LECTURES

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DELIVERED AT THE

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VOL. II.

STRUCTURE OF THE SKELETON OF PLANTS AND INVERTEBRATE ANIMALS.

ILLUSTRATED BY TWO HUNDRED AND SIXTY-FOUR WOODCUTS.

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PREFACE.

So favourable a reception having been given to the First Volume of these Lectures, the Author is induced to bring a Second before the Public, and he hopes it will be found both instructive and interesting. The minute structure of the Skeleton of Plants and Invertebrate Animals is a study of the greatest interest, and one which will fully repay the most careful investigation. To the Zoologist, the Geologist, and even to the Amateur in Microscopic Science, a knowledge of this subject must prove of the highest value, not only on account of the great variety of beautiful structures embraced by it, but from the well-marked characters that each part of the skeleton presents—characters not wholly obliterated even in the fossil state, and by which alone the smallest fragments of particular structures can be satisfactorily recognised.

The great demand for information on Histological subjects is made evident, not only by the large number of first-rate instruments now being manufactured, but also by the fact that several skilful artists are entirely employed in the preparation of microscopic objects, many thousands of which are annually sold in this metropolis. In publishing these Lectures, the Author is most anxious to point out that collections of specimens are not only valuable for their beauty or their peculiarity of structure, but are eapable of an arrangement as systematic and eomplete as the parts from which the speeimens themselves were taken, the object of sueh colleetions, when rightly considered, being not simply that of affording amusement to the eurious, but of eontributing to the sueeessful cultivation of Natural Seience.

The plan hitherto adopted in the choice of a subjeet for these Lectures has been, to follow the order laid down in the Table of Tissues, given in Vol. I. page 117. In that volume are described the principal tissues of vegetables, and three of those belonging to animals, viz., Simple Membrane, Fibrous Tissues, and Cellular Tissues. The Sclerous, or hard tissues, follow next in order: under this head the Rudimentary Skeleton of Invertebrate Animals is included, a subject to which the present work is almost entirely devoted.

In this volume upwards of six hundred preparations are described; of these, above four hundred were exhibited to the class during the course, the remainder having been alluded to more or less in detail.

In conclusion, the author would beg again to thank his friend Dr. P. B. Ayres, for his very kind assistanee during the progress of the work.

39, Lincoln's Inn Fields,
April 5th, 1854.

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HISTOLOGY OF ANIMALS.

ON THE STRUCTURE OF THE SKELETON OF INVERTEBRATE ANIMALS.

LECTURE I.

SKELETON OF SPONGES.

Gentlemen,

The season has now arrived when it devolves upon me to resume my annual course of Histological Lectures, and I take this opportunity of assuring you of the pleasure it gives me, after a long recess, to meet you again in this theatre.

The first part of the preceding course was principally occupied by the examination of the different tissues entering into the composition of certain members of the vegetable kingdom; the second, by the consideration of a few of those employed in the formation of the bodies of animals: illustrated by the examples enumerated in the four first classes of the table, already given in page 117 of the first volume of these Lectures. They will be found, on reference, to be: 1st. Simple membrane; 2nd. the fibrous tissues; and, lastly, those termed cellular, in which were included the cartilaginous, the adipose, and the pigmental tissues. The course concluded with a series of illustrations of the mode in which such substances as lime and silica, strictly belonging to the inorganic kingdom, may be taken up from surrounding media by plants and animals, through a vital action, and be deposited as a secretion in the interior of cells, so as to form an organized whole.

In the present course, I shall commence the fourth class of tissues enumerated in our table, viz.: the *sclerous* or *hard tissues*, which form the rudimentary skeletons of invertebrate animals, together with those occurring in the vertebrate class, in which the skeleton is wholly or partially composed of a material termed bone.

The first class of animals that we shall consider are the *Poriphera*, or *Sponges*, which have long formed a subject of controversy; being considered by some authorities to belong to the vegetable, and by others to the animal kingdom. Recent investigations, however, have shown that they possess certain organs appertaining almost exclusively to animals; and these, with many other characters, to which I shall hereafter allude, seem to render their animal nature unquestionable. I shall then pass on through the other invertebrate classes in succession, to the more highly organized skeleton of the vertebrata, and with it include the teeth, which although composed of a modified osseous structure, belong more strictly to the organs of digestion than to the skeleton.

The term skeleton is applied to the solid framework, giving support to the digestive, locomotive, nervous, and other systems of all animals, and is as remarkable for its endless variety of form as they are themselves. The skeleton is not exclusively confined to animals, since many plants, such as the grasses, have a framework of silica, indestructible both by fire and acids, which may be strictly and appropriately viewed as a skeleton, while other organisms, claimed by the botanist as *Algæ*, have also a siliceous skeleton. In all, the organic is so intimately blended with the inorganic material, that if the former be removed, the latter retains the peculiar forms and markings which existed prior to the destruction of the organic substance.

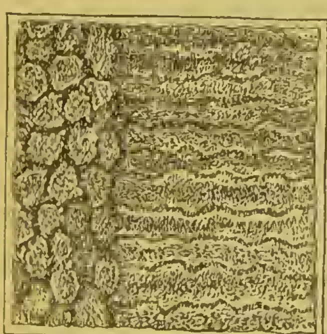
The skeleton may be composed of one or of many pieces, and be either external or internal to the soft parts. In the first case, growth takes place by the addition of new matter, chiefly to the circumference, so that it may keep pace with the development of the soft parts, or it may be periodically shed and formed anew. In these instances, it is generally said that the skeleton possesses no inherent power of repair; but it will be hereafter shown that this opinion is incorrect. When the skeleton is internal to the soft parts, as in the *Vertebrata*, it is provided with blood-vessels, and in process of growth, not only is there a deposition of new material, but an absorption of that which has become old and effete: such skeletons, also, possess the means of self-reparation after injury or disease.

In the lowest animals, as in the *Sponges* and *Infusoria*, and also in vegetables, the skeleton is chiefly composed of silica; in the *Crustacea* and *Mollusca*, of carbonate of lime; and in the *Vertebrata*, of a mixture of phosphate and carbonate; while in the *Insecta*, and certain of the *Zoophytes*, it is formed of a substance resembling horn.

Before commencing the subject of the present course, I must again remind you that in the vegetable and animal kingdoms wherever inorganic material, such as lime or silica, is employed to form the skeleton, it has been originally taken up from the surrounding media by a vital action, or deposited from the circulating fluid in the interior of cells. You may also recollect another fact of great importance, which was frequently alluded to in the former course of Lectures, viz., that in most instances the earthy matter is deposited in a homogeneous form by the cell, although cases are not unfrequent in which the force of crystallization has overcome the modelling power of the cell-wall; and I adduced as examples the brown horny layer found in the *Oyster*, which is composed of minute cells, each containing a rhombohedral crystal of carbonate of lime. In the cells of the rudimentary shell of the common *Slug*, erystallized earbonate of lime is frequently seen, and in the tooth of *Mya arenaria*, as was first shown by Dr. Carpenter, eaeh eell presents a radiated erystallized arrangement of its eontents; this, however, is not a eonstant, but rather an aeeidental occurrenee. I have made numerous seetions of the tooth in different shells, but I have only once met with the eontents in a erystalline state; and in this instanee, the erystals were less plainly marked than in the speeimens deseribed and figured by Dr. Carpenter.

Another point of great interest is, that after the earthy material composing the skeleton has been deposited within the eell, the eell-wall may be either wholly or partially absorbed in proeess of growth. There is a well-marked instanee of this in the nacreous substanee of shell, for the laminæ seen after deealeifying this structure, are due to the partial absorption of the walls of the eells in which the lime was deposited. Another example, whieh I have repeatedly notieed, oecurs also in the tooth of *Mya arenaria*, represented in Plate XVII, Fig. 16, Vol. I., of the Histologieal Catalogue, of which Fig. 1 is a eopy. In one part of the seetion per-

FIG. 1.



A vertical section of a portion of tooth of *Mya arenaria*, showing partial absorption of cell-walls, and the production of laminæ.

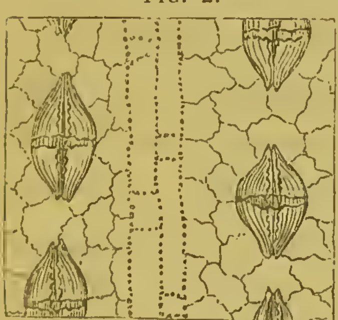
fect hexagonal cells are seen, but in another immediately contiguous to it, the cell-walls have been absorbed on two opposite sides, and parallel laminæ result.

In certain plants, especially in the grasses, canes and *Equisetaceæ*, the outer framework, which may be truly named the dermal skeleton, is composed of silica, intimately blended with the organic tissue; so that if we subject any of these plants to the action of heat, or boiling nitric acid, the original structure of the tissue remains undestroyed. Silica is most abundant in the canes, but it occurs also, in very large quantities, in the husks of *Rice* and *Wheat*, in both of which it not only is met with in the epidermoid cells, but also in the spiral vessels and woody fibres. In the *Equisetum* (especially *Equisetum hyemale*), known in commerce as the *Dutch Rush*, the silica is so abundant, and imparts so great a roughness to its exterior, that it is largely employed by cabinet-makers and sculptors, as a substitute for sand-paper. In the stems of the common grasses of this country the silica is accumulated in the epidermis, and as the stems contain potass and lime, when hay- or corn-ricks are burned, masses of a brittle glassy substance, are often found among the ashes. It is indeed possible, by carefully burning a straw before the blow-pipe, to produce a bead of glass. It will be remembered that the presence of silica in plants was fully considered in the preceding course of Lectures, when it occupied our attention as a cell-secretion; but I now allude to it again as forming the skeleton of many plants.

Another part of a plant sometimes called the skeleton, is that met with in the leaves, which after maceration and cleansing exhibit a most beautiful lace-like structure, being particularly evident in most of the species of *Magnolia* and *Fig*. Many very beautiful specimens of this kind were to be seen in the Great Exhibition, and a large collection of skeleton leaves, prepared in the same way, was purchased many years ago by the Council of this College from Dr. Buchan, the well-known author of "Domestic Medicine." These skeletons, however, are composed of bundles of woody fibres and vessels, and contain no earthy ingredient.

In plants, as I have before stated,* inorganic salts occur in a crystalline form, under the name of raphides; these, however abundant, may be regarded as accidental deposits, since it has been shown that they can be produced by artificial means. For the benefit of those who may not have been present on former occasions, I will give a few examples of the dermal siliceous skeleton of plants.

FIG. 2.



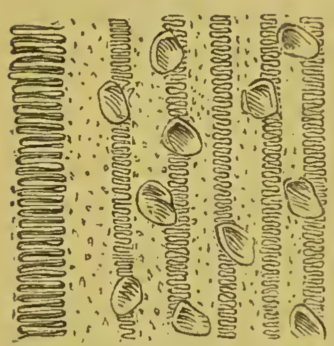
A portion of the cuticle of *Equisetum hyemale*, after long boiling in nitric acid.

The first specimen is a portion of the *Equisetum hyemale*, Fig. 2, which has been boiled

* Histological Lectures, Vol. I, p. 42.

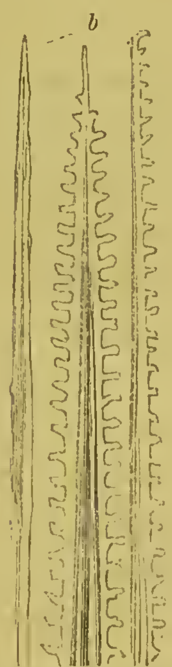
for a long time in nitric acid, and not only exhibits the cells of the cuticle, with their serrated edges, but also longitudinal rows of oval bodies, which are the stomata.

FIG. 3.



A portion of the husk of a grain of *Wheat.*

FIG. 4.



Portions of woody fibres from the husk of the *Rice.*

Another good example is a portion of the husk of the *Wheat*, Fig. 3, in which, in addition to the cells of the cuticle, the spiral vessels, recognized by the coiled-up fibre, also have a skeleton of silica. In the husk of the *Rice* the peculiar cells of the cuticle are seen, with bundles of woody fibre and vessels below them. The specimen is composed entirely of silica, and there may be noticed in one spot, where the cuticle has been torn, a series of elongated fusiform bodies, with serrated edges, Fig. 4, which are all that remain of the woody fibres, proving that in this plant the silica is not confined to the cuticle. All the fibres, however, are not thus serrated; some, as represented at *b*, may be seen in bundles, which are both longer and thinner than the first mentioned, with perfectly smooth edges.

On the upper surfaee of the leaf of a plant eommon in our gardens—the *Deutzia scabra*—there are numerous stellate hairs, whieh mueh resemble *Star-fishes* in miniature, Fig. 5; these are eovered with little tubereles, each star being attached to the euticle by its centre. If the eutiele be removed, and boiled in nitrie acid, the stellate hairs may be as plainly seen as in the natural eondition of the leaf; the erenated lines found in all parts of the objeet representing the eell-walls of the eutiele. This speeimen will serve to show, which it does in a striking manner, that siliea is not confined to the cells of the eutiele, but is equally abundant in the hairs and spines developed upon it.

FIG. 5.

Siliceous cuticle from the under surface of the leaf of *Deutzia scabra*.

Sueh, then, is a slight sketeh of the silieeous skeleton of vegetables; there are, however, some few plants in which lime is said to perform the same offiee as silica. One of these is our eommon *Dianthus*, in whieh the lime oeeupies the interior of eells. I cannot quit this subjeet without briefly noticing the *Lithophytes*, or *Stone-plants*, with whieh are ineluded our eommon *Corallines* and *Nullipores*. These plants are remarkable for the large quantity of ealeareous material, arranged in a smooth and regular form upon their external surfaee. The *Corallines* were originally considered as animals, and polyp eells have been described by Ellis and Lamarck as existing upon their outer surface; such, however, is not the case, the calcareous material existing in the form of a coating of variable thickness to a mass of cells, evidently of a vegetable nature. If a transverse section of one of these plants be made, the interior will be found composed of a series of cells, some of which contain a green colouring matter, like chlorophylle, analogous in character to starch.

In the *Nullipores*, which are the densest form of *Lithophytes*, all the intercellular spaces are filled with lime, so that it would appear that the external surface of the cell-wall possesses the power of separating lime from the sea-water, and arranging it in a certain definite form; in the *Corallina officinalis* every joint is uniformly coated, and we never meet with anything like an exostosis, or greater abundance of the lime in one part than another, neither are the joints consolidated, but always remain free and flexible. This I consider to be a totally distinct process from that occurring in the common *Chara*, in which the lime is not unfrequently in a crystalline condition, and also from that termed petrifaction; because, in both these cases, the deposit is continuous, and often so extensive that all trace of vegetable, or filamentous structure is entirely lost, and the mass becomes as solid as stone, whereas, in the *Nullipores* and *Corallines*, each filament preserves its original character: the first being a vital, the second an accidental process. As the *Corallines* and *Nullipores* have been, and are even now, associated with the *Corals* in works on marine zoology, and as they frequently occur in the same situations, I have thought it best to defer giving an account of their minute structure till I take that of the *Corals* under consideration, as then the differences between them may be readily contrasted.

Concluding this brief and hasty account of the skeleton of vegetables, I pass on to the lowest order of the animal kingdom, the *Poriphera*, or *Sponges*. These are characterized by a member of our own profession, Dr. Johnston, of Berwick-upon-Tweed, in his work on British Sponges, as "organized bodies, growing in a variety of forms, permanently rooted, unmoving and unirritable, fleshy, fibro-reticular, or irregularly cellular, elastic and bibulous, composed of a fibro-carneous axis or skeleton, often interwoven with siliceous or calcareous spicula, and containing an organic gelatine in the interstices and interior canals. They are reproduced by gelatinous granules called *gemmules*, which are generated in the interior, but in no special organ. All are aquatic, and with few exceptions, marine."

Sponges present a greater variety in their external form and consistency, than is seen in any other class of animals; some are as soft as jelly, while others are hard and brittle as flint. On the table before you are many varieties, some soft and elastic, others hard and unyielding; the former are extensively employed for domestic purposes, the latter are preserved only in museums. Of these, one in particular is of large size, and from its cup-like form has received the name of Neptune's Goblet. If the external surface of any sponge be examined, two sets of holes, of different sizes, will be seen, which are the mouths of canals, the one set termed in-current, the other ex-current. Through these, in the living state, water is continually passing, entering by the small canals, and escaping in strong currents through the larger ones. This was first discovered by Professor Grant, to whom we are indebted for the earliest and most accurate account of these animals, published many years ago, in the Edinburgh Philosophical Journal. The circulation of water through the sponges has been, and is even now, doubted by many observers; but any resident at the sea-coast, where sponges of the genus *Grantia*, or *Halichondria*, are found, may easily recognize the phenomenon by placing them in a vessel of sea-water with which small black particles, such as powdered coal or sealing-wax, have been mixed; these will plainly indicate any movement in the water, however feeble, caused by the currents above described. These currents have been ascertained to be produced by the action of cilia, which were first discovered by Dr. Dobie. Mr. Bowerbank has since observed them in motion in a small sponge (*Grantia compressa*), as shown at *g*, in Fig. 10. The presence of cilia in the canals of sponges, which canals may be regarded either as respiratory or digestive cavities, would appear to be another proof of the animal nature of these bodies.

I commence with the examination of the skeleton of those sponges in daily use; and before you is a collection of the principal species, in the condition in which they are imported into this country, with the wholesale price of each affixed, as a measure of their comparative value. They are all in the dry state, and a person who has never seen a sponge recently taken from the sea, can form but little idea of its structure from these specimens, for when living the elastic keratose, or horny skeleton, is enveloped in a mass of gelatinous substance, which has been destroyed by maceration and drying. Sponges are principally imported from the Mediterranean and the West Indies. The former are generally known as Turkey Sponges, and are considered the most valuable, being of the finest fibre and remarkable for their elasticity, whilst the latter are principally purchased by Jews, and sold in the streets. Some kinds are procured from the Bahama Islands, and are remarkable for the number of fragments of corals and foraminiferous shells imbedded in them. One of these loses 75 per cent of its weight when deprived of its calcareous matter, and such a sponge is worth only 7*d.* per lb. in the market. A variety of other specimens are nearly equally valueless for domestic use.

We will now proceed to consider the minute structure of the horny skeleton of some of these sponges, and shall take as a first example a portion of the fibre of one of the finest *Turkey Sponges*. It consists, as shown in Fig. 6, of a series of delicate, solid, branching filaments, averaging $\frac{1}{900}$th of an inch in diameter. In another specimen the fibre is much coarser, and of a browner tint; but in those sponges that are so stiff as to render them unfit for use the fibre is of larger size, and tubular; some are almost as stiff as wire, and belong to the genus *Verongia*, Fig. 7. It sometimes happens, however, that amongst the fibres of the finest Turkey sponge we meet here and there with a few fibres nearly double the size of the rest, which not unfrequently contain siliceous bodies, termed spicula; these may be considered as the first indication of the siliceous element of the skeleton. In many sponges of the genus *Halichondria*, as shown in Fig. 8, nearly every fibre is full of spicula; these are readily seen through the transparent horny matter. It may be readily demonstrated that the spicula, which are remarkable both for their peculiar

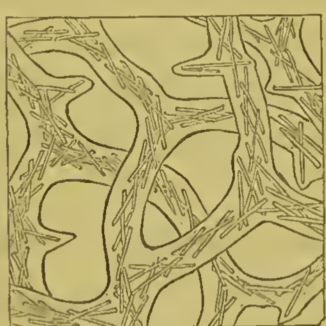
FIG. 6.

A portion of the horny skeleton of a *Turkey Sponge*.

FIG. 7.

A portion of the horny skeleton of a sponge of the genus *Verongia*, with tubular fibres.

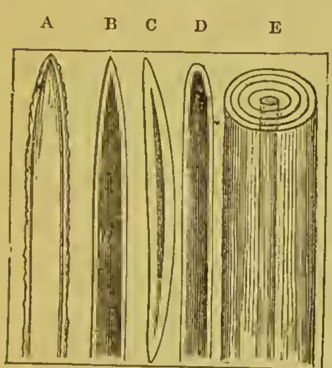
FIG. 8.



Horny fibres of a sponge of the genus *Halichondria*, having spicula within them.

forms, and for their cylindrical shape, are not mere masses of silica, but are composed of a mixture of that material and animal matter intimately blended, which renders it probable that they are developed originally in the interior of cells. Each spiculum exhibits more or less of a central cavity, and if a portion of sponge containing some of the larger kinds be subjected to the action of the blow-pipe flame, the external surface, as shown at A, Fig. 9, as well as the internal cavity, as seen at B C D, will exhibit traces of charred animal matter, when the heat has not been so intense, or long-continued, as to destroy it by complete combustion.

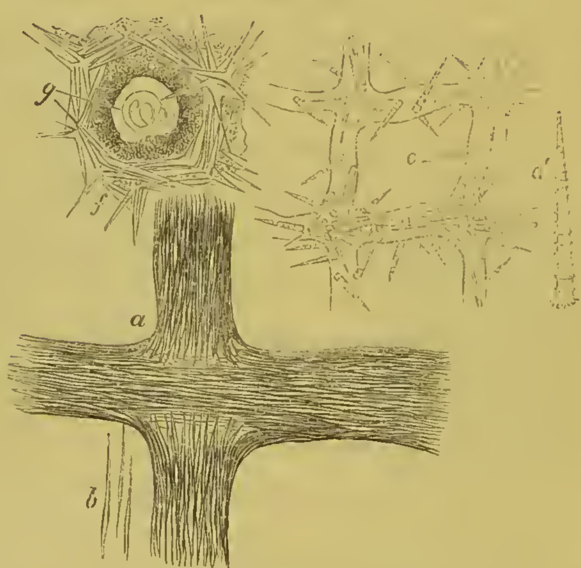
FIG. 9.



A B C D, spicula of *Sponge* imperfectly decarbonized. E, portion of a large spiculum, showing its laminated arrangement.

The spicula, represented by A B C D, are from a species of *Tethea.* I am not aware of any chemical means of dissolving the silica of the siliceous spicula and leaving the organic basis untouched; but in the genus *Grantia* the spicula being calcareous, the lime may be dissolved by dilute hydrochloric acid, and the organic basis, remaining will be found to retain, to a considerable extent, the original form of the spiculum. The concentric laminated arrangement of the large spicula, as shown in Fig. 9, E, will be noticed on a future occasion. As a general rule, the spicula are most abundant in those sponges in which the animal matter is the softest. In our common fresh-water sponge, *Spongilla fluviatilis*, there is a framework of siliceous spicula, pointed at both extremities, and held together by a soft, transparent, gelatinous substance; these spicula occur in bundles of three or more, and their disposition is precisely that of the horny fibres in the Turkey sponge. In another specimen, probably belonging to the genus *Halichondria*, the whole fibrous framework, Fig. 10, *a*, is composed of a delicate horny

FIG. 10.



a, sponge fibres full of spicula; *b*, detached spicula ; *c*, tuberculated spicula projecting from the horny fibres; *d*, detached spiculum; *f*, portion of *Grantia compressa ; g*, cilia in an in-current canal.

substance, completely filled with minute spicula like those represented at *b* ; they are arranged in parallel lines, and always follow the direction of the fibres. In *Halichondria*, a sponge of firm consistency, the skeleton is made up of horny fibres, from the sides of which sharp-pointed, conical, and spinous spicula project into the cavities of the sponge; these, as shown at *c d*, Fig. 10, articulate with the fibre by a globular, expanded portion, or head. When such a sponge is dried, the spicula appear without any investment, but in the moist state they are completely covered with a corneous substance. Their office appears to be, that of preventing the entrance of foreign bodies between the fibres composing the framework. Sometimes the framework is made up entirely of silica, as in the siliceous sponge of Barbadoes, *Dictyochalix pumiceus*, specimens of which are preserved in the British Museum, and in that of the Bristol Institution. In this species, the silica forms a coarse fibrous net-work, similar in arrangement to the horny fibre of some of the *keratose* sponges, as shown at *a a*, Fig. 11, but many of the fibres are covered with minute tubercles, and the silica itself is as transparent as the finest glass. The thick fibres represented by *a a*, form all the coarser parts of the sponge, but there are other elongated spiculum-like bodies, *b*, *c* and *d*, which are employed to complete the framework. Some of these spicula are of quadri-radiate figure, as shown at *c*; a few, as represented at *d d*, are much more minute, and form a framework of themselves.

In addition to these peculiar spicula are others of still more remarkable figure, shown at *e e*, consisting of a number of very minute equal-sized, pin-shaped bodies, projecting from a central nucleus; these vary considerably in size, and occur in very great numbers on the

FIG. 11.

a a, coarse framework of a siliceous sponge, *Dictyochalix pumiceus*; *b*, *c*, elongated spiculum-like bodies; *d d*, portions of minute framework; *e e*, peculiar compound pin-shaped spicula from the same sponge.

outer surface of the sponge, occupying precisely the same situation as the stellate spicula of many species of *Tethea*. In the next Lecture I shall demonstrate some of the most remarkable forms of spicula, detached from the animal matter, many of which are characteristic of particular genera and species, and shall also notice the reproductive bodies, or Gemmules.

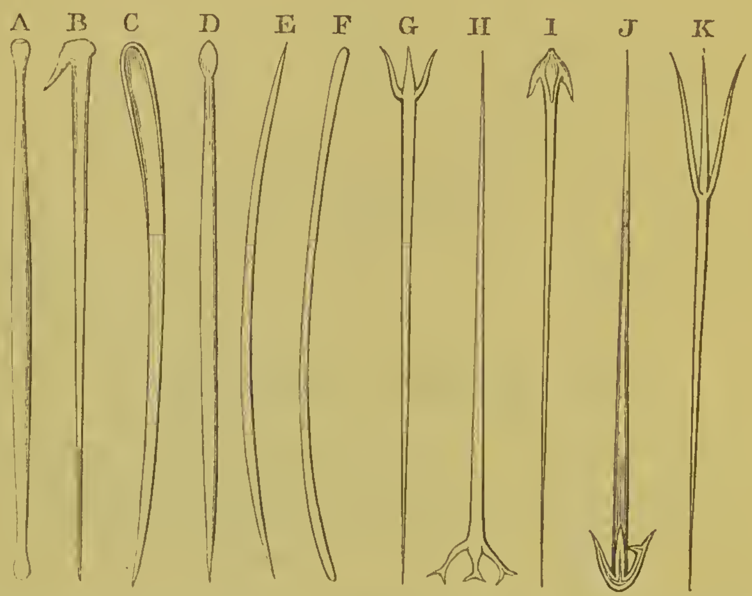
LECTURE II.

SKELETON OF SPONGES.

In the preceding Lecture, after a cursory glance at the structure of the siliceous and calcareous skeletons of plants, I described the horny element of the skeleton of sponges, and the mode in which this is further strengthened by the addition of acicular bodies, composed of silica or lime, called spicula. I now proceed to consider some of the most remarkable of such spicula, which have been detached from their horny investment either by burning, or by the action of boiling nitric acid.

The first is of frequent occurrence in most of our fresh-water sponges, which, from being pointed at both extremities, is termed, *bi-acerate,* and may be either straight or slightly curved, as shown at E, in Fig. 12, and *b*, in Fig. 10. Other spicula are very common in which both extremities are rounded, and the shaft is of equal size throughout, such specimens are termed *cylindrical;* the shaft is occasionally curved, as shown at F, Fig. 12. Another, and more peculiar

FIG. 12.

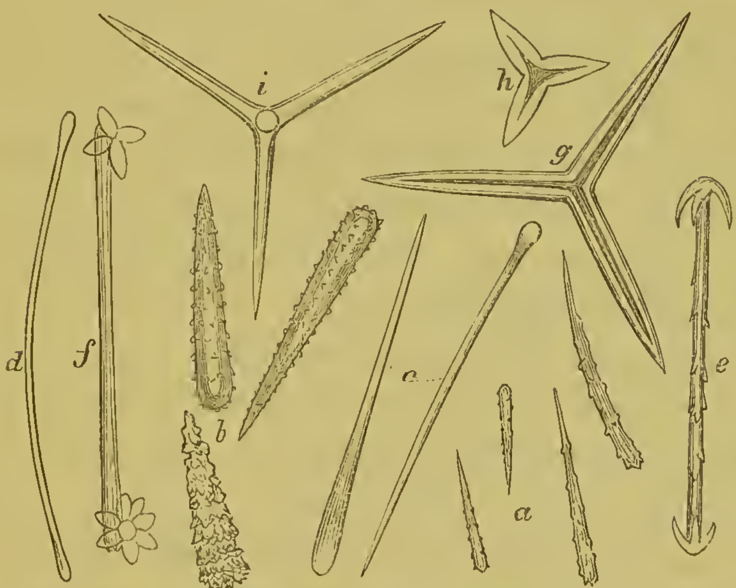


A, bi-spinulate spiculum. B, spiculum with a single-hooked extremity. C, curved conical spiculum. D, spinulate spiculum. E, bi-acerate spiculum. F, curved cylindrical spiculum. G, expando-ternate spiculum. H, dichotomo-expando-ternate spiculum. I, hooked or recurvate spiculum. J, hooked spiculum, with bifurcated extremities. K, peculiar expando-ternate spiculum.

form of spiculum, shown at D, is called *spinulate*, from its resemblance to a pin; one extremity being globular, like the head of a pin, the other pointed. Some sponges contain spicula having both extremities expanded into a knob, like that shown at A, to which the term bi-spinulate has been given; these may either be straight or slightly curved, as seen at *d*, in Fig. 13.

Another form of spiculum is *conical*, and may also be either straight and smooth throughout, or slightly bent, as shown at c. Conical spicula, having minute spines or tubercles, arranged with or without much order, are very common, such, for instance, as those represented at *a*, in Fig. 13; others occur, as seen at *b*, which are

FIG. 13.



a, conical spicula with spines; *b*, conical spicula with spines arranged in parallel rows, and in the form of rings; *c*, spinulate spicula; *d*, curved bi-spinulate spiculum; *e*, spiculum with hooks at both extremities; *f*, spiculum with stellate extremities; *g*, *h*, tri-radiate siliceous spicula; *i*, quadri-radiate spiculum.

surrounded by a series of rings of minute spines. In many sponges having conical spicula, as for instance, those shown at *c*, *d*, in Fig. 10, the extremity or base, by which they are attached to the firm horny frame-work of the sponge, is slightly expanded, the remaining portion projecting into the cavities or canals.

When perfectly developed and dried, these spicula appear to be invested with little or no organic matter; their office cannot be that of adding strength to the skeleton, but like the spines of plants, they are probably employed as a means of defence. Another form of spiculum is remarkable for its length, and for having one of its extremities pointed and the other divided into two or more branches, as shown at G and K, in Fig. 12; these are called either *expando-binate* or *ternate*, according to the number of branches, those represented at G and K being both of the latter kind; it sometimes happens, however, as shown at H, that the expanded extremities again divide, to such spicula the term *dichotomo-expando-ternate* is applied.

Some spicula, very much elongated, and of smaller diameter than the finest spun glass, are common in certain species of *Pachymatisma;* these are pointed at one extremity, but have one, two, three, or even four recurved hooks at the other, resembling the flukes of an anchor, as shown at B and I, Fig. 12: one very curious variety of this last spiculum is shown at J, each fluke being bifurcated. The spicula represented by G and I, were obtained from a sponge of the genus *Tethea*, and their office appears to be that of attaching the crust to the central part of the sponge; they occur in large bundles, and are visible to the naked eye as brilliant white radii.

All the long spicula above described have one extremity pointed, but there are sponges in which shorter spicula occasionally occur having the shaft of cylindrical figure, with one extremity rounded, and the other provided with six or more short hooks; one of these is represented at *f*, in Plate X, Fig. 11, of the first volume of the Histological Catalogue. A still more curious form of spiculum is that represented at *e*, in Fig. 13; it is of small size, but is provided with spines upon the shaft, and recurved hooks at either extremity. In a sponge, probably of the genus *Geodia*, was found the peculiar spiculum represented at *f*, in Fig. 13; it consists of a cylindrical shaft, having at both extremities a series of radiated spinous processes, somewhat resembling the petals of a flower.

Other spicula are very peculiar, consisting of a central portion, or shaft, the extremities of which are furnished with two or three branches, each of these again subdividing into two or three still smaller branches. These spicula interlace with each other, and produce a sort of coarse net-work; they are generally found in small sponges, attached to masses of coral; two specimens of the largest kind are shown at *g g*, in Fig. 14. In the same sponge were others of smaller size, and with fewer branches, as represented by *d*, *e* and *f*: to such spicula the term *branched* may be well applied. Another sponge contains spicula of the form I have termed *tuberculated;* they are of large size, and covered with rows of flattened tubercles, as shown at *c*, in Fig. 14. The sponges to which they naturally belong I have never seen, but all my specimens were obtained from the root of an Alcyonium, *Alcyonium favosum*, from Sumatra, and were mixed with

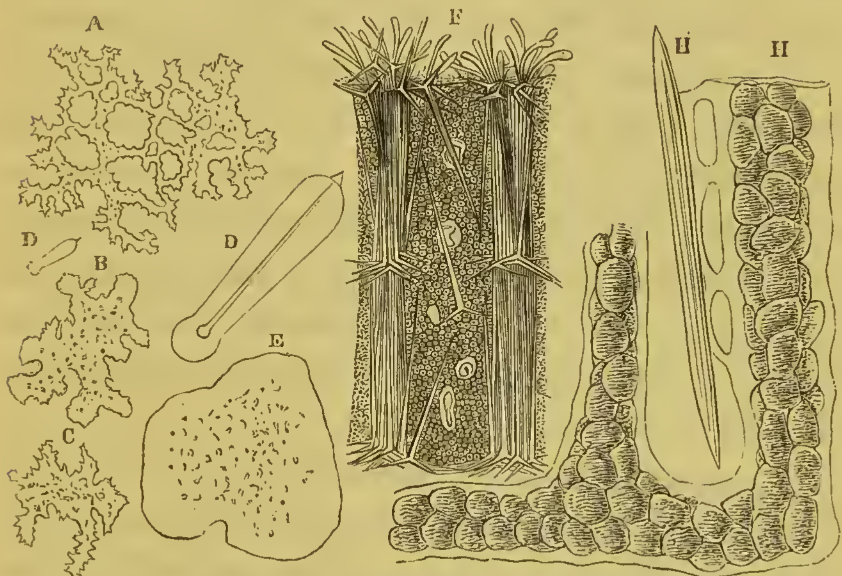
FIG. 14.

a, bi-curvate spiculum; *b*, curved spiculum; *c*, tuberculated spiculum; *d*, *e*, *f*, *g g*, branched spicula; *h*, bi-curvate anchorate spicula; *i*, stellate spicula; *k*, *l*, *m*, multi-radiate spicula.

grains of sand and spicula of various kinds, from other sponges. A similar species, from a different part of the world, in the possession of a friend, when boiled in nitric acid yielded spicula of precisely the same kind; so much so, that when a specimen was shown me, I pronounced from whence it came.

The siliceous remains of a small sponge, attached to the root of a Gorgonia, *Isis ochracea*, I found extremely rich in peculiar forms of spicula. The most striking was of a reticular figure, covered with minute spines, as shown at A, in Fig. 15. It forcibly reminded me of the siliceous skeleton of the *Dictyochalix pumiceus,* before alluded to, and probably may be a portion

FIG 15.



