

All animals resemble each other at the earliest period of their development, which commences with the manifestation of the assimilative and fissiparous properties of the polygastric animalcule: the potential germ of the Mammal can be compared, in form and vital actions with the Monad alone, and, at this period, unity of organisation may be predicated of the two extremes of the Animal Kingdom. The germ of the Polype pushes the resemblance farther, and acquires the locomotive organs of the Monad, — the superficial vibratile cilia, — before it takes on its special radiated type. The Acalephe passes through both the Infusorial and Polype stages, and propagates by gemmation, as well as spontaneous fission, before it acquires its mature form and sexual organs. The fulness of the unity of organisation which prevails through the Polypes and larval Acalephes, is diminished as the latter acquire maturity and assume their special form.

The Ascidian Mollusks typify more feebly and transiently the polype state in passing from that of the cercarii-form ciliated larva to the special molluscous form. The Gasteropods and Bivalves obey the law of unity of organisation in the spontaneous fissions of their amorphous germ, and in its ciliated epithelium, by which it gyrates in the ovum; but they proceed at once to assume the molluscous type without assuming that of the Polype; the Bivalve retaining the acephalous condition, the Univalve ascending in its development to the acquisition of its appropriate head, jaws, and organs of sense.

Thus all mollusks are at one period like Monads, at another Acephalans; but scarcely any typify the Polypes, and none the Acalephes. In the Encephalous division we meet with many interesting examples of the prevalence of unity of organisation at early periods, which is lost in the diversity of the special forms as development proceeds. Thus the embryos of the various orders of Gasteropods are nudibranchiate; but only a few retain that condition of the respiratory system through life. The naked Gasteropods are at first univalve Mollusks, like the great bulk of the class at all periods. The testaceous Cephalopods first construct an unilocular shell, which is the common persistent form in Gasteropods, and afterwards superadd the characteristic chambers and siphon. This simple fact would of itself have disproved the theory of evolution, if other observations of the phenomena of development had not long since rendered that once favourite doctrine untenable.

Thus as we trace the development of the Molluscous animal, we find the application of the term unity of organisation progressively narrowed as development advances: for whilst all Mollusca manifest, at their earliest and most transitory period, a resemblance to the lowest or monadiform zoophytes, only the lowest order of Mollusca in the next stage of development represents the polypes; and all analogy to the radiated type is afterwards lost, until we reach the summit of the Molluscous series, when we find it illusively, though interestingly, sketched by the crown of locomotive and prehensile organs upon the head of the Cephalopods.

In the great Articulated branch of the animal kingdom, there is unity of organisation with the Molluscous series at the earliest periods of development, in so far as the germ divides and subdivides and multiplies itself; but the correspondence does not extend to the acquisition of the locomotive power by superficial vibratile cilia: the progeny of the fissiparous primitive nucleated cell begin at once to arrange themselves into the form of the Vibrio or apodal worm, while those of the Molluscous germ diverge into the polype-form or into a more special type.

Unity of organisation prevails through a very great proportion of the Articulate series in reference to their primitive condition as apodal worms. Only in the Arachnida apparently, the nucleated cells are aggregated under a form more nearly like that of the mature animal, before they are metamorphosed into its several tissues. In lower or more vermiform Condylopods, the rudimental conditions of the locomotive appendages, which are retained in the Anellides and the lower Crustaceans, are passed through in the progress of the development of the complex-jointed limbs. In the great series of air-breathing insects, we have seen that the diverging branch of Myriapoda manifests at an early period the prevailing hexapod type, and that all Insects are at first apterous, and acquire the jointed legs before the wings are fully developed. An articulate animal never passes through the form of the Polype, the Acalephe, the Echinoderm, or the Mollusk: it is obedient to the law of unity of organisation only in its monad stage: on quitting this, it manifests the next widest relations of uniformity as a Vibrio or apodal worm; after which the exact expression of the law must be progressively contracted in its application as the various Articulata progressively diverge to their special types in the acquisition of their mature forms.

In the proper Radiated series itself we discern the same principle: the radiated type culminates in the Echinoderms; but the most typical forms, called emphatically star-fishes, are pedunculated in the embryo-state, at least in one family, and so far manifest conformity of organisation with the Polypes and the vast and almost extinct tribes of the Pentacrinites, before acquiring their free and locomotive maturity.

It will be found when we enter upon the consideration of the development of the Vertebrate embryo, that its unity of organisation with the Invertebrata is restricted to as narrow and transitory a point as that of the Articulate with the Molluscous series. Manifesting the same monad-like properties of the germ, the fissiparous products proceed to arrange and metamorphose themselves into a vermiform apodal organism, distinguished from the corresponding stage of the Insect by the Vertebrate characteristics of the nervous centres, — viz. the spinal chord and its dorsal position; whereby it is more justly comparable to the apodal fish than to the worm.

Thus every animal in the course of its development typifies or represents some of the permanent forms of animals inferior to itself; but it does not represent all the inferior forms, nor acquire the organization of any of the forms which it transitorily represents. Had the animal kingdom formed, as was once supposed, a single and continuous chain of being progressively ascending from the Monad to the Man, unity of organisation might then have been demonstrated to the extent in which the theory has been maintained by the disciples of the Geoffroyan school.

There is only one animal form which is either permanently or transitorily represented throughout the animal kingdom: it is that of the infusorial Monad, with the consideration of which the present survey of the Invertebrate animals was commenced, and which is to be regarded as the fundamental or primary form.

Other forms are represented less exclusively in the development of the animal kingdom, and may be regarded as secondary forms. These are, the Polype, the Worm, the Tunicary, and the Lamprey; they are secondary in relation to the animal kingdom at large, but are primary in respect of the primary divisions or sub-kingdoms.

Thus the *Radiata*, after having passed through the monad-stage enter that of the polype; many there find their final development; others proceed to be metamorphosed into the Acalephe or the Echinoderm.

All the *Articulata*, at an early stage of their development, assume the form or condition of the apodal and acephalous worm; some find their mature development at that stage, as the parasitic Entozoa; others proceed to acquire annulations, a head, rudimental feet, jointed feet, and finally wings: radiating in various directions and degrees from the primary or fundamental form of their sub-kingdom.

The *Mollusca* pass from the condition of the ciliated Monad to that of the shell-less Acephalan, and in like manner either remain to work out the perfections of that stage, or diverge to achieve the development of shells, of a head, of a ventral foot, or of cephalic arms, with all the complexities of organisation which have been demonstrated in the concluding Lectures of this Course.

The *Vertebrated* ovum having manifested its monadiform relations by the spontaneous fission, growth, and multiplication of the primordial nucleated cells, next assumes, by their metamorphosis and primary arrangement, the form and condition of the finless cartilaginous fish, from which fundamental form development radiates in as many and diversified directions and extents, and attains more extraordinary heights of complication and perfection than any of the lower secondary types appear to be susceptible of. The ultimate stages of these developments, the various permanent or mature structures of the Vertebrated series, with their physiological and other relations, will form the subjects of succeeding lectures.

For the kind and patient attention with which the present course has been honoured, I must again, Mr. President and Gentlemen, express my most sincere thanks, and, with every good wish, respectfully bid you Farewell!

To Mr. Cooper's notes of the Lectures, as orally delivered, I have added the details contained in my written notes, which, for want of time, were omitted, or only briefly alluded to in the theatre. R. O.

GLOSSARY

OF ANATOMICAL AND OTHER SCIENTIFIC TERMS USED IN THESE LECTURES.

ABDOMEN. (Lat. *abdo*, I conceal.) The posterior and principal cavity containing the bowels and many other viscera of the animal. The abdomen is distinct from the thorax in crustaceans, spiders, and insects.

ABDOMINALES. (Lat. *abdomen.*) An order of fishes, so called from the attachment of the ventral fins to the abdomen behind the pectorals.

ABERRANT. (Lat. *aberro*, I wander from.) This term is applied to those species which deviate most from the type of their natural group.

ABRANCHIATE. (Gr. *a*, without; *brugchia*, gills.) When an animal is devoid of gills.

ACALEPHA. (Gr. *akalephe*, a nettle.) The class of radiated animals with soft skins, which have the property of stinging like a nettle.

ACANTHOCEPHALA. (Gr. *akanthos*, a spine; *kephale*, a head.) The order of intestinal worms having the head armed with spines or hooks.

ACARUS. (Gr. *akari*, a mite.) The name of a genus of Arachnida, to which the cheese-mite and allied species belong.

ACARIDÆ. The family of which the genus *Acarus* is the type.

ACASTA. (Gr. *akuste.*) A name arbitrarily applied to a genus of Barnacles, parasitic upon sponges.

ACEPHALOUS. (Gr. *a*, without; *kephale*, head.) Headless. The animals in which a distinct head is never developed.

ACEPHALOCYST. The parasitic hydatid, which consists of a cyst or bag without a head.

ACETABULA. (Lat. *acetabulum*, a shallow cup.) The fleshy sucking-cups with which many of the invertebrate animals are provided.

ACINI. (Lat. *acinum*, a berry.) The secerning parts of glands, when they are suspended like grains or small berries to a slender stem.

ACOUSTIC. (Gr. *akouo*, I hear.) Appertaining to sound, or the organ of hearing.

ACRITA. (Gr. *akritos*, confused.) A term applied to the lowest animals, in which the organs, and especially the nervous system, were supposed to be confusedly blended with the other tissues.

ACTINIA. (Gr. *aktin*, a ray.) The genus of Polypes, which have many arms radiating from around the mouth.

ACTINOCEROS. (Gr. *aktin*, a ray; *keras*, a horn.) A generic term, signifying the radiated disposition of the horns or feelers.

ADIPOSE. (Lat. *adeps*, fat.) Fatty.

AKERA. (Gr. *a*, without; *keras*, a horn.) The family of Mollusca, without horns or feelers.

ALAR. (Lat. *ala*, a wing.) Belonging to a wing.

ALBUMINOUS. (Lat. *albumen*, white of egg.) Consisting of albumen, or the substance which forms the white of an egg.

ALIFORM. Shaped like a wing.

ALULA. A little wing.

AMBULACRA. (Lat. *ambulacrum*, an avenue or place for walking.) The perforated series of plates in the shell of the sea-star or sea-urchin.

AMBULATORY. (Lat. *ambulo*, I walk.) An animal or a limb made for walking.

AMMONITES. An extinct genus of Mollusca, allied to the Nautilus, which inhabited a chambered shell, called Ammonite from its resemblance to the horns on the statues of Jupiter Ammon.

AMORPHOUS. (Gr. *a*, without; *morphe*, form.) Bodies devoid of regular form.

AMPHIPODS. (Gr. *amphi*, on both sides; *pous*, a foot.) The order of Crustacea, which have feet for both walking and swimming.

AMPHISTOMA. (Gr. *amphi; stoma*, a mouth.) The genus of suctorial parasitic worms, which have pores like mouths at both ends of the body.

AMPULLA. (Lat. a bottle.) A membranous bag, shaped like a leathern bottle.

ANAIMA. (Gr. *a*, without; *aima*, blood.) The name given by Aristotle to the animals which have no red blood, and which he supposed to be without blood.

ANALOGUE. A part or organ in one animal which has the same function as another part or organ in a different animal. *See* HOMOLOGUE.

ANASTOMOSE. (Gr. *ana*, through; *stoma*, mouth.) When the mouths of two vessels come into contact and blend together, or when two vessels unite as if such kind of union had taken place.

ANDROGYNOUS. (Gr. *anèr*, a man; *gunè*, a woman.) The combination of male and female parts in the same individual.

ANELLATA. (Lat. *annellus*, a little ring.) The worms in which the body seems to be composed of a succession of little rings, characterised by their red blood.

ANELLIDE. The anglicised singular of *Anellata*.

ANENTEROUS. (Gr. *a*, without; *enteron*, a bowel.) The animalcules of infusions which have no intestinal canal.

ANNULATED. (Lat. *annulus*, a ring.) When an animal or part appears to be composed of a succession of rings.

ANOUROUS. (Gr. *a*, without; *oura*, a tail.) Tail-less.

ANTENNA. (From the Latin for yard-arm.) Applied to the jointed feelers or horns upon the heads of insects and crustacea, and sometimes to the analogous parts, which are not jointed in worms and other animals.

ANTHOZOA. (Gr. *anthos*, a flower; *zoon*, an animal.) The class of Polypes, including the actinia and allied species, commonly called animal-flowers.

ANTIPERISTALTIC. (Gr. *anti*, against; and *peristaltic*.) When the vermicular contractions of a muscular tube follow each other in a direction the reverse of the ordinary one.

ANTLIA. (From the Latin for pump.) Restrictively applied to the spiral instrument of the mouth of butterflies and allied insects, by which they pump up the juices of plants.

AORTA. (Gr. *aorte*, the wind-pipe; and also the name of the great vessel springing from the heart, which is the trunk of the systemic arteries.) It is exclusively applied in the latter sense in modern anatomy.

APHIDIAN. Belonging to the insect called *aphis*, or plant-louse.

APICAL. (Lat. *apex*, the top of a cone.) Belonging to the pointed end of a cone-shaped body.

APODAL. (Gr. *a*, without; *poda*, feet.) Footless; without feet or locomotive organs: fishes are so called which have no ventral fins.

APTEROUS. (Gr. *a*, without; *pteron*, a wing.) Wingless species of Insects or Birds.

ARACHNIDA. (Gr. *arachne*, a spider.) Spiders, and the animals allied to them in structure.

ARBORESCENT. (Lat. *arbor*, a tree.) Branched like a tree.

ARTHRODIAL. (Gr. *arthron*, a joint.) It is restricted to that form of joint in which a ball is received into a shallow cup.

ARTICULATA. (Lat. *articulus*, a joint.) Animals with external jointed skeletons or jointed limbs.

ASCIDIAN. (Gr. *askos*, a bottle.) The shell-less acephalous Mollusks, which are shaped like a leathern bottle.

AUTOMATIC. (Gr. *automatos*, self-moving.) A movement in a living body without the intervention or excitement of the will.

AXILLA (from the Latin for armpit); and applied to other parts of the animal body which form a similar angle.

AZYGOS. (Gr. *a*, without; *zugos*, yoke.) Single, without fellow.

BACULITE. An extinct genus of molluscous animals allied to the Nautilus, which inhabited a straight-chambered shell, resembling a staff; whence the name of the genus, from *baculus*, a staff.

BALANOIDS. (Gr. *balanos*, an acorn.) A family of sessile Cirripeds, the shells of which are commonly called acorn-shells.

BASILAR. (Lat. *basis*, a base.) Belonging to the base of the skull.