A, portion of the skeleton of a siliceous sponge. B, C, E, flattened spicula. D D, pin-shaped spicula. F, tri-radiate spicula in *Grantia compressa.* H, granules of sand imbedded in horny fibre of *Dysidea.*

of a siliceous sponge. Other spicula occur in the same specimen, the most remarkable of these are in the form of scales, as shown at B, C, E; they may be known by their flattened figure, and by having black dots in the centre. The edges of some of these spicula are smooth, but in most cases they are serrated. Another very singular form of spiculum, is also found in the same sponge: it is of small size, and pin-shaped at one extremity, and at the other is rounded, but in the centre of the rotundity there is a short conical spine; two of these spicula are shown at D D. Spicula of the shape termed *curved,* are occasionally met with in certain small sponges; one of these, of peculiar figure, is represented at *b*, in Fig. 14. In another sponge from the South Seas *bi-curvate* spicula, of the shape shown at *a*, are very common. Mr. Shadbolt, however, has detected some still more curious spicula than these last; they are twice curved, like that shown at *a*, but each extremity is expanded, so as to resemble the fluke of an anchor; to such form, the term *bi-curvate anchorate* has been given; two of these spicula are represented at *h*. The sponge in which they occurred, like that of the preceding, was of small size, and brought from the South Seas.

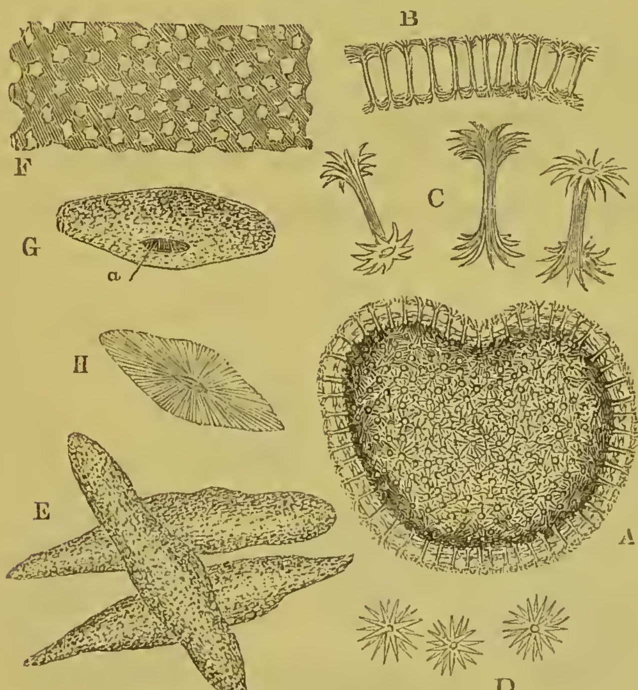
In sponges of the genus *Grantia*, the spicula are generally of *tri-radiate* figure, as shown at *f*, in Fig. 10, and F, in Fig. 15; they are composed of carbonate of lime; tri-radiate spicula of silica, however, are not uncommon: two of these are represented at *g* and *h*, in Fig. 13. Another large spiculum, shown at *i*, appears at first sight to belong to the tri-radiate variety; but it will be seen that there is a circular marking in the centre, where the three arms meet, which proves that there must have been another arm, or a shaft, projecting from this situation. Minute spicula, having six or more arms, are very abundant in sponges of the genus *Tethea;* they are principally found in the crust; three varieties are represented at *k*, *l*, *m*, in Fig. 14.

Having noticed some of the principal forms of spicula in the framework of sponges, I next proceed to those occurring in the interspaces between the elongated varieties, and which are generally of the *stellate* form, that is, consisting of a central spherical nucleus, from which a large number of conical spines radiate. Those shown at *h*, in Fig. 14, were also found in a sponge of the genus *Tethea*, and it may be noticed that the nucleus is of large size, in proportion to the spines, while in other specimens of this variety the spicula are of the same diameter, but the spines are much larger, and the nucleus hardly perceptible. In the sponges containing these spicula, most of which belong to the genus *Tethea* or *Geodia*, other stellate forms occur in very great abundance, but they are principally confined to the crust; they are about one-fourth the size of the two preceding, and not very unlike the representations given of stars of the first magnitude on our maps and globes.

I must now speak of a very remarkable sponge, first accurately described by Mr. Bowerbank, which selects minute, nearly equal-sized particles of sand, and envelopes them with horny matter, so as, with a few long spicula, to form the skeleton. This sponge was found at Brighton by Mr. Bowerbank, and from its being exceedingly brittle it has been named by him, *Dysidea fragilis*. There is another sponge of the same genus, in which a similar structure is found, and both have been described by Mr. Bowerbank, in the first volume of the Transactions of the Microscopical Society. This selection of grains of sand differs from that of certain Annellides, which merely cement together small portions of all kinds of foreign bodies, but do not entirely enclose them in animal matter. Parts of two of the horny fibres of this sponge, with the grains of sand contained within them, are represented at H, in Fig. 15.

There are other peculiar bodies found in sponges—the reproductive organs, or Gemmules. If a portion of the fresh-water sponge, *Spongilla fluviatilis*, be shaken in a little water, a number of minute grains, of a yellow colour, will be washed out from the tissue composing the skeleton. When slightly acted on by nitric acid, and examined with a power of 200 diameters, the surface of the gemmules, as shown at A, in Fig. 16, or still better at D, is seen to be studded with minute stellæ, which are the outer extremities of a crust of spicula of a peculiar form, termed *bi-rotulate*, from their resemblance to an axle and two wheels. They were first described by Ehrenberg, under the name of *Amphidiscus rotula*, he imagining them to be infusoria. It will be found, however, that they form a distinct coating to the gemmules, one wheel being imbedded in the crust, and the other projecting externally. Their true position may be distinctly seen by bringing a portion of the edge of the gemmule into focus, as shown at B. When a sponge in which such gemmules are contained is boiled in nitric acid the animal matter is destroyed and the spicula detached. In a portion of the siliceous remains of one of these sponges a great number of the bi-rotulate spicula, three of which are represented at C, will be found intermixed with other slightly spinous ones, having pointed extremities. This sponge, *Spongilla fluviatilis*, is very common in large sheets of water, especially where there are piles driven into the ground in

FIG. 16.



A, gemmule of *Spongilla fluviatilis*. B, spicula on the surface (side view). C, three spicula, magnified 600 diameters. D, end view of same spicula. E, gemmules of undescribed sponge. F, portion of the surface of the same highly magnified. G, oval gemmule. *a*, pore. H, oval gemmule, showing spicula and pore.

deep water. In the Commercial Docks, at Rotherhithe, where timber is kept, pieces that have remained undisturbed for a long time have generally specimens adhering to them. Spicula from a small sponge found in a pond at Blackheath, and given to me by Mr. Hudson, of Greenwich, as in all probability those of a new species, I discovered, on careful examination, to be malformed specimens of *Spongilla fluviatilis*. Some of the long spicula, as shown in Fig. 17, present a moniliform appearance, others have portions of spicula

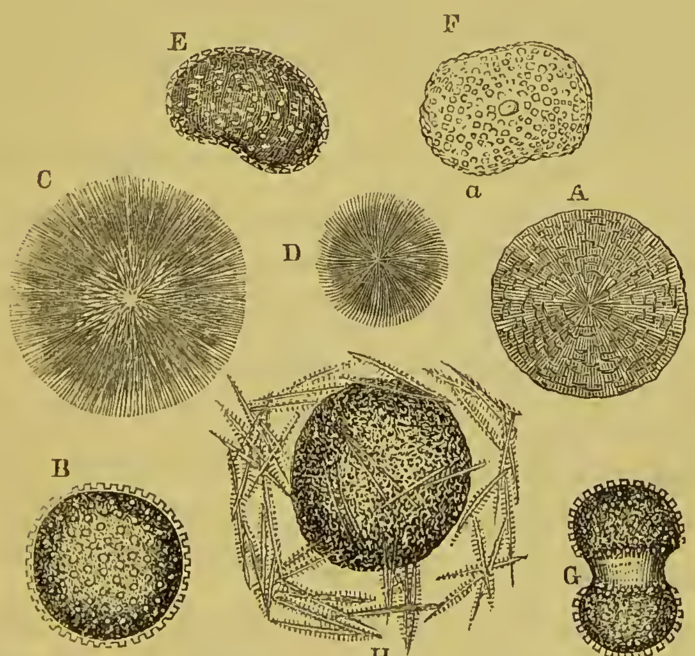
FIG. 17.

Malformed spicula of *Spongilla fluviatilis*; *a a a*, spicula of the gemmules.

projecting from them at a more or less acute angle. The spicula of the gemmules are present, they likewise are malformed, one or both of the wheels having its rays sometimes developed to a very great extent, but those shown at *a a a*, are sufficient to prove that it belongs to the species to which I have referred it. In order to exhibit these spicula, a power of 250 diameters is required, consequently, only a few can be seen in the field at one time, but by moving the stage adjustments, many, both perfeet and malformed speeimens are seen. Gemmules are found abundantly in other sponges, but their silieeous framework is more extensive, and oeeurs in the form of minute spicula.

In many species the gemmules are confined to the outer erust, in others they are situated in the interior. In some, as in *Pachymatisma*, they form a hard external eoating, whieh, when removed and boiled in nitrie aeid, is seen to be almost entirely eomposed of the beautiful objects represented in Fig. 18, some of

FIG. 18.



A, circular gemmule. B, C, D, gemmules, showing the radiated disposition of the spicula. E, F, G, oval gemmules, showing the ends of their spicula. H, gemmule of *Spongilla fluviatilis* protected by spicula.

whieh are eireular, as shown at A, B, C, others oval, as at E, F, G, and all have a central pore or depression, as shown at *a*, in Fig. 16, G, and at C and F, Fig. 18, upon some part of their external surface. The smaller gemmules, as seen at D, Fig. 18, are covered with pointed spicula, which radiate from the centre; the larger ones, as shown at B and G, have the projecting extremities of the spicula more angular, but still their radiated disposition may be observed in all but the very opaque specimens. The gemmules of a sponge of the genus *Tethea*, as shown at A and C, have the spicula exceedingly abundant, almost all are of an oval figure, and the central circular spot, or pore, is very distinct; this, when carefully examined, will exhibit a dark or light appearance, according as it is either in or out of focus.

In an undescribed species of the genus *Pachymatisma* the whole outer portion of the crust, which is extremely brittle, is almost entirely composed of gemmules, remarkable for the peculiarity of their figure, being somewhat fiddle-shaped, as seen at E, Fig. 16; they are flattened, and covered with minute tubercles, which are in reality the ends of the spicula. I could not at first discover what these were, but when, after prolonged examination, I saw the central pore, I was satisfied from this circumstance, and from their position, that they must be gemmules: the surface, when viewed with a power of 600 diameters, presented the tuberculated appearance shown at F. If a minute portion of the crust of this sponge be sufficiently magnified, it is seen to be almost entirely composed of gemmules. The sponge in which I first found the large tuberculated spicula, contained gemmules belonging to another species, probably of the same genus, but shorter, and more oval than the others; amongst them are a few imperfectly developed, as shown at H, Fig. 16, which, like those of the *Tethea*, exhibit radiating spicula. Gemmules of a somewhat similar shape to those last described were obtained from the crust of a sponge, probably of the genus *Pachymatisma*. They are of uniform size, but rather larger, and more decidedly oval than the last, and the pore, as shown at *a*, Fig. 16, G, is more conspicuous than the extremities of the spicula, although the specimen from which they were obtained was not larger than a filbert.

The gemmules, or ova, as they are sometimes called, when in the living state are said to be provided with cilia, by the movements of which they escape from the parent, and each is capable of developing an entire animal. I have never had an opportunity of seeing the gemmules in a living state in any marine sponge, although I have often met with them in our common fresh-water species, *Spongilla fluviatilis;* but as yet I have paid little or no attention to their development. This has been very carefully done by Mr. Carter, an Assistant Surgeon in the East India Company's service, who discovered several species of *Spongilla* in great abundance in some of the water-tanks in the Island of Bombay. He states that the fresh-water sponge is composed of a fleshy mass, supported by a fibrous reticulated horny skeleton. The gemmules, or seed-like bodies, occur in the base or root of the sponge, and are generally protected by a framework of spicula, as shown at H, in Fig. 18. They are of a yellow colour, globular or ovoid, each presenting a single infundibular depression, or pore, on its surface, which communicates with the interior. Within the tough, coriaceous membrane and its coating of spicula are a multitude of more or less transparent cells, which when pressed out under water are at first irregular in form and motionless, but soon swell out by endosmose, and burst in a few hours. Their visible contents, according to Mr. Carter, consisting of a mass of germs occupying about two-thirds of the cavity of the cell, subside, and gradually spread over the bottom of the vessel in which they are contained. They vary in diameter from the $\frac{1}{3000}$th of an inch, and are endowed with locomotive powers. Each germ consists of a discoid, circular, well-defined, translucent cell, which is green or yellowish-green at the circumference, pale and colourless towards the centre, and this cell appears to be surrounded by a colourless transparent capsule, the nature of which is unknown. Soon after the germs have escaped from the gemmule they collect into insulated groups, united by a semi-transparent mucilage; the contents of the largest germs then undergo a change, and the germs themselves gradually disappear, their place being occupied by a successive development of protean, or active polymorphic cells. These proteans are of various forms, and their cell-walls assume the most fantastic figures—spheroidal, polygonal, asteroid, dendritic, &c., as shown at *b, c, d, e, f,* in Fig. 19.

FIG. 19.

a, sponge in an early stage of development; *b, c, d, e, f,* protean cells; *g g,* cells developing into fibres; *h*, spicula; *j, k,* germ cells.

Shortly after the formation of the mucilage a series of threads are developed in its substance, which extend like a net-work from any thread already present, or from any germs or particles contained in the water. The fleshy substance of the sponge is composed of cells, about the $\frac{1}{7000}$th of an inch in diameter, within which are a number of granules, and one or more contracting protean vesicles. These cells are continually changing their form and position, like those derived from the gemmules, with which they are closely allied, if not identical. The horny skeleton is developed in the intercellular substance, probably from a series of elongated cells like those I have described when speaking of the structure of the *Boleti* and *Mushrooms*. Within the cells of this horny matter the spicula are secreted, and in many of the fibres, when examined by polarized light, transverse markings may be seen, which are doubtless the remains of the cell-walls.

It would appear from Mr. Carter's observations that the growth of fresh-water sponges takes place during the autumn, by a rapid development of the fleshy substance; towards winter the gemmules are formed, and when these are set free their outer case is ruptured, and each of the numerous cells therein contained is capable of producing a new individual.

LECTURE III.

SKELETON OF SPONGES, DESMIDIEÆ AND DIATOMACEÆ.

In my last Lecture I described the structure of the skeleton of recent fresh-water and marine sponges, and some of the most remarkable forms of the calcareous and siliceous spicula imbedded in the horny substance; I now proceed to notice the position these spicula occupy in the body of the animal.

Almost all sponges are parasitic; they are attached by a broad portion, or base, to pebbles, corals, shells, and some few are even found upon active, moving *Crustaceans*. In the extensive collection of Mr. Bowerbank, are many specimens in which the sponge has covered small *Crabs* to such an extent as almost to impede their movements. Other sponges assume a confervoid form, and make their way through the foramina of corals, and in more than one instance I have found a sponge forming a coarse net-work between the outer and inner laminæ of the shells of large *Pinnæ*. The fresh-water sponges will grow even upon light bodies, sueh as pieces of straw floating upon the surfaee of the water, as was first pointed out by Mr. Carter, in a species of *Spongilla* found by him in the Island of Bombay.

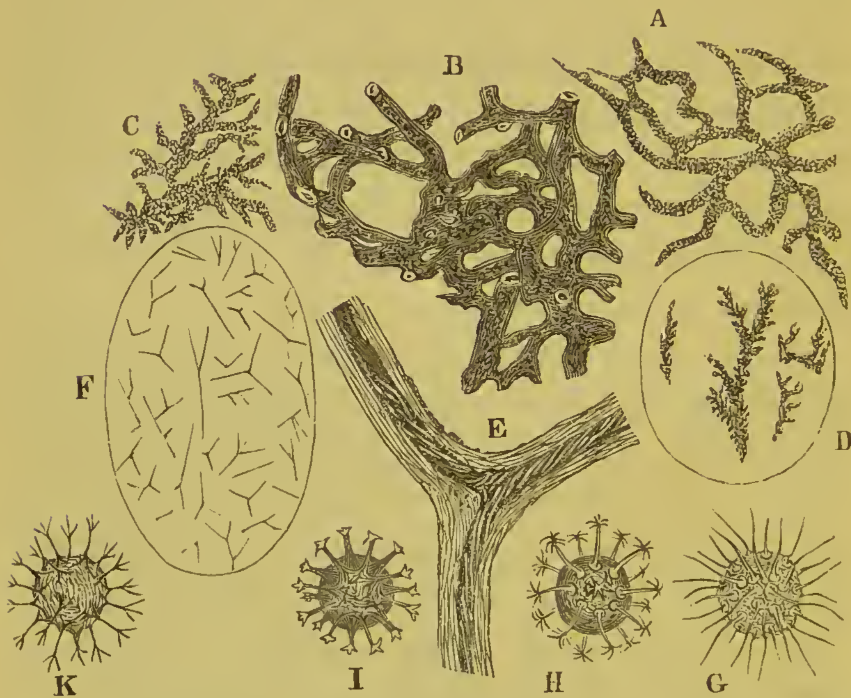
Sponges, it would appear, were more numerous in the seas of the later geological epochs than at present, for there is every reason to believe that most flints were originally sponges, those from the chalk even retain their original form, and are found in the beds or layers in which they formerly lived, whilst those occurring as pebbles on our sea-shores, owe their rounded shape to the rolling action of the water. Many of those, however, which are common on the shore at Brighton, exhibit the remains of sponge tissue even to the naked eye. I possess some flints from the chalk of Wiltshire, whieh have not only retained their original shape, but still plainly show their in-current and ex-current eanals. Recent sponges from the Sussex coast present forms preeisely similar to some chalk flints, but it is from sections made sufficiently thin to be transparent, and examined by the microscope, that we learn their true nature and origin.

It must not be imagined that sponges in their living state present the same appearance as those seen in museums; these last must be regarded simply as skeletons. Every horny sponge, when living, was invested with a coating of a jelly-like substance, which can only be preserved by placing the sponge in spirit immediately after its removal from the water. This gelatinous substance is composed of cells, probably proteïform, as in the fresh-water sponges alluded to in my last Lecture, and it is by it, and not by the horny skeleton, that the silica is attracted from the surrounding water. In sections of many flints the horny skeleton is frequently present, and in some cases the spicula are contained within its fibres.

Most of the sponges of the earlier geological periods had tubular fibres, but in all the existing species, with the exception of the *Spongia fistularis* of Dr. Grant, as shown at E, Fig. 20, and one other species, they are solid. These tubular fibres are very commonly filled with ferruginous matters, which accounts for the colour of many of the remains in flint. The *Moss-Agates*, which are so frequently cut and polished for brooches and other ornaments, are flints containing the fossilized remains of sponges; many of these are found among the pebbles at Brighton, but the London market is chiefly supplied from Oberstein, in Germany, where they are cut and polished by water-power, and sold in large numbers from 10*d.* to 1*s.* per specimen. All the beautiful moss-like figures shown at A, B, C, Fig. 20, are produced by the remains of the skeletons of sponges, as was first pointed out by Mr. Bowerbank, in a paper published in the Transactions of the Geological Society. The coloured fibres seen in the *Green*

Jaspers of the East are of the same character. Sections of *Moss-Agates*, in which the presence of the

FIG. 20.



A, B, C, remains of sponge-tissue found in *Moss-Agates*. D, a *Mocha-Stone*, showing a metallic crystallization. E, portion of the skeleton of a large sponge found in a *Moss-Agate*. F, section of a *chert-flint*, exhibiting spicula of sponge. G, *Xanthidium spinosum*. H, *Xanthidium recurvatum*. I, *Xanthidium* tubiferum. K, *Xanthidium ramosum*, all found in sections of flint-stones.

fibrous skeleton of sponges may be distinctly recognized, are very commonly of a bright-red colour, the surrounding flint being more or less transparent, and almost colourless. In other rarer specimens the sponge-fibres are of a beautiful green colour, and resemble those of a recent conferva, which has been viewed by some as a strong proof of the vegetable nature of sponges.

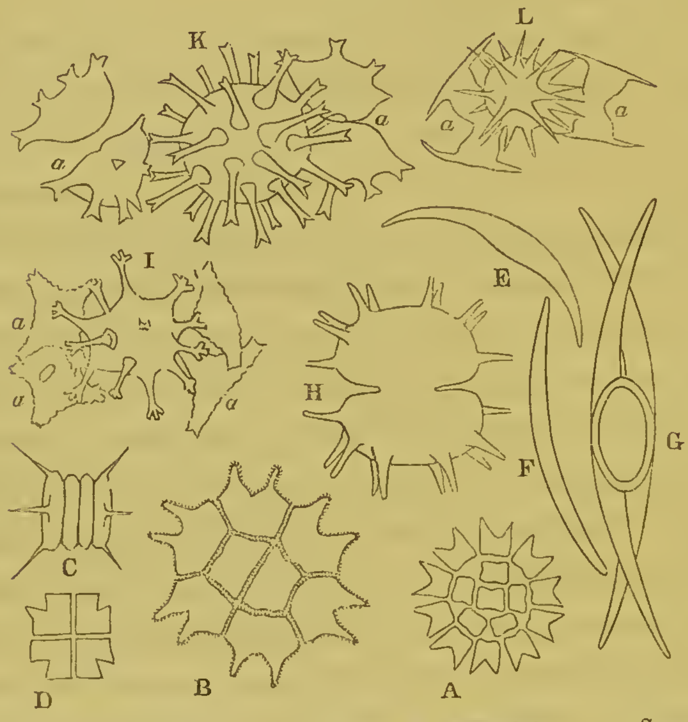
A bloek of flint of eonsiderable size, from Wiltshire, I found on examination to be made up of a silicified sponge, remarkable for the beauty of its skeleton, and composed of branehing fibres of a rieh red colour. In addition to the horny skeleton, the spieula, and even the gemmules of sponges are often present, and, as recent sponges eontain portions of sand, shells and eorals in their eavities, these remains also are oeeasionally met with in flint. In a transparent kind, eommonly called *chert-flint*, as shown at F, in Fig. 20, there are large spieula, visible even to the naked eye, and amongst them a few of the tri-radiate form, whieh I have said before are peeuliar to sponges of the genus *Grantia*. In other sections of *Moss-Agate*, with numerous spieula and horny fibres, are gemmules, having minute spines projeeting from their outer surfaee.

In other sections of flint, fragments of minute corals, which may be known by their large size and reticulate arrangement, are easily seen, and I found a pieee of wood, about two inehes in length, imbedded in a rough flint from Gravesend. Fish-scales are very eommon in some kinds of flint, as well as the horny skeletons of various speeies of *Xanthidium*, four of which are represented by G, H, I, K, in Fig. 20. It must, however, be borne in mind that the moss-like appearanee, in the so-called *Mocha-stones*, as shown at D, in Fig. 20, is not due to sponge-tissue, but in all probability to some metallic crystallization. Before leaving the subject of sponges, I must notice a portion of the shell of the *Pinna-Oyster*, in which a series of branching filaments, running between the outer and inner layers of the shell, may be seen by the unassisted eye. When these are viewed with a power of 40 diameters, they are found to be composed of the fibrous skeleton of a sponge, of a species reminding us again of a confervoid growth, but when exposed to a red heat the characteristic odour given off from the fibres is very perceptible, and indicative of their animal nature.

Our attention is next demanded by a class of organized beings, the true position of many of which in the kingdom of nature is still doubtful; some authorities considering them to be *Algæ*, whilst others regard them as *Infusoria*. According to botanists, the *Algæ*—one of the lowest classes of vegetables—are divided into five orders: viz., *Diatomaceæ*, *Confervaceæ*, *Fucaceæ*, *Ceramiaceæ* and *Characeæ*. The *Diatomaceæ* are characterized as angular fragmentary bodies, brittle, and multiplying by spontaneous fission; they are divided into three sub-orders, *Cymbelleæ*, *Hydrolineæ* and *Desmidieæ*. The *Cymbelleæ* have a siliceous, the two others a membranous or horny skeleton, and the *Desmidieæ* are further distinguished from the rest by containing starch, a substance peculiar to vegetables, and therefore excluding them from the animal kingdom. The *Cymbelleæ*, although possessing no starch, are now classed with *Algæ*; but it is of little importance for our present purpose whether they be animals or vegetables, as we have merely to consider the nature of their skeletons, which are interesting not only for the beauty of form and delicacy of marking, exhibited by their surfaces, but on account of the important part they have played in the formation of the crust of our planet.

I shall first notice the *Desmidieæ*, and before considering their skeletons will briefly point out some of their principal characters. The *Desmidieæ* have been accurately described by Mr. John Ralfs, a member of the medical profession, in his beautiful and elaborate work, from which I have gained the greater part of the information I shall be able to give on this subject. With the exception of the genus *Closterium*, which is sometimes brown, all are of a green colour, and inhabit fresh-water, whereas the *Diatomaceæ* are mostly marine. Each cell or frond of the *Desmidieæ* consists of two symmetrical valves or segments, united by a central suture, between which the newly-formed portions are interposed. They are reproduced in two ways, either by the escape of the granular contents of the mature frond, or by the formation of sporangia, the result of conjugation, as shown at *G* and by *a a* in I, K, L, Fig. 21. In most of the species, the frond divides spontaneously, which, however, is now considered as the growth, and not the reproduction of the plant, as all the cells arrive at maturity about the same time. The conjugation, or coupling of the confervæ, has been described in the first volume of the Histological Lectures; these, however, conjugate whilst the cells still form part of a filament, but the *Desmidieæ* invariably separate into single joints before their conjugation and a communication being established between

FIG. 21.



A, *Pediastrum pertusum.* B, *Pediastrum granulatum.* C, *Scenedesmus quadricauda.* D, *Pediastrum tetras.* E, F, *Closteria.* G, conjugation of *Closterium acutum.* H, *Xanthidium cristatum.* I, *Staurastrum polymorphum* in conjugation. K, *Staurastrum spinosum* in conjugation. L, *Arthrodesmus incus* in conjugation.

two cells, a seed-like mass, or sporangium, is the result. According to Mr. Ralfs, in most of the species, the valves of the shells become detached after they are emptied of their contents. The sporangia, in some genera, continue smooth and unaltered; in others they pass through a series of changes, and in consequence are liable to be mistaken for so many different species. All the *Desmidieæ* are more or less gelatinous, the gelatinous substance investing the fronds and binding them firmly to each other. In certain specimens of *Closterium*, there is a molecular movement of granules, and a circulation of fluid between the horny shell and the endochrome; a spontaneous motion of the entire organism is also often seen in the field of the microscope.

The *Desmidieæ* resist decomposition, and possess the power, like many of the *Algæ* and the green parts of plants in general, of decomposing carbonic acid under the influence of light, appropriating the carbon to themselves and exhaling oxygen. The *Sphærozosma vertebratum* affords a good example of the filamentous species of this tribe, and consists of a series of cells, of an elongated oval figure, joined end to end, each cell being composed of a horny membrane, containing within its cavity the green colouring matter, or endochrome. In some species of the genus *Closterium*, Fig. 21, E, F, G, the horny skeleton is of a brown colour, and in these the circulation of fluid, and movement of minute molecules, was first noticed and accurately described by the late Mr. Dalrymple. The genera *Pediastrum*, Fig. 21, A, B, D, *Xanthidium*, H, *Staurastrum*, I, K, and *Arthrodesmus*, L, are remarkable for their beautiful stellate or cruciform shape, and a well-defined central division or fissure; they sufficiently illustrate the structure of the skeleton of this tribe of plants, the most durable part of which is composed of a transparent horny material.

The skeletons of the next sub-order of the *Diatomaceæ*, the *Cymbelleæ*, are composed of organic matter intimately blended with silica, and indestructible both by heat and acids. All the members of this sub-order, like those of the *Desmidieæ*, are remarkable not only for the beauty of their form, but still more so for the extreme delicacy of their markings, some of which even defy the highest powers of the microscope to define, and on this account they are generally employed as test-objects. These are the minute bodies which constitute the *Bacillariæ*, or stick-like animalcules of Ehrenberg, some of which inhabit fresh, others brackish water, but a few are exclusively marine. Many of the *Diatomaceæ* occur as single frustules, or cells, others are joined end to end, and form long, flattened ribbons; some are connected by their corners, so as to resemble zig-zag chains, others again are attached to foreign bodies by means of a simple or branching stem, whilst a few genera are invested with a gelatinous envelope.

The *Naviculæ*, so abundant in our ditches, ponds and marshes, are, as their name implies, more or less boat-shaped, and of a green hue, in consequence of containing a number of granules of that colour. They possess the power of spontaneous mobility, and may be occasionally seen to glide slowly across the field of the microscope. In the living state the markings on their surfaces are not very apparent, but after boiling in nitric acid, the green matter entirely disappears, and with the same magnifying power the surfaces are seen to be covered with delicate striæ, which, under the highest powers, and with careful management of the light, are readily resolved into cells, dots, or lines.

Since the employment of these objects as tests of the definition of microscopes, observers have differed greatly as to the nature of their markings: the striæ were regarded at first as lines, but recent investigation has shown that the lines are clearly made up of dots, and it is now disputed whether these dots are caused by elevations or depressions of the surface. In my opinion, all the coarser markings are of cellular form, and those having a dotted appearance, as shown at B, in Fig. 28, are due rather to pits, or depressions, than to elevations of the surface; they are not, however, foramina, there being a thin layer of silica beneath them. In order to satisfy myself of the true nature of the markings of many of the *Diatomaceæ,* I select a slide in which there are several species of the same genus, and examine carefully those specimens in which the markings are the coarsest, and therefore, most easily recognized; having made up my mind as to their nature, I then pursue the same mode of investigation with those having more delicate markings, but yet of the same character, and thus arrive at a definite conclusion.

LECTURE IV.

SKELETON OF DIATOMACEÆ.

Having in the last Lecture made a few remarks upon the *Desmidieæ* and *Diatomaceæ*, and the probable nature of the markings on the surfaces of the latter, I now proceed to consider the mode in which the silica and organic matter in the individual specimens, or frustules as they are termed by the botanist, are disposed.

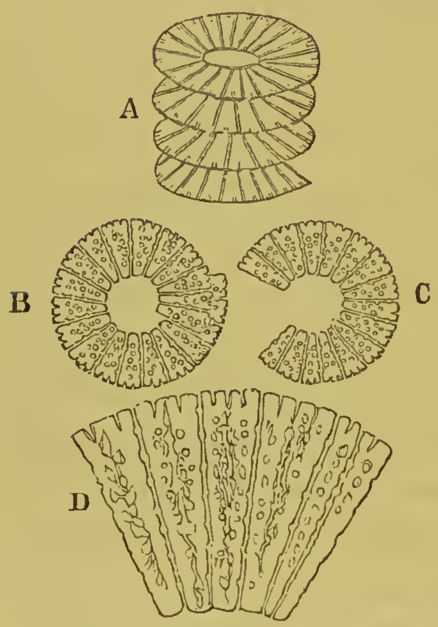
Each frustule may be regarded as a cell, in which, occasionally, a nucleus and nucleolus are contained. By boiling in nitric acid, or by the action of fire, all the organic matter will be removed, and the silica left; but if hydrofluoric acid be employed instead of nitric, as was first done by Professor Baily, the silica will be dissolved, and a flexible internal membrane, probably composed of the same horn-like material as the skeleton of the *Desmidieæ*, will remain, retaining the general form of the frustule, even to the delicate markings. It is this organic structure that selects the silica from the water, and deposits it as a thin film upon its external surface. In the young state, each furstule consists of two valves, investing a closed membranous sac or cell, within which are contained a mucilaginous fluid, and minute coloured granules, constituting the endochrome; as the frustule increases in age, the two valves are separated by the development of a third plate, which forms a band between the valves. According to the Rev. W. Smith,* no portion of the internal cell-membrane can be exposed to the action of the surrounding water without secreting a coating of silica, and the moment the valves become separated in the process of self-division, the secretion of a third plate of silica in the form of a band, commences; this third plate has been termed by Mr. Smith the "connecting membrane." The water is admitted to the internal cell-membrane, in many species that are of circular figure, along the line of suture between the valves; but in the elongated forms through perforations in the siliceous envelope, situated generally at the extremities: none of the other markings, however large, being perforations.

Some of the simplest of the Diatomaceæ are those which still retain the generic name of *Diatoma;* of these one, *D. flocculosum*, represented at F, in

* British Diatomaceæ, p. 14.

Fig. 24, occurs in considerable abundance in the form of zig-zag chains: each frustule consisting of a quadrangular plate, having its middle and two outer edges thicker than the other parts, so that in section, or when viewed end-ways, it presents the appearance shown at *f*. Other species of this genus vary considerably in shape, one in particular has frustules much longer than they are broad, and is consequently named *D. elongatum*. A very interesting and beautiful species of *Diatoma* is the *Meridion circulare*, which in the fresh state consists of a series of wedge-shaped frustules, as shown at D, Fig. 22, arranged in the form of circular bands, as at C; these, however, are not flat, but when perfect, as represented at B, have one end raised above the other; a better view, however, is obtained when the chains are thrown on one edge, they then present the flattened screw-like form represented by A. This species is met with in tolerable abundance in England and, also, according to Professor Bailey, "occurs in immense quantities in the mountain brooks around

FIG. 22.



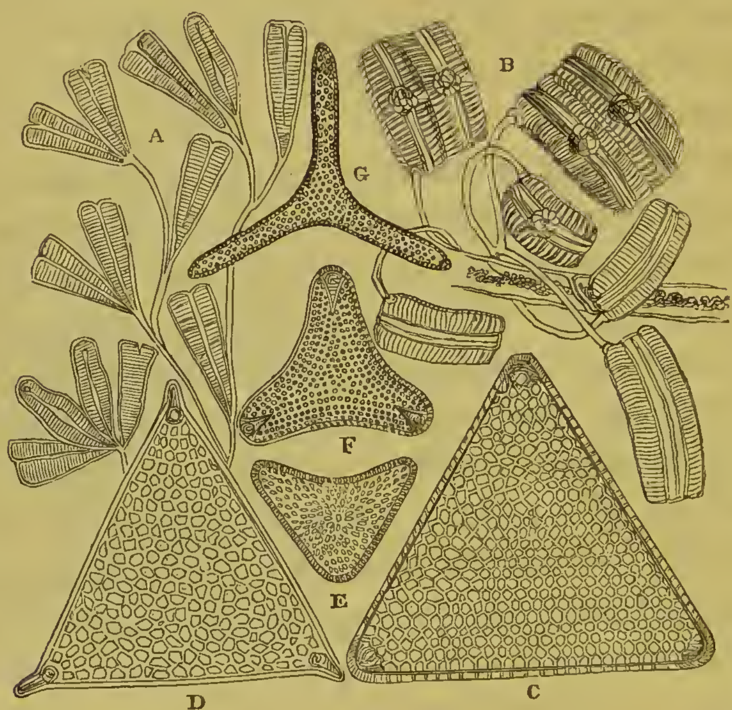
A, frustules of *Meridion circulare* seen edgeways. B C, frustules disposed in a circular form. D, five frustules more highly magnified.

West Point, the bottoms of which are literally covered in the first warm days of spring with a ferruginous coloured, mucous matter, about $\frac{1}{4}$ of an inch thick, which, on examination by the microscope, proves to be filled with millions and millions of these exquisitely beautiful siliceous bodies. Every submerged stone, twig, and spear of grass is enveloped by them, and the waving plume-like appearance of a filamentous body covered in this way is often very elegant."