Batrachia. (Gr. *batrachos*, a frog.) The order of reptiles including the frog.
Belemnite. (Gr. *belemnon*, a dart.) An extinct genus of molluscous animals allied to the sepia, and provided with a long, straight, chambered, conical shell in the interior of the body.
Bifid. Cleft into two parts, or forked.
Bifurcate. Divided into two prongs or forks.
Bilateral. Having two symmetrical sides.
Bilobed. Divided into two lobes.
Bipartite. Divided into two parts.
Bituberculate. With two knobs or tubercles.
Bivalve. When a shell consists of two parts, closing like a double door. The Mollusca, so protected, are commonly called bivalves.
Bothriocephalus. (Gr. *bothros*, a pit; *kephale*, a head.) The genus of tape-worms with depressions on the head.
Botrylli. (Gr. *botrus*, a bunch of grapes.) A little cluster of berry-shaped bodies.
Brachial. (Gr. *brachion*, the arm.) Belonging to the arm.
Brachiopoda. (Gr. *brachion*; *poda*, feet.) A class of acephalous Mollusca, with two long spiral fleshy arms continued from the side of the mouth.
Brachyura. (Gr. *brachus*, short; *oura*, tail.) The tribe of Crustacea with short tails, as the crabs.
Brachyurous. Short tailed; usually restricted to the Crustacea.
Branchia. (Gr. *bragchia*, the gills of a fish.) The respiratory organs which extract the oxygen from air contained in water.
Branchiopods. (Gr. *bragchia*, gills; *poda*, feet.) Crustacea in which the feet support the gills.
Bryozoa. (Gr. *bruon*, moss; *zoon*, animal.) A class of highly-organised Polypes, most of the species of which incrust other animals or bodies like moss.
Buccal. (Lat. *bucca*, mouth or cheeks.) Belonging to the mouth.
Byssus (from the Greek word, signifying the silky filaments which project from the bivalve called Pinna). Applied to the analogous parts in other Mollusks.

Cæcum and Cæca. (Lat. *cœcus*, blind.) A blind tube, or productions of a tube which terminate in closed ends.
Canthus. (Gr. *kanthos*.) The corner of the eye.
Capitate. (Lat. *caput*, head.) When a part is terminated by a knob like the head of a pin.
Carapace. The upper shell of the crab or tortoise.
Cardia. (Gr. *kardia*, the heart or stomach.) The opening which admits the food into the stomach; also the region called the pit of the stomach.
Carnivorous. (Lat. *caro*, flesh; *voro*, I devour.) The animals which feed on flesh.
Caruncle. (Lat. *caruncula*.) A soft wart-like eminence.
Caudal. (Lat. *cauda*, a tail.) Belonging to the tail.
Cauda Equina. The brush of nerves which terminates the spinal marrow in the human subject, and the analogous part in the lower animals.
Cellular tissue. (Lat. *cella*, a cell.) The elastic connecting tissue of the different parts of the body, which every where forms cells or interspaces containing fluid.
Centipede. (Lat. *centum*, a hundred; *pes*, a foot.) A genus of insects with very numerous feet.
Cephalo-thorax. (Gr. *kephale*, head; *thorax*, chest.) The anterior division of the body in spiders, scorpions, &c., which consists of the head and chest blended together.
Cephalic. (Gr. *kephale*, head.) Belonging to the head.
Cephalopoda. (Gr. *kephale*; *poda*, feet.) The class of molluscous animals in which long prehensile processes or feet project from the head.
Cercariæ. (Gr. *kerkos*, a tail.) The animalcules whose body is terminated by a tail-like appendage.
Cercariiform. Shaped like Cercariæ.
Cercæ. (Gr. *kerkos*, a tail.) The feelers which project from the hind part of the body in some insects.

CEREALIA. (*Ceres*, the Goddess of corn.) The name of the natural family of plants which produce corn, oats, rye, &c.

CESTOIDEA. (Gr. *kestos*, a girdle.) The order of intestinal worms with long and flat bodies like tape, usually called tape-worms.

CHELONIA. (Gr. *chelone*, a turtle.) The order of reptiles including the tortoises and turtles.

CHELE. (Gr. *chele*, a claw.) Applied to the bifid claws of the Crustacea, scorpions, &c.

CHELICERA. (Gr. *chele*, a claw; *keras*, a horn.) The prehensile claws of the scorpion, which are the homologues of Antennæ.

CHILOGNATHA. (Gr. *cheilos*, a lip; *gnathos*, a jaw.) The order of many-footed insects typified by the Gally-worm or Iulus.

CHILOPODA. (Gr. *cheilos*, a lip; *poda*, feet.) An order of many-footed insects typified by the Centipede.

CHITINE. (Gr. *chiton*, a coat.) The peculiar chemical principle which hardens the integument of insects.

CHOLEDOCHUS. (Gr. *cholè*, bile; *dòche*, receptacle.) The tube formed by the union of the hepatic and cystic ducts.

CHORION. From the Greek word signifying the membrane which encloses the fœtus, and applied generally to the outer covering of the ovum.

CHRYSALIDS. (Gr. *chrusos*, gold.) The stage of the butterfly immediately preceding its period of flight, when it is passive, and enclosed in a case which sometimes glitters like gold.

CHYLE. (Gr. *chulos*, juice.) The nutrient fluid extracted from the digested food by the action of the bile.

CHYME. (Gr. *chumos*, juice.) The digested food which passes from the stomach into the intestines.

CICATRIX. From the Latin, signifying scar.

CILIA. (Lat. *cilium*, an eyelash.) The microscopic hair-like bodies which cause, by their vibratile action, currents in the contiguous fluid, or a motion of the body to which they are attached.

CILIATED. Provided with vibratile cilia.

CILIOBRACHIATA. The class of Polypes in which the arms are provided with vibratile cilia.

CILIOGRADES. (Lat. *cilium*; and *gradior*, I walk.) The order of Acalephæ which swim by the action of cilia.

CIRCUMGYRATIONS. (Lat. *circum*, around; *gyrus*, a circle.) Motions in a circle.

CIRRI. (Lat. *cirrus*, a curl.) The curled filamentary appendages, as the feet of the barnacles.

CIRRIGEROUS. Supporting cirri.

CIRRIGRADES. Moving by cirri.

CIRRIPEDS or CIRRIPEDIA. (Lat. *cirrus*, a curl; *pes*, a foot.) A class of articulate animals having curled jointed feet. Sometimes written *Cirrhipedia* and *Cirrhopoda*.

CLAVATE. (Lat. *clavus*, a club.) Club-shaped; linear at the base, but growing gradually thicker towards the end.

CLOACA. (Lat. *cloaca*, a sink.) The cavity common to the termination of the intestinal, urinary, and generative tubes.

CLYPEIFORM. (Lat. *clypeus*, a shield; *forma*, shape.) Shield-shaped; applied to the large prothorax in beetles.

COARCTATE. (Lat. *coarcto*, I compress.) The pupa of an insect, which is enveloped by a case, which gives no indication of the parts it covers.

CŒLELMINTHA. (Gr. *koilos*, hollow; *helmins*, an intestinal worm.) The intestinal worms which are hollow, and contain an alimentary tube in the cavity of the body.

COLEOPTERA. (Gr. *koleos*, a sheath; *pteron*, a wing.) The order of insects in which the first pair of wings serves as a sheath to defend the second pair.