Some of the Diatomaceæ have a horny stem, by which they are attached to the weeds and other foreign bodies on which they are found. The *Achnanthes longipes*, A, Fig. 23, is one of these, having a stem of considerable length; the frustules exhibit striated markings on their outer surface, and contain granules of green colouring matter. If these specimens be boiled in nitric acid the horny stem disappears, and nothing is left but the silica, on which the markings of the loricæ or valves, are more plainly seen, proving that these markings are confined to the siliceous skeleton. Another species provided with a horny branching stem, the *Gomphonema geminatum*, is represented at B, in Fig. 23; some of the frustules are there shown with the front of their valves towards the eye, whilst of the majority only a side view is exhibited. The siliceous skeletons of Diatomaceæ being indestructible, are very frequently found in the mud of ponds and rivers; that of the

Thames contains large quantities of them, and amongst the number, a peculiar shell is occasionally found, which, from having a horn-like process at each angle, has been named *Triceratium favus.* At C, in Fig. 23, is represented one of the valves,

FIG. 23.

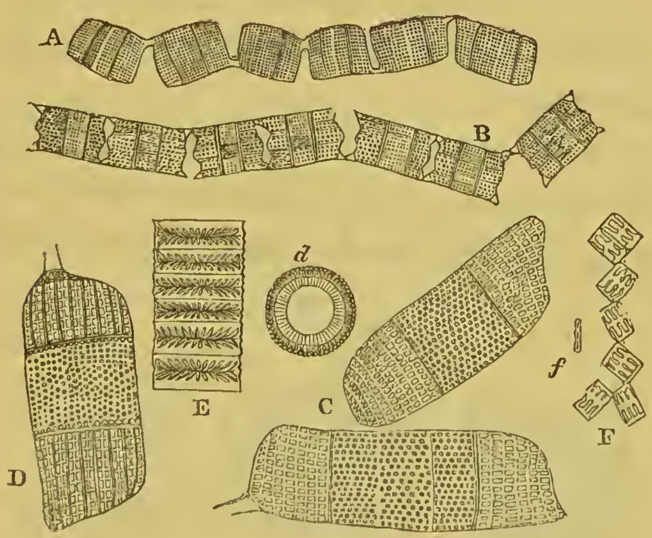


A, *Achnanthes longipes.* B, *Gomphonema geminatum.* C, a single valve of *Triceratium favus.* D, E, F, G, fossil *Triceratia* from Bermuda.

there being two such, which are separated from each other by an intermediate valve, this species of *Triceratium* is of triangular form, and appears to be made up of equal-sized hexagonal cells, like those of vegetable tissue. A great variety of *Triceratia* occur in the infusorial earth from Bermuda, some of the principal forms of the valves of which, are represented at D, E, F, G, in Fig. 23, and a great number of others are described by Mr. Brightwell, in the first volume of the "Quarterly Journal of Microscopical Science," the true figure of each being correctly delineated.

The genus *Isthmia* is of very peculiar form, consisting of two apparently distinct bodies united by a narrow portion, whence the name. There are two species commonly met with on our coasts, the *I. enervis* and *I. obliquata*, they are generally found attached to portions of sea-weed; some of the individuals being single, whilst others are connected by means of a short pedicle, coming off from one of the corners, so as to

FIG. 24.

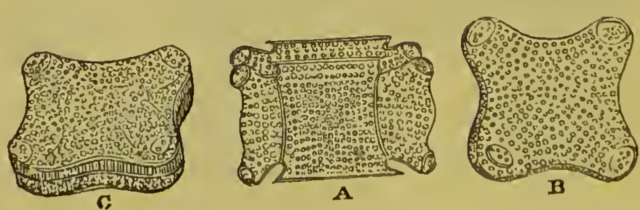


A, *Amphitetras antediluviana*. B, *Biddulphia quinquelocularis*. C, *Isthmia enervis*. D, *Isthmia obliquata*. E, *Gallionella sulcata*; *d*, detached joint of the same. F, *Diatoma flocculosum*; *f*, end view of frustule.

form a zig-zag chain, the surfaces of all the specimens of *I. enervis*, are covered with hexagonal markings, and two transverse lines, or bands, divide each into three parts. They are propagated by the separation of the terminal portions from the body, each becoming a distinct individual, whilst the body forms the case in which they are contained, as shown at C, in Fig. 24. The other species of *Isthmia*, the *I. obliquata*, Fig. 24, D, is rather broader and larger than the preceding, and is also divided into three parts by two transverse bands, the terminal portions being strengthened by a row of parallel ribs, which are placed in the direction of the long axis of the specimen, and are somewhat raised above the general surface. The mode of increase is precisely similar to that of *Isthmia enervis*, and in the preparation before you there is one specimen larger than the rest, in which two individuals are enclosed in a common case.

In an allied genus, the *Amphitetras antediluviana*, found on the coast near Ilfracombe, each individual frustule, A, Fig. 25, is of a square figure, somewhat

FIG. 25.

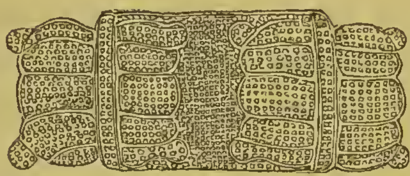


Amphitetras antediluviana entire. B, C, upper and under surface of the two lateral portions.

resembling a box, and like the *Isthmia* consisting of three portions, the terminal ones, B, C, composing the top and bottom of the box, and having a triangular spot or hole, at each of the four corners. In the recent state, the frustules are connected by means of a pedicle developed from one of the corners, so that it is usual to find long chains of them, like those represented at A, in Fig. 24. In the interior of each frustule, in the living condition, a number of green granules are observed, but there is little or no trace of markings on their exterior, if the specimen, however, be boiled in nitric acid the siliceous framework will be found entirely covered with hexagonal markings ; some of the frustules remain perfect, others are separated into three parts, the top and bottom being alike, as shown at B, C, and the central piece resembling a box without the ends.

In a genus allied to that just described, *Biddulphia*, each frustule consists of three portions, the central one being more or less square, and those at each end, which may be termed lateral, having either one or three rounded projections between the angles, which do not equal the lateral parts in length ; from the sides of the central portion, large striæ or ribs proceed as far as the margins of the projections, but in some cases the striæ are divergent, in others united by anastomosing lines. The entire surface of each specimen is covered with rounded projections or dots, which, as in *Isthmia*, are smaller in the central than in the lateral portions. Two specimens of *Biddulphia pulchella*, enclosed in the same case, are represented in Fig. 26; when young, and in the recent state, the frustules are attached to each other by the angles, but occasionally they cohere by the alternate angles only, and thus form a zig-zag chain, as shown by *Biddulphia quinquelocularis*, Fig. 24, B.

FIG. 26.

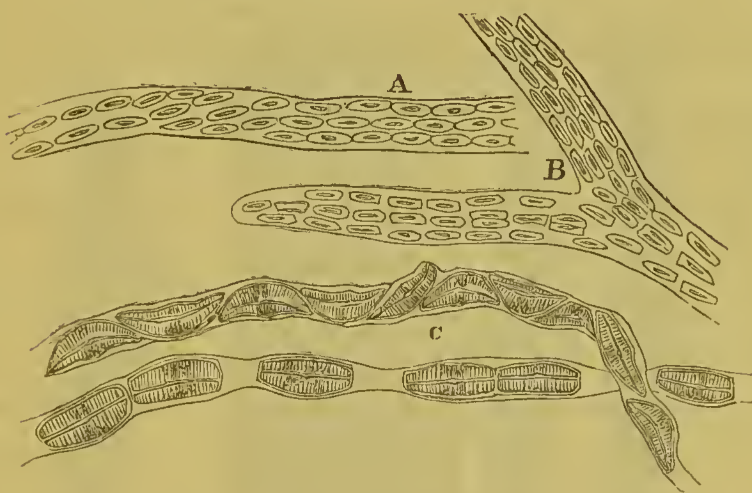


Two frustules of *Biddulphia pulchella* enclosed in a common case.

All the specimens of Diatomaceæ described in this and the preceding Lecture have the frustules naked, that is, according to the Rev. W. Smith, not imbedded in gelatine, nor enclosed in membranaceous tubes; but for the sake of contrast, three species must be briefly noticed in which the frustules are invested with a gelatinous or membranous envelope, these being represented in Fig. 27. At A is shown a specimen of *Schizonema rutilans*, at B one of *S. Ehrenbergii*, both having a transparent envelope, through which the individual frustules may be seen; the frustules, however, may be more plainly recognized in *Encyonema paradoxum*, figured at C.

The Diatomaceæ are the most widely distributed of any of the classes of organized beings, and although minute, contribute not a little to the formation of certain of the strata of our planet, generation succeeding generation, each in its turn adding its siliceous skeletons to the common heap. They are very abundant on the weeds of our ponds and rivers, and especially in summer in the

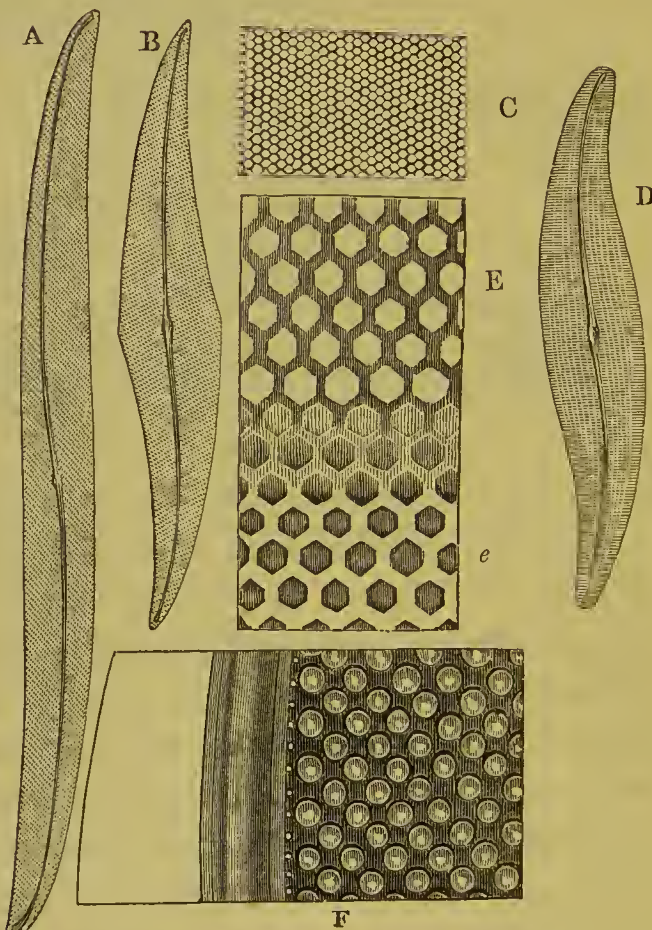
FIG. 27.



A, *Schizonema rutilans.* B, *Schizonema Ehrenbergii.* C, *Encyonema paradoxum.*

marshes about Greenwich and Woolwich, where they form a slimy or muddy layer on the surface of the leaves and stems of aquatic plants. The mass on the table before you consists almost entirely of specimens of *Pleurosigma*, especially the species known as *P. hippocampus* and *angulatum*, both of which are employed by opticians and amateurs, as tests of the defining power of their object-glasses. In the fresh state very few of the beautiful markings that exist on their surfaces can be distinguished, but if they be dried, or subjected to the action of boiling nitric acid, the organic matter is removed, and the markings can then be well brought out by careful manipulation. In Fig. 28, three of the species of *Pleurosigma*, most commonly used as tests,

FIG. 28.

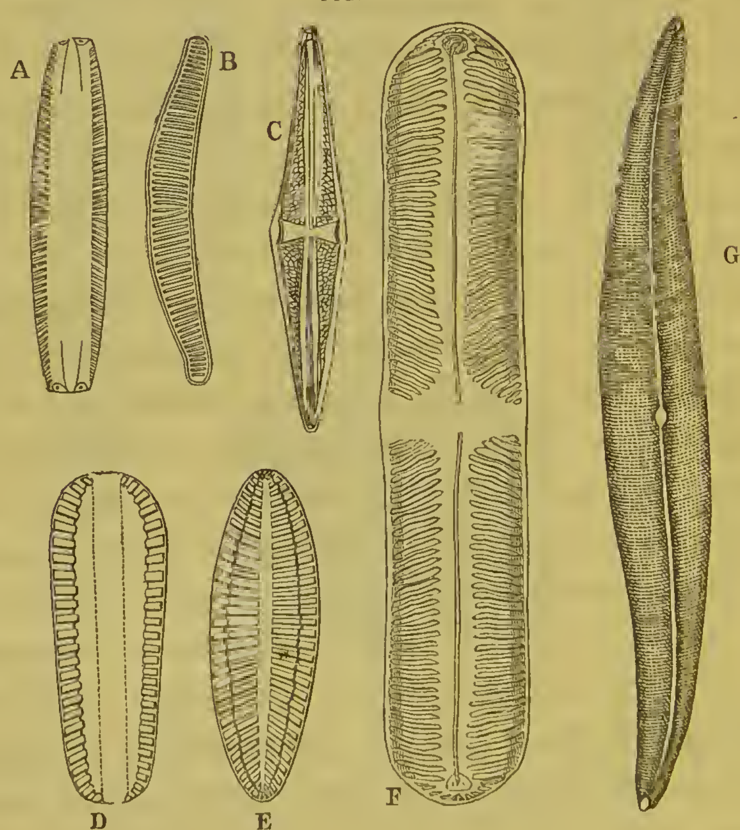


A, *Pleurosigma formosum*. B, *P. angulatum*. C, portion of the same magnified 1300 diameters. D, *P. hippocampus*. E, portion of *P. angulatum* magnified 15,000 diameters, showing at E a part in focus, and at *e* a part out of focus. F, portion of *P. formosum* magnified 5500 diameters.

are exhibited; that at A, being *P. formosum*, at B, *P. angulatum*, and at D, *P. hippocampus*. A representation of the markings of *Pleurosigma angulatum*, as seen with the $\frac{1}{12}$th of an inch object-glass by Mr. Wenham, is given at C; in certain states of the focus the valve appears covered with oblique lines, but by careful management of the light, Mr. Wenham has found that these can be resolved into hexagons. In *Pleurosigma hippocampus* the same lined appearance is seen, the lines, however, are at right angles to each other, and not as in *P. angulatum*, arranged at an angle of 60°, as represented at B. Mr. Wenham has proved beyond doubt the structure of *P. angulatum* by means of photographs taken under a power of 15,000 diameters; all the parts accurately in focus exhibit hexagons with a white centre, as shown at E, but in those out of focus, at *e*, the centre is black.

Fig. 28, A, is a representation of *Pleurosigma formosum*, a marine species not uncommon in tidal harbours, and in ditches filled with sea-water; it is certainly one of the most beautiful of our British Diatomaceæ, and is large enough to be visible to the naked eye. The markings when seen under a power of 250 diameters, appear oblique, as in *P. angulatum*, but when a very high power is employed, according to the Rev. Mr. Kingsley, of Cambridge, the lines are resolved into dots; a representation is given at F, of a portion of one of the valves, as seen under a magnifying power of 5500 diameters, the markings being resolved into so many studs or beads; but notwithstanding the enormous power employed on this occasion there are many observers who still regard these markings as depressions, and not as elevations. An American species of *Pleurosigma*, *P. Spencerii*, a few years since was employed as a test object, it has been carefully examined by Mr. Warren de la Rue, and its markings were by him first resolved into dots; the representation given at G, in Fig. 29, is from that gentleman's drawing, a species allied to it is found in this country.

FIG. 29



A, B, front and side view of *Eunotia arcus*. C, *Navicula*, from New Zealand. D, E, front and side view of *Navicula striatula*. F. *Pinnularia Cardinalis*. *Navicula*, now *Pleurosigma Spencerii*.

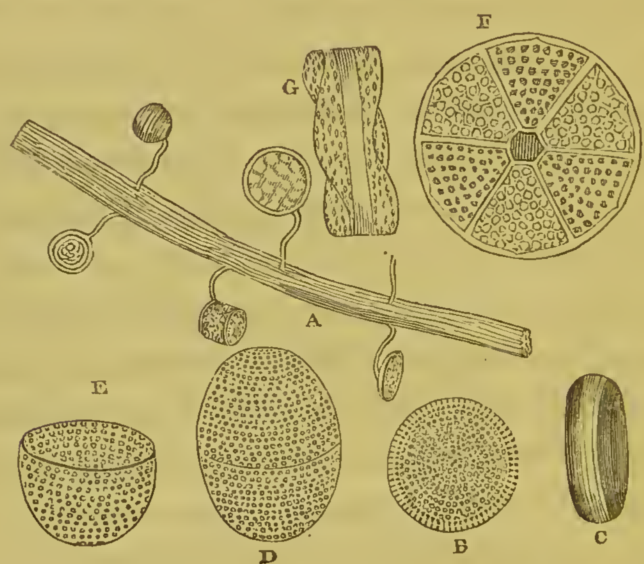
There are some *Naviculæ*, D, E and F, in Fig. 29, that have striæ in the form of ribs or costæ, which cannot be resolved into dots; to one of these F the generic name of *Pinnularia* has been applied by the Rev. W. Smith, the species figured being named *Cardinalis;* other species of *Navicula* and *Pleurosigma*, sometimes occur, on which the markings are so delicate that they may almost be said to defy every object-glass hitherto constructed; but if opticians progress in the wonderful way they have done within the last five years, we may hope that at some future time the markings of even the most difficult species will be readily resolved.

From the skeletons of Diatomaceæ still found in a living state, I shall proceed to describe a few of those which existed in ages long antecedent to the creation of man, and which from their abundance constitute no unimportant part of some of the strata of the crust of our globe. We are told by Professor Rogers that at and near the city of Richmond, in Virginia, there is a stratum twenty miles in length and several feet in depth, composed almost entirely of fossil Diatomaceæ. This earth, which was first sent to England by Professor Bailey, of West Point, New York, has been carefully examined by that gentleman, and an account of some of the interesting forms found in it has been published in the "American Journal of Science," Vol. XLII. Amongst these Diatomaceæ are several species of the genera *Actinocyclus* and *Coscinodiscus*, both being circular and remarkable for the beauty of their markings. *Gallionella sulcata*, also occurs abundantly in this earth; it has the form of a long jointed cylinder, Fig. 24, E, one of the joints being represented at *d*. In other parts of America, as for instance, at Petersburg, in Virginia, and Piscataway, in Maryland, infusorial earths are met with in which Diatomaceæ of singular beauty abound; these also have been described by Professor Bailey in the work quoted above. The *Eunotia arcus*, represented at A, B, in Fig. 29, is found in both these deposits.

Most of the fossil infusorial earths are employed in the arts for the polishing of metals, as for example, Tripoli, and the polishing-powder of Bilin, in Bohemia; this last occurs in a series of beds, averaging fourteen feet in thickness, and is almost entirely composed of the remains of Diatomaceæ, which are supposed to have been subjected at some time to the action of a high temperature. The well-known Turkey-stone, so celebrated for the sharpening of the hardest edge tools, is partly made up of infusorial remains; the pavement of the quadrangle of the Royal Exchange is composed of this mineral. The Rotten-stone of commerce, another polishing material, consists principally of the remains of Diatomaceæ; and in Ireland, in the county of Down, on the banks of the River Upper Bann, there is a white deposit, formed almost entirely of the siliceous loricæ of Bacillariæ, amongst which are joints of a small *Gallionella*, Fig. 42, F, and peeuliar eireular lorieæ, exhibiting a radiated structure as represented at E. The *berg-mehl,* or mountain mcal of Swedcn and Lapland, washed down by the mountain torrents, and whieh from its lightness and resemblance to flour is employed in times of great searcity by the poor, mixed with that article of diet, is composcd of little else than pure silica, existing in the form of skeletons of Diatomaceæ. A polishing slate is found in Jutland, in which a number of beautiful silieeous remains of Diatomaeeæ oeeur, amongst thcm may be distinguished a *Triceratium,* somewhat resembling in shape that met with in the mud of the Thames, and represented by F, in Fig. 41. The richest deposit, perhaps, is that from Bermuda, but in what part I have not yet been able to ascertain; it in some respeets resembles that from Riehmond, in Virginia, ehiefly, however, in eontaining specimens of the discoid lorieæ of *Actinocyclus* and *Coscinodiscus* which in the rccent state are composed of two valves, separated from each other by a thin rim. When a student of this Collcge, in 1841, I found many small species of these loricæ attaehed to Zoophytes, which had been brought home in spirit from Melville Island, in the Arctic regions, by Captain, now Sir Edward Parry. In the sediment at the bottom of the bottle, I diseovered no less than thirty-four varieties of Diatomaecæ, some of whieh are represented in Fig. 30; and amongst them were eertain species of *Coscinodiscus,* at that timc only known as oceurring in the

Richmond earth. There were, also, some small pieces of sea-weed in the sediment, and on these were found some minute bivalve, circular discs, of a brown colour, and of the shape shown at A, Fig. 30; they were attached to the sea-weed by means of a thin horny stem, and when treated with nitric acid, were found to be covered with delicate markings. *Coscinodiscus patina* represented in front view by B, and in side-

FIG. 30.



A, portion of sea-weed with discoid loricæ attached. B, front view of small *Coscinodiscus*. C, end view of the same. D, *Pyxidicula* entire. E, one valve of the same. F G, front and end view of *Actinocyclus undulatus*.

view by C, was not unfrequent in this sediment; the still more remarkable specimen probably of *Pyxidicula*, one valve of which is represented at E, and an entire one at D, also occurred in tolerable abundance. Professor Bailey has described this species as existing in the Richmond earth, and it is curious to observe, as will be seen by a paper of mine on this subject, published in the second volume of "The Microscopic Journal," how many species in this sediment are analogous to those found in a fossil state at Richmond, in Virginia. There is another stratum, discovered by Ehrenberg at Soos, near Eger in Bohemia, that consists almost entirely of the remarkable discoid forms, represented at B, C, Fig. 42, they are of an oval figure, curved twice in opposite directions, and from their resemblance to a shield, have been named by him *Campylodiscus clypeus;* when the learned Professor visited this country in 1841, he brought with him the first specimens that had been seen of this earth. The discs in almost every instance are very perfect, and in addition to their curious shapes, have markings worthy of notice.

An *Infusorial* stratum, discovered by Mr. Walter Mantell, the son of the late Dr. Mantell, at New Plymouth, in New Zealand, is remarkable for containing many species of *Naviculæ,* one of which, as shown at C in Fig. 29, has a central marking in the shape of a cross. Dr. Mantell told me that his son could procure no more of this deposit; being very light, it has been swept away by strong currents of wind, and distributed through all parts of the country, in the same way as we hear that showers of pollen, red snow, sand and even of shells and fish, have fallen in various parts of the globe, all having been taken up by currents of air, and carried in some instances many hundreds of miles, and then suddenly dropped as a shower. Many instances are on record, in which, vessels sailing on the Atlantic, several hundred miles from land, have had their decks covered with sand an inch or more deep. Ehrenberg has examined many specimens of this sand, and has discovered that it is principally composed of the siliceous spicula of Sponges and of the skeletons of Diatomaceæ. He has given beautiful figures of most of the species in a paper entitled "Passat-Staub und Blut-Regen ein grosses organisches unsichtbares Wirken und Leben in der Atmosphäre," published in "The Transactions of the Prussian Academy of Sciences" for 1849.

Last, but not least in importance, is the substance known as *Guano;* it is composed principally of the excrement of sea-fowl, especially penguins, which return to roost in vast numbers upon the coast of Peru, as well as upon certain small islands in the Pacific; during the lapse of years, this substance has accumulated to so great an extent, that many thousand tons of it are annually imported into this country as manure; it contains a large quantity of ammonia, as may be readily known by the peculiar odour given off even from the smallest quantity.

The Guano obtained from the island of Ichaboe was examined microscopically by my late brother, Mr. Edwin Quekett, and in it he detected the siliceous remains of numerous Diatomaceæ, principally those of the discoid form. In a paper on this subject, read at one of the Meetings of the Microscopical Society, held in 1845, and published in the second volume of their "Transactions," he gives an account of the differences in character between the guano of Ichaboe and that of Peru, and how the former may be readily distinguished from the latter by the greater abundance of discoid skeletons. The mode of isolating these siliceous remains was only briefly alluded to by my brother, but very soon after the fact of their occurrence was made known, the method of obtaining them was rendered tolerably easy by a process contrived by Mr. Deane of Clapham, and published in the second volume of the work last quoted; it is copied nearly verbatim in my Treatise on the Microscope.

The probable cause of the presence of these remains in the Guano, appears to be that penguins feed chiefly on fish, and sometimes on shell-fish, these last it is well known, from the researches of the Rev. J. B. Reade, have always more or less sand in their stomachs, amongst which numerous Diatomaceæ occur; fish and birds both eat the shell-fish, and as the silica is not capable of digestion by the latter, it is voided with their excrement, and hence the source of these beautiful discs. It is a remarkable fact, that the first specimens of guano imported were the richest; many persons have examined large quantities of that sold in the shops without finding any siliceous remains whatever—no doubt in consequence of adulteration. The best Peruvian guano is, at present, imported by the house of Anthony Gibbs and Co., Lime Street, City, who have a contract for it with the Peruvian Government.

When we consider the vast amount of silica that must be taken from the soil by the straw of grasses of various kinds, it is possible that, besides the nitrogenous principles which guano contains, the silica in it, may also be of considerable service; it is certain that the cereal plants must take it up from the soil, for the atmosphere cannot supply it, and it could hardly be given to them in a more finely divided state: thus constituting another valuable quality of this material as a manure. The process of dissolving the silica and taking it up to be deposited in the tissues, as is done by the grasses, is probably an electrical one; and in a recent visit to Somersetshire, I witnessed the following most striking experiment in the laboratory of Mr. Crosse, a true philosopher, of whom doubtless you have heard as being so celebrated for his experiments in voltaic electricity.

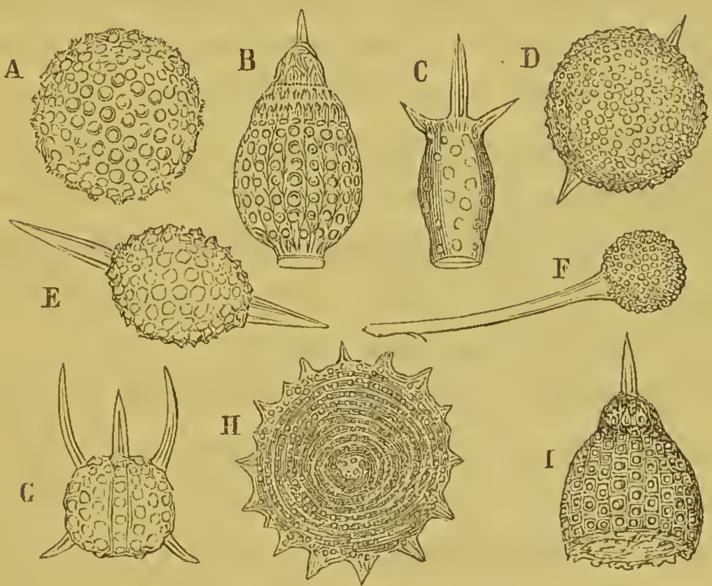
In a common tumbler filled with distilled water were placed, on opposite sides, a portion of silver—if I recollect rightly, a sixpence—and a piece of slate; one was connected with the positive, the other with the negative pole of a voltaic battery, consisting of a copper vessel containing a solution of sulphate of copper, in which was placed a porous tube and a zinc rod, the tube being full of a solution of sugar; by this means slow electrical action was kept up, and the silver on the one side was actually dissolved by the water, carried across, and deposited in a crystalline form upon the slate on the opposite side of the tumbler; had a piece of flint occupied the place of the silver, the same effect, in all probability, would have been produced. It occurred to me immediately that it might be by electrical agency that the silica, lime, and other inorganic materials were dissolved and assimilated by plants.

LECTURE V.

SKELETON OF DIATOMACEÆ AND FORAMINIFERA.

In addition to the various localities of fossil *Diatomaceæ* mentioned in my last Lecture, two others must be noticed; one of them is Springfield in the island of Barbadoes, the other Santa Fiora in Italy. The former is remarkable for the peculiarity of its organic remains, which are totally unlike those found in any other stratum, as may be seen by referring to Fig. 40, in which are represented nine of the forms most commonly met with. Some of these, as shown by A, D, E, are of spherical, others of oval figure, and are composed of a coarse network of cells or silicified cell-walls, somewhat like those of the Echinodermata; most of the specimens having one or more sharp spines projecting from some part of their outer margins. One peculiar kind is circular and flattened, or made up of a series of concentric zones of variable size, arranged one above

FIG. 40.



the other, as represented at H, each zone being composed of a network of cells precisely similar to those just mentioned, with spines projecting from the margins; others are met with of larger size, in which there is no trace of concentric zones, but the reticulations or cells of the framework are disposed in radii. I have also found among these remains, a globular and an oval body composed of the same structures as the preceding specimens, each having, as shown by D and E, a large conical spine protruding from two opposite sides of the circumference.

The forms represented by C, G and F are more rare, but the two former are well provided with spines.

The earth containing these remarkable remains was brought to this country in 1849, by Prof. Ehrenberg, but, as far as I am aware, the true nature of the skeletons has not yet been correctly ascertained; Ehrenberg himself, however, has described many of them under the generic name of *Polycystina.* Others of these skeletons are dome-shaped, and have a short spine projecting from their summit, as shown at B and I, others again have two conical diverging spines from their base; both kinds have markings similar to those in the specimens first noticed.

The Infusorial earth from Santa Fiora in Italy is extremely rich in the genera *Gallionella, Eunotia* and *Navicula,* and among these a Navicula of large size, named on this account, *Navicula grandis;* it measures about $\frac{1}{50}$th of an inch in length, and the oblique markings on its surface are not capable of being resolved into dots, like those of many smaller species. This Navicula occurs in England both in the recent and fossil state; it has been called by Ehrenberg *Pinnularia nobilis,* and under this name is represented in the "British Diatomaceæ" of the Rev. W. Smith.

The circular discoid skeletons belonging to the genera *Actinocyclus, Coscinodiscus, Arachnoidiscus, Tripodiscus* and others remarkable for the beauty of their markings, are found both in the recent and fossil state; in the former condition they were met with by Ehrenberg at Cuxhaven, and many of them have been described and figured in a paper in the

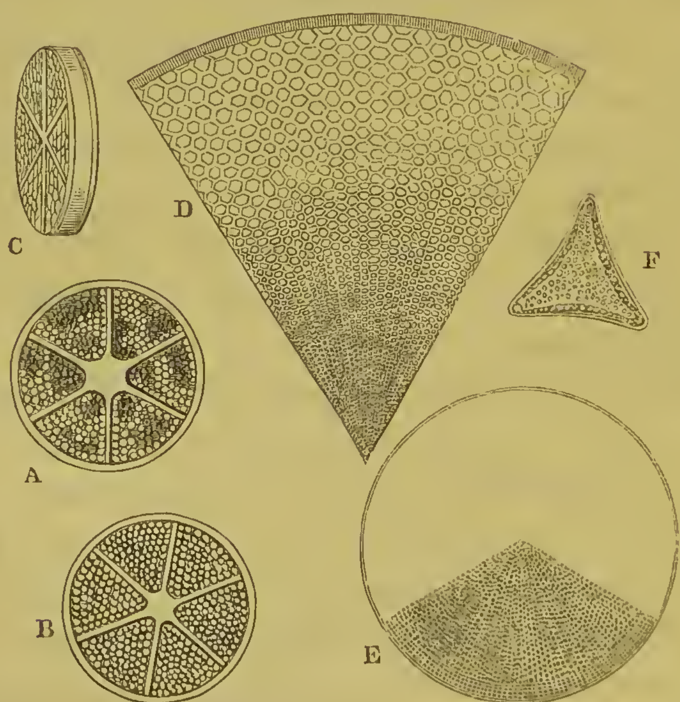
"Berlin Transactions," which has been translated and published in the third volume of Taylor's "Scientific Memoirs." They are all characterized as being composed of two more or less flattened or convex *loricæ*, separated from each other by a central part or rim.

In the genus *Actinocyclus* the loricæ are composed of alternate radii or segments, having different structural markings, and not unfrequently arranged in different planes, so that in one focus, a set of rays on the same plane is brought into view, and by altering the focus, another set is rendered visible; both sets cannot be well seen at the same time, unless under a low magnifying power, and on this account the specific name in most instances denotes the number of rays.

In the genus *Coscinodiscus* there are no rays, but the markings take the form of a hexagonal network. In some species a few cells in the centre are largest, all the rest being nearly of uniform size; in certain other species the cells are smallest near the centre, and increase gradually in size towards the margin; they all abound in the earth from Bermuda and Richmond, and in Guano, as shown by E in Fig. 41.

The generic name *Arachnoidiscus* is applied to certain siliceous loricæ generally found attached to a sea-weed from Japan, which is employed by the Japanese in the manufacture of soup, the term *Arachnoidiscus* being derived from the resemblance of the markings to the web of the spider. In the Richmond earth *Actinocyclus senarius*, Fig. 41, A, is found, so named from its having six rays, every alternate one differently marked, three of the rays being on one, the remaining three on another plane; there are various other species in the same deposit, one in particular of large size, having as many as twenty rays. In this earth, in Guano, and even on our own coasts, is found the *Actinocyclus undulatus*, represented by F in Fig. 30, being so named from the undulating character of its valves, as seen in the lateral view given at G.

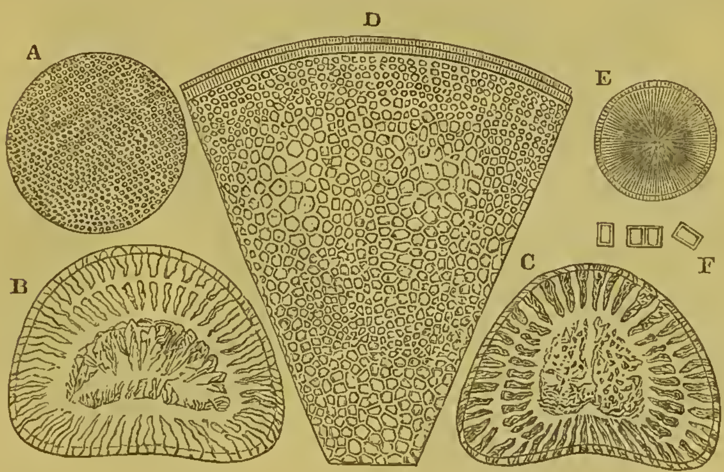
FIG. 41.



A, recent specimen of *Actinocyclus senarius*. B, skeleton of the same. C, side-view of the same. D, segment of *Coscinodiscus radiatus*. E, segment of a disc from guano. F, *Triceratium* from Jutland slate.

Several species of *Coscinodiscus* are also found in the Richmond earth; for instance, *C. lineatus*, Fig. 42, A, and *C. radiatus*; the latter, a segment of which is shown at D in Fig. 41, is $\frac{1}{250}$th of an inch in diameter; its cells are of hexagonal figure, and gradually increase in size from the centre to the circumference. The *Coscinodiscus oculus iridis* of Ehrenberg, obtained

FIG. 42.

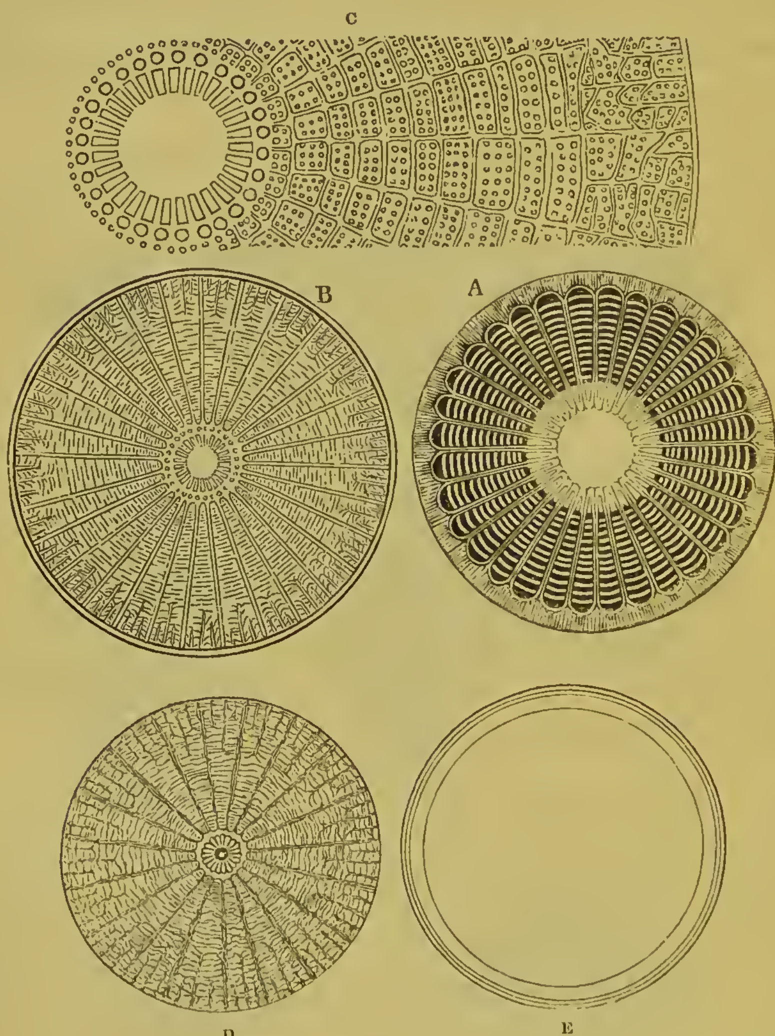


A, *Coscinodiscus lineatus*. B C, *Campylodiscus clypeus*. D, Segment of *Coscinodiscus oculus iridis*. E, disc found in earth from the river Upper Bann. F, joints of a *Gallionella* from the same earth.

from Ichaboe guano, attains the great size of $\frac{1}{100}$th of an inch in diameter, and will occupy nearly the whole field of view when examined with a power of 250 diameters; the central cells are larger than the rest, and are arranged in the form of a star, the others being disposed in radiating lines, neither of the valves is flat, both being curved somewhat like a lunette watch-glass.

The *Arachnoidiscus Ehrenbergii*, one valve of which is represented by B in Fig. 43, has been carefully examined by Mr. Shadbolt, and an account of its skeleton published in the third volume of the "Trans-

FIG. 43.



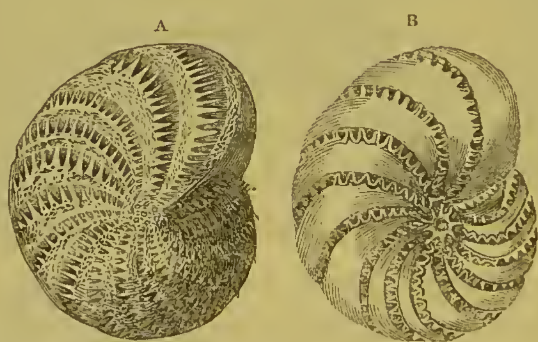
A, the siliceous framework of a disc of *Arachnoidiscus Ehrenbergii*. B, disc of the same in its natural condition. C, portion of a disc magnified 500 diameters. D, thin horny membrane composing the outer coating of a disc. E, annular valve.

actions of the Microscopical Society." According to this gentleman, each perfect specimen consists of two discoid portions and two annular valves; the discs are each made up of a thin flexible horny membrane and of a siliceous framework, the former is indestructible by boiling nitric acid, and has the peculiar spider's web-like markings situated upon it. This membrane is represented by D, the siliceous framework by A; the latter can occasionally be separated entire from the horny layer, but not without much difficulty. The annular valves are seen at E, they consist of a ring of silica, within which, and extending a short distance towards the centre, is an annular membrane, and when the specimen is entire it is by these two membranes that the discs are connected together so as to form a box; the markings of the discs are very beautiful, as may be seen by the portion represented at C, which has been drawn under a power of 500 diameters. According to the Rev. W. Smith, this species has been found at Ilfracombe, it also occurs very abundantly on certain *Algæ* from California and South Africa.

From the description of the skeleton of the various species of Diatomaceæ found both in the recent and fossil state, I pass on to that of the *Polythalamia* or *Foraminifera*, a class of lowly organized beings occurring in the greatest abundance in many of the strata composing the crust of our planet; the first name being given from their consisting of a number of chambers, the second from the numerous foramina opening on the external surface of the shell of the greater number of species. They are almost exclusively fossil, only two or three representatives of the class still existing, one of these however—*Polystomella crispa*—has been lately described by Prof. Williamson of Manchester, in the second volume of the "Transactions of the Microscopical Society," as being found in great abundance upon a large *Laminaria* floating on the sea near Falmouth.

Through the kindness of Prof. Williamson, I am enabled to show you some of these recent specimens, they are of minute size, and when magnified 40 diameters, appear as represented by A in Fig. 44; the

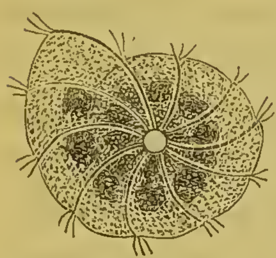
FIG. 44.



A, recent shell of *Polystomella crispa*. B, animal of the same.

shell is calcareous, and when acted on by acid, the animal remains, as shown by B, retain to a considerable extent the perfect shape of the shell. The *Foraminifera*, as before stated, were very abundant in the earlier periods of the earth's history, and some strata, such as the chalk and the limestone of the Eocene formation, appear to be almost entirely composed of their minute calcareous shells. They have been termed *Rhizopoda* by M. Dujardin, on account of the delicate root-like character of their locomotive organs, which, according to Ehrenberg, as shown in Fig. 45, pass out through the foramina in the shell; these organs are called *pseudopodia*. The shape of the shell or skeleton is very peculiar in the majority of species, bearing a strong resemblance to that of a minute *Nautilus* or *Ammonite*, but differing from these in having no *siphuncle* or tube of communication between the chambers, although there are several small foramina in the septa dividing one chamber from another. Each chamber contains a single animal, from which, by a process of budding or gemmation, a second is formed, and as soon as it is perfected, it secretes the calcareous shell, so that a single foraminiferous shell is, as we shall presently see, made up of a colony of individuals.

FIG. 45.



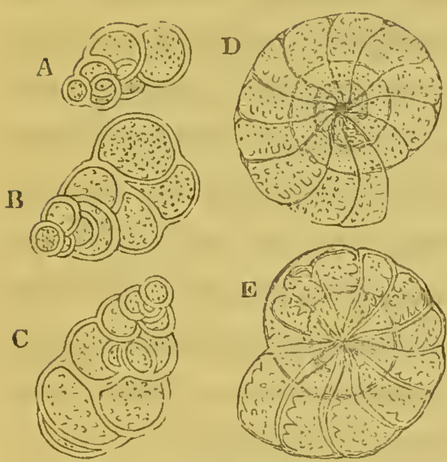
Recent foraminiferous shell, *Nonionina Germanica*, with its pseudopodia.

The chambers are usually arranged in the form of a continuous spiral, but there are some kinds, as for instance, the genus *Clavulina*, represented by A in Fig. 48, in which they are disposed almost in a straight line, like the chambered shells of gigantic size called *Orthoceratites*. The shells, as before stated, exist in great abundance in the chalk, and in order to show them to the greatest advantage in this deposit, it is necessary that the chalk should be washed, and the larger particles separated.

The mode adopted in the preparation of the *Creta preparata* of our Pharmacopæia is a good one, but the best is that recommended by my friend Dr. Southby, which is a modification of the process employed to test the strength of bricks. A piece of the chalk is boiled in a saturated solution of sulphate of soda; the subsequent crystallization of the sulphate, tears the chalk to atoms without injuring the shells, which would inevitably occur during the process of pulverization by the ordinary mechanical means. Dr. Southby once resided at Bridgewater in Somersetshire, where bricks are made in great numbers, and he there learnt this plan, which he ingeniously applied to the extraction of these beautiful objects from the chalk. The species, however, in this deposit alone, are so numerous that it would take me a great length of time to point out those occurring even in a single slide; I must therefore content myself with selecting for illustration a few of the most interesting specimens, and those who feel interested in the subject, and require more information than can be given in a single lecture, I would refer to the splendid work of D'Orbigny, entitled "Foraminiferes fossiles," which will be found in the College Library.

The chalk from Gravesend contains many bodies of considerable size, of a conical shape, as shown at A, B, C in Fig. 46, which appear to be composed of a series

FIG. 46.

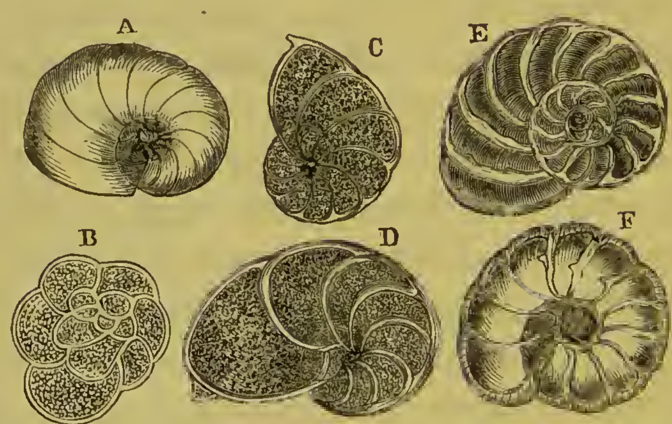


A, B, C, *Textilariæ* from the chalk of Gravesend. D, E, larger *Foraminifera* from the chalk.

of cireular cells; these are Foraminifera, of the gènus *Textilaria*, and the eells are the ehambers. In another speeimen, as shown by D E, the shells are suffieiently large to be seen by the unassisted eye; these have been pieked out from chalk, and mounted separately, they elosely resemble the *Nautilus* in shape, the ehambers are nearly of equal size, and the minute dots seen upon the surfaee of eaeh are the foramina.

The ehalk from Salisbury Plain eontains numerous Foraminifera, whieh are even larger than those last mentioned; the foramina are equally numerous, but the shape of the shell is different. In the neighbourhood of Brighton—the harbour of Shoreham, I believe—these shells have been oeeasionally found lying on the sand quite free from admixture with other bodies, and remarkable for the beauty of their forms; they show the foramina extremely well, in consequenee of all trace of the animal substanee having been removed from the interior of the ehambers, and there is every reason to believe that they have been washed out of the chalk by the sea-water. The sand from the sea-shore in various parts of the world is very rieh in Foraminiferous remains; that from the beach at Dover contains them in great abundance, but they are still more numerous in the sand from the shores of the Dead Sea, which, in fact, consists of little else than *Polythalamia* and the spicules of *Gorgoniæ;* some of the latter may even be recognized by the naked eye, being of a pink colour, they can be easily detected. The tertiary limestone formations of Bordeaux are also extremely rich in these remains; two of the most common kinds are shown by A B in Fig. 47.

FIG. 47.



A, B, *Foraminifera* from the tertiary limestone of Bordeaux. C, D, silicified *Foraminifera*. E, F, *Foraminifera* from Delos.

All the species of which I have spoken exhibit foramina of variable size on their surface; but, with the exception of the ridges produced by the projections of the septa of the chambers, the outer surface is comparatively smooth. There are, however, many species—as, for instance, *Polystomella crispa*, represented by A, Fig. 44—in which spines project from some part of the external surface, more especially from the outer convex margin; I possess many examples of shells with spines, as shown by C, in Fig. 48, and in one of remarkable beauty the spines, which are prismatic, are arranged in a radiated manner: from this cause the specimen has received the name of the radiated *Sideralite.* At first sight the shell, which also exhibits the foramina very beautifully, appears as if covered with minute *Diatomaceæ:* like the preceding species, it was obtained from the Straits of Magellan.

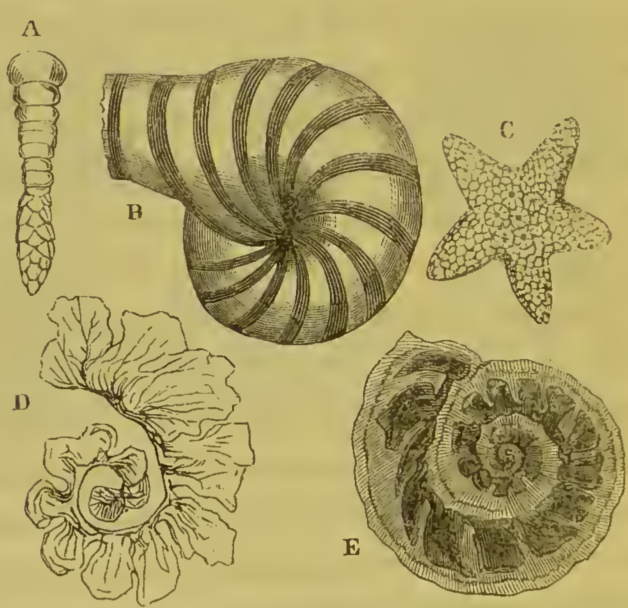
The least troublesome plan of obtaining specimens of these foraminiferous shells is to procure from a dealer in sponge some of the sand out of the bins in which the sponges are kept; it will almost always be found to contain several species, and they can be easily picked out by sifting, or with a fine-pointed sable pencil. Some sponges have about 75 per cent of their weight made up of sand, these yield an abundance of Foraminifera.

Of all the sands I have mentioned, however, none can be compared, for richness in these shells, to that obtained from the shores of the classic island of Delos; in some specimens—as, for instance, that represented by B in Fig. 48—the last formed chambers are prolonged in a straight line like the beak of certain *Ammonites* from the Oxford clay. Two of the more common kinds are shown by E and F in Fig. 47; occasionally some of these are so fractured that the interior of the chambers may be well seen.

G 2

The specimens that I have hitherto described have the shell or skeleton composed of calcareous material; it not unfrequently happens, however, that this has been replaced by silica. In sections of flints, Foraminifera of various kinds are commonly met with in which the shell has been converted into silica; but in Fig. 47, C D, are shown two perfect specimens from the chalk in which the same change in the chemical composition of the shell has taken place, they can be boiled in nitric acid without injury.

FIG. 48.



A, a foraminiferous shell of the genus *Clavulina*; B, beaked shell from Delos; C, shell with spines, from the Straits of Magellan; D, remains of *Rotalia* from the chalk; E, *Rotalia* found in flint (Mantell).

Not only do we find in the chalk and flint the shells of Foraminifera, but even the soft parts of the animal also, as has been abundantly shown by

Mr. Deane of Clapham, and by the late Dr. Mantell. The remains most common are those of the genus *Rotalia*, one of which is represented by E in Fig. 48, with the body of the animal almost entire, as found in a section of flint; a portion of another is shown at D, both being copied from Dr. Mantell's paper, in the "Philosophical Transactions" for 1846.

All the Foraminifera above alluded to, have been rendered transparent by being mounted in Canada balsam; but as it is frequently a difficult matter to get rid of the air from the chambers, which, when present, completely obscures all the minute markings, I will briefly point out the method by which this can be done with comparative certainty. The shells having been covered with rather fluid Canada balsam, must be placed under the exhausted receiver of an air-pump, and allowed to remain for some time. The best apparatus for this purpose is a strong copper box, sufficiently large to hold two or three slides on its upper surface, this is to be filled with boiling water, and when the slides have been laid on the top, the box is placed under the receiver, and the air exhausted. The balsam being thus preserved in a very fluid condition, and the air contained in the chambers being at the same time expanded both by the heat, and by the removal of the atmospheric pressure, it escapes, and the balsam runs in, to occupy the vacuum.

LECTURE VI.

SKELETON OF NUMMULITES, ORBITOIDES AND ORBITOLITES.

From the *Foraminifera* I proceed to examine and describe the structure of a class of organized beings, of whieh few, if any, now exist in a living state, but whieh were so abundant in the earlier periods of the earth's history, as to eontribute largely to the formation of some of its strata; these are the *Nummulites*, so named from their resemblance in form to pieees of money, or *Nummi*. Aceording to Sir Charles Lyell,* the nummulitic formation, with its eharaeteristic fossils, plays a far more eonspieuous part than any other tertiary group in the solid framework of the earth's crust, whether in Europe, Asia, or Africa, it often attains a

* Manual of Elementary Geology, 3rd Edition, p. 234.

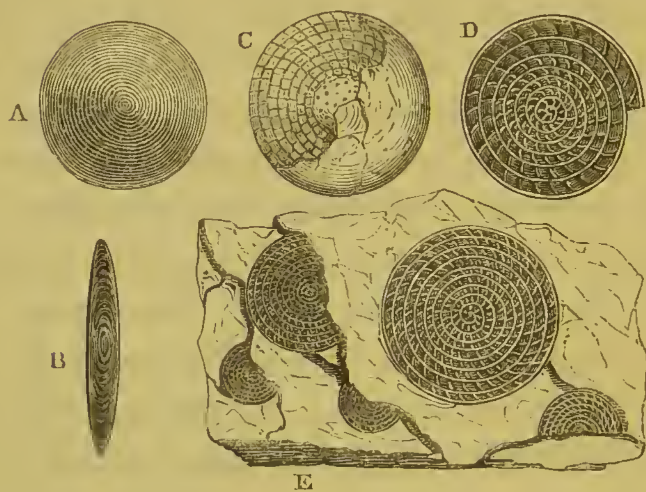
thickness of many thousand feet, and extends from the Alps to the Appeninnes. It is found in the Carpathians, and in full force in the North of Africa, as for example, in Algeria and Morocco. It has also been traced from Egypt into Aisa Minor, and across Persia by Bagdad to the mouths of the Indus. I may mention, as an interesting fact, that the great pyramid of Egypt is built of Nummulitic limestone. Strabo alludes to these nummulites under the supposition that they were lentils which had been scattered about by the workmen and had become converted into stone. One species, *Nummulites complanata*, is exceedingly common in the London clay formation; and Bracklesham Bay is one of the localities in which this species occurs in great abundance.

For a knowledge of the minute structure of Nummulites we are principally indebted to the labours of Dr. Carpenter,* M. D'Orbigny, and Prof. Williamson of Manchester. According to these authorities, they vary in diameter from the size of a penny piece to almost microscopical dimensions, they are flattened and circular, of a more or less discoid figure; as shown by A in Fig. 49, most of them are bi-convex, as represented by D, their external surfaces are smooth like pebbles, and exhibit few, if any, markings that are visible to the naked eye. The skeletons of two other forms of organized beings have been con-

* Quart. Journ. of Geol. Soc. Vol. VI, Feb. 1850.

founded with Nummulites, but they have been divided by Dr. Carpenter into the genera *Orbitoides* and

FIG. 49.

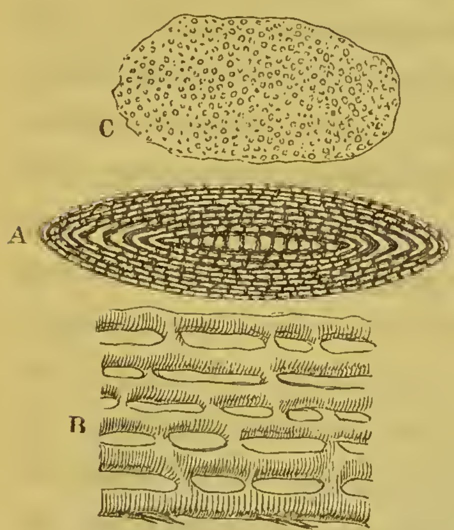


A, *Nummulites atacica*, outer surface; B, *Nummutites atacica* divided vertically; C, *Nummulite* with its outer surface partly removed; D, the same divided horizontally; E, the same species in a block of limestone, divided horizontally.

Orbitolites; the former is allied to the *Foraminifera*, whilst the latter is supposed to belong to an animal of the class *Bryozoa*, which class is now placed in the molluscous sub-kingdom.

A horizontal section of a Nummulite, as shown at D and E in Fig. 49, exhibits a series of chambers arranged in a spiral form, resembling in some respects those of the foraminiferous shells, but much more numerous; the smallest of these chambers occupy the centre, but they increase gradually in size towards the margin, here and there larger cells may occasionally be seen interspersed among the smaller ones; these, however, are to be regarded as abnormal. Vertical sections of most Nummulites as shown by A in Fig. 50, present several layers of super-imposed chambers, those in the median line being largest; when viewed with a power of 100 diameters, as shown at B in Fig. 50, all the septa between the chambers exhibit vertical striæ, which are minute tubes or foramina forming communications between the chambers; in addition to these, there are larger tubes opening externally, through which it is supposed the rudimentary locomotive organs, or *pseudopodia* protrude. The central chambers communicate with each other either by means of a large circular opening, or by other openings of smaller size, arranged in a radiating manner, which are plainly visible in the most convex parts of the septa of the largest chambers. In another horizontal section of the same Nummulite, viewed by a power of 250 diameters, as shown at C, the minute tubuli of the septa being cut at right angles to their length,

FIG. 50.



A, vertical section of *Nummulina lævigata* from the London clay; B, portion of the same, more highly magnified; C, portion of the external surface of the same showing the foramina.

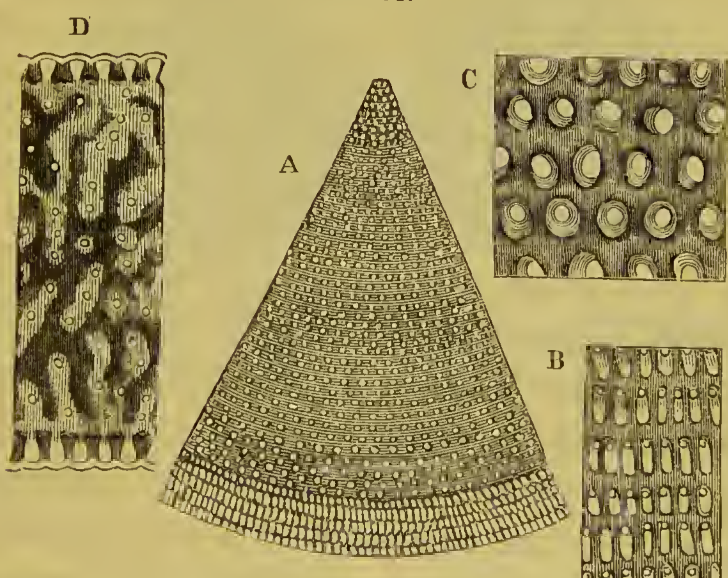
appear as so many black dots, from being filled up with calcareous material.

Each chamber has its own proper walls, these, however, are not in close contact, a space, termed by Dr. Carpenter interseptal, existing between each of them; every septum is perforated by minute tubes, which form a communication between the contiguous chambers and the adjoining interseptal spaces, and the cavity of each chamber also communicates with those on each side of it by the openings I have already described. Another vertical section of *Nummulina lævigata*, under a power of 30 diameters, exhibits a row of large tubes somewhat of a conical figure, which proceed from the outer surface and pass down to the interseptal spaces of the chambers in the central plane. Although these tubuli open upon the external surface, they are not always visible, their mouths being coated over with limestone; but if this be removed by means of an acid, they are rendered apparent. The Pseudopodia pass through these large tubes, and by their means a direct communication is established between all the chambers and the surrounding water; the chambers are very well seen in all the specimens, but in the majority of instances they are filled with crystalline carbonate of lime.

The skeleton of Nummulites, like that of the Foraminifera is composed of carbonate of lime, secreted by the organic basis of the animal, the entire series of chambers being formed by a process of gemmation like that of the polyp-cells of Zoophytes, and every successive whorl not only surrounding the preceding one, but completely investing it.

Sections of two or more species of *Orbitoides*, according to Dr. Carpenter, exhibit certain characters which belong especially to *Nummulites;* but the genus *Orbitolites*, or *Marginopora* as it has been termed by Quoy and Gaimard, is considered by Dr. Carpenter not to belong to the Foraminifera, but to be formed by an animal, or collection of animals, of the *Bryozoal* type. A segment of a horizontal section of a recent *Orbitolite* from the Australian seas is represented by A in Fig. 51, the cells are arranged in concentric rows; those near

FIG. 51.



A, segment of a horizontal section of a recent *Orbitolite* from Australia, magnified 10 diameters. B, portion of the same, showing the cells near the surface. C, portion from the centre. D, vertical section magnified 60 diameters (after Carpenter).

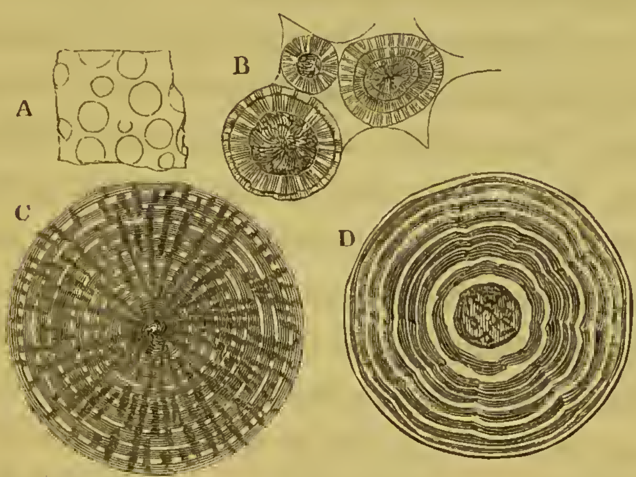
the surface are of oval figure, as may be seen on the margin of the section, or more highly magnified at B; sections taken from the centre, as shown at C, exhibit the cells of circular figure. If a disc be divided vertically, as shown at D, the oval cells of the surfaces are well displayed, the other parts of the section being occupied by circular apertures arranged irregularly; all these last communicate with a series of round passages which open on the margin, and, probably constitute the habitation of the animal. The discs, therefore, according to this view, are Corals; they are found on reefs, and also occur abundantly in the fossil state.

Before I leave this part of my subject, I must say a few words on the *Oolites*, which were formerly supposed to consist of the remains of organized beings of a globular figure, like the roe or eggs of fishes, but which are usually nothing more than grains of sand, each surrounded by a globular deposit of carbonate of lime and cemented together so as to form masses of limestone rock. The Oolites make up no inconsiderable part of the strata of this island; according to Ure,* they form a zone 30 miles broad in England, and are divided by geologists into the upper, middle and lower Oolites. They furnish a most valuable material for architectural purposes; and are exceedingly rich in fossil remains, especially those of reptiles and corals.

* Dict. of Arts and Manufactures. Art. Oolite.

The egg-like particles vary considerably in size, being in some cases almost invisible to the naked eye, whilst in others they are nearly as large as peas; this last form of Oolite has received the name of *Pisolite*, differing, however, from the true Oolites only in the relative size of the globular concretions. Bath stone, Portland stone, and the slate of Stonesfield, near Oxford, are all examples of Oolite. In Fig. 52, A, is represented

FIG. 52.



A, Portion of oolite termed *Roe-stone* or *Pisolite*. B, Granules from Britannia rock, magnified 40 diameters. C, Granule of *Pisolite* magnified 12 diameters. D, Granule of *Oolite* from Germany, magnified 20 diameters.

a portion of that form of Oolite termed Pisolite of its natural size; the granules are $\frac{1}{6}$th of an inch in diameter, one of them, shown in section at C, is magnified 12 diameters, and the concentric laminæ of which it is composed are well displayed.

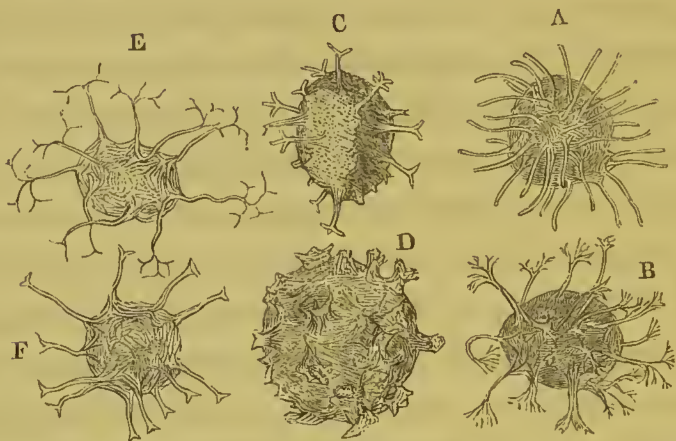
In Germany there is an Oolite in which the granules are nearly as large as they are in the Pisolite, but the concentric laminated arrangement, as shown at D, and the presence of a central nucleus, are more strongly marked; the rock supporting the Britannia bridge is a firm Oolite, in which the granules are remarkably small, those represented by B being magnified 40 diameters. The specimens just described are all very compact, the granules being firmly cemented together by the calcareous material forming the matrix; it sometimes happens, however, in oolitic districts, that the granules are separated from the matrix, and the soil will be seen to be in a great measure made up of them, this is especially the case in the neighbourhood of Bath; the soil of High Barrow Hill, I found to be so rich in oolitic granules, that when turned up by the plough, it appeared as if thickly sown with minute yellow seeds.

Before I leave the subject of chalk and flint, I must say a few words on certain remains of organized beings which have been met with in both the above substances; they were first discovered in flint by the Rev. J. B. Reade, in 1838, who published an account of them in "The Annals of Natural History" for that year, and named them *Xanthidia*, from their resemblance, both in form and colour, to some recent animalcules described by Ehrenberg under the genus *Xanthidium*. Many species were obtained by the Rev. J. B. Reade, which, with a number of new ones, were subsequently described by Mr. Henry Hopley White in the first volume of "The Transactions of the Microscopical Society." They consist for the most part of a hollow spherical body, from whieh a number of spines or arms radiate, some of these arms terminating in a point, others more eommonly dividing into two or three branehes, whieh, like those of the spieula of eertain sponges, are expanded or hamular; the spines, like the body, are hollow, and in the speeies termed by Mr. White, *tubiferum*, the extremity of eaeh spine is expanded like a sueking disc.

Xanthidia of the form represented by I in Fig. 20, were diseovered alive in the neighbourhood of West Point, New York, by Professor Bailey, and were sent to this eountry in a living state; living Xanthidia werc subsequently diseovered in many pools in the vieinity of London. From their green eolour and their mode of inerease by eonjugation, whieh has been so well deseribed and figured by Mr. Ralfs, there is every reason to believe that they belong to the *Desmidieæ*, and in proof of this it ean be shown that their skeleton is eomposed of horn, and not of siliea, as was at first imagined.

In *Xanthidium spinosum*, Fig. 20, G, the arms, or tentaeula, as they have been termed by Mr. White, are sharp pointed, but in *X. ramosum*, shown at K, they are mueh branehed at their free extremities, while in *Xanthidium recurvatum*, represented by H, the extremities of the spines, generally from four to six in number, are all bent baek like so many hooks. The Xanthidia, when first diseovered in flint, ereated a great sensation amongst mieroseopists; and sueh was the anxiety to obtain speeimens, that from first to last, several tons of flints were broken up, or cut, in order to find them. Fossil Xanthidia are not confined

FIG. 53.



A, B, C, D, *Xanthidia* discovered in the mud of the Thames at Greenhithe. E, F, *Xanthidia* from the chalk.

to flints, they have been obtained by Mr. Deane from the chalk between Folkstone and Dover, in which there were no flint nodules; two well-marked species are represented by E and F in Fig. 53. In one piece of a greyish kind of chalk from this locality, Mr. Deane discovered no less than six species by treating the chalk with hydrochloric acid; they were accompanied by *Polythalamia* and the remains of other organized bodies named *Rotalia*, as shown at D in Fig. 48, and he was enabled to prove clearly that the *Xanthidia* possess a horny skeleton.

A short time after the discovery of Xanthidia in the chalk, recent specimens were obtained by Mr. J. T. Norman from some mud adhering to one of the piles supporting the pier at Greenhithe, on the Thames, a neighbourhood abounding in chalk. The skeleton of each is of a brown colour precisely like horn, and the arms are generally more or less bent.

An account of these Xanthidia is given in the second volume of "The Transactions of the Microscopical Society," by Mr. S. J. Wilkinson, and from the illustrations accompanying the paper, the four species represented by A B C D, in Fig. 53, have been copied. The slides containing the identical specimens, have been presented to me by Mr. Norman, and you will have an opportunity of noticing a large opening communicating with the interior in almost every individual. Each slide contains numerous spicula of sponge, of the bi-acuate form, and several species of Navicula; the mud was treated both with nitric and sulphuric acids, yet the skeletons of the Xanthidia were not destroyed. Mr. Norman has been very fortunate in finding Xanthidia in flints, and a slice of a small pebble picked up in the street at Islington, he has found to contain no less than thirty-two specimens of fossil Xanthidia.

LECTURE VII.

SKELETON OF POLYGASTRICA, AND ZOOPHYTES.

Before proceeding to describe the structure of the skeleton of the Infusoria, or Polygastric animalcules, the most minute of the organized beings inhabiting the surface of the earth, I must be permitted to digress somewhat, in order to demonstrate the great importance of these atoms in the economy of Nature.

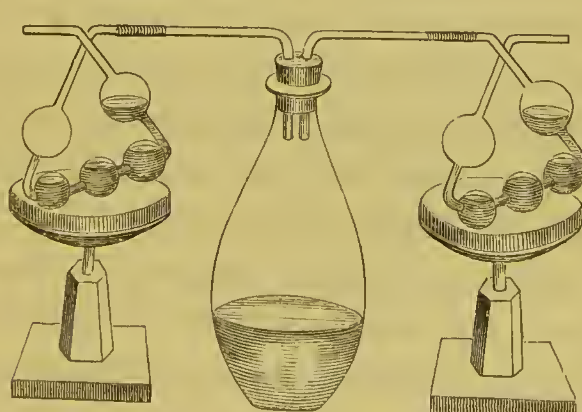
Prior to the invention of the microscope, no conception could be entertained by naturalists of the vast world of animated nature contained even in a single drop of water after exposure to the atmosphere. It was found, by so early an observer as Leeuwenhock, that when leaves of hay, straw, or other vegetable matters were left in contact with water for a few hours, or days, the water became crowded with an infinitude of microscopic forms, many of them possessed of the highest activity of locomotion; and that a similar train of events ensued when pure water was for a longer time exposed to the atmosphere, by which it becomes charged with the minute particles of organic matter and the germs of these infusorial animals, which subsequently are developed and live on the organic matters and on one another. If a vessel of water be left exposed to the open air, under the influence of the sun's rays and a sufficiently high temperature, it becomes covered, after a few days, with a greenish film; this when examined by the microscope, is found to consist of the germs of minute Algæ, but after a longer interval, myriads of moving animalcules are developed, which feed on the vegetable matter, and in their turn become the food of the more highly organized *Polygastrica*.