COLUMELLA. (From the Latin for a small column.) Used in Conchology to signify the central pillar around which the spiral shell is wound.

COMMISSURAL. (Lat. *committo*, I solder.) Belonging to a line or part by which other parts are connected together.

CONCHIFERS. (Lat. *concha*, a shell; *fero*, I bear.) Shell-fish; usually restricted to those with bivalve shells.
CONDYLOPODS. (Gr. *kondulos*, a joint; *pous*, a foot.) The articulate animals with jointed legs, as insects, crabs, and spiders.
CORIACEOUS. (Lat. *corium*, hide.) When a part has the texture of tough skin.
CORNUA. (Lat. *cornu*, a horn.) Horns or horn-like processes.
CORNEA. (Lat. *corneus*, horny.) The transparent horny membrane in front of the eye.
CORNEOUS. Horny.
CORNEULE. Diminutive of cornea; applied to the minute transparent segments which defend the compound eyes of insects.
CRETACEOUS. (Lat. *creta*, chalk.) Belonging to chalk.
CRINOID. (Gr. *krinon*, a lily; *eidos*, like.) Belonging to the Echinoderma which resemble lilies; the fossils called stone-lilies or encrinites are examples.
CRURA. (Lat. *crus*, a leg.) The legs of an animal, or processes resembling legs.
CRUSTACEA. (Lat. *crusta*, a crust.) The class of articulate animals with a hard skin or crust, which they cast periodically.
CRYPTOBRANCHIATE. (Gr. *kruptos*, hidden; *bragchia*, gills.) Those molluscous and articulate animals, which have no conspicuous gills.
CRYPTOGAMIC. (Gr. *kruptos*, concealed; *gamos*, marriage.) The animals or plants in which the organs of generation are concealed.
CYCLOBRANCHIATA. (Gr. *kuklos*, round; *bragchia*, gills.) The molluscous animals which have the gills disposed in a circle.

DECAPODA. (Gr. *deca*, ten; *pous*, a foot.) The crustaceous and molluscous animals which have ten feet.
DECOLLATED. (Lat. *decollo*, to behead.) The univalve shells in which the apex or head is worn off in the progress of growth.
DECIDUOUS. Parts which are shed, or do not last the lifetime of the animal.
DEHISCENCE. (Lat. *dehisco*, to gape.) The splitting open of the bag containing the eggs.
DEFLECTED. Bent down.
DEMODEX. (Gr. *demos*, lard; *dex*, a boring worm.) The worm-like parasite of the human sebaceous follicles.
DENDRITIC. (Gr. *dendron*, a tree.) Branched like a tree.
DERMAL. (Gr. *derma*, skin.) Belonging to the skin.
DIBRANCHIATA. (Gr. *dis*, twice; *bragchia*, gills.) The order of Cephalopods having two gills.
DICŒLOUS. (Gr. *dis*; *koilos*, a cavity.) A heart with two cavities.
DIDACTYLE. (Gr. *dis*; and *dactulos*, a finger.) A limb terminated by two fingers.
DIGITATE. (Lat. *digitus*, a finger.) When a part supports processes like fingers.
DIMIDIATE. (Lat. *dimidium*, half.) Divided into two halves.
DIŒCIOUS. (Gr. *dis*, twice, and *oikos*, a house.) The species which consist of male and female individuals.
DIMYARY. (Gr. *dis*; *muon*, a muscle.) A bivalve whose shell is closed by two muscles.
DIPTERA. (Gr. *dis*; *pteron*, a wing.) The insects which have two wings.
DISCOID. (Lat. *discus*, a quoit.) Quoit-shaped.
DISTOMA. (Gr. *dis*; *stoma*, mouth.) The intestinal worms with two pores.
DIVERTICULUM. (From the Latin for a bye-road.) Applied to a blind tube branching out from the course of a longer one.
DORSAD. (Lat. *dorsum*, the back.) Towards the back.
DORSIBRANCHIATE. (Lat. *dorsum*; and *branchia*, gills.) The Mollusca with gills attached to the back.
DORSO-INTESTINAL. A part which is on the dorsal aspect of the intestine.
DUCTUS. A duct or tube which conveys away the secretion of a gland.
DUODENUM. The first portion of the small intestine, which, in the human subject, equals the breadth of twelve fingers.

ECDYSIS. (From the Greek, signifying the act of stripping.) Moulting of the skin.

Echinoderms. (Gr. *echinos*, a hedgehog; *derma*, skin.) The class of radiated animals, most of which have spiny skins.

Edentulous. From the Latin word for toothless.

Edriophthalma. (Gr. *edraios*, sitting or sessile; and *ophthalmos*, an eye.) The Crustacea with sessile eyes.

Elytra. (Gr. *elutron*, a sheath.) The wing sheaths formed by the modified anterior pair of wings of beetles.

Emarginate. (Lat. *emargino*, to remove an edge.) When an edge or margin has, as it were, a part bitten out.

Emunctories. (Lat. *emungo*, to wipe the nose.) Parts which carry out of the body useless or noxious particles.

Enaliosaur. (Gr. *enalios*, marine; *sauros*, a lizard.) An extinct order of marine gigantic reptiles allied to crocodiles and fishes.

Encephala. (Gr. *en*, in; *kephale*, head.) The molluscous animals which have a distinct head.

Entomology. (Gr. *entoma*, insects; *logos*, a discourse.) The department of Natural History which treats of insects.

Entomostraca. (Gr. *entoma*, insects; *ostracon*, a shell.) The order of small Crustaceans, many of which are enclosed in an integument, like a bivalve shell.

Entozoa. (Gr. *entos*, within; *zoon*, animal.) The animals which exist within other animals.

Eocene. (Gr. *eos*, the dawn; *kainos*, recent.) The tertiary period, in which the extremely small proportion of living species indicates the first commencement or dawn of the existing state of animate creation.

Epidermal. (Gr. *epidermis*, the cuticle.) Belonging to the cuticle or scarf-skin.

Epimeral. (Gr. *epi*, upon; *meron*, a limb.) The part of the segment of an articulate animal which is above the joint of the limb.

Epiploon. (From the Greek.) It is the fatty membrane which covers or occupies the interspaces of the entrails in the abdomen.

Episternal. (Gr. *epi*, upon; *sternon*, the breast-bone.) The piece of the segment of an articulate animal which is immediately above the middle inferior piece or sternum.

Epithelium. The thin membrane which covers the mucous membranes: it is analogous to the epiderm of the skin.

Epizoa. (Gr. *epi*, upon; *zoon*, animal.) The class of low organised parasitic Crustaceans which live upon other animals.

Errantes. (Lat. *erro*, I wander.) An order of the class Annelida, remarkable for their locomotive powers.

Excito-motory. The function of the nervous system by which an impression is transmitted to a centre, and reflected so as to produce contraction of a muscle without sensation or volition.

Exosmose. (Gr. *ex*, out of; *otheo*, I expel.) The act in which a denser fluid is expelled from a membranous sac by the entry of a lighter fluid from without.

Exuvium. (From the Latin, signifying the skin of a serpent.) The skin which is shed in moulting.

Exuvial. Any part which is moulted.

Facet. (From the French.) A flat surface, with a definite boundary.

Fascicle. (From the Latin *fasciculus*.) A small bundle.

Filiform. (Lat. *filum*, a thread; *forma*, a shape.) Thread-shaped.