During the early stages of this colonization of the water, putrefaction goes on, and the fluid emits an offensive odour; but so soon as the free development of vegetable and animal life takes place, the signs of putrefaction disappear and the water becomes pure and fit for use, and remains in this condition so long as the vegetation continues healthy. In this way the vessel of water on the table before you has remained pure and clear without change for four years, being tenanted during that time by growing plants and numerous species of animalcules, also by Hydræ and other zoophytes. Thus Nature employs these minute organisms in one of her most important operations—that of preserving the water of ponds, lakes, rivers, and even the mighty oeean itself, free from putrefaetion and fitting it for the purposes of animal life—the exuviæ and rejeetamenta of animals, whieh would otherwise prove most noxious, being absorbed, elaborated and rendered innoeuous by the process of vegetation. Mueh outery has been ignorantly raised, and mueh disgust aroused in the publie mind within the last two years, by representations of the plants and animals, to say nothing of the filth of all kinds, in the water supplied to our houses by the Metropolitan Water Companies. This outery, so far as the filth is eoneerned, is well and good, but that the presenee of healthy animalcules or plants is injurious I am prepared to deny, sinee they aetually perform the offiee of seavengers to the water, removing all dead and putrefying organie matters, and rendering the water pure, bright and inodorous. Thus, the water of a diteh or pond, although not perhaps the most agreeable to the palate, is generally suffieiently pure to be innoeuous, in eonsequenee of the natural balanee between the animals and plants inhabiting it, and the destruetion of the lower forms of Algæ by the Infusoria which feed upon them.

So rapid is the growth of minute vegetation and the development of animaleules in water freely exposed to air and light, that it has been a question whether these atomie beings are not developed by spontaneous generation out of the dead but organizable matter contained in the water. The notion of spontaneous generation, however, has yielded to the more accurate investigations of modern times, which have demonstrated that the germs of these minute beings are derived from the atmosphere, and that they themselves are endowed with an astonishing faculty of reproduction, by which many genera are enabled to produce an immense progeny even in a few hours.

It is a well-known fact, that if animal and vegetable substances be freed from air by boiling, and sealed up hermetically in vessels, as is done with soups and meats, they may be preserved for any number of years; but the moment air is admitted, putrefaction accompanied by a rapid development of minute vegetable growths and animalcules, occurs. In order to put this to the test, Professor Schulze contrived the apparatus represented in the accompanying figure (Fig. 54). This consists of

FIG. 54.

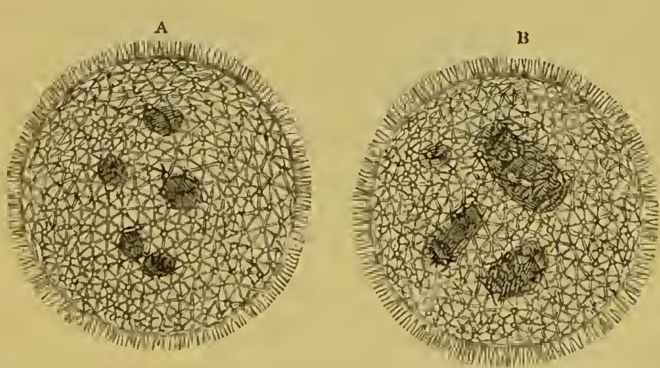


a thin glass flask, fitted with a cork perforated by two tubes bent at right angles, with which are connected two of the potass-tubes employed in the process of organic analysis. Each of these tubes has five bulbs blown upon it, and being bent in the form of a triangle, has one or more bulbs on each of its sides, so that when partially filled with fluid, bubbles of air propelled through the tube, pass from bulb to bulb, and are freely exposed to the fluid. Some fresh animal or vegetable matter being placed in the flask and covered with distilled water, the cork with its bent tubes is inserted and the contents boiled to destroy all germs of organic life both in the fluid and the air contained in the flask. While still hot, the two potass-tubes, one filled with concentrated sulphuric acid, the other with a solution of caustic potass, are adapted, and the connections of the tubes and the cork well luted so as to prevent any access of the external air. By sucking gently at the extremity of the tube containing the solution of potass, air is slowly drawn, bubble by bubble, through the sulphuric acid, which destroys all germs of organic life contained in the air; and this may be repeated at intervals so long as the experiment is continued, fresh oxygen being then brought into contact with the substances contained in the flasks. After several months, no trace of organic growth can be observed in the flask by the aid of a pocket-lens; and when the flask is opened and the fluid carefully examined by the microscope, if the lutings have been perfect, no trace of animalcules or vegetable growths will be found in it; but if the cork be taken out and the flask exposed to the air for a few hours, abundance of both will be discovered. As long, therefore, as the air admitted to the flask is cleared of the germs of the plants and animals existing in it, by means of the two corrosive fluids, no development of animal or vegetable life will take place, but as soon as free contact of the atmosphere is allowed, the work of destruction commences.

In a previous Lecture I described the skeletons of several species of organized beings, both recent and fossil, which Ehrenberg has classed with the Infusoria, although other high authorities view them as plants. They all possess a siliceous skeleton, are denizens of ponds and rivers, but they differ so greatly from the proper Polygastric animalcules in many of their characters, that they cannot be appropriately placed in the same order. While the Diatomaceæ possess very feeble powers of locomotion, have no distinct mouth or digestive system, the true Polygastrica are most active, and have not only a distinct mouth, but, as their name implies, several stomachs; I should therefore feel inclined to separate them from the Infusoria, and to restrict that term to the Polygastrica. The Polygastrica vary much in size, some species being so minute as to elude the highest powers of the microscope, whilst others attain so large a size as to be distinctly seen by the naked eye. The greater number of them are free and in a state of continual motion, no rest being taken either by day or night; while others are attached by a stalk to weeds and other submerged substances. They are much more abundant in the summer than in the winter, and from their restless habits are amongst the most difficult objects to exhibit. The *Volvox globator* has always been a great favourite with microscopists, on account of its large size, peculiar rolling motion, and the development of several successive generations within the adult animalcule. It occurs in the greatest abundance in some of the small ponds on Hampstead Heath, in the spring and summer, but is not so common in winter. The *Volvox* is globular, and of a green colour, the colouring matter being situated in certain cells of the tunic, and consisting of minute molecules of endochrome resembling those of chlorophylle in plants. Within each of the adult animalcules two or more smaller globes, also of green colour, are occasionally seen; these are young individuals, and in some cases there are no less than three generations one within the other. The continuous rolling motion of these curious beings is produced by minute cilia, which under favourable circumstances, as shown in Fig. 55, A, are visible on the outer surface.

The *Volvox* was discovered by Leeuwenhoek nearly two hundred years ago, and was regarded by him as a single animal. Ehrenberg, however, considered it as an association of similar individuals united so as to form a hollow sphere; but the more recent researches of Professor Williamson and Mr. Busk tend to prove that in all probability this interesting organism belongs to the confervæ rather than to the polygastric animalcules; the presence of cilia, and the peculiar locomotion produced by these organs, are nothing more than are possessed by the spores of many confervæ; the green colouring matter contained within the cells is also precisely similar to that of many fresh-water Algæ, and is rendered of a brown colour by the action of iodine. It matters not, however, for our present purpose, to which of the two kingdoms the Volvox may belong, the object of introducing it here, under the head of Polygastrica, is merely to furnish you with a good example of locomotion produced by cilia, and to state, on the authority of Professor Williamson, that its outer tunic is composed of a series of cells of hexagonal figure.

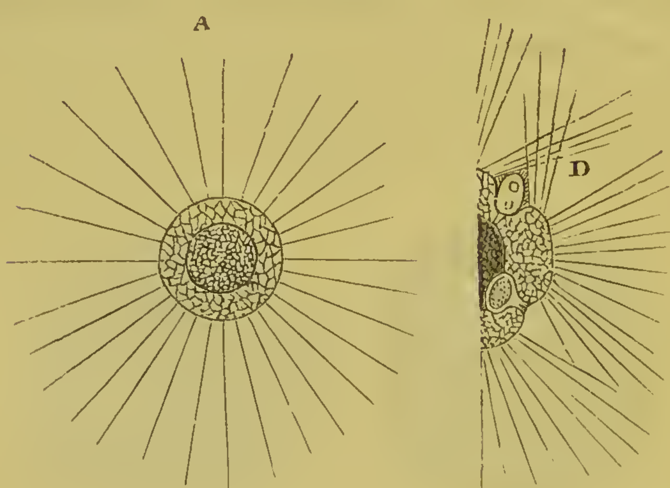
FIG. 55.



A, *Volvox globator* with young ones in the interior. B, *Volvox* enclosing Rotifers.

There is no mouth, or trace of digestive apparatus in any of these creatures, yet animalcules, especially Rotifers, as represented at B, are not unfrequently found within them. I once saw no less than four large Rotifers in the interior of a *Volvox* which did not seem to cause inconvenience, for it rolled about as actively as ever, although the Rotifers appeared to feed on the green granules. How these Rotifers obtained entrance into the body of the *Volvox*, although no opening or rent could be observed in the outer tunic, may perhaps be explained by the observations of Kölliker on the *Actinophrys Sol*, represented by A, in Fig. 56. The body of the

FIG. 56.



A, *Actinophrys Sol.* D, a portion of the same more highly magnified, showing the mode in which animalcules are taken into the interior of the body of the creature.

Actinophrys is globular, like that of the *Volvox*, and from its outer surface a number of filiform rays are given off, amongst which other animalcules are sometimes entangled, as if they had been seized by them; being brought close to the body, this very soon becomes indented, as shown at D, and the animalcule is, as it were, firmly imbedded in it, the indentation becoming deeper and deeper, until finally the tunic entirely closes over the animalcule, and it is then fairly within the body of the *Actinophrys*. In one individual as many as three or four animalcules have been seen, all of which had gained admittance in this way; it is therefore probable that the Rotifers may enter the *Volvox* by the same means.

Another very remarkable animal of this order is the *Amœba* or *Proteus*, so named from the continual change of figure it undergoes while in motion. In Fig. 57, A, B, C, are shown three of the most common shapes of this curious creature, but the shape is hardly ever the same for two minutes together; perhaps a globular form may be considered as the typical one. When seen for the first time, a *Proteus* might readily be mistaken for a mass of jelly, but by careful watching it will be found to undergo almost every variety of shape. These creatures are also remarkable for grasping and folding themselves around other animalcules, but it is questionable whether the animalcules really become enclosed within the outer tunic or not, as they certainly are in the *Volvox* and *Actinophrys*. I agree in opinion with Dr. Carpenter, that they do not enter the *Proteus*, but that nutritive absorption takes place by the outer surface in this animalcule.

An animalcule nearly allied to *Amœba* has lately been discovered and accurately described by Professor Bailey, in the "American Journal," vol. xv., under the name of *Pamphagus mutabilis*. It consists of a soft, transparent, extensible tunic or body, capable of assuming every variety of shape, those shown at G and I, in Fig. 57, being the most common; around the mouth are a few branched tentacula, or

FIG. 57.

A, B, C, three very common shapes of the *Amœba*, or *Proteus*. D, *Chilodon cucullulus*. E, *Paramecium aurelia*. F, *Leucophrys patula*. G, H, I, K four different aspects of *Pamphagus mutabilis*.

feelers, by means of which these animals pull themselves along very slowly. The most remarkable feature the *Pamphagus* possesses, is the utter want of discrimination it seems to have in the food it takes; for fibres of cotton, linen and wool, starch, crystals of quartz and Diatomaceæ without end are swallowed by it, these are retained for a short time, and are then ejected by the mouth, which is the only aperture for their reception and discharge.

These animals, like many Polygastrica, are multiplied by spontaneous fission, as shown at H; occasionally, however, such masses as those represented by K are seen; these result from a swelling or distortion of the tunic produced by the quantity of ingesta combined with that of the partial spontaneous fission, or budding, of the animal.

We have here one of the simplest forms of animal life, consisting, it may be safely said, of little else than a stomach and certain organs for seizing food, its external framework, or rudimentary integument, being soft, colourless, highly elastic and extensible, and coloured yellow by tincture of iodine. In such creatures there is abundant evidence of the food being taken into the interior of the body, which was found not to be so satisfactorily proved in the case of the *Amœba*.

In all rapidly decomposing animal and vegetable substances, certain kinds of animalcules very soon make their appearance; one of the first—the *Spirillum* —is very minute and spirally twisted, like a corkscrew, it is readily recognized by its worm-like movements. Amongst these may occasionally be seen gliding rapidly across the field of view, by means of well developed cilia, certain large flat animalcules, belonging to the genera *Chilodon*, *Paramecium* and *Leucophrys*, all of which, as shown by D, E, F, exhibit, more or less plainly, the complex nature, or rather the great subdivision of the stomach, by which these creatures are distinguished and classified. The stomachs, of most Polygastric animalcules, can be readily demonstrated by adding a small quantity of carmine or indigo to the water in which the animalcules are found; the particles of colouring matter are swallowed, and the stomachs are then easily distinguished from any of the other viscera.

Vorticella nebulifera, or Bell Polype (Fig. 58), is,

FIG. 58.

A group of *Vorticella nebulifera*, showing the expanded and contracted state of the stem.

as its English name implies, bell-shaped, with a large oral opening surmounted by active vibratile cilia, which produce currents in the surrounding water sufficiently powerful to form a sort of vortex or whirlpool, and draw other animalcules into its mouth. The polype is seated on an extensile and contractile filament, by which it is attached to submerged substances, and the filament extends and straightens when the cilia around the mouths are in active motion, but if another animalcule swims against it, or if a sudden shock be communicated to the microscope, the filament immediately coils up spirally, like a bell-spring, withdrawing the entire body from danger, while the cilia are retracted within the mouth of the animal. After a few seconds the filament is again gradually elongated, the cilia are extended, and their movements recommence with great activity. The addition of carmine to the water containing these animalcules, also causes a number of previously invisible stomachs to appear, and the small particles of the colouring matter in the surrounding water exhibit more strongly the action of the cilia. In this species of Vorticella the filament is simple and single, but other species exist, as, for instance, *Charchesium polypinum* (Fig. 59), in which the bodies are supported on branched filaments, each branch supporting a terminal body. The stem is highly contractile in *V. nebulifera*, in this species it is much firmer, and appears to contain a central cavity.

Very little can be said of the structure of the skeleton of the Polygastrica; it is either membranous or horny, seldom, if ever, silieeous or ealcareous, and presenting little, if any, traees of structure; the animalcules them-

FIG. 59.

Charchesium polypinum, or Arborescent vorticella.

selves forming the chief food of some insects and fishes. The wheel animalcules were formerly included in this class, but reecnt investigations having demonstrated in them a far greater complexity of organization than belongs to the Polygastrica, they have been removed to the Artieulate sub-kingdom, under the designation of *Rotifera*.

From the Polygastriea we pass to a tribe of animals which, from their arboreseent forms, have obtained the name of animal-plants, or *Zoophytes*. These, on account of their great diversity and beauty, have attracted the especial attention of naturalists from the earliest ages; neither have they escaped the penetrating eye of the artist, for we find Hogarth thus writing to his friend Ellis: "As for your pretty little seed-cups or vases, they are a sweet confirmation of the pleasure Nature seems to take in super-adding an elegance of form to most of her works, wherever you find them. How poor and bungling are all the imitations of Art! When I have the pleasure of seeing you next, we will sit down—nay, kneel down, if you will—and admire these things."

The word *Zoophyte* literally signifies animal-plant, and is a term very applicable to certain groups of species, but not to all that have, from time to time, been included in this order. According to Johnston,* "all Zoophytes are aquatic, soft, irritable, and contractile; many are asexual, and it is doubtful whether any species has distinct sexes. The individuals (Polypes) of a few families are separate and perfect in themselves, but the great majority of Zoophytes are compound animals—viz.: each Zoophyte consists of an indefinite number of individuals, or polypes, organically connected and placed in calcareous, horny, or membranous cases, or cells, forming by their aggregation, corals or plant-like Polypidoms." They are divided into two classes, termed *Anthozoa* and *Polyzoa;* the first of these is

* "History of British Zoophytes," 2nd Edition, 1847.

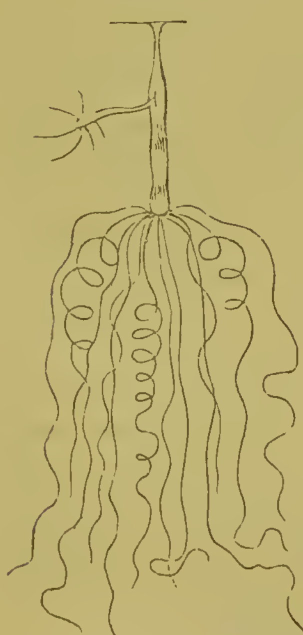
sub-divided into three orders, as follows: *Hydroida*, *Asteroida* and *Helianthoida;* the second, or *Polyzoa*, into two orders only, these being the *Infundibulata* and *Hyppocrepia.* The *Hydroida*, with the exception of the two genera *Hydra* and *Cordylophora*, are all marine, and vary in height from a few lines to a foot. A few of them are naked, but the remainder are invested with a transparent horny sheath, or skeleton, of a yellow colour—the Polypidom—which is of a tubular character, investing the soft parts of the animal, as shown in Fig. 62 C. The stem is frequently branched, and the sides or the extremities of these branches are expanded into little cups for polypes resembling the Hydra in form. At certain seasons of the year, other and larger cells, or ovarian capsules, Fig. 62 A, are formed, within which a mass of gemmiform bodies are generated; these, instead of becoming polypes, assume the form of *Medusæ*, in some of which, sperm-cells, whilst in others, germ-cells, or ova, are developed. Each ovum produces a new individual, which, in process of growth or gemmation, forms a polypidom. The polypidom, however, is not formed by the polypes, but from the central fleshy substance, and it is not until after the formation of the polypidom that the rudimentary polypes become visible. The polypes are the active prehensile stomachs of the Zoophyte; they consist of a stomach surmounted by an oral aperture, and surrounded by a circle of vibratile cilia, which, by their motion, create a vortex, and bring the prey within the grasp of the tentacula, or cilia, by which it is embraced and conveyed to the stomach. The digested food is conveyed through the peduncle of the polype to the flesh, through which it circulates and serves for the nutrition of the entire animal.

The Polypidom is not always in one piece; there are frequently transverse markings below the cells, as shown in Fig. 62, which act the part of joints. The polypes themselves die periodically, and are cast off. This accounts for the comparatively naked appearance of the stems of some specimens; there is, however, every reason to suppose that in certain species new cells and new polypes are developed upon an old stem.

The *Hydræ* are the most interesting animals of the Hydroid tribe of Zoophytes, and have attracted the universal attention and interest of naturalists, on account of their extraordinary powers of fissiparous reproduction. Two kinds, viz., *H. viridis* and *H. vulgaris*, are commonly met with around London; a third species, *H. fusca*, Fig. 60, is more rare. The *Hydra vulgaris*, repesented by A B, in Fig. 61, was discovered by Leeuwenhoek in 1703, but its wonderful powers of digestion and of multiplication after division were first described by Trembley in 1740; in 1743, our countryman, Baker, repeated the experiments of Trembley, and published a work entitled "An Attempt towards a Natural History of the Polype."

The other Hydra, also very common in our ponds, viz., *Hydra viridis*—possesses the same powers of digestion and multiplication. Both species consist of an elongated cylindrical body, terminating at the posterior extremity by a sucking-disc, and at the anterior by an oral opening surrounded by eight or ten tentacula, which are much longer in *H. fusca* than in *H. viridis* or *vulgaris*. The body is a hollow cylinder, or stomach, without any special organization for digestion, since the animal may be turned inside out, like the finger of a glove, so that the external surface becomes internal, and yet digestion will proceed as vigorously as in the ordinary condition. They are continually changing their figure, being sometimes elongated and cylindrical, as shown at A, at others contracted and almost spheroidal, as at B.

FIG. 60.



Hydra fusca or long armed Polype.

The arms, or tentacula, are arranged in a circle around the mouth, as represented at B, in Fig. 61, and when examined with a power of 4 diameters, as shown at A, are seen to be covered with a series of tubercles arranged in whorls, some of these tubercles being provided with a central spine surrounded by a number of smaller spines. There can be little doubt that these spines are furnished with some poisonous fluid which possesses the power of benumbing the creatures that come within the grasp of the tentacula, since animals as large as Newts are often killed by them, and worms many times larger than the Hydra itself, fall easy victims. If you have a Hydra in a vessel of water, and carry within reach of its arms one of the small red worms, found in the mud on the banks of the Thames at low water, it will be instantly seized by the Hydra, as shown at E,

FIG. 61.

A, *Hydra vulgaris* in its expanded state. B, the same contracted, both being magnified. C, a young individual. *d, d, d,* three specimens of the natural size. E, a worm seized by the tentacula.

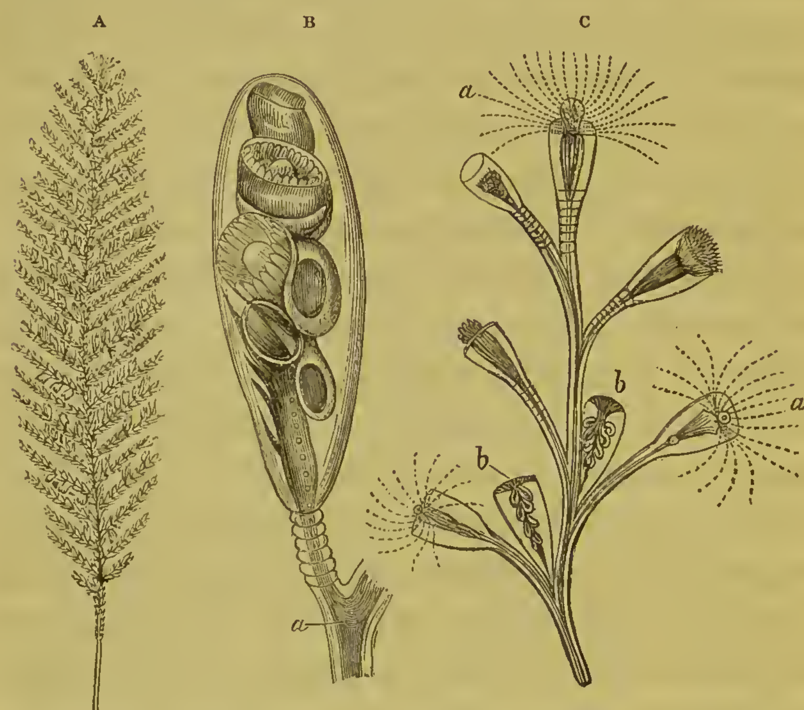
and almost immediately deprived of life; in a few minutes morc, the worm will be swallowed and the Hydra will then be ready to take another, and again another, until three or four have been eaten, and this in a eomparatively short spaee of time. The very remarkable eircumstanee before mentioned, as conneetcd with the Hydræ, viz., that they can turn themselves inside out, so that the part which was eutaneous and proteetive will take on the function of digestion, proves that the structure of the two surfaees is analogous.

The power possessed by the Hydra of destroying animals many times larger than itself, to whieh I have before alluded, I ean attest from my own observation of the habits of these zoophytes. About two years sinee I had a large number of Hydræ in a vessel of water, into whieh I introdueed some newts about a day old. The newts were found to avoid the sides and bottom of the vessel, in order to keep out of reaeh of the Hydræ; but when, as was seen on more than one oceasion, an unfortunate newt came in contaet with the arms of a Hydra, it was immediately thrown into a fit of convulsions. The newts after this, took refuge in a spout on one side of the vessel, but the Hydræ quickly followed them, and the whole were soon destroyed. Even a full-grown newt, that I afterwards placed in the same vessel, was killed by the Hydræ.

The Hydra is multiplied in two ways, by budding or gemmation, and by ova. Gemmation oceurs so rapidly in the summer months, that a Hydra ean scareely be under observation for two days without the development of a young Hydra from its side, as shown at *a*; but in the winter, ova or sperm-cells are formed either by the same or different individuals, and the ova, after being fertilized by the sperm-cells, fall to the bottom of the vessel, and are hatched in the spring. Trembley found that not only were these animals capable of multiplication by gemmation and ovation, but that they were equally so by mechanical subdivision. Thus, when cut into a number of fragments, each fragment in a short time became a perfect animal, and this to so great an extent that thirty or forty new animals have been often procured from a single Hydra. It was of little importance whether the divisions were transverse, longitudinal, or irregular; in either case, the fragments replaced what was wanting, and became perfect animals. The tubercles on the tentacula, as shown at D, are distinctly visible with a power of 40 diameters. The Hydra can scarcely be said to have any skeleton, the external membrane or skin, which presents a cellular structure, being the only representative of it.

In most of the Hydroid Zoophytes there is abundant evidence of a skeleton in the form of a horny sheath or case, as before described. In the genera *Tubularia*, *Sertularia*, *Plumularia*, *Antennularia*, and *Campanularia*, names which, to a certain extent, explain the shape of the Polypidom; the polyp-cells are visible to the naked eye, but in most Zoophytes, at certain seasons of the year, larger cells, termed ovarian capsules, in which the gemmæ are developed make their appearance, these are represented of their natural size in *Sertularia pinaster*, Fig. 62, A; and are shown, slightly magnified, at *b*, *b*, in Fig. 62, C.

FIG. 62.



A, *Sertularia pinaster*, showing the ovarian capsules. B, ovarian capsule of *Campanularia gelatinosa*, showing the gemmæ in various stages of development. *a*, fleshy substance in the interior of the horny case. C, diagram of a Zoophyte, probably *Campanularia gelatinosa* (after Johnston); *a*, *a*, polypes expanded; *b*, *b*, ovarian capsules.

If a portion of the stem of a *Campanularia* which has been preserved in a moist condition, be examined by a low power, it will be seen as represented in Fig. 62, C, that the external horny case is more or less transparent and structureless, containing within the tube an opaque, fleshy pulp, which may be traced to the base of the polype with which it is continuous, and the polype-cell is also seen to be continuous with the tubular horny sheath. When these horny polypidoms are examined with the highest powers of the microscope, no trace of cellular or other structure can be discerned, the horn appears to be simply a consolidation of the outer integument, the skeleton, therefore, is a dermal one. Portions of *Sertularia*, particularly *S. abietina* and *operculata*, when dried and mounted in Canada balsam, especially if they have been prepared in the manner recommended by Dr. Golding Bird,* are amongst some of the loveliest objects that can be viewed by polarized light; for, independent of the splendid colours, all the most minute parts of the skeleton are brought out in the greatest perfection.

Regarding the general structure of the skeleton of the Hydraform Zoophytes, there is then little further to remark; but we shall see in a future Lecture, that the most beautiful forms and structures occur in the stony polypidoms of the Asteroida.

* "Quarterly Journal of Microscopical Science," vol. I, p. 85.

LECTURE VIII.

SKELETON OF ZOOPHYTES.

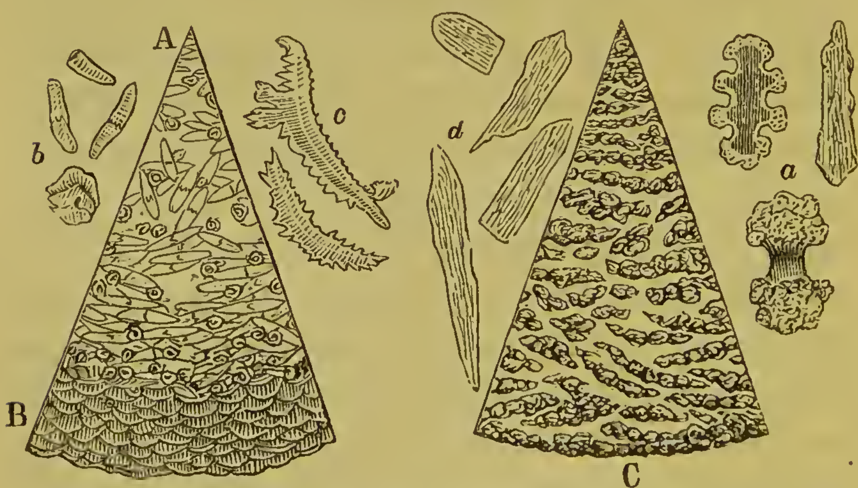
In the last Lecture the strueture of the skeleton of some of the *Hydraform Zoophytes*, whieh is entirely dermal and composed of a yellowish horny material, enclosing the fleshy pulp of the animal by whieh it is developed, was briefly described. This horny skeleton, as shown in Fig. 62, expands at certain regular distanees into cups or eells for the lodgment of the Polypes, whose offiee it is to seize and digest the food for the nutrition of the flesh. These Zoophytes, as the name of the class implies, have been compared by many naturalists to plants, for although undoubtedly animals, their mode of growth, nutrition, and organs present striking analogies to those of the flowering plants. These analogies have been placed by Dr. Carpenter in the subjoined tabular form:

PLANT.	ZOOPHYTE.
Seed.	Egg.
Stem and Leaves.	Stem and Polypes.
Leaf-buds.	New Polypes.
Flower-buds.	Medusæ.

It is evident then that the individual Zoophyte, like the individual branch, is propagated by gemmation while the species is reproduced by ova.

The second order, *Asteroida*, is so named from the resemblance the polypes bear to a star. The polypes in this tribe have invariably eight tentacles, and the skeleton is composed either of horn or calcareous matter, in the form of a central axis or shaft, surrounded by the external flesh of the animal. The order contains three families, the *Gorgoniadæ*, *Pennatulidæ*, and the *Alcyonidæ*. I commence with the *Gorgoniadæ*, because the structure of the skeleton of this family is easily understood, and forms a good key to the comprehension of that in the other two families. The *Gorgoniadæ* are not only remarkable for elegance of shape, but some of them for beauty of colour; when branched, as in *Isis hippuris*, Fig. 64, *a*, they are called Sea-shrubs; but when all the branches are joined together in a reticulated manner, as in *Gorgonia flabellum*, they have received the name of Sea-fans. Whatever be the shape of the Polypidom, three parts require special notice—viz.: the central axis, the fleshy crust which surrounds it, and the polypes. As in this course of lectures our attention is confined to the structure of the skeleton, the polypes demand and can receive only a passing notice. I may here mention that if any specimen still retaining the fleshy crust, be examined, a number of minute depressions will be observed, in which the polypes were located during the life of the animal; these polypes have eight tentacula, and at their base are a few tuberculated spicula, to which I shall advert when speaking of the *Alcyonidæ*. The central axis of most of the *Gorgoniadæ* is composed of horn, which in some species is of yellow or brownish colour, in others black; these last formerly received the generic name of *Antipathes*. In one species—*G. Americana*, Fig. 63, C—the axis consists of horny matter, in which spicula are imbedded in concentric circles; in *Gorgonia petechialis*, Fig. 63, A B, it is principally composed of spicula so arranged

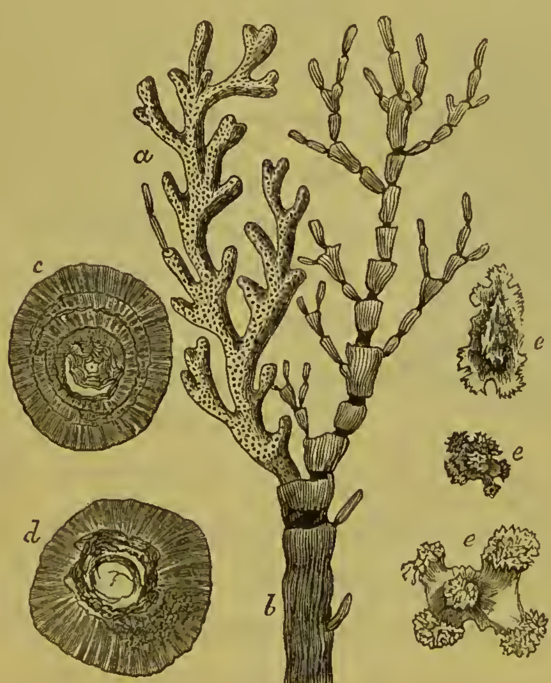
FIG. 63.



A B, segment of a transverse section of the axis of *Gorgonia petechialis*. *b*, spicula from the centre. *c*, spicula from the margin. C, segment of a transverse section of the axis of *Gorgonia Americana*. *a*, spicula from the crust of *G. Americana*. *d*, spicula from the axis of the same.

as to leave a number of large canals which run from one end of the specimen to the other, and the spicula near the surface are much larger than those in the centre. In the Red Coral, Fig. 67, A, as well as in the beautiful pink *Oculina rosea*, the axis, D, is composed of laminæ of dense calcareous matter, exhibiting occasionally traces of spicula and of the cells in which the carbonate of lime was secreted. In the genus *Isis* the axis is made up of alternate joints of horny and calcareous matter; this curious structure is well seen in the *Isis hippuris*, Fig. 64, *a, b*, so named

FIG 64.

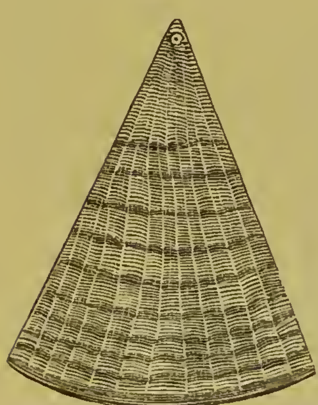


a, portion of a branch of *Isis hippuris*, showing the crust with the apertures in which the polypes were lodged. *b*, axis composed of alternate layers of horn and calcareous matter. *c*, transverse section of the calcareous part of the axis. *d*, transverse section, through a joint at *b*, that has been covered with calcareous matter. *e, e, e*, spicula of the crust.

from its resemblance to the *Equisetæ*, or Horse Tails. The axis in some of these Zoophytes is perfeetly smooth on its exterior surfaee, in others slightly grooved, as in the Red Coral, Fig. 67, A, whilst a few speeies show certain depressions whieh indieate the situation of the polypes, and some speeimens, are eovered with minute spines.

There are eonsiderable differenees in the strueture of the horny axis of the *Gorgoniæ*; some are eomposed simply of eoneentrie laminæ of brown horn, others as *G. spiralis*, Fig. 65, show not only eoneentrie laminæ of horn, but a number of large radiating lines whieh look like tubes, but are in reality eonneeted with the spines seen on the surfaee; in others, as *Gorgonia Americana*, Fig. 63, C, the axis is composed of horny matter having numerous short spieula of the shape represented by *d*, imbedded in its substanee, which are disposed in a somewhat eoneentrie manner. The axis of *Melitæa ochracea*, Fig. 66, A, is jointed like that of *Isis hippuris*, but the horny matter is so small in quantity as only to suffiee to hold together the numerous spieula of whieh the ealeareous part of the axis is eomposed. These spieula are of a reddish eolour in the more solid parts of the axis, those on the surface being larger and

FIG. 65.



Segment of a transverse section of the axis of *Gorgonia spiralis*, showing concentric laminæ and radii.

darker than those in the centre, as shown at B; but those in the joints are of a yellow colour and smaller,

FIG. 66.

A, axis of *Melitæa ochracea.* *a, a,* joints in the axis. B, portion of a transverse section of the axis made through the most solid part. C, transverse section of the axis made through a joint.

as shown at C. The axis of the *Corallium rubrum,* or red coral, is very dense, and capable of taking a high polish; it is even manufactured into beads, bracelets, and other ornaments, although it every here and there exhibits traces of being formed of spicula; these, however, are shorter and more completely blended together than they are in *M. ochracea*, and there is in addition a concentric laminated arrangement, as shown in

Fig. 67, D. Notwithstanding this, however, there is abundant evidence to prove that even the most solid axis was originally composed of spicula.