Fissiparous. (Lat. *findo*, I cleave; *pario*, I produce.) The multiplication of a species by the voluntary cleavage of the individual into two parts.

Flabelliform. (Lat. *flabellum*, a fan.) Fan-shaped.

Flagellum. (From the Latin.) An appendage to the legs of the Crustacea resembling a whip.

Flexors. (Lat. *flecto*, I bend.) The muscles employed in bending a limb.

Flexuous. A bending course.

Foliaceous. (Lat. *folium*, a leaf.) Shaped or arranged like leaves.

Follicle. (Lat. *folliculus*, a small bag.) Minute secreting bags which commonly open upon mucous membranes.

Fossiliferous. (Lat. *fossilis*, any thing dug out of the earth; and *ferro*, I bear.)

Applied to the strata which contain the remains of animals and plants, to which remains Geologists now restrict the term Fossil.

FUCIVOROUS. (Lat. *fucus*, sea-weed; and *voro*, I devour.) Animals which subsist on sea-weed.

FUSIFORM. (Lat. *fusus*, a spindle; and *forma*, a shape.) Spindle-shaped.

GANGLION. (Gr. *gagglion*, a knot.) A mass of nervous matter, forming a centre from which nervous fibres radiate.

GASTEROPODA. (Gr. *gaster*, stomach; *pous*, a foot.) That class of molluscous animals which have the locomotive organ attached to the under part of the body.

GEMMIPAROUS. (Lat. *gemma*, a bud; *pario*, I bring forth.) Propagation by the growth of the young, like a bud from the parent.

GEMMULE. (Dim. of *gemma*.) The embryos of the radiated animals at that stage when they resemble ciliated monads.

GLOBOSE. (Lat. *globus*, a globe.) Globe-shaped.

GLOSSOLOGY. (Gr. *glosse*, the tongue; Gr. *logos*, discourse.) The science of scientific language.

GRANULES. (Dim. of *granum*, a grain.) Little grains.

GYNGLYMOID. (Gr. *gigglumos*, a hinge.) A joint formed for motion on one plane.

HAUSTELLATE. (Lat. *haurio*, I drink.) The structure of mouth adapted for drinking or pumping up liquids; also the insects which possess that kind of mouth.

HELMINTHOID. (Gr. *helmins*, an intestinal worm.) Worm-shaped.

HEMELYTRA. (Gr. *hemisu*, half; *elytron*, a sheath.) A wing, of which one half is opaque and firm like an elytrum.

HEMIPTERA. (Gr. *hemisu*, half; *pteron*, a wing.) The order of insects in which the anterior wings are hemilytra.

HEPATIC. (Lat. *hepar*, liver.) Belonging to the liver.

HERBIVOROUS. (Lat. *herba*, grass; *voro*, I devour.) The animals which subsist on grass.

HERMAPHRODITE. (*Hermes*, Mercury; *Aphrodita*, Venus.) An individual in which male and female characteristics are combined.

HETEROGANGLIATE. (Gr. *heteros*, diverse; *gagglion*.) The animals with the ganglionic nervous system, and the ganglions scattered often unsymmetrically.

HETEROMORPHOUS. (Gr. *heteros*, another; *morphe*, form.) Of an irregular or unusual form, applied to the larvæ of certain insects which differ in form from the imago, and applicable to the true larval state of all insects.

HEXAPOD. (Gr. *hexa*, six; *pous*, a foot.) The animals with six legs, such as true insects.

HISTOLOGICAL. (Gr. *histos*, a tissue; *logos*, discourse.) The doctrine of the tissues which enter into the formation of an animal and its different organs.

HOMOGANGLIATE. (Gr. *homos*, like; *ganglion*.) The animals with the ganglionic nervous system and symmetrical arrangement of the ganglions.

HOMOLOGUE. (Gr. *homos*; *logos*, speech.) The same organ in different animals under every variety of form and function.

HOMOMORPHOUS. (Gr. *homos*, like; *morphe*, form.) Of similar form.

HOMOPTERA. (Gr. *homos*, like; *pteron*, a wing.) The insects in which the four wings have a similar structure, but restricted in its application, to a section of Hemiptera.

HYALINE. (Gr. *hualos*, crystal.) The pellucid substance which determines the spontaneous fission of cells.

HYDATID. (Gr. *hudatis*, a vesicle.) A bladder of albuminous membrane, containing serous fluid; generally detached; sometimes with an organised head and neck.

HYDRA. (Gr. *hudra*, a water-serpent.) The modern generic name of freshwater Polypes.

HYDRIFORM. Similarly-formed Polypes.

HYDROZOA. (Gr. *hudra*; *zoon*, animal.) The class of Polypi organised like the Hydra.

HYMENOPTERA. (Gr. *humen*, a membrane; *pteron*, a wing.) The order of insects including the bee, wasp, &c. which have four membranous wings.

IMBRICATED. (Lat. *imbricatus*, tiled.) Scales which lie one upon another like tiles.
INGLUVIES. A crop or partial dilatation of the œsophagus.
INOPERCULAR. Univalve shells which have no operculum or lid.
INSTRUMENTA CIBARIA. (Lat. *cibus*, food.) The parts of the mouth in insects concerned in the acquisition and preparation of the food.
INTERAMBULACRA. The imperforate plates which occupy the intervals of the perforated ones, or ambulacra, in the shells of the Echinoderms. See *Ambulacra*.
INTERGANGLIONIC. (Lat. *inter*, between; and *ganglion*.) The nervous chords in the intervals of the ganglions, which they connect together.
INTERSTITIAL. (Lat. *interstitium*.) Relating to the intervals between parts.
INTR-AUTERINE. (Lat. *intra*, within; *uterus*, the womb.) The development of the embryo which takes place within the womb.
INTUSSUSCEPTION. (Lat. *intus*, within; *suscipio*, I take up.) When part of a tube is inverted within a contiguous part.
INVERTEBRATA. (Lat. *in*, used in composition to signify *not*, like *un*; *vertebra*, a bone of the back.) Animals without back-bones.
ISOCYCLUS. (Gr. *isos*, equal; *kuklos*, a ring.) An animal composed of a succession of equal rings.
ISOPODA. (Gr. *isos*, equal; *pous*, a foot.) An order of Crustaceans in which the feet are alike, and equal.

LABIUM. Latin for a lip; but applied only to the lower lip in Entomology.
LABRUM. Latin for a lip; but applied only to the upper lip in Entomology.
LAMELLIBRANCHIATA. (Lat. *lamella*, a plate; *bragchia*, gills.) The class of acephalous Mollusks with gills in the form of membranous plates.
LAMELLIFORM. Shaped like a thin leaf or plate.
LANIARIFORM. (Lat. *lanio*, to cut or tear; *forma*, shape.) Shaped like the canine teeth of the Carnivora, which are called *laniaries* from their office.
LARVA. (Lat. *larva*, a mask.) Applied to an insect in its first active state, which is generally different from, and as it were masks the ultimate form. Larviform, shaped like a larva.
LARVIPAROUS. (Lat. *larva*; *pario*, I produce.) The insects which produce their young in the condition of larvæ.
LEMNISCUS. (The Latin for riband.) Applied to the minute riband-shaped appendages of the generative pores in *Entozoa*.
LEPIDOPTERA. (Gr. *lepis*, a scale; *pteron*, a wing.) The order of insects in which the wings are clothed with fine scales, as butterflies and moths.