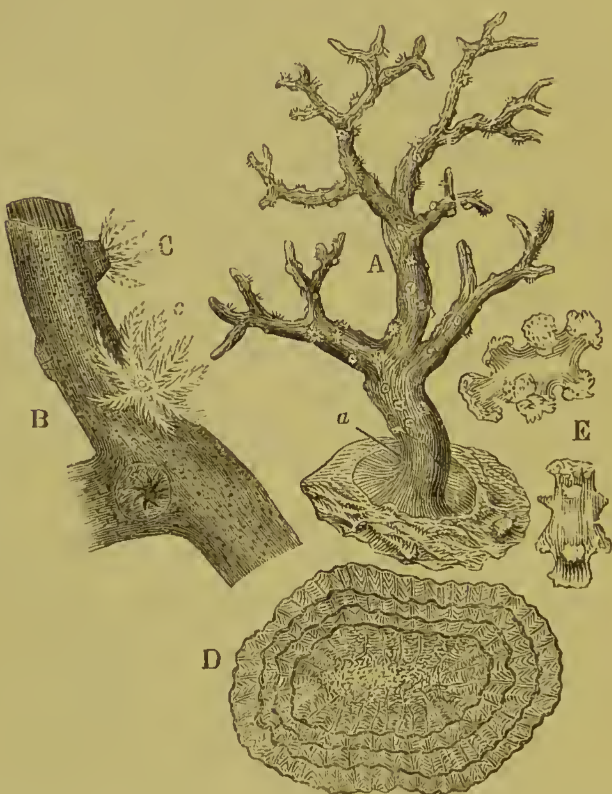
Vertical and horizontal sections of the axis of *Isis hippuris*, to the general structure of which I have already alluded, exhibit many points of interest. All the young branches, as shown in Fig. 64, *a*, are composed of horn and calcareous matter alternately, and the joints are well marked; but when the axis has become old, as shown at *b*, the joints are coated over with the calcareous matter, and a transverse section through such a joint will still exhibit horny matter in the centre, as represented by *d*, a section through any other part than the joint, as shown at *c*, will exhibit no horn, but concentric laminæ of calcareous matter only. Vertical sections of the axis show the same points, there is always a well-marked line between the two, the horn being of a brown colour contrasts strongly with the whiteness of the calcareous portion. There are, however, so very many points of interest in the structure and mode of growth of the axis of the *Gorgoniadæ*, that it will be necessary to allude to the subject again, after the other parts of the animal have been briefly described.

We have now to turn our attention to the fleshy substance, or *crust*, investing the axis, which is the seat of the beautiful colours of many of the specimens. Some naturalists regard colour as a distinction of species; but I cannot coincide in this opinion. I possess two elegant specimens of *Gorgonia*, the one of a rich yellow, the other of a brown colour, both are similarly branched, both have spicula alike, except in colour, and both are attached to Pinna-shells; I therefore regard them as identical. No person having seen *Gorgoniæ* in the dry state only, can form any idea of the nature of the crust in recent specimens; in the living state the axis is covered with a soft gelatinous substance with which the polypes are connected, as shown at B, in Fig. 67; but when the polypidom is dried, little more remains than the numerous tuberculated calcareous spicula imbedded in it, and which are generally of the same colour as the crust itself.

In *Isis hippuris*, as shown at *a*, in Fig. 64, the crust is thick and massive, and readily crumbles, but it is not until this has been removed, that the jointed condition of the axis *b* can be seen. The crust completely invests the axis, but never enters into its substance, although the marks of the polypes are sometimes left on the surface of it; these however are merely slight impressions which are easily erased. In the Red Coral, as shown by A and B, in Fig. 67, the crust is exceedingly thin and of a lighter colour than the axis; that none of it has been removed from the specimen under consideration is evident, for the polypes are still present.

Another beautifully branched species—*Gorgonia Americana*—has a yellow crust quite as thin as that of the Red Coral, being in some parts a mere film; but when removed, the black horny axis is brought

FIG. 67.



A, a branch of Red Coral, *Corallium rubrum*, with its polypes in situ. *a*, portion of the axis denuded of its crust. B, portion of a branch of the same, slightly magnified. C, *c*, the eight-armed polypes. D, transverse section of the axis. E, spicula of the crust.

into view. In *Melitæa ochracea*, the crust, which is of a yellow colour, is also very thin, and can scarcely be distinguished from the axis; but in *Gorgonia flammea* it is even thicker than in *Isis hippuris*, and when detached, the black axis is found to be very small as compared with the mass of the crust. If a portion of the crust of any Gorgonia be removed and examined under the microscope, it will be found to be principally composed of spicula imbedded in organic matter; in order to ascertain their form, the organic matter cementing them must be removed, which is easily done by boiling in liquor potassæ. A small piece of the crust placed in a watch-glass containing liquor potassæ, and heated over a spirit-lamp, will be observed to crumble to pieces as soon as the liquid approaches the boiling-point; care should now be taken to maintain this heat for a few minutes, or so long as there are any lumps remaining. The vessel may then be placed aside to allow the spicula to settle, the liquid being poured off, distilled water should be added, and the heat again applied; after one or two washings of distilled water, they must be dried, and are then ready for mounting in Canada balsam.

The spicula from the crust of *Isis hippuris*, as shown by *e e e*, in Fig. 64, are of a whitish colour and of two principal shapes, the one clavate, the other more or less cruciform, the tubercles in both being covered with minute spines. The spicula of the crust of *Gorgonia umbraculum* are either of large size, stellate figure, and rich brown colour, or much smaller and covered with nodulated tubercles. In another species of the same genus, some of the spicula from certain parts of the crust are remarkable for their rich lake colour, whilst those from others are colourless; all are large, either simple or of a tri or quadri-radiate figure, and covered with small tubercles; the coloured spicula being easily seen by the unassisted eye. When decalcified by the action of an acid, the colouring matter of the spicula still remains attached to the organic basis.

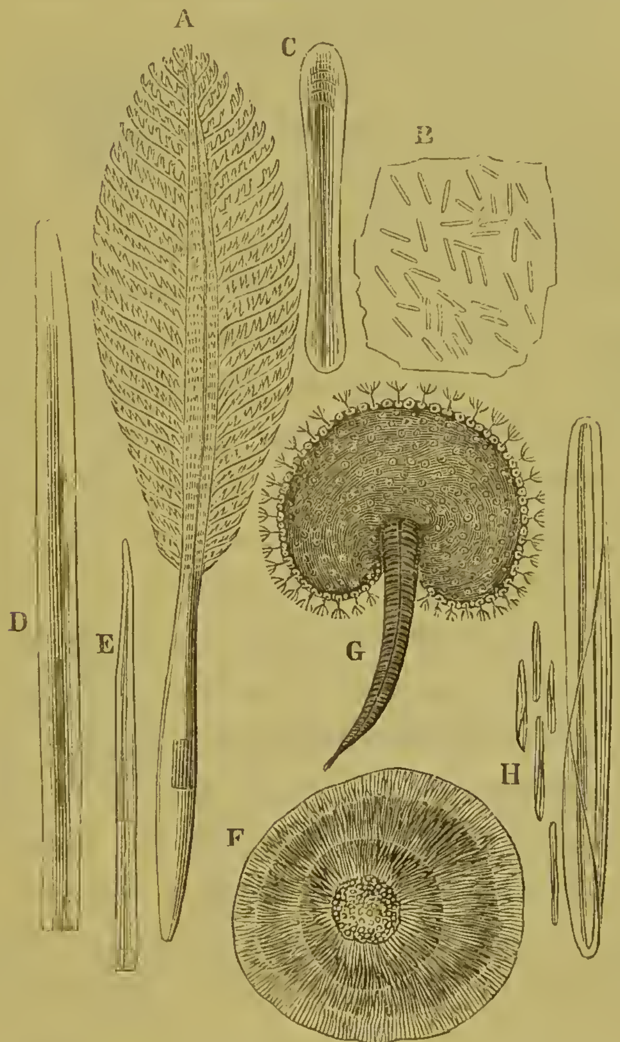
One or two other varieties of spicula, which are extremely variable in form, here require a brief notice. Some of these are flask-shaped, as shown at *a b*, in Fig. 68, the greater part of their surface being covered with minute spines; others, as seen at *c*, have a row of tubercles on each side, but those represented by *d*, which were obtained from the crust of *G. elongata*, have tubercles projecting from one side only. The spicula are not mere masses of inorganic material, but have an organic basis like that of shell and bone; this, however, will be spoken of in detail in a future Lecture.

FIG. 68.

a b, flask-shaped spicula. *c*, tuberculated spicula. *d*, spicula of *Gorgonia elongata*.

In the *Pennatulidæ*, as in the *Gorgoniadæ*, the central axis, the crust, and the polypes, each demand our attention. In the *Pennatulæ*, or Sea Pens, as shown by A, in Fig. 69, the polypidom consists of a central part, or shaft, of cylindrical figure, and naked at one extremity, whilst the other is clothed with a series of pinnæ which bear the polypes on their upper margin; this part corresponds to the plume of the pen. The axis consists of a long, more

FIG. 69.



A, *Pennatula phosphorea*. B, spicula from the flesh of the stem of *P. grisea*. C, one of the spicula magnified 250 diameters. D, E, portions of spicula from the plume magnified 20 diameters. F, transverse section of axis of *P. grisea* magnified 20 diameters. G, *Renilla Americana*, or kidney-shaped sea-pen. H, spicula from the same.

or less cylindrical stem, tapering slightly to a point at each end; it is of a dirty-white colour, and does not extend the entire length of the stalk, both ends being soft and curved slightly like a shepherd's crook. The *Pennatulæ* are phosphorescent, and were formerly thought to move rapidly through the water by means of the pinnæ, but it is now generally considered that they have little, if any, power of locomotion, and when in their native element are said to stand erect, the conical naked extremity being buried in the mud. The fleshy matter of the stalk and of the pinnæ is largely supplied with calcareous spicula; in the latter these are often half an inch in length, and of a white or red colour, projecting upwards in the form of spines. When magnified 20 diameters, they present internally, a fibrous appearance as seen at D E. In the lower part of the stalk, as represented at B, the spicula are smaller, but very abundant, and of nearly uniform diameter, with rounded extremities, as shown at C, under a power of 250 diameters; they are arranged in parallel lines, and their long axis is in the same direction as that of the stalk, like the spicula of the plume, they also present internally a fibrous structure. In Britain we have only one species of Pennatula, the small, *P. phosphorea*, all the larger species are exotic.

A very peculiar form of the Pennatula is the *Renilla Americana*, represented by G, which consists of a small, short, brown stalk supporting an expanded reniform portion, one surface being of a beautiful purple, whilst the other is brown like the stalk; on the former the polypes, which are large, are seated. From its shape this species is commonly called the Kidney-shaped Sea Pen. The skeleton of these Zoophytes consists of spicula which abound in all parts of the purple surface; but as far as I have examined they have no central axis. The Sea Rush—*Virgularia mirabilis*, Fig. 70, A—not unfrequently met with in the northern coasts of this island, like the *Pennatula phosphorea*, probably stands erect in soft mud, for it is generally found where the bottom is slightly muddy, and rarely where sandy. When perfect, the Virgulariæ are from six to ten inches in length, and consist of a central calcareous axis invested with a thin, soft, membranous flesh-like substance, the greater part of which is covered with lobes or pinnæ, each bearing small eight-armed polypes: the disposition of these pinnæ, as shown at D, is somewhat oblique, so that in some specimens the entire series appears to be arranged in a spiral direction. In this genus, the axis is very large in proportion to the pinnæ, and in perfect specimens, as represented

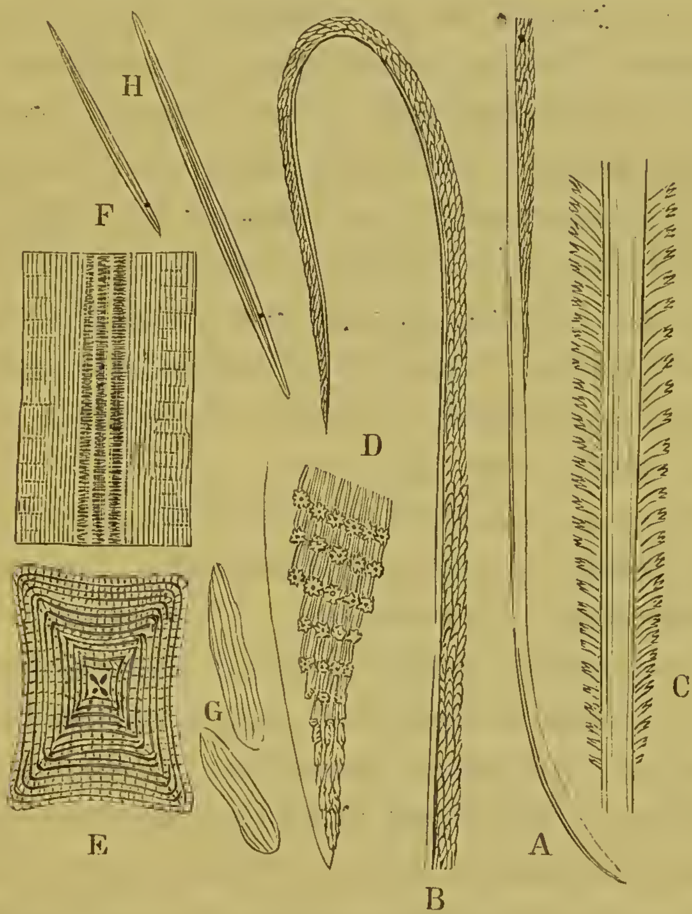
FIG. 70.

A, *Virgularia mirabilis* (reduced in size). B, the base of the stalk. C, centre of the stalk (both of the natural size). D, portion showing the polypes (after Johnston). E, transverse section of the axis. F, longitudinal section of the same.

by A, the upper as well as the lower extremity of the stalk is without pinnæ. The axis is cylindrical, and is the only trace of the skeleton, there being no spicula in any part of the soft membranous investment, as in the Pennatulæ.

A gigantic specimen of this class is the rare and beautiful *Pavonaria*, Fig. 71, A, B, contained in the tall glass on the table. It was presented to the museum of this College about four years since by Professor Edward Forbes, who, in company with Mr. MacAndrew of Liverpool, dredged it up from a muddy bottom at a depth of from twelve to fifteen fathoms, near Oban, on the coast of Argyllshire, where it is supposed to stand erect in the mud, like the Pennatula and Virgularia, its lower extremity being slightly expanded and curved as if for the purpose of support. It has been named *Pavonaria* on account of its general resemblance to the feather of a peacock's tail, whilst the specific name *quadrangularis* is expressive of the quadrangular shape of the axis; which as in the *Virgularia*, is large when compared with the animal crust, and slightly flexible. All portions of its outer surface are covered with a fleshy skin having a slimy feel, but the parts projecting from the shaft or axis, as shown by B, C, D, are the polypes; those at the lower extremity are small, and according to Professor Forbes, occur in a single row on each side; but they gradually increase in size and become more numerous, till they form oblique transverse rows of four, five, or six polypes, as shown at D, the most external being the largest. The back of the axis is yellow and smooth,

FIG. 71.



A, lower part of the stem of *Pavonaria quadrangularis*. B, upper part of the same (reduced in size). C D, portions of the stem showing the polypes. E, transverse section of the axis. F, longitudinal section of the same. G, spicula from the flesh of the lower part of the stem magnified 130 diameters. H, spicula from the sheath enclosing the polypes slightly magnified.

and free from polypes; but, when living, all the polypiferous part was of a pink or rose colour. In the account of this remarkable Zoophyte, given by Forbes and Johnston, no mention is made of the structure of the skin. During my investigations preparatory to the publication of that part of the first volume of the "Histological Catalogue" relating to the structure of the skeleton of the Asteroid Zoophytes, knowing that spicula abounded in the skin of the *Pennatula*, I was desirous of ascertaining whether they were present in this animal, and after some search, was rewarded by finding them in the flesh at the lower part of the stem. Spicula of large size, however, are met with around the margin of the sheath into which the polypes retract themselves; they are very different from those in the flesh of the naked portion of the stem.

Having now described the general form and position of the skeleton in the family Pennatulidæ, I proceed to illustrate the minute structure of these parts. The transverse section of the bony axis of *Pennatula grisea* is of a cylindrical figure, and appears laminated to the naked eye, but when viewed with a power of 40 diameters, as shown by F, in Fig. 69, the outer margin or crust is found to be of a fibrous nature; the fibres taking a vertical direction, whilst the central portion, more dense than the rest, shows a cellular structure, the cells appearing to be filled with calcareous matter. The spicula in the skin from the base of the stalk, as shown at B, C, are of cylindrical figure, and somewhat twisted so as to produce the appearance of a central cavity; the ends are hemispherical, but their surface is smooth and free from tubercles, and they average about $\frac{1}{100}$th of an inch in length. The spicula from the pinnæ are fully half an inch long, they occur in bundles, some being pointed at both extremities, whilst others have one extremity expanded like the feather of an arrow, all being more or less striated internally; portions of two of these spicula showing striæ are represented by D, E; a similar striated appearance is exhibited by the spicula from the flesh at the base of the stalk, as shown at C. The spicula of the *Renilla* are precisely similar in shape to those of the *Pennatula*, but are of a rich purple colour, most of them average $\frac{1}{70}$th of an inch in length; all, as shown at H, are twisted in the same peculiar manner as those of the *Pennatulæ* before noticed.

Transverse sections of the calcareous axis of the *Virgularia* are of a circular figure, and exhibit a radiated structure, as shown by E, in Fig. 70, the true nature of the radii, however, is better seen in a vertical section, F, under a power of 130 diameters; they are then found to be produced by a series of minute sinuous canals, opening on the free surface, and passing in curved lines towards the centre of the stem, which is apparently more dense and opaque than the outer portion. The tissue between the tubes presents longitudinal striæ, and after the carbonate of lime has been removed by an acid, the organic residuum exhibits a more or less fibrous appearance. The transverse section of the bony axis of *Pavonaria quadrangularis* is of a square figure, with concave margins, and, as represented by E, in Fig. 71, consists of a series of laminæ of fibro-calcareous matter arranged around a small central cross; the outer layer or crust is extremely hard and cannot easily be cut with a knife. The longitudinal section of the axis, as shown at F, exhibits a dark granular centre with vertical striæ on each side, and the organic basis of this structure appears to be of a fibrous nature. The spicula from the flesh in the neighbourhood of the polypes are of considerable length, and have both extremities pointed; they appear to be arranged in bundles, which project above the free surface in the form of bristles and alternate with the polypes, those represented by H being of the natural size. The spicula from the lower part of the stem are much more minute and of a flattened oval figure, most of them exhibiting traces of a striated structure, as shown at G; the long diameter of the oval, however, is placed in the same direction as that of the axis, as in the Pennatulæ before described.

LECTURE IX.

SKELETON OF ZOOPHYTES.

In the preceding Lecture I described the structure of the skeleton of some of the Asteroid Zoophytes, and I have now to make a few further remarks upon the nature of the axis in two of the species to which I have already alluded.

The structure of the axis of the Gorgoniadæ has been the subject of controversy ever since the time of Ellis. Many authorities consider it to be inorganic, there can, however, be no doubt that although the polypes do not form the axis, they are mainly concerned in preserving its vitality, and as long as the polypes are alive, changes both in the interior and on the exterior of the axis are continually going on. In those axes having a horny stem the increase takes place by the addition of concentric laminæ without much external alteration; in the axis of *Isis hippuris*, however, the horny portion of the base, where no polypes exist, is gradually eonverted into ealeareous material. In *Isis*, now *Melitæa ochracea* (Fig. 66, A), the ehanges are very remarkable; the axis, although jointed, has only a small portion of horny matter entering into its composition, it is almost wholly made up of spieula; the joints are easily eut with a knife, but the other parts are mueh harder. All the joints are eomposed of spieula of a yellow colour arranged in a peeuliar form of net-work, as shown at C; the intermediate harder parts are made up of red-eoloured spieula, internally like those of the joint, but externally, as shown at B, these have eoalesced to form a solid mass; the same thing has taken plaee in the Red Coral, and spieula ean be recognized in some portion or other of its substanee, and although in all the hardest parts a erystalline strueture appears, there is always a traee of cells to be seen.

In one speeies of Red Coral the eells of the axis are disposed more or less eoncentrieally, the eells themselves being of small size, with their walls still visible; in another speeies the walls have disappeared, but the eoneentrie laminæ indieating the sueeessive stages of growth are very evident, and beautifully arranged in undulating lines. The organie basis of these axes was known to Hunter, and was more espeeially noticed by the late Mr. Hatehett, who so long ago as the year 1800 prepared a speeimen illustrative of this fact, which is preserved in the Museum. I shall now mention the result of some investigations, which I believe to be new, regarding the development of these calcareous axes, viz.: that the axis of certain of the Asteroid Zoophytes is at first composed of a mass of cells which secrete and deposit the carbonate of lime in their interior. In some species the cell-walls are persistent, in others they are absorbed and disappear, leaving a solid mass of carbonate of lime in which little or no traces of structure can be distinguished.

There is another point of great interest which has come under my notice whilst examining the horny and calcareous skeleton of Zoophytes and still more highly organized beings—viz.: the power they possess of repairing accidental injuries. Mr. Busk, in his paper on the *Anguinaria spatulata*, published in the second volume of "The Transactions of the Microscopical Society," threw out a hint that some polyp-cells appeared as if they had undergone repair, and this, no doubt, was the fact. The repair of a portion of the horny skeleton is plainly visible in a specimen of *Gorgonia flabellum* in the Museum of this College; there has been at some time or other an extensive fracture nearly across the centre, and the line of it is indicated by the large, rough cicatrix. If one of the principal branches be examined it will be found that it has been broken transversely, the fractured ends are not exactly in a line, and the cicatrix, or callus, now fills up the space between them. As I proceed I shall bring forward other striking examples in proof of the power of repair of non-vascular tissues.

I now pass on to describe the structure of the skeleton of the last and most highly-organized members of the asteroid group of Zoophytes—the *Alcyonidæ;* and many mention as a familiar example the *Alcyonium digitatum,* so common on our coasts. All the individuals of this family are more or less lobed, and on this account, and from the resemblance of the lobes to certain natural objects, have received the names of Cow's Paps, Dead Man's Toes, Dead Man's Fingers, &c. The species just noticed — *Alcyonium digitatum,* Fig. 72,—is met with in great abundance on our southern coast, especially on old oyster-shells in the oyster-beds of Newhaven and Shoreham harbours: indeed, so abundant are they, that scarcely an oyster of any size, is dredged up from the bed newly discovered about midway between the English and French coasts, on which there are not one or more of these Zoophytes; and even at Billingsgate, where the oysters are sold, small specimens may be obtained, but the polypes are generally dead before they arrive in London. The majority of the polypidoms are of a pinkish-white

FIG. 72.

Alcyonium digitatum with retracted Polypes.

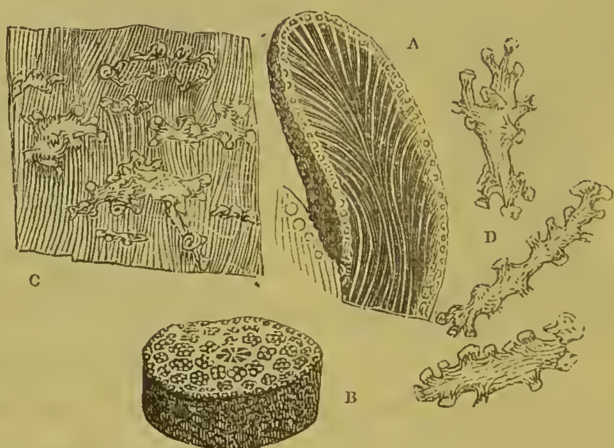
colour, but some are yellow or reddish-brown; they all, however, belong to the same speeies. When handled or pressed, they feel soft and pappy, and some of the polypes will make their appearanee; but if the outer surfaee only of the polypidom be touched, it communieates a gritty sensation to the finger, leading one to suspeet that there must be some calcareous matter present. On a eareful examination of this surfaee, the situation of the polypes may be at once recognized by the stellate markings, and if the polypes should happen to be extruded, as shown in Fig. 73, they will be found to have eight short arms, or tentaeula, provided with cilia on their edges.

FIG. 73.

A portion of *Alcyonium digitatum* with the polypes extruded (after Johnston).

The body of the polype, aeeording to Johnston, is enelosed in a thin, transparent, vesicular membrane, in whieh a great number of minute tuberculated ealcareous spicula are imbedded; the body is also marked with eight white longitudinal lines, or septa, whieh, stretching between the membrane and the central stomaeh, divide the intermediate spaee into an equal number of eompartments; these lines not only extend to the base of the tentacula, but run across the oral disc, and terminate in the central mouth. The stomach is not closed at its free extremity, but opens into certain large canals, which ramify through the fleshy central part of the polypidom and the eight white lines are continued from the stomach down the canals, being at first strongly developed, but gradually disappearing near the base of the polypidom. If a vertical section of the polypidom be made, as shown at A, in Fig. 74, the large branching canals will be

FIG. 74.



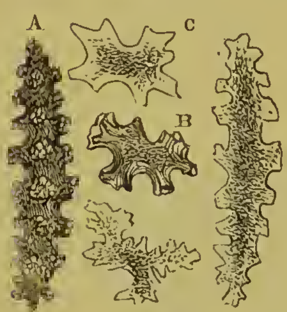
A, vertical section of a polypidom of *Alcyonium digitatum*. B, transverse section of the same. C, portion of the fleshy matter containing spicula. D, spicula of the flesh magnified 250 diameters.

easily seen; they are largest at the base, and become gradually smaller near the surface. The termination of each is slightly dilated to form a cell for the polype, and the tissue between the tubes is composed of minute fibres containing a transparent gelatinous flesh within its meshes, in which numerous tuberculated spicula, as shown at C, are imbedded. If a transverse section of the polypidom be made, as seen at B, the diameter and stellate form of the tubes produced by the septa prolonged from the stomach may be distinctly seen. The polype removed from the polypidom presents to our notice the eight tentacula around the mouth, and an abundance of tuberculated spicula which are present in the tissue supporting its body; many of these spicula are very long and thin, but still tuberculated. When the specimens have been preserved in spirit for some months, the tentacula are not so distinct as in a fresh polype. A thin slice of the outer gritty integument of the polypidom shows very clearly, under a power of 250 diameters, that the grittiness is due to the presence of myriads of tuberculated spicula, some of fusiform, others of cruciform figure. If a portion of this crust be decalcified by maceration in dilute acid, it will be at once seen that cavities are left in the organic basis corresponding exactly in form to the spicula previously lodged in this part of the animal.

When speaking of the structure of the spicula in a previous Lecture, I mentioned that all these bodies, both in the Zoophytes and in the Sponges, are developed in cells, and that their shape is determined by the form of the cell in which each is, as it were, moulded. The spicula, when separated from the gelatinous tissue in which they are imbedded, are not composed solely of calcareous material, but all have an organic basis; for if a large spiculum which has been removed from the polypidom by boiling liquor potassæ, be acted on by dilute hydrochloric acid, an organic basis will be left which retains to some extent the shape of the original spiculum, proving that every portion of the calcareous matter is in intimate connection with the organic basis.

In Fig. 75, A, B, are shown two tuberculated spicula from a purple-coloured Gorgonia which had been separated from the flesh by means of caustic potash; three of the same spicula having been treated with dilute hydrochloric acid to remove the lime, were found to retain the shape of the originals, as shown at C, but instead of being hard and calcareous, the organic basis was quite soft and flexible; when the lime was not wholly removed, the interior of the organic mass, or cell, always presented a more or less granular appearance. A vertical section of a portion of the soft internal part of the polypidom, or that occupying the space between the canals, shows that it is traversed by long tubes containing granular matter of a greenish colour, the tubes themselves being surrounded by delicate interlacing fibres, in the meshes of which are numbers of large tuberculated spicula, as shown at C, in Fig. 74, not so closely arranged but that their shape can be distinctly seen. There being no trace of an internal calcareous axis in the *Alcyonium*, as in

FIG. 75.



A, B, tuberculated spicula of a *Gorgonia*. C, three specimens of the same after decalcification.

other Zoophytes of this order, the spicula of the crust, which are very numerous, must be viewed as forming an exo- rather than an endo-skeleton.

The Alcyonidæ are propagated by ova, which are globular and of a dark brown colour; they are developed in the canals, and after fertilization are discharged through the mouth. Only three or four species of Alcyonium are found in the British seas, but many others have been discovered in various parts of the globe; some specimens brought to this country from the Navigator Islands by Sir Everard Home, although dry, will afford an idea of the quantity of calcareous material entering into the formation of their skeletons. The largest of these is of purple colour and somewhat like a cauliflower in appearance; in this, as in the others, the spicula are not only very abundant, but of large size, in some of the specimens they are white, but in that first described they are both purple and white. Certain Zoophytes of the genus *Xenia* are nearly allied to the Alcyonidæ; the specimens upon which my observations have been made, were brought from the Philippine Islands by Mr. Cumming. They so strongly resemble the inflorescence of umbelliferous plants that they might readily be taken for them; they are of various colours, some being bright purple, others rich yellow. The colour in all these animals depends on the presence of large spicula, which are very visible to the naked eye on every part of the stem, and project in the form of sharp spines from those parts containing the polypes which represent the blossom of the plant. These creatures, even now, after having been in spirit for

FIG. 76.

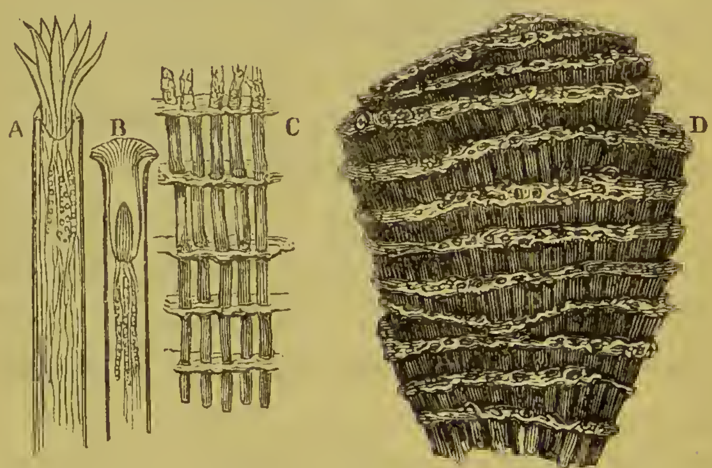
A, Polypidom of *Xenia* showing the spicula of the crust and of the polypes. B, C, spicula of the crust magnified 20 diameters.

some years, are sufficiently elegant to excite our admiration, but what they must have been when living, and with their polypes extruded, we can easily imagine, from the representations given in the splendid Atlas to "Dana's Zoophytes," being a part of the series published by the United States' Exploring Expedition, and a work that would do credit to any nation. The skeleton of all the species of *Xenia* which I have examined is strictly dermal, there being no spicula in the soft, gelatinous interior of the polypidom as in the Alcyonium; all being of large size and confined to the stem, the branches, and the neighbourhood of the polypes. Those in the stem and branches are arranged for the most part in diagonal lines, as shown at A, in Fig. 76, whilst those in the neighbourhood of the polypes project outwards, like spines, or like the large spicula in the plumes of the *Pennatulæ*. In addition to these, there are very minute spicula which form the skeleton of the outer framework of the polypes themselves.

If a portion of the outer skin of the stem of one of these specimens be viewed even with a power of 30 diameters, it will be found that the spicula are so long that only a portion of each can be seen in the field of view at one time; they are of a light brown colour, and covered with very minute tubercles, as shown at B. The spicula taken from the neighbourhood of the polypes are much smaller, as shown at C, but have tubercles like those occurring in the same situation in the Alcyonium; their colour is a rich brown. The skeleton, therefore, of these beautiful creatures, like that of *Alcyonium digitatum*, is dermal.

The last specimen I shall describe as belonging to this order of Zoophytes is the *Tubipora Musica*, or Organ-pipe coral, Fig. 77, D, which is always of a brilliant red colour, and easily recognized by being made up of a series of tubes arranged in rows one above the other. Considering them as a whole, the tubes are disposed in a radiated manner, they are about half an inch long, and as soon as they have arrived at the proper length, a frill or flange is, as it were, secreted by the outer portion of the tube which joins similar ones developed from adjacent tubes on either side, and the result is that a horizontal shelf or septum, as shown at C, is formed, from the upper surface of which, new tubes are given off; the radiated disposition of those first formed allowing space for the new ones on the portions of the shelf between their mouths. When living, the entire mass of tubes is covered with gelatinous matter, or flesh as it is sometimes called, and each tube, as represented by A, B,

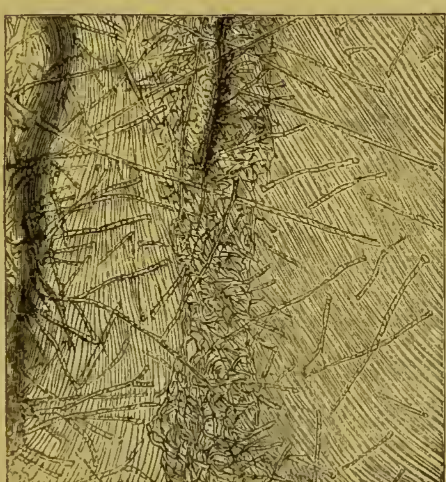
FIG. 77.



contains a polype of a grass-green colour, so that a living coral must be an elegant thing indeed. The outer portion of the polype is connected with the interior of the tube by means of a thin membranous lining, another portion of which is reflected over the lip of the tube, and is united to the gelatinous matter on the outside, whilst an intermediate portion secretes calcareous matter, and forms the tube.

In a specimen in the museum, prepared by Hunter, the polypes are seen in situ, and in the small specimen represented by C, Hunter demonstrated the organic basis of the tubes, after removal of the calcareous material by acid. Thin sections of this coral, which is very brittle, occasionally exhibit a cellular structure, with the openings of numerous foramina, and in a specimen I possess, the fibres of a sponge have penetrated some of these foramina, as in the case of the Pinna-shell mentioned in a former Lecture, at page 37. This is a very common circumstance in all corals, and by acting on thin sections with hydrochloric acid, the calcareous matter is removed and the true nature of the fibres easily made out; but being familiar with the sponge-fibres, I soon recognized those in the *Tubipora* as old acquaintances. Confervoid growths also are very frequently met with in the skeleton of corals, as all these bodies possess animal matter, which, decomposing after death, becomes a nidus for the development of confervæ, and hardly a section can be examined without exhibiting such an appearance as that shown in Fig. 78.

FIG. 78.



A section of *Coral* exhibiting confervoid growths.

LECTURE X.

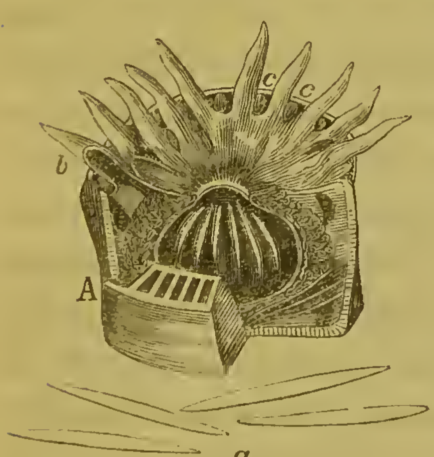
SKELETON OF ZOOPHYTES.

In the last order of the class Anthozoa, the *Helianthoida*, the polypes are single, free or permanently attached; fleshy, naked or encrusted with a calcareous polypidom, the upper surface of which is crossed by radiating lamellæ. The most familiar examples of this order are the *Actiniæ*, familiarly known as Sea-Anemonies or Animal Flowers, some species of which are common on all parts of our coasts. In certain states of the atmosphere, especially when the weather is stormy, the Actiniæ appear as conical masses of fleshy substance, but when the sea is calm and the sun bright, they expand themselves, and then they resemble beautiful flowers; their tentacula disposed in one or more circles and beautifully coloured, are very like the petals of a flower. The *Actinia mesem-*

bryanthemum, in particular, which is very common on the coast of Sussex, has a row of large tubercles of a most splendid blue colour, like lapis-lazuli, on the outside of the tentacula. These animals live a very long time, and it is said that the late Sir John Dalyell kept some of them alive for upwards of twenty years by giving them fresh sea-water nearly every day. The external or cuticular coating of the Actinia is thin and coloured, the inner or corium, thick, leathery, and more or less white; the inferior surface is flattened to form a discoid base, or foot. Some species are covered with tubercles, others have numerous pigment spots scattered irregularly on their outer surface.