MACROURA. (Gr. *makros*, long; *oura*, tail.) The tribe of decapod Crustacea which have long tails, as the lobster.
MALACOLOGY. (Gr. *malakos*, soft; *logos*, discourse.) The history of the soft-bodied or molluscous animals, which were termed *Malakia* by Aristotle.
MALACOSTRACA. (Gr. *malakos*; *ostrakon*, a shell.) The name given by Aristotle to the modern Crustacea, because their shells were softer than those of the Mollusca, or ordinary shell-fish.
MAMMALIA. (Lat. *mamma*, a breast.) The class of animals which give suck to their young.
MANDIBULATA. (Lat. *mandibula*, a jaw.) The insects which have mouths provided with jaws for mastication; the term mandible is restricted in Entomology to the upper and outer pair of jaws.
MANTLE. The external soft contractile skin of the Mollusca, which covers the viscera and a great part of the body like a cloak.
MARSUPIAL. (Lat. *marsupium*, a purse.) The tegumentary pouch, in which the embryo is received after birth, and protected during the completion of its development.
MASTODON. (Gr. *mastos*, a teat; *odon*, a tooth.) A genus of extinct quadrupeds allied to the elephant, but having the grinders covered with conical protuberances like teats.
MAXILLA. (From the Latin for a jaw.) In Entomology restricted to the inferior pair of jaws.

MEDIAN. Having reference to the middle line of the body.
MEDULLA OBLONGATA. The oblong medullary column at the base of the brain, from which the spinal chord or marrow is continued.
MEDUSÆ. A genus or family of soft radiated animals or acalephes, so called because their organs of motion and prehension are spread out like the snaky hair of the fabulous Medusa.
MESENTERY. (Gr. *mesos*, intermediate; and *enteros*, entrail.) The membrane which forms the medium of connection between the small intestines and the abdomen.
MESOGASTRIC. (Gr. *mesos;* and *gaster*, stomach.) The membrane which forms the medium of attachment of the stomach to the walls of the abdomen.
MESONOTUM. (Gr. *mesos*, middle; *notos*, back.) The middle piece of that half of the segment which covers the back.
MESOSTERNUM. (Gr. *mesos; sternon*, the breast.) The middle part of that half of the segment which covers the breast.
MESOTHORAX. (Gr. *mesos*, middle; and *thorax*, the chest.) The intermediate of the three segments which form the thorax in insects.
METATHORAX. (Gr. *meta*, after; *thorax*.) The hindmost of the three segments which compose the thorax of an insect.
MIOCENE. (Gr. *meion*, less; *kainos*, recent.) The tertiary epoch in which a minority of fossil shells are of the recent species.
MOLECULES. (Dim. of *moles*, a mass.) Microscopic particles.
MOLLUSCA. (Lat. *mollis*, soft.) The primary division of the Animal Kingdom, characterised at page 13.
MONAD. (Gr. *monas*, unity.) The genus of the most minute and simple microscopic animalcules, and shaped like spherical cells. Monadiform, like a monad.
MONOCULUS. (Gr. *monos*, single; Lat. *oculus*, an eye.) The animals which have but one eye.
MONOMYARY. (Gr. *monos*, single; *muon*, a muscle.) A bivalve whose shell is closed by one adductor muscle.
MONOTHALAMOUS. (Gr. *monos; thalamos*, a chamber.) A shell forming a single chamber, like that of the whelk.
MORPHOLOGICAL. (Gr. *morphe*, form; *logos*, a discourse.) The history of the modifications of form which the same organ undergoes in different animals.
MOTORY. The nerves which control motion.
MULTIVALVE. (Lat. *multus*, many; *valvæ*, folding-doors.) Shells composed of many pieces or valves.
MYELENCEPHALA. (Gr. *muelos*, marrow; *egkephalon*, brain.) The primary division of animals characterised by a brain and spinal marrow.
MYRIAPODA. (Gr. *murios*, ten thousand; *pous*, foot.) The order of insects characterised by their numerous feet.

NACREOUS. Pearly, like mother-of-pearl.
NATATORY. An animal or part formed for swimming.
NEMATOIDEA. (Gr. *nema*, a thread; *eidos*, like.) The intestinal worms, which are long, slender and cylindrical like threads.
NEMATONEURA. (Gr. *nema*, a thread; *neuron*, a nerve.) The animals in which the nervous system is filamentary, as in the star-fish.
NERVURES. (Lat. *nervus*, a sinew.) The delicate frame-work of the membranous wings of insects.
NEURILEMMA. (Gr. *neuron*, a nerve; *lemma*, a covering.) The membrane which surrounds the nervous fibre.
NEUROLOGY (Gr. *neuron* a nerve; *logos*, a discourse.) The science of the nervous system.
NEUROPTERA. (Gr. *neuron*, a nerve; *pteron*, a wing.) The order of insects with four wings, characterised by their numerous nervures, like those of the dragon-fly.
NIDAMENTAL. (Lat. *nidus*, a nest.) Relating to the protection of the egg and young, especially applied to the organs that secrete the material of which many animals construct their nests.
NODULE. (Dim of *nodus*, a knot.) A little knot-like eminence.
NORMAL. (Lat. *norma*, rule.) According to rule, ordinary or natural.

NOTAL. (Gr. *notos*, the back.) Belonging to the back.
NUCLEATED. Having a nucleus or central particle; applied to the elementary cells of animal tissues, the most important properties of which reside in the nucleus.
NUDIBRACHIATE. (Lat. *nudus*, naked; *brachia*, arms.) The Polypes, whose arms are not clothed with vibratile cilia.
NUDIBRANCHIATE. (Lat. *nudus*, naked; *bragchia*, gills.) An order of Gasteropods in which the gills are exposed.

OCTOPODA. (Gr. *octo*, eight; *pous*, a foot.) Animals with eight feet. The name of the tribe of Cephalopods with eight prehensile organs attached to the head.
ŒSOPHAGUS. The gullet or tube leading from the mouth to the stomach.
OLFACTORY. (Lat. *olfactus*, the sense of smelling.) Relating to that sense.
ONYCHOTEUTHIS. (Gr. *onux*, a hook; *teuthis*, a calamary.) The genus of Calamaries armed with hooks or claws.
OOLITE. (Gr. *oon*, egg; *lithos*, stone.) An extensive group of secondary limestones composed of rounded particles, like the roe or eggs of a fish.
OPERCULUM. (From the Latin for lid.) Applied to the horny or shelly plate which closes certain univalve shells; also to the covering of the gills in fish, and to the lids of certain eggs.
ORAL. (Lat. *os*, the mouth.) Belonging to the mouth or to speech.
ORTHOCERA and ORTHOCERATITE. (Gr. *orthos*, straight; *keras*, horn.) The extinct Cephalopods which inhabited long conical chambered shells like a straight horn.
ORTHOPTERA. (Gr. *orthos*, straight; *pteron*, a wing.) The order of insects, with elytra and longitudinally folded wings.
OSSEOUS. (Lat. *os*, a bone.) Bony.
OTOLITHES. (Gr. *ous*, an ear; *lithos*, a stone.) The stony or chalky bodies belonging to the internal ear.
OVARIUM. (Lat. *ovum*, an egg.) The organ in which the eggs or their elementary and essential parts are formed.
OVIGEROUS. (Lat. *ovum*, an egg; *gero*, I bear.) Parts containing or supporting eggs.
OVIPAROUS. (Lat. *ovum*; *pario*, I bring forth.) The animals which bring forth eggs.
OVIPOSITOR. (Lat. *ovum*; *pono*, I place.) The organ in insects, which is often large and complicated, for the transmission of the eggs, during exclusion, to their appropriate place.
OVOVIVIPAROUS. (Lat. *ovum*, egg; *vivus*, alive; *pario*, I produce.) The animals which produce living young, hatched in the egg within the body of the parent, without any connection with the womb.