A vertical section of the entire animal, as shown in Fig. 79, exhibits a circular perforation, the mouth, surrounded by the coloured tentacula, *b*, leading to a flask-shaped stomach, which, instead of occupying the entire cavity of the body, as in the Hydra, is suspended within that cavity by a number of vertical septa, forming a corresponding number of cavities, or chambers, which contain the ovaries and testes. The cavities for the lodgment of the

FIG. 79.



A, vertical section of an *Actinia* showing its internal structure. *a*, spicula from the tubercles magnified 250 diameters. *b*, tentacula. *c*, tubercles between the tentacula.

ovaries are large, and situated near to the external tunic; those for the testes are smaller, and in immediate contact with the coats of the stomach. The upper part of all the septa is perforated, so that each chamber communicates not only with those adjoining, but also with the interior of the tentacula, each of which, as shown at *b*, is tubular and perforated at its free extremity, so that water taken into the chambers is propelled, by the contraction of the walls of the chambers, into the tentacula, distending them, and by this means causing their protrusion and the expansion of the entire animal.

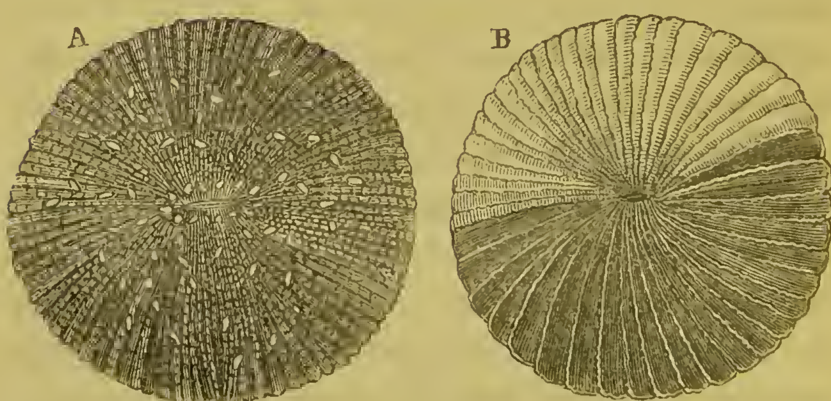
The microscope reveals to us no trace of calcareous or siliceous skeleton in these animals, with the exception of spicula in certain tubercles, *c c*, which occur in some species between or external to the tentacula. These spicula, as shown at *a*, are of nearly equal size, measuring on the average $\frac{1}{200}$th of an inch in length, and pointed at both extremities. Professor Bailey, of New York, who discovered them, believed that they were composed of silica, like those of the sponges; but as they are destroyed by a red heat and not acted on by acids, it is more probable that they consist of horny matter. The Actiniæ subsist for the most part on small crabs and other crustacea that come within the reach of the tentacles; they do not appear to move to any extent in search of their prey, being generally fixed to the rock by the discoid sucker on their inferior surface. The soft parts of the food are rapidly digested, while the indigestible portions are rejected by the mouth, there being but a single opening to the stomach, from which viscus the nutriment is directly absorbed. For the purpose of better securing the animals that they seize, the tentacula are said to be furnished with poison vesicles and spicula, somewhat similar to those in the Hydra; if the finger be placed in contact with the tentacula of most of the common species of our shores, a stinging sensation will be felt.

The Actiniæ are propagated by ova, which are developed in the lobulated glandular ovaries situated in the interseptal chambers, and impregnated by the sperm-cells of the twisted testicular tubuli also seated in the same chambers. The ova, after fertilization, are said to remain in the interseptal chambers, and the young Actiniæ escape by the mouth of the parent, but it is still uncertain how they find their way into the stomach. It is equally certain that the Actiniæ occasionally, although unfrequently, propagate by gemmation.

During a visit to Brighton last year, I had the opportunity of verifying this statement, having seen as many as five or six young Actiniæ adhering to the base of a full-grown animal, from which they subsequently separated, and attached themselves to the sides of the glass jar in which they were kept. Like the Hydræ, they possess the power of reproducing lost parts, and when one of them is divided into two or more pieces, each part is capable of becoming a perfect animal. The spicula from the tubercles of *Actinia mesembryanthemum*, as shown at *a*, are linear, elongated, pointed at both extremities, and might readily be taken for those of some sponges of the genus *Halichondria*, but, as I have already said, they probably consist of a horny material. In the thick, leathery corium which forms the external tunic of the animal, there is neither calcareous matter nor any trace of spicula, but an abundance of unstriped muscular fibres.

The laminated or lamelliform Corals belonging to the same family as the Actiniæ, are provided with a hard calcareous skeleton. When of a circular form, they are called *Fungiæ*, or Mushroom Corals, but when elongated and oval, have received the name of Sea Slugs. The situation of the mouth in these solitary polypes is indicated by a deep fissure at the centre, as represented by A and B, in Fig. 80; all the other parts, as shown at A, are covered by the flesh which

FIG. 80.

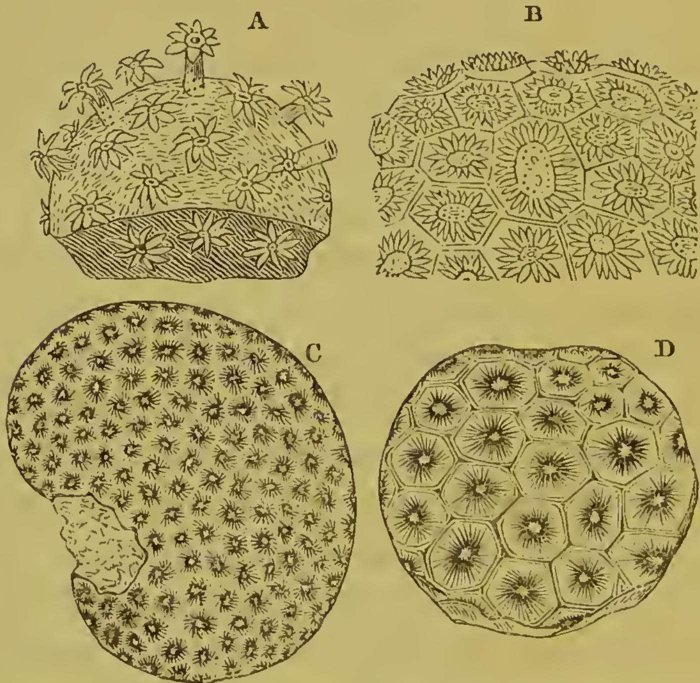


A, *Fungia agariciformis* showing the soft parts of the animal. B, skeleton of the same.

dips down between each of the laminæ. The grooves between the laminæ are deep, extending to the base of the calcareous skeleton which forms a thin solid layer connecting the laminæ like the pileus of a mushroom. The tentacula are tolerably numerous, arising from the flesh, as shown at A. In the dried specimens of these elegant skeletons, although all visible traces of the flesh have been removed, the organic basis by which the carbonate of lime was secreted and deposited, remains and may be readily demonstrated. In a specimen from the Museum, prepared long ago by Mr. Hatchett, the calcareous matter has been removed from a part of the skeleton by the action of an acid, which retains the perfect form of the remainder of the coral mass. Sections of the coral and the organic basis, when examined under the microscope, occasionally show traces of the cells by which the calcareous matter is assimilated and within which it is deposited.

The Fungiæ then are examples of the skeleton of a single animal, like an Actinia, and may be termed simple corals, but there are many species in which the polypes are exceedingly numerous; these, by way of distinction, may be considered as compound polype masses, or corals; they are recognized by clusters of cells of nearly uniform size, each exhibiting a radiated laminated structure, as shown by A, B, C, D, in Fig. 81. The number of the arms of the polypes is indicated, as in the Alcyonidæ, by the number of the laminæ. These corals are called Madrepores; in many species, as in *Madrepora galaxea*, C, there is little or no space between the cells, but in others there is an

FIG. 81.



A, *Astræa viridis* with its polypes. B, *Astræa purpurea* showing the polypes. C, *Madrepora galaxea*. D, *Madrepora ananas*.

intermediate portion of the same stony material separating the cells, which may be on the same level as the cells, or, as in the arborescent corals, may take the form of a stem or axis, as in the *Oculina ramea*, Fig. 82, B. In some genera and species the cells are not circular or hexagonal, but elongated and wavy, with the laminæ still projecting inwards towards a central median furrow.

In those Madrepores commonly called brain-stones, (on account of the continuous wavy lines on their surface resembling the convolutions of the brain, and their globular figure,) the polype-cells have coalesced, and

FIG. 82.

A, a portion of a Coral in which two branches have been repaired after fracture. B, a branch of *Oculina ramea*, the upper part being invested with the soft parts of the animal, the lower being denuded.

by these means the wavy superficial markings have been produced. Such is the nature of the very large and beautiful specimen contained in the Museum of this College, and with which most of you no doubt are familiar. There are other corals, formed precisely in the same manner as the Madrepores, but the cells being exceedingly small, they have been termed Millepores, and the fine polypidom now before you, from its resemblance to the horns of a stag, has been named *Millepora alcicornis.* Other genera being altogether destitute of polype-cells and pores, were called Nullipores ; but it is now satisfactorily ascertained that these are in reality plants having an external coating or skeleton of carbonate of lime.

Corals are chiefly inhabitants of the tropical seas, where they form islands and reefs many hundreds of miles in extent, so much dreaded by the navigator, but of the greatest possible interest to the geologist and naturalist; the former looking upon these animals as mighty agents in elevating the crust of our planet, the latter having regard to their development and the variety and beauty of their forms.

Mr. Darwin, whose name is so familiar to all naturalists in connection with the voyage of the 'Beagle,' has paid the greatest attention to the structure of the rocks produced by these Zoophytes, and has distinguished them as Atolls, barrier-reefs, and fringing-reefs. The word Atoll is applied by the inhabitants of the Indian Archipelago to coral islands of circular figure, with a pool or lake, termed a lagoon, in the centre, generally communicating at some point of its circumference with the surrounding ocean by a small channel. A barrier-reef may be viewed as an Atoll spread out in a straight line, running parallel to a line of coast having deep water on the outside, while the channel between it and the main land, or, in other words, the lagoon, is broad, smooth, and deep. A fringing-reef has shallower water on its outside, and a narrow and shallow lagoon between it and the coast. An Atoll is generally found where the water is deep, the outer side of the coral bank shelving down at an angle of 45 degrees to the depth of 200 or 300 fathoms, whilst the inner side gradually slopes so as to form a cavity somewhat like a saucer; but this also is in great measure filled up by fragments of coral detached by the surf from the outer part of the reef, so that even in the centre of a lagoon the water is rarely more than 50 feet deep. The outer surface is continually washed by a strong surf which renders the island difficult of approach, unless it should happen, as it not unfrequently does, that the force of the surf has been sufficient to make a breach in the coral; then, however rough may be the passage to the breach, the navigator will be amply repaid by the smooth water of the lagoon, and if he be a Zoologist, no spot that he could choose is more fertile in animal life. Here fishes swarm, here is found the gigantic Clam, with an endless variety of smaller shell-fish; here the coral animals and other Zoophytes revel in enjoyment, here sea-weeds grow in abundance, and turtles are not wanting to feed upon them.

Many of these Atolls are of large size, and the coral barrier is covered with a luxuriant vegetation. As the coral animals cannot live in more than 20 or 30 fathoms below the surface, it may be asked, how can the reef be formed at a depth of 200 or 300 fathoms? Mr. Darwin holds the opinion that the Atolls are based upon land which was once dry, but has since subsided, carrying with it the dead corals. He has found also that the surface of the coral is generally covered with Nullipores, sea-weeds and shells, and that the detritus of these, the dead coral, shells and sand together, form a soil fitted for the growth of stray seeds and fruits, such as the cocoa-nut, carried to them by the ocean currents. Some idea may be formed of the beauty of one of these Atolls by the diagram before you, which is a representation of Whitsunday Island in the Pacific; the vegetation is most luxuriant, and capable, as has been proved on more than one occasion, of supporting for a considerable period the shipwrecked mariner; the cocoa-nut, the turtles, and shell-fish of the lagoon furnishing him with abundance of food, whilst fresh water was readily obtained by digging small wells in the sand, into which water from the sea gradually found its way, and having a large stratum to pass through, was deprived of nearly all its saline constituents. The largest barrier-reef, upwards of 1000 miles in length, occurs on the north-east coast of Australia, rendering the navigation of this part of the globe exceedingly dangerous. It has been described by Mr. Joseph B. Jukes,* who was employed during the years 1842—1846 as naturalist to the expedition under Captain Blackwood, of H.M.S. 'Fly,' for the purpose of surveying Torres Straits, New Guinea, and

* "Narrative of the Surveying Voyage of H.M.S. 'Fly,'" London, 1847.

other islands of the Eastern Archipelago. The upper and outer parts of the reef are composed of living species of the genera *Porites* and *Millepora*, the former being described by Darwin as forming masses from four to eight feet broad, and of similar thickness, and by the naturalists of the United States' Exploring Expedition as of a more or less nodulated figure, while the Millepore is composed of thick vertical plates, intersecting each other at various angles, forming an exceedingly strong honey-comb mass of a circular figure, the external plates alone retaining their vitality.

These corals are found near the surface, but lower down there are other large stony species. Small fragments of *Millepora alcicornis* have been brought up from a depth of twelve fathoms; but so firmly are the corals bound together, even at this depth on the margins of the reef, that chains and anchors have been lost in the attempt to detach them. Shells of different species are also occasionally found forming a stratum of two or three feet thick, within reach of the tide or spray of the water.

The remains of Madrepores and other corals abound and were mainly concerned, in the formation of many limestone rocks. The specimens constantly exposed for sale at Clifton are principally Madrepores and Oolites, and some of the former still clearly exhibit the large cells for the polypes and the radiated disposition of the septa, the cells being closely approximated, and the interseptal spaces filled with transparent calcareous matter.

In other specimens, the cells are more widely separated, and the intervening spaces occupied by dark calcareous material, fractured in such a manner as to produce a cellular appearance, so that even in the fossil state the indications of coral structure are very evident. As the entire mass of the coral is composed of cells filled with carbonate of lime, it follows that the vulgar opinion of its being built up by polypes is erroneous; indeed, the study of the development of these animals clearly proves that the cells are formed before the polypes, and that their function is that of collecting and digesting food—in fact, that they constitute the digestive system for the nutrition of the flesh of the entire animal. This connection of the polypes with the flesh, and the conveyance of the nutritious matter to the latter, is strikingly evident in the tubular keratophytes. The polypes then, perform the same function towards the coral-mass as the oyster to its shell; for if the oyster die the shell also dies, but so long as the oyster retains its vitality, every portion of the shell, however distant from the animal, is endowed with life; and in the same manner, so long as the polypes remain alive, the vitality of the entire coral mass will be sustained. Collectors of shells can immediately distinguish those that have been taken out of the water alive, from dead shells; the former always retain their polish and colour; the latter are dull, opaque, and of little value.

Corals, like shells, possess the power of repairing injuries; this I had long suspected, although I had no direct proof of the fact until, having occasion to examine an old collection belonging to the Museum of this College, I found some specimens in which fractures had occurred. In one of these, as shown at A in Fig. 82, several branches had been broken off and cemented to others in the position in which they had fallen; in another species—*Millepora alcicornis*—there are several examples of a similar repair of fractures; whilst a third, of an extremely interesting character, shows that the broken extremities of the branches have been subsequently rounded off and covered by the flesh, in the same manner as a bone after amputation of a limb. These specimens all belonged to John Hunter, and were probably selected by him for the illustration of the process of repair after injury.

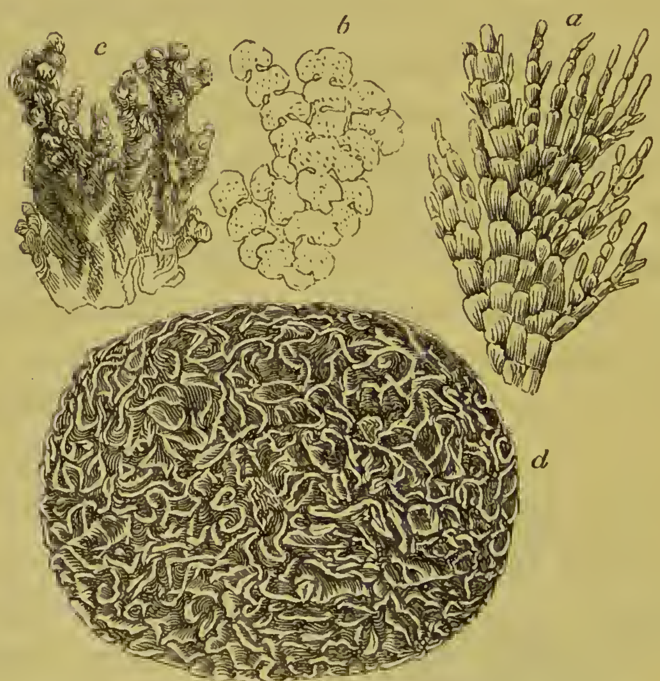
When speaking of lime as forming the skeleton of plants in my first Lecture, I made brief allusion to a class of organized beings termed *Lithophytes;* these were considered by Lamarck and other high authorities to be animals; modern investigation has proved that the Corallines, and even the harder Nullipores, are essentially plants more or less coated with calcareous material.

FIG. 83.

Corallina officinalis.

One of the commonest of the Lithophytes found on our coasts is the *Corallina officinalis*, represented in Fig. 83; it consists, as you well know, of a series of minute joints; when acted on by dilute hydrochloric acid, the coating of lime is removed, and it then becomes quite as flexible as any plant, and most of the terminal branches, which are of a round figure, will exhibit the organs of fructification. Other species of Corallines, such as *C. monile*, Fig. 84, *a*, and *C. opuntia*, *b*, are

FIG. 84.



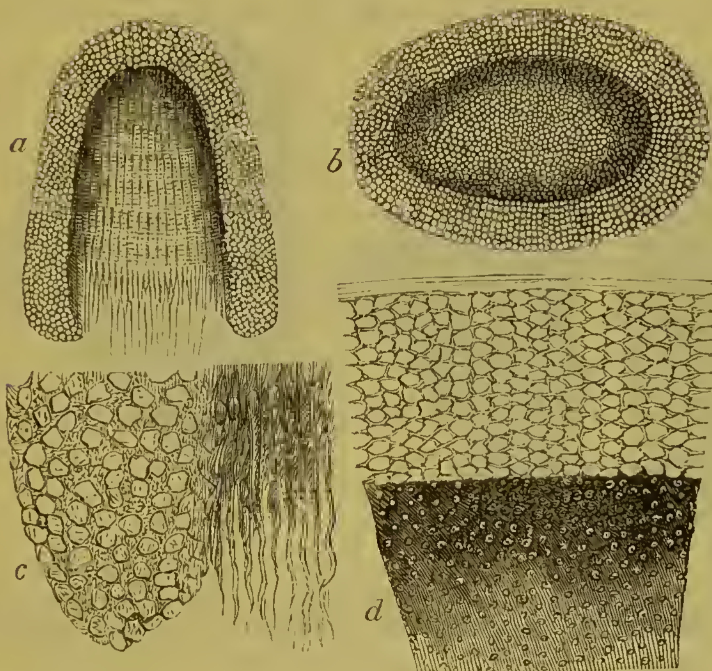
a, *Corallina monile*, (of Ellis). *b*, *Corallina opuntia*. *c*, *Nullipora polymorpha*. *d*, *Nullipora agariciformis*.

both largely coated with lime, but their joints are more evident than those of *C. officinalis*. The harder Lithophytes have received the name of Nullipores; one of these, *N. polymorpha*, represented by *c*, is common on our coasts; it is found so abundantly in Falmouth Harbour, that it is dredged up to manure the land. It consists of a series of irregularly branched nodules, and is of stony hardness. Another species, *N. agariciformis*, represented by *d*, is not so common; it grows in globular masses, varying from an inch to four inches in diameter, and is made up of a series of foliaceous laminæ; when acted on by dilute hydrochloric acid, this and the preceding species, like the two Corallines above mentioned, exhibit a soft, flexible mass, which retains the shape of the original specimen, but which, on being burnt, gives off a decidedly vegetable odour.

As the Lithophytes occur in the greatest abundance upon coral-reefs, where it would appear that the water is highly charged with carbonate of lime, and, as in former times, they were considered to be Zoophytes, I have thought proper to speak of their minute structure at this time, in order that you may have an opportunity of comparing it with that of the stony axis of the Corallidæ, and I must therefore beg of you to bear in mind that the comparison is of the greatest interest; for in both instances we have a great abundance of calcareous material which has been separated from the water by a vital process, that in the one case being effected by a vegetable, the other by an animal basis requiring the presence of digestive sacs, or polypes, to maintain its integrity. If a vertical section be made of any Coralline, such for example as the *C. officinalis*,

Fig. 85, *a*, we shall find that, on examination with the lowest powers, it will exhibit two kinds of structure, both of whieh are essentially cellular, that on the exterior being composed of small cells of hexagonal figure, whilst in the interior they are more elongated, and generally of a brownish eolour; this is espeeially the case if a seetion should include a joint. In the fresh state the contents of the cells can be easily made out, and the central ones are not unfrequently full of greenish granules like Chlorophylle. The lime is not in the interior of the cells, but appears to be on the outside of the cell-walls, whieh are rendered opaque and thick in consequence. A portion of the vertical section, as seen under a power of 200 diameters, is represented at *c*, the dark parts on the outside of the eells there shown, are the caleareous material; the eells in the centre, as before notieed, are of an elongated figure, having little or no lime about them; these also are exhibited at *c*, but the loose cells on the right side of the lower part of the figure, formed part of the articulation, and are entirely destitute of lime. A transverse section of one of the joints of the same Coralline, as shown at *b*, is wholly made up of cells, those on the margin being rather larger than the central ones; both have an abundance of lime around them, as represented under a power of 200 diameters at *d*. The eells seen upon the upper portion of this figure having been deprived of their lime, are in consequence rendered very apparent. All the Corallines exhibit nearly the same structure, the outer portions being composed of cells of hexagonal figure, and the central of elongated ones; the former are

FIG. 85.

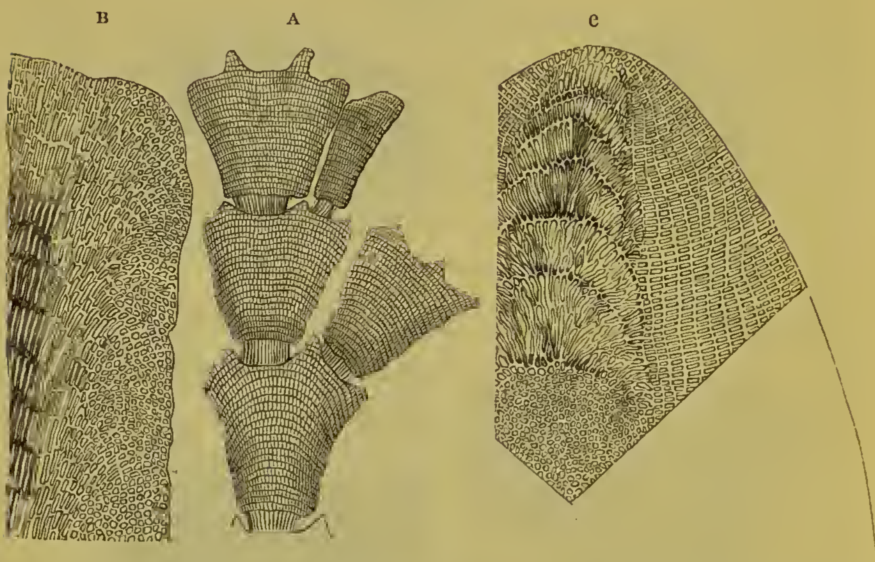


a, a vertical section of a joint of *Corallina officinalis* magnified 50 diameters. *b*, a transverse section of the same. *c*, a portion of the vertical section magnified 200 diameters. *d*, a portion of the transverse section magnified 200 diameters.

always coated with lime, whilst the latter are only partially so, and it is by the absence of the lime from these cells, at particular points, that the articulations are formed.

A very striking specimen for exhibiting the structure of the articulations is *Corallina incrassata;* a vertical section of this plant is represented by A in Fig. 86. The joints, as there shown, are composed of elongated cells, and from having no lime about them, are soft and flexible, and even of a green colour. A magnified portion of one of the joints is shown at B, and a transverse section at C, both are made up of cells,

FIG. 86.

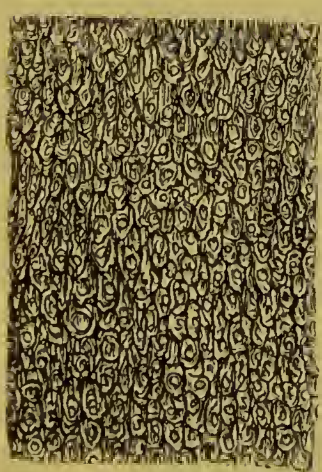


A, a vertical section of *Corallina incrassata*, showing the joints. B, a portion of one of the joints. C, a transverse section of the same, both magnified 130 diameters.

of which the central ones are much elongated. That the calcareous investment of the Lithophytes is not a mere precipitation from the water, as happens with many of the *Characeæ*, is, I think, very evident, for I have never yet seen any specimen of Coralline in which the part forming the articulation was coated over, nor has any section shown that the calcareous matter is ever present except as a coating to the cell-walls or the spaces between them. In the Nullipores which have no joints, the cellular structure is of the same nature throughout; there are no elongated cells in the centre, as in the Corallines, consequently it would appear that the articulation is the result of a vital action in some of these cells, whereby they are deprived of the power of selecting a calcareous coating from the surrounding water, their energies being entirely devoted to the function of growth.

I now proceed to describe the structure of some of those corals which consist of a series of branches like the Nullipores, but all of which exhibit cells for the lodgment of polypes. When divided transversely or longitudinally, a branch of coral will always present a porous character, the pores being continuous with the polype-cells; but when examined microscopically, many of the parts which appear to be composed of solid lime will be found to exhibit traces of a cellular structure, as shown in Fig. 87. The cells, when present, will be found to differ very materially from those of any Nullipore, and all the calcareous material is contained within them. The presence of cells is not always so plainly discernible as is represented in Fig. 87, for changes are continually going on, both in the cell-walls and in the calcareous material which they enclose, the former, as before stated in page 5, being absorbed, whilst the latter undergoes a species of crystallization. I have made a very great

FIG. 87.



A vertical section of Coral, showing its cellular structure.

number of sections of the stony skeletons of corals, and have repeatedly failed in detecting any trace of cellular structure in every specimen; those parts newly formed should be selected in order to see them to advantage. I have already spoken of the development of the stony axes of the *Gorgoniadæ;* these appear to differ from the true Corals in having a spicular origin, which spicula, in process of growth, coalesce and become converted into a solid mass. Thus then, independently of the minute structural difference between a Nullipore and a Coral, there is also this striking fact, that both are developed by an organic basis, the one having the calcareous material external to the basis, whilst in the other it is always internal to it.

LECTURE XI.

SKELETON OF ZOOPHYTES.

Having now examined the structure of the skeleton in the orders *Hydroida, Asteroida* and *Helianthoida* of the class *Anthozoa*, I proceed to the class *Polyzoa,* which is divided by Dr. Johnston into two orders, the *Infundibulata* and *Hyppocrepia.* The Infundibulata (*Cilio brachiata* of Dr. A. Farre) are all marine animals with compound polypes, each of which has a mouth surrounded by filiform retractile tentacula provided with ciliated arms, by which they are distinguished from the Hydroida. The *Hyppocrepia,* on the contrary, are all lacustrine, or natives of fresh water; but in them the mouth is also surrounded with ciliated retractile tentacula. In the *Anthozoa* the polype is either naked, as the Hydra, or enclosed in a horny skeleton formed by soft animal matter continuous with the polypes, but not by the polypes themselves. In the *Asteroida* the skeleton, as in the Gorgoniæ, is also internal, whilst in the *Helianthoida* it is again external; but in the present class, *Polyzoa*, the skeleton forms a portion of the polype itself, hardened by the deposition either of horny tissue or calcareous matter.

In the *Anthozoa* we found the polypes developed from a common central mass, but in this class each polype is distinct and enclosed in its own peculiar cell. In the *Anthozoa*, as in the case of the Hydræ and Actiniæ, the polypes occur in a separate or naked form, but, according to Johnston, in the *Polyzoa* there is always some kind of case or skeleton to protect them; a tunic, which after investing the body of the polype as in a pouch, is reflected over the aperture of the cell, the reflected portion becoming external and solidified either by calcareous depositions in its texture, or by a mutation of its thin membranous tissue into a horny investment, better suited to the office it has to perform of protecting the sentient body from too rough a contact with the medium in which the animals live, and from other accidents.

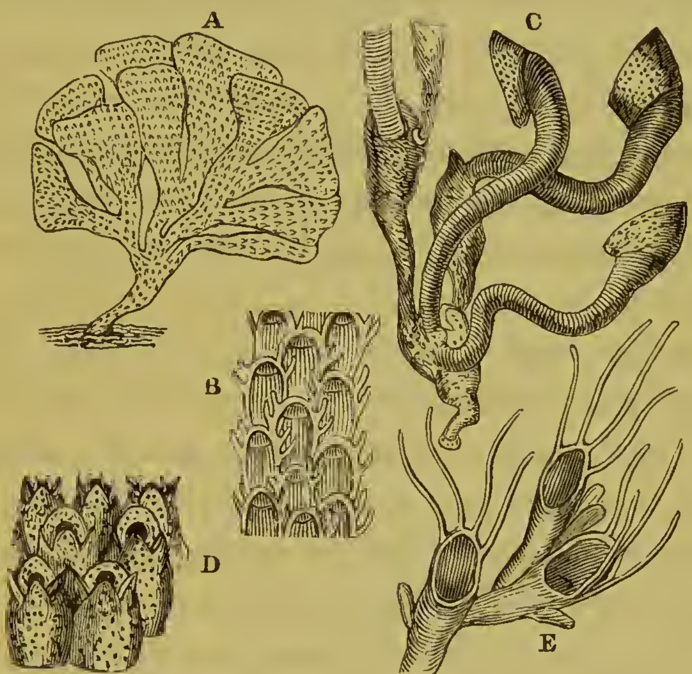
When the polype retires within its cell, the mouth of the cell is closed by that portion of the tunic which they push before them when they protrude themselves, and some species of *Flustra*, are provided with a tendinous apparatus for lengthening the body, which is doubled up in the interior of the cell, when they are at rest.

The order *Infundibulata* is divided by zoologists into seven families, viz.: *Tubuliporidæ, Crisiadæ, Eucratiadæ, Celleporidæ, Escharidæ, Vesiculariadæ* and *Pedicellinæ.* Of the two first of these I possess no speeimens, but of the third, or *Eucratiadæ*, I have one of great interest—the *Anguinaria spatulata*, or Snake's Head eoralline of Ellis—whieh, from possessing a higher organization than the other members of the family, and from the presence of striped museular fibre, should be elassed with the *Bryozoa* among the Mollusea; but as its external form and the strueture of its skeleton somewhat resembles that of the Hydraform Zoophytes, I shall describe it here. This Zoophyte, shown at C in Fig. 88, attaehes itself to pieees of sea-weed, along whieh it ereeps in a spiral manner, sending up here and there a curved tube, with its free extremity dilated into a polype-cell resembling the head of a snake, on which account the animal has reeeived the name of Snake's-head Coralline. The tubular proeesses eontaining the polypes, are eomposed of ealeareous matter; the part eorresponding to the body of the snake is surrounded by a series of rings, whilst the dilated portion, or head, exhibits a minutely hexagonal or granular structure, as if made up of eells of that figure. When aeted on by dilute aeid, the ealeareous matter is removed, and a very transparent horny membrane is left, which retains much of the original strueture.

The best deseription of this Zoophyte is that given by Mr. Busk in the second volume of the "Transaetions of the Microscopical Society," who states, that in the creeping or radical portion, the calcareous matter is deposited in the form of minute angular or rounded particles, presenting faint traces of a linear arrangement; but in the main body of the polype-cell, or the tubular process, as I have before described it, the calcareous element takes an annular form; this must be dissolved before the polype can be well seen. We have here then a good instance of a true skeleton, strengthened by a deposit of earthy material. Mr. Busk has described the polype, and the transversely striated character of its muscular fibres; but I merely mention these in passing, being now chiefly occupied with the structure of the skeleton.

Of the *Celleporidæ* I possess but one example, a species of the genus *Lepralia*, consisting of a series of egg-shaped cells, of a shining-white or grey colour, arranged in a single layer, forming a coating over shells, sea-weeds, corals and other submarine bodies. Each cell has a more or less oval aperture, as shown at D, in Fig. 88, out of which the polype is protruded; the cells are disposed in regular rows, those in one row, according to Johnston, being a little in advance or behind those in other rows; that is to say, the apertures in the cells of one row, are in a line with those in the third row from it. The structure of the cell is granular, and it contains so large an amount of calcareous matter as to render the entire mass exceedingly brittle. I possess a portion of a shell entirely covered with *Lepralia Ballii*, Fig. 88, D, the apertures of the cells of which

FIG. 88.



A, *Flustra foliacea.* B, portion of the same magnified in order to show the cells. C, *Anguinaria spatulata.* D, *Lepralia Ballii.* E, *Cellularia ciliata.*

are visible to the naked eye. In the next family, *Escharidæ*, the *Flustra foliacea*, Fig. 88, A, resembles foliaceous sea-weeds in appearance, is of a brown colour, and composed of a number of polype-cells arranged in a single or double layer; each cell is of a more or less square figure, being a little broader and more rounded at its distal, than at its proximal extremity. The aperture from which the polype is protruded is of a semi-circular figure, and surrounding it, as well as the wall of the cell, are some short spines. When mounted as an opaque preparation, the cells and their apertures are distinctly visible; but when examined in the fresh state, or after having been placed in spirit or some other preservative solution, the polypes may be seen in their cells in some cases with the tentacles extended; in almost every cell the tendinous apparatus for lengthening the body, which is of an opaque brown colour, and bent upon itself nearly at a right angle, may also be recognized.

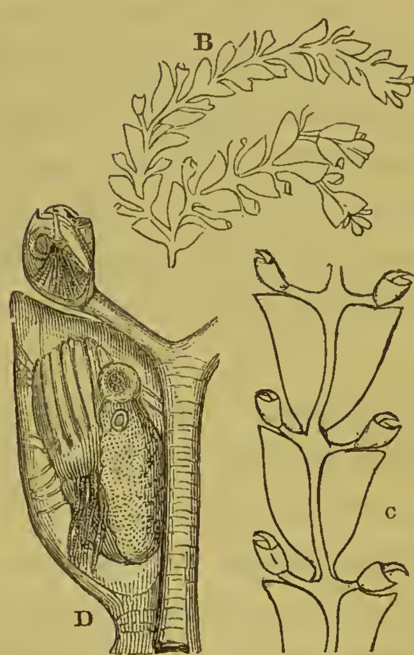
Another small frondose species of *Flustra* is the *F. cartacea*, which is never more than two inches high; in the mass, the cells always present a glistening aspect, as if they had been coated with varnish; it is not uncommon on the Sussex coast. The skeleton of the foliaceous *Flustræ* is composed of horn, but the incrusting species, *Flustra coriacea* and *lineata*, have more or less calcareous matter in their skeletons, like the *Lepraliæ;* these, however, do not form distinct fronds like *F. foliacea*, being found chiefly upon shells and sea-weeds. All the incrusting species, especially *F. truncata*, when prepared and mounted in Canada balsam according to the plan recommended by Dr. Golding Bird in the first volume of "The Quarterly Journal of Microscopical Science," page 85, exhibit the most splendid tints under polarized light. The polypidom appears to be covered with a series of minute spherical masses or concretions of carbonate of lime, the centre of each being occupied by a black cross with tinted quadrants, and the whole circumscribed by a black circle. When acted on by dilute hydrochloric acid, the spherules are dissolved with effervescence, and the beautiful tints disappear.