PALÆONTOLOGY. (Gr. *palaios*, ancient; *onta*, beings; *logos*, discourse.) The history of ancient extinct organised beings.
PALLIAL. (Lat. *pallium*, a cloak.) Relating to the mantle or cloak of the Mollusca.
PALLIOBRANCHIATA. (Lat. *pallium*; *branchia*, gills.) The class of acephalous Mollusca in which the gills are developed from the mantle.
PALPI. (Lat. *palpo*, I touch.) The organs of touch developed from the labium and maxillæ of insects.
PAPILLA. (Lat. for nipple.) Minute soft prominences, generally adapted for delicate sensation.
PAPYRACEOUS. (Gr. *papuros*, paper.) Of the consistency of paper.
PARENCHYMA. The soft tissue of organs; generally applied to that of glands.
PARIETES. (Lat. *paries*, a wall.) The walls of the different cavities of an animal body.
PECTINATED. (Lat. *pecten*, a comb.) Toothed like a comb.
PECTINIBRANCHIATA. (Lat. *pecten*, a comb; *branchia*, gills.) The order of Gasteropods in which the gills are shaped like a comb.
PEDIFORM. (Lat. *pes*, a foot.) Shaped like a foot.
PEDUNCLE. From the Latin *pedunculus*, a stalk.
PEDUNCULATED. Suspended or supported by a stalk.
PELAGIC. (Gr. *pelagos*, sea.) Belonging to the deep sea.

PENTACRINITE. (Gr. *penta*, five; *krinos*, hair.) A pedunculated star-fish with five rays: they are, for the most part, fossil.

PERGAMENEOUS. (Lat. *pergamen*, parchment.) Of the texture of parchment.

PERIOSTRACUM. (Gr. *peri*, around; *ostrakon*, shell.) The membrane analogous to scarf-skin, which covers shell.

PERISTALTIC. (Gr. *peri; stello*, to range.) The vermicular contractions and motions of muscular canals, as the alimentary, the circulating, and generative tubes.

PERITONEAL. (Gr. *peritonaios*, the covering of the abdomen.) Restricted to the lining membrane of that cavity.

PERITREMA. (Gr. *peri*, around; *trema*, hole.) The raised margin which surrounds the breathing holes of scorpions.

PETIOLATE. (Lat. *petiolus*, a fruit stalk.) Ducts supported or suspended by a slender stalk.

PHARYNX. The dilated beginning of the gullet.

PHARYNGEAL. Belonging to the pharynx.

PHRAGMOCONE. (Gr. *phragma*, a partition; *konos*, a cone.) The chambered cone of the shell of the Belemnite.

PHYTOPHAGOUS. (Gr. *phuton*, a plant; *phago*, I eat.) Plant-eating animals.

PIGMENTAL. (Lat. *pigmentum*, paint.) The cells which secrete the coloured particles of the skin and eye, and the membrane formed by such cells.

PINNATE. (Lat. *pinna*, a feather or fin.) Shaped like a feather, or provided with fins.

PLASMA. The fluid part of the blood, in which the red corpuscles float: also called *liquor sanguinis.*

PLASTRON. The under part of the shell of the crab and tortoise.

PLEXUS. (Gr. *pleko*, I twine.) A bundle of nerves or vessels interwoven or twined together.

PLEIOCENE. (Gr. *pleion*, more; *kainos*, recent.) The tertiary strata, which are more recent than the miocene, and in which the major part of the fossil testacea belong to recent species.

PLEISTOCENE. (Gr. *pleistos*, most; *kainos*, recent.) The newest of the tertiary strata, which contains the largest proportion of living species of shells.

PLICÆ. (Lat. *plica*, a fold.) Folds of membrane.

PLUMOSE. (Lat. *pluma*, a feather.) Feathery, or like a plume of feathers.

PNEUMATIC. (Gr. *pneuma*, breath.) Belonging to the air and air-breathing organs.

PODOPHTHALMA. (Gr. *pous*, a foot; *ophthalmos*, an eye.) The tribe of Crustacea in which the eyes are supported upon stalks.

POLYGASTRIA. (Gr. *polus*, many; *gaster*, a stomach.) The class of infusorial animalcules which have many assimilative sacs or stomachs.

POLYPI. (Gr. *polus; pous*, a foot.) The class of radiated animals with many prehensile organs radiating from around the mouth.

PROLEGS. The wart-like tubercles which represent legs on the hinder segment of caterpillars.

PROTHORAX. (Gr. *pro*, before, and *thorax.*) The first of the three segments which constitute the thorax in insects.

PSYCHICAL. (Gr. *psuche*, the soul.) Relating to the phenomena of the soul, and to analogous phenomena in the lower animals.

PTEROPODA. (Gr. *pteron*, a wing; *pous*, a foot.) The class of Mollusca in which the organs of motion are shaped like wings.

PULMOGRADE. (Lat. *pulmo*, a lung; *gradior*, I walk.) The tribe of Medusæ, which swim by contractions of the respiratory disc.

PULMONATA. (Lat. *pulmo.*) The order of Gasteropods that breathe by lungs.

PUPA. (From the Latin for a doll or little image.) The passive state of an insect immediately preceding the last.

PUPIPAROUS. (Lat. *pupa; pario*, I produce.) The insects that bring forth their young in the pupa state.

PYLORUS. From the Greek. The aperture which leads from the stomach to the intestine.

PYRIFORM. (Lat. *pyrum*, a pear.) Pear-shaped.

QUADRIFID. Cleft in four parts.

Radiata. (Lat. *radius*, a ray.) The name of the lowest primary division of the animal kingdom.
Ramose. (Lat. *ramus*, a branch.) Branched.
Reniform. (Lat. *ren*, a kidney.) Kidney-shaped.
Reptilia. (Lat. *repto*, I creep.) The class of Vertebrate animals with imperfect respiration and cold blood.
Rete Mucosum. The cellular layer between the scarf-skin and true skin, which is the seat of the peculiar colour of the skin.
Rhyncholithes. (Gr. *rhunchos*, a beak ; *lithos*, a stone.) Beak-shaped fossils ; the extremities of the mandibles of Cephalopods, allied to the Nautilus.
Rotifera. (Lat. *rota*, a wheel ; *fero*, I bear.) The name of the class of infusorial animalcules, characterised by the vibratile and apparently rotating ciliary organs upon the head.