In the genus *Cellularia*, as for instance, *C. ciliata*, Fig. 88, E, the polypidom is composed of a mixture of horny and calcareous matter; the cells are of an oblong figure, and each has a spine on its superior outer angle. This specimen is remarkable for the expansion of the polypes, which are all protruded, the cilia being still visible on some of the tentacula, and also for the manner in which the skeleton is strengthened by calcareous matter distributed through the horny texture. When the polypidom is mounted in Canada balsam and viewed by polarized light, the plates of carbonate of lime with which the cells are covered, exhibit most splendid colours, like those of the *Flustra truncata* above described.

The structure of the polypidom of the *Cellularia plumosa* very much resembles that of the preceding species, but about the middle of most of the polype-cells there is a peculiar moveable process like the beak of a bird, which has on this account been called the Bird's-head process. It consists of a globular head having a projecting part corresponding to the upper mandible, which is met by a smaller mandible below, and upon the head a fan-shaped muscle is spread, composed of striated or voluntary muscular fibre; during life, not only are these mandibles constantly in motion and ready to seize any objects that may come within their grasp, but the head itself is capable of being moved. A few days since I saw a specimen of this Zoophyte in which a worm had been seized and was still held fast between the mandibles, and they seemed to me to perform a function analogous to that of the Pedicellariæ of the *Echinodermata*, which I shall hereafter describe.

The *Notamia bursaria*, or Shepherd's Purse coralline, Fig. 89, B, said by Johnston to be very rare, but dredged in considerable abundance by Mr. Busk on the coast of Dorset, and described by him in the second volume of the "Transactions of the Microscopical Society," consists of a series of cells of triangular figure, occurring in pairs, as shown at C, the base of the triangle being uppermost. Upon this base, in each cell, is a bird's-head process supplied with voluntary muscular fibres, keeping the mandibles continually in action while the Zoophyte is living. These bird's-head processes have been

FIG. 89.

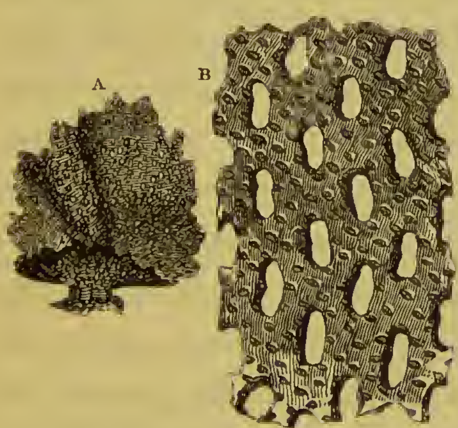


B, *Notamia bursaria*, Shepherd's Purse coralline. C, a portion of the same magnified. D, one of the triangular cells magnified 250 diameters, showing the polype and the "bird's-head" process with its striped muscular fibres (after Busk).

minutely described by the late Dr. John Reid and M. Van Benéden; they are of three or four kinds, like the Pedicellariæ, and have received various names from their fancied resemblance to certain instruments in common use. Their skeleton is like that of the polypidom, and for the best account of their structure, as well as for everything else relating to British Zoophytes, I would refer you to the excellent work of Dr. Johnston, to which I have so often alluded.

We have only a few specimens of Zoophytes in the British seas, that have sufficient calcareous matter in their composition to entitle them to the name of Corals, as commonly understood; those, however, which approach most nearly to this character, are species of the genera *Eschara* and *Retepora;* of the latter, the *R. Beaniana,* represented of its natural size at A, in Fig. 90, and a portion of which, when magnified, is shown at B, is so nearly allied to the Lace Coral of the Mediterranean — *Retepora cellulosa* — that Dr. Johnston and others at one time considered them to be identical. The polypidom is about an inch high, and is attached to rocks by a short, broad stalk; when dried, the calcareous matter is

FIG. 90.

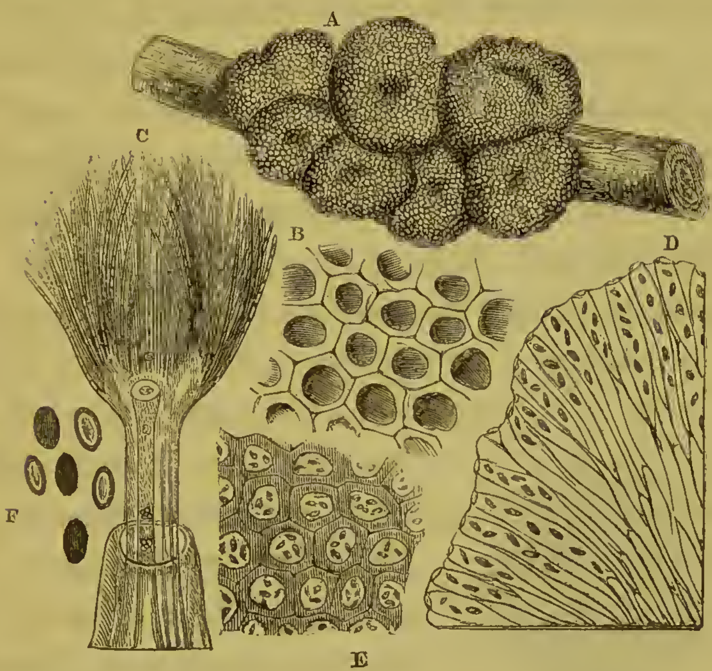


A, *Retepora Beaniana* of the natural size. B, portion of the same magnified.

quite white, and when portions are acted on by dilute hydrochloric acid, an organic basis is left, which retains the perfect shape of the original specimens. The large oval apertures, represented at B, give to the specimen its lace-like appearance; the smaller holes are for the lodgment of the polypes, which are provided with ciliated arms, like those of the *Flustra*. With this coral, I must conclude the structure of the skeleton of the first order of the Polyzoa, viz.: *Infundibulata*, and proceed to that of the second, or *Hyppocrepia*.

All the members of the order *Hyppocrepia* are inhabitants of fresh water, and are generally found attached to timber, or upon the under side of the large leaves of aquatic plants; one of the most common species, and that which first attracted the attention of naturalists, is the *Alcyonella stagnorum*, said to have been discovered by Trembley as long ago as the year 1741; it occurs in the greatest abundance on floating logs of timber in the West India Docks, and when first taken out of the water, is of a lobulated figure and brown colour, and its surface, as shown of the natural size at A, in Fig. 91, or magnified at B, exhibits a reticulated structure; these are the mouths of the polype-cells, in each of which, a polype with ciliated filiform tentacula, as shown at C, resides. The polypidom is soft and elastic, and feels very much like a sponge; when divided vertically, as represented at D, or horizontally at E, it is found to be principally made up of tubes, in the sides of which, numerous dark-coloured ova,

FIG. 91.

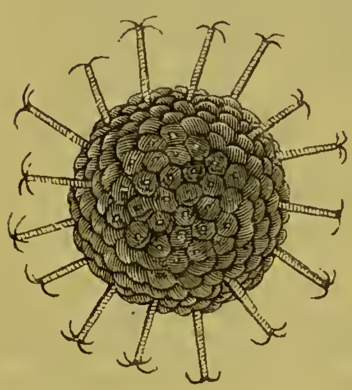


A, polypidom of *Alcyonella stagnorum* of the natural size. B, portion of the surface magnified. C, one of the polypes. D, vertical section of the polypidom, E, horizontal section of the same. F, ova (after Johnston).

as shown at F, are developed. The tubes themselves are composed of a transparent horny material, having a peculiar smell when the polypidom is alive, but which, after death, rapidly becomes black and putrid, and very offensive. No calcareous matter enters into the composition of the skeleton of this animal; my principal object in selecting it for description, is to point out to you the commonest, as well as the largest of the fresh-water Zoophytes, and one which will repay any investigator by the beauty of its polypes.

Another Zoophyte, also remarkable for the beauty of its polypes, is the *Cristatella mucedo* occasionally met with in ponds, in the neighbourhood of this metropolis; unlike the last described, the polypidom is a locomotive one. I rather think the ova are more commonly found than the Zoophyte itself, and when once seen are not easily forgotten, being of a globular figure, and surrounded with spines having recurved hooked extremities, as shown in Fig. 92; they might readily be mistaken for Xanthidia, and the specimen which you will have the opportunity of seeing, was brought to me as such. These ova are sometimes met with in searching for Infusoria; they should be kept carefully, and watched, as the young Zoophyte is one of the most beautiful objects imaginable. When collecting the *Alcyonella* from logs of timber in the docks, you can hardly fail in obtaining another Zoophyte, viz.: *Cordylophora lacustris*, which is often parasitic on the former. Its polypidom is horny, branched and tubular, each branch bearing a non-ciliated polype at its extremity; it was first discovered by Professor Allman, of Dublin, and classed by him with the Tubularidæ.

FIG. 92.



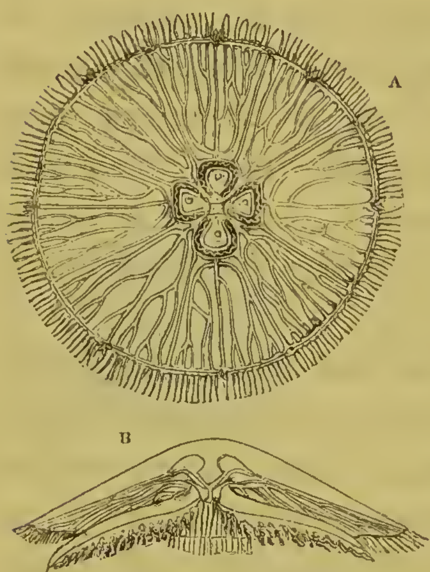
Ovum of *Cristatella mucedo*.

The next primary division of the Radiata to which I shall direct attention is that of the *Acalephæ*. From their soft and fragile texture, they are eommonly called "jelly-fish," or "sea-blubber," and from their stinging propensities, "sea-nettles." They are all inhabitants of the sea or of brackish water; many of them are phosphoreseent, and oeeur in vast shoals in the open sea, to which they give most splendid rainbow tints when the sun shines brightly on them, and almost every species is more or less remarkable for the beauty of its colours. In the Aealephæ we have a very slight rudiment of a skeleton, for the solid matter, which in external appearance more resembles eartilage than any other tissue, is so small in quantity, that a Medusa weighing ten or twenty pounds, when dried, will perhaps hardly weigh as many grains.

The only genera of this elass that ean be said to possess a true skeleton, are the *Porpita* and *Velella*, and in these it is composed of horn. The Aealephæ are divided by modern zoologists into four orders, the *Pulmograda*, *Ciliograda*, *Physograda* and *Cirrhigrada*, aeeording to the mode of progression. The *Pulmograda* are sub-divided by Professor Edward Forbes into the *Steganopthalmata*, or hooded-eyed, and the *Gymnopthalmata*, or naked-eyed. In the first the rudimentary eye, whieh is situated at the margin of the disc, is covered by a hood-like projeetion, whilst in the second the oeelli are exposed and unproteeted.

To the order *Pulmograda* belong all those soft, floating animals called Medusæ; each animal has an expanded disc, bearing a strong resemblance to the head of a mushroom, by the alternate contraction and expansion of which, it progresses rapidly through the water. The superior surface of the disc is generally convex, the inferior more or less concave, and in some species, as the *Cyanæa aurita*, Fig. 93, A B, four long fleshy tentacula, which are provided with prehensile stinging organs on their inner surfaces, project from the centre of the inferior surface of the disc; they surround a small mouth which leads into a quadrangular stomach, from each angle of which a ramified tubular prolongation passes towards the margin of the disc, where some of the extreme ramifications terminate in oval orifices. The margin of the disc, as shown at A, is provided with cirrhi, which are concerned rather in the function of locomotion, than in the prehension of food. The opaque parts seen in the centre of the disc near the attachment of the tentacula are the ovaries, these like the stomach, are quadripartite.

FIG. 93.



A, under surface of the disc of *Cyanæa aurita*. B, vertical section of the disc showing two of the tentacles.

Among the original preparations of John Hunter in the Museum of the College of Surgeons, are several Medusæ in which he had sueeeeded in filling the digestive cavities with eoloured injeetion, and in one of them the injeetion has not only passed down into the tentaeula, but also through the ramified prolongations of the stomach into a rich network of vessels distributed on the margin of the dise, bearing a strong resemblanee to the structure of the lung; he consequently plaeed it among the lowest of the series of preparations illustrative of the respiratory function, but the general opinion of modern physiologists is, that they represent a rudimentary vascular, rather than a respiratory apparatus. Under the microscope, a thin seetion of the substance of the disc of a Medusa is seen to consist of minute granular cells, like those of eartilage, imbedded in a homogeneous matrix; and in a slice removed from the outer surface, not only are there a multitude of these cells, but also numerous minute radiating fibres, which are probably the rudimentary eondition of the museular fibres said by Wagner to exist in the discs of *Oceania* and *Pelagia*. The outer integument of this specimen, however, is studded with a number of stellate crystalline masses somewhat like raphides in shape, but whether these are aeeidental or not I am unable to determine.

All the large Medusæ, sueh as those I have deseribed, belong to the family *Steganopthalmata* of Forbes, but almost all the smaller species are included in that of *Gymnopthalmata ;* for detailed descriptions of the British species, I must refer to the splendid monograph of Professor Forbes, published by the Royal Society. The most familiar example of the order *Ciliograda,* is the *Cydippe* or *Beroe pileus,* Fig. 94, which is found in great abundance in the Thames about Greenhithe and Gravesend in the summer season when the tide is flowing. It is very interesting to observe the movements of this animal when placed in a glass vessel of water; it will then be seen to consist of a transparent globular body, on the outer surface of which are eight bands of cilia, these by their rapid vibration, carry the animal through the water, and in direct sunlight each band presents all the colours of the rainbow. When undisturbed, two long, branched, filiform processes are protruded from cavities situated on the posterior part of the body, which may probably be concerned in the prehension of food. The stomach of the *Cydippe* occupies the centre of the globe, and from it a series of branches extend to all parts of the surface, as in the Medusæ. To this order also belongs the elongated *Cestum Veneris,* or Venus' Girdle, a ribbon-shaped animal provided with cilia on

FIG. 94.

Cydippe, or *Beroe pileus.*

its margins and remarkable for the brilliancy of its colours as it progresses through the water. In these animals there is nothing that can strictly be called a skeleton; the parts supporting the cilia in *Cydippe* are firmer than the others, but even these exhibit little or no structure.

As an example of the *Physograda* we have the well-known *Physalia pelagica,* or Portuguese man-of-war, Fig. 95, which, like the Medusæ, is remarkable for the beauty of its colours and its stinging propensities. This animal consists of a membranous sac, or bag, very like a stomach filled with air, which forms a float, one extremity being prolonged in the shape of a beak or snout, and provided with an opening through which the air may escape. Above the air-sac is a membranous crest, serving the purpose of a sail, and below it the digestive cavity from which depend two sets of organs, the tentacula and cirrhi; the former prehensile and stinging, the latter tubular and provided with a suctorial extremity or mouth, through which the food is conveyed to the stomach. The tentacula are capable of being drawn up nearly close to the air-bladder and then suddenly

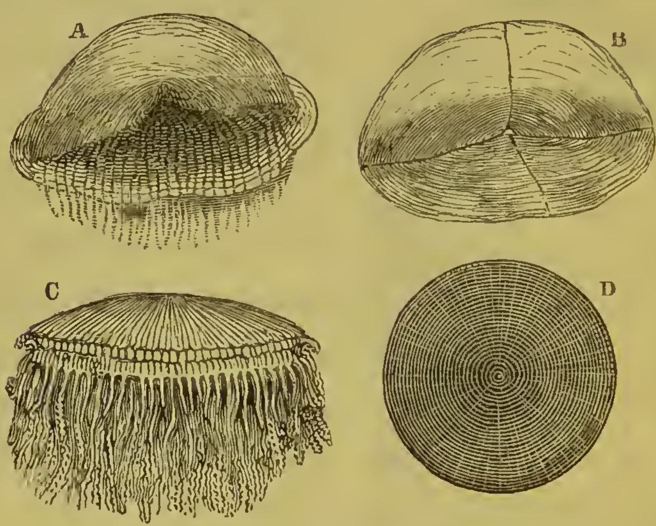
FIG. 95.

Physalia pelagica, or Portuguese man-of-war.

shot out to the distance of several feet, and by these, small fishes or other prey are rapidly seized and conveyed to the suctorial cirrhi.

There being scarcely any rudiment of a skeleton in these animals, I shall pass on to the last order, the *Cirrhigrada*, of which we may take the *Porpitæ* and *Velellæ* as types. The form of the Porpita, Fig. 96, C, is that of a flat circular disc, having a small mouth in the centre of its under surface,

FIG. 96.



A, *Velella limbosa.* B, horny skeleton of the same. C, *Porpita gigantea.* D, horny disc or skeleton of *Porpita.*

to which numerous dependent cirrhi are attached. Within the disc is a flat circular horny plate, D, occupying the greater part of its interior; this, which may be considered as the skeleton, presents radiating and circular striæ, and is composed of horny tissue so folded as to form radiating laminæ, and from its inferior surface, in some species, small tubular processes, like hairs, project. The alimentary and generative organs are so small in these creatures, as compared with the bulk of the horny skeleton, that the soft parts of the entire animal, when placed in spirit, can scarcely be distinguished from it.

When the horny skeleton is examined with a power of 40 diameters, its upper surface is seen to be covered with radiating furrows having interposed ridges, on each of which are seated two rows of small projecting spines. The under surface, or that to which the greater portion of the soft parts of the animal are attached, is more deeply furrowed, and plicæ, or folds of the mantle, fit accurately into the furrows, from which they can easily be removed by the application of a gentle force. The concentric markings have in all cases small scalloped edges, they occur at regular intervals, and are so many indications of the lines of growth; in the centre there is a circular depression, and between its circumference and that of the first concentric marking, there are eight flattened radii. If the under surface be examined with a power of 100 diameters, the ridges will all be found to have small jointed tubular processes, like hairs, projecting from them, which are the cirrhi; but in no part of the horny tissue is there any trace of a cellular or reticular structure. In the *Velella*, Fig. 97, A, the skeleton, B, is formed of an oval horizontal and of a vertical horny plate attached to the former at a right angle. The vertical plate, clear and transparent, is covered with a thin film of membrane, but it is to the horizontal plate that the organs of digestion and generation are attached, and in the centre of the under surface of this plate is the probosciform mouth, surrounded with a series of cirrhi, some of which are tubular, like those of the *Physalia.* The stomach, as in the Medusæ, is ramified, and extends to the margin of the disc; and as the animal floats on the surface of the sea, the vertical plate performs the office of a sail. When the horny skeleton is examined microscopically with a power of 100 diameters no trace of cellular structure can be discovered; it is nothing more than a mass of structureless horn, with concentric laminæ indicating the successive stages of growth.

LECTURE XII.

SKELETON OF ECHINODERMATA.

THE Echinodermata, so named from the circumstance of the bodies of these animals being covered with spines, form the third and last primary group of the Radiata. They are subdivided by Professor E. Forbes, the greatest British authority on this subject, into six orders, the division being founded on the mode of progression, or rather on the organs employed in locomotion.

These orders are the following :

1. Pinnigrada	Crinoideæ.
2. Spinigrada	Ophiuridæ.
3. Cirrhigrada	Asteriadæ.
4. Cirrhi Spinigrada	Echinidæ.
5. Cirrhi Vermigrada	Holothuriadæ.
6. Vermigrada	Sipunculidæ.

Of the first order, *Crinoideæ*, very few living representatives remain, and only one is found in the British seas; but in the earlier geological epochs the seas teemed with these animals, and they played a most important part in submarine life. Professor Forbes has so eloquently touched on this subject, that I cannot forbear citing a quotation from his work on British Star-fishes.

"One of the most remarkable phenomena displayed to us by the researches of the geologist, is the evidence of the existence, in primeval times, of animals and plants, the analogies of which are now rare or wanting on our lands and in our seas. Among those tribes which have become all but extinct, but which once presented numerous generic modifications of form and structure, the order of Crinoid Star-fishes is most prominent. Now scarcely a dozen kinds of these beautiful animals live in the seas of our globe, and individuals of these kinds are comparatively rarely to be met with: formerly they were among the most numerous of the ocean's inhabitants—so numerous that the remains of their skeletons constitute great tracts of the dry land as it now appears. For miles and miles we may walk over the stony fragments of the Crinoideæ, fragments which were once built up in animated forms, encased in living flesh, and obeying the will of the creatures among the loveliest of the inhabitants of the ocean. Even in their present disjointed and petrified state, they excite the admiration, not only of the naturalist, but of the common gazer, and the name of Stone-lily popularly applied to them, indieates a popular appreeiation of their beauty. To the philosopher they have long been subjeets of contemplation as well as of admiration. In him they raise up a vision of an early world, a world the potentates of whieh were not men, but animals—of seas on whose tranquil surfaees myriads of eonvoluted Nautili sported, and in whose depths millions of Lily-stars waved wilfully on their slender stems. Now the Lily-stars and the Nautili are almost gone; a few lovely stragglers of these onee abounding tribes remain to evidence the wondrous forms and struetures of their eomrades. Other beings, not less wonderful, and scarcely less graeeful, have replaeed them, while the seas in whieh they flourished have beeome lands, whereon man, in his columned eathedrals and mazy palaces, emulates the beauty and symmetry of their fluted stems and chambered shells."

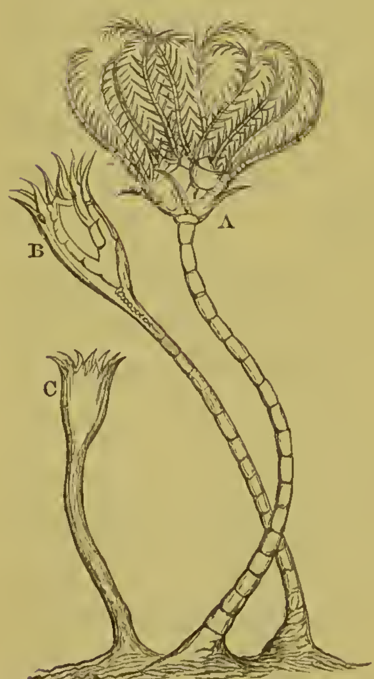
FIG. 98.

Comatula rosacea.

The only Crinoid animal that now inhabits the British seas is the *Comatula rosacea*, and I am happy to have the opportunity, through the kindness of my friend Dr. Aeland, of showing you an undoubted British specimen. I have here also a foreign speeies of Comatula, the *Comatula* or *Alecto glacialis*. According to Forbes the British species, Fig. 98, consists of a central portion, or disc, from which five short arms radiate, each of these very soon bifurcates and has a single row of small processes termed pinnæ attached to its sides. The arms are more or less solid, and composed of a series of joints which are made up principally of calcareous matter. The British *Comatula* is much smaller than the one I have just shown you, and as there is a curious history attached to this animal. I shall briefly relate it.

In the year 1823, Mr. J. V. Thomson discovered in the Cove of Cork a very minute Crinoid animal which he named *Pentacrinus Europæus*, Fig. 99; it was attached by a jointed stem to various sea-weeds, and measured not more than three-fourths of an inch in height. The stellate part of the animal was like a Comatula, but the stem was flexible and composed of about twenty-four joints, the lowest joint being expanded for the purpose of support. The discovery excited great interest in

FIG. 99.



A B C, enlarged view of *Pentacrinus Europæus* in various stages of development (after Forbes).

the zoological world, as this was the first Encrinite that had been seen in the living state. Mr. Thompson subsequently discovered that the *Pentacrinus Europæus* was only the young, or larval condition of the Comatula, which, commencing life as an Encrinite and subsequently becoming a Star-fish, was then capable of swimming rapidly through the water.

A few specimens of a living Pentacrinite have been found in the West Indian seas, similar to this one from the Museum, but these are so extremely rare that only four or five individuals have ever been brought to Europe. The recent Pentacrinite, represented in Fig. 100, resembles a Comatula mounted upon a long jointed stem, from which, at certain regular distances, five small rudimentary arms arise without any lateral pinnæ developed from them. The upper part of the stem is dilated, and on this, the disc of the animal is seated, from which, five radiating arms, resembling those of the Comatula in shape,

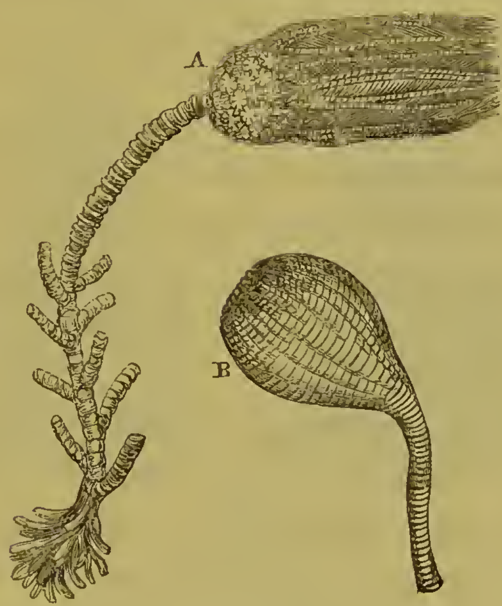
FIG. 100.

The body and upper part of the stem of a recent Pentacrinite, *Pentacrinus caput Medusæ*, from Barbadoes.

are given off, and in the specimen represented by Fig. 100, are very gracefully curved. The stem is about fourteen or fifteen inches long, and is composed of narrow equal-sized pentagonal discs, as shown at A, in Fig. 103. The arms also are composed of joints, or discs, but the lower part of the stem by which the animal was attached to the submarine rocks is lost. The discs are so numerous in some species of Pentacrinites, that they have been computed to exceed one hundred and fifty thousand.

Although so rare in the living state, fossil *Crinoideæ* are so exceedingly abundant in the lias and other limestones of this country, that some of these rocks seem to be almost wholly composed of their remains. The fossil species have been divided by naturalists into two genera—the *Pentacrinites*, in which the stem is composed of pentagonal discs, and the *Encrinites* proper, in which these discs are circular. The heads, or rather bodies of the Encrinites, especially when their arms are contracted, as shown at A B, in Fig. 101, so resemble the flower of the lily in form, that they are commonly called "stone-lilies," and the joints of the stem, which are frequently perforated, are called "wheel-stones," but in the north of England, from having been used as rosaries, are termed "St. Cuthbert's beads." The cavity of the stem in some species is very peculiar, and in the ironstone of Derbyshire, specimens are met with in which the joints have disappeared, and nothing more is left than the ironstone which filled the cavity in the centre of the stem, and from this resembling the thread

FIG. 101.



A, restored specimen of an Encrinite *Actinocrinites*. B, head of *Cyathocrinites pyriformis* (after Mantell).

of a screw, as shown at E, in Fig. 102, these stones are called "screw-stones." The body of a Pentacrinite

FIG. 102.

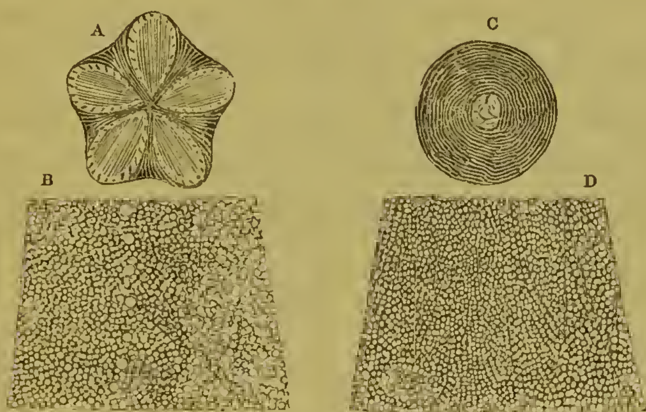
A, portion of the stalk of an *Encrinite*. B, C, articulating surfaces of joints of an *Encrinite*. D, portion of the stalk of a *Pentacrinite*. E, screw-stone of Derbyshire, being the cast of the hollow of an Encrinital stalk.

is more like a star-fish than that of the Encrinite, as will be seen by comparing Fig. 100 with A, in Fig. 101.

The general structure of the calcareous skeleton of the Echinodermata is well illustrated by sections of the shell of the Comatula, which is composed of a reticulated or areolar tissue, thickened by the deposition of calcareous matter; in some parts of the specimen an hexagonal network is visible, in others it has disappeared, and the calcareous matter of all the hexagons has become blended together, so that nothing but the areolæ are apparent, and these, from having no deposit, resemble so many holes.

I am so fortunate as to possess a portion of the stem of a recent Pentacrinite which will elucidate the true structure of the fossil species. Viewing the entire horizontal section of a joint of any Pentacrinite by a low power so as to bring the whole section into the field of view, it is seen to be composed of a central spot or cavity, from which radiate five leaf-shaped, figured portions, which are not arms, but only composed of hexagonal cells of smaller size than those in the other parts; on this account they are easily recognized by the naked eye, being always more conspicuous than the other portions of the joint, as shown at D, in Fig. 102, or A, in Fig. 103. In the recent specimen the margins of the figured portions are comparatively smooth, but in the section of a joint of a fossil Pentacrinite, represented by D, in Fig. 102, the margin of the figured portion is more or less indented. When a section of a joint of a Pentacrinite is examined with a power of 18 diameters, as shown at B, it is seen to be composed of an areolar structure, like that of cells having their walls thickened with calcareous material, a tissue identical with

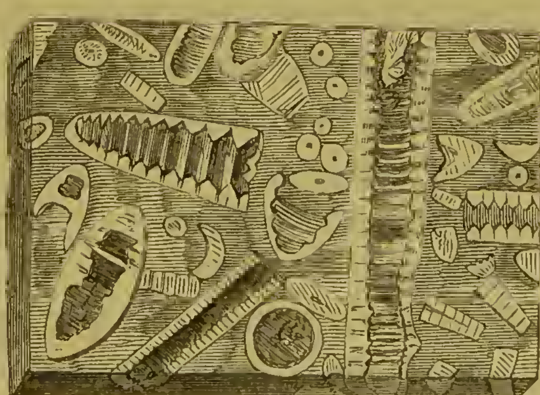
FIG. 103.



A, the articulating surface of a joint of a *Pentacrinite*. B, portion of the same magnified 18 diameters. C, articulating surface of a joint of an *Encrinite*. D, portion of the same magnified 18 diameters.

that forming the shell of the Echini and other Echinodermata. If, as frequently happens, portions of every part of a Crinoid animal occur in sections of limestone, as shown in Fig. 104, they are readily detected, but an observer familiar with their minute structure can

FIG. 104.



A section of Derbyshire marble full of the remains of *Encrinites*.

rceognize with the mieroseope even the smallest frag-ments.

Seetions of the joints of Enerinites have a large eentral eavity, whieh is often partially filled with crystalline deposit not present in the living animal, but the original areolar strueture is still visible throughout the substanee of the joint. The artieular surfaees of the joints are sometimes very beautifully marked, as shown at B and C, in Fig. 102, but the five-leaf-shaped figures eharaeteristie of the Pentaerinite are rarely present; as a general rule, the seetions exhibit little else than eoneentrie and radiating striæ.

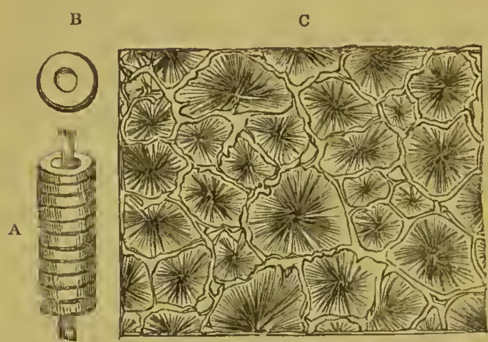
I have met with one speeimen, as shown in Plate XV, Fig. 4, of the "Histologieal Catalogue," in whieh there is a faint traee of the outline of a series of small leaf-shaped figures, but this is not a eonstant eharaeter, although it was very evident in the speeimen from whieh the drawing was made. When viewed with a power of 18 diameters, as shown at D, in Fig. 103, very little differenee is diseernible between the minute strueture of the joints of Enerinites and Pentaerinites, except that the areolæ are of uniform size, and more square in the former than the latter. In consequenee of there being a hole in the eentre of each of the joints of the Enerinite, they were employed in former times as rosaries, the joints, from this eireumstanee, having been ealled beads; and in the north of England, as before mentioned, whether first used by St. Cuthbert or not, they have reeeived his name.

In the shops at the east end of this metropolis, where objects of natural history and curiosities of all kinds are sold, necklaces may be met with consisting of a series of flattened discs quite white, each having a hole in its centre, through which a string is passed; in some cases pieces of leather are placed between the discs, but more commonly nothing of the kind is employed. These necklaces are said to be brought from New Zealand, or from the islands in the Pacific, but they in all probability come from some part of the coast of Africa, and are supposed to be joints of Encrinites.

About twelve months since I had a section made of one of these discs, and its structure turned out to be very peculiar; it certainly was not Encrinital, and I concluded that it was a portion of some shell; but about two months after this, I was shown a section of the egg-shell of an Ostrich which precisely corresponded in structure with the beads of the necklace, so that, in fact, these necklaces are not composed of the joints of Encrinites, but of portions of the egg-shell of the Ostrich, which have been rounded and drilled—a work of no small labour, especially if the necklace be of the length of the one I possess, which is upwards of three yards. A portion of this necklace is represented of the actual size at A, in Fig. 105, and one of the discs at B. When magnified 50 diameters, after being reduced sufficiently thin to be transparent, it presents the appearance shown at C.

From the structure of the beads then, there is every reason to believe that these necklaces are brought from the coast of Africa, and not from New Zealand; but if from the latter place, the shell must be that of the Dinornis, although this differs in structure from that of the Ostrich, with which these beads agree in every particular. A section from the upper surface of one of these beads, exhibits a series of more or less triangular crystals, corresponding precisely with the structure of the outer part of the shell of the Ostrich, which is made up of crystallized carbonate of lime.

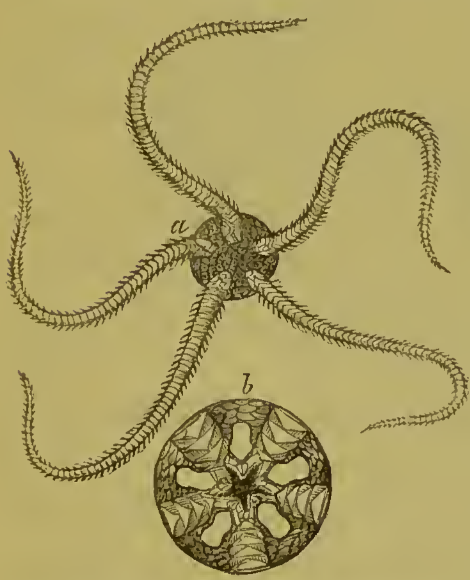
FIG. 105.



A, portion