Salpians. (Gr. *Salpe*, a kind of fish.) The order of tunicated Mollusca which float in the open sea.
Sarcophaga. (Gr. *sarx*, flesh ; *phago*, I eat.) Flesh-eating animals.
Sacciform. Shaped like a sac or bag.
Scutibranchiata. (Lat. *scutum*, a shield ; *branchia*, gills.) The order of gasteropodous Mollusca, in which the gills are protected by a shield-shaped shell.
Sebaceous. (Lat. *sebum*, tallow.) Like lard or tallow.
Segmentation. The act of dividing into segments.
Semilunar. Crescent-shaped, like a half-moon.
Sepal. The divisions of the calyx of a flower.
Septa. Partitions.
Sericteria. (Gr. *serikos*, silky.) The glands which secrete the silk in the silk-worm.
Serrated. (Lat. *serra*, a saw.) Toothed like a saw.
Sessile. Attached by a base.
Setæ. (From the Latin for a bristle.) Bristles, or similar parts.
Setigerous. Bristly.
Siliceous. (Lat. *silex*, flint.) Flinty.
Sinus. A dilated vein or receptacle of blood.
Siphonostomous. (Gr. *siphon*, a tube ; *stoma*, a mouth.) Animals furnished with a suctorious mouth like a tube. The term is usually applied to Crustacea so characterised.
Spatulate. (Lat. *spatula*.) Shaped like a spatula.
Spermatheca. (Gr. *sperma*, seed ; *theke*, sheath.) A receptacle attached to the oviducts of insects.
Spermatophora. (Gr. *sperma* ; *phero*, I bear.) The cylindrical capsules or sheaths in the Cephalopods which convey the sperm. They are also called the moving filaments of Needham, their discoverer.
Spermatozoa. (Gr. *sperma* ; *zoon*, an animal.) The peculiar microscopic moving filament and essential parts of the fertilising fluid.
Sphincter. (Gr. *sphigkter*.) The circular muscles which contract or close natural apertures.
Spicula. (Lat. *spiculum*, a point or dart.) Fine pointed bodies like needles.
Spinnaret. The articulated tubes with which spiders fabricate their webs.
Spiracles. (Lat. *spiro*, I breathe.) The breathing pores in insects.
Squamous. (Lat. *squama*, a scale.) Arranged like scales.
Stemmata. (Lat. *stemma*.) The simple and minute eyes of worms, and those which are added to the large compound eyes.
Sterelmintha. (Gr. *stereos*, solid ; *helmins*, an intestinal worm.) Intestinal worms which have no true abdominal cavity, and which were called "parenchymatous" by Cuvier, as the tape-worms.
Sternal. The aspect of the body where the sternum or breast bone is situated.
Stigmata. (Gr. *stigma*, a mark.) The breathing pores of insects.
Stomato-gastric. (Gr. *stoma*, a mouth ; *gaster*, a stomach.) The system of nerves which are principally distributed upon the stomach and intestinal canal.
Strepsiptera. (Gr. *strepho*, I twist ; *pteron*, a wing.) The singular order of in-

sects discovered by Mr. Kirby, in which the first pair of wings is represented by twisted rudiments.

SUBMUSCULAR. Beneath muscles or muscular layer.

SUBŒSOPHAGEAL. Beneath the gullet.

SUCTORIA. (Lat. *sugo*, I suck.) The animals provided with mouths for sucking, and the appendages of other parts organised for sucking or adhesion.

SUPRA-ŒSOPHAGEAL. Above the gullet.

SUTURAL. Appertaining to a suture.

SUTURE. (Lat. *suo*, I sew.) The immoveable junction of two parts by their margins.

TÆNIOID. (Gr. *tainia*, a riband; *eidos*, like.) Riband-shaped, like the Tænia or tape-worm.

TAPETUM. (Lat. *tapetum*, a carpet.) The coloured layer of the choroid coat of the eye.

TARSUS. (Gr. *tarsos*, a part of the foot.) Applied to the last segments of the legs of insects.

TECTIBRANCHIATE. (Lat. *tego*, I cover; *branchia*, gills.) The order of Mollusca in which the gills are covered by the mantle.

TERGAL. (Lat. *tergum*, the back.) Belonging to the back.

TETRABRANCHIATE. (Gr. *tetra*, four; *bragchia*, gills.) The order of Cephalopods with four gills.

TEUTHIDÆ. (Gr. *teuthis*, a calamary.) The family of Cephalopods, of which the calamary is the type.

THORACIC. Belonging to the thorax.

THYSANOURA. (Gr. *thusanoi*, fringes; *oura*, a tail.) A family of apterous insects with fringed tails.

TRACHEÆ. (Gr. *tracheia*, the rough artery or windpipe.) The breathing tubes of insects.

TRACHELIPODS. (Gr. *trachelos*, the neck; *pous*, a foot.) The Mollusca which have the locomotive disc or foot attached to the head.

TREMATODA. (Gr. *trema*, a pore.) The order of Entozoa characterised by suctorial pores.

TRENCHANT. Sharp-edged, cutting.

TRIDACTYLE. Three-fingered.

TRILOBATE. Divided into three lobes.

TRILOBITE. An extinct genus of Crustacea, the upper surface of whose body is divided into three lobes.

TRIRADIATE. Consisting of three spokes or rays.

TROPHI. (Gr. *trophos*, a nourisher.) In insects, the parts of the mouth employed in acquiring and preparing the food.

TUBERCULATE. Warty, or covered with small rounded knobs.

TUNICATA. (Lat. *tunica*, a cloak.) The class of acephalous Mollusca which are enveloped in an elastic tunic not defended by a shell.

UNCINATED. Beset with bent spines like hooks.

UNIVALVE. (Lat. *unus*, one; *valvæ*, doors.) A shell composed of one calcareous piece.

VASIFORM. (Lat. *vas*, a vessel.) Shaped like a bloodvessel or tube.

VENTRAL. Relating to the inferior surface of the body.

VENTRICULAR. (Lat. *ventriculus*, a ventricle or small cavity, like those of the heart or brain.) Belonging to a ventricle.

VERMES. (Lat. *vermis*, a worm.) Worm-like animals: applied in a very extensive sense by Linnæus.

VERTEBRATA. (Lat. *vertebra*, a bone of the back; from *vertere*, to turn.) The highest division of the Animal Kingdom, characterised by having a back bone.

VERTICILLATE (Lat. *verticillus*, a whirl.) Arranged like the rays of a wheel or spindle.

VERMIFORM. Worm-shaped.

VESICULÆ. (Lat. *vesica*, a bladder.) Receptacles like little bladders.

Villi. Small processes like the pile of velvet.

Vitelline. (Lat. *vitellus*, yolk.) Of or belonging to the yolk.

Viviparous. (Lat. *vivus*, alive; *pario*, I bring forth.) The animals which bring forth their young alive.

Xiphosura. (Gr. *xiphos*, a sword; *oura*, a tail.) A family of Crustacea with sword-shaped tails, as the Limulus.

Zoophyte. (Gr. *zoon*, animal; *phyton*, plant.) The lowest primary division of the Animal Kingdom, which includes many animals that are fixed to the ground, and have the form of plants.

INDEX.

THE END.

ERRATA.

Page 15. line 10. from bottom, for " several," read " earlier."
15. line 9. from bottom, for " one," read " ones."
148. line 8., for " 87," read " 78."
156. line 13., for " fine," read " five."
192. line 7. from bottom, for " insects." read " insects,".
215. line 16. from bottom, for " canine," read " incisive."
215. line 5. from bottom, for " appendage," read " process."
227. line 16., for " Teh," read " The."
243. line 22., for " ength," read " length."
249. line 10. from bottom, for " do," read " does."
267. line 6. from bottom, for " Cirripeda," read " Cirripedia."
272. line 4. from bottom, for " 115," read " 116."
289. line 11., for " litoralis," read " littoralis."

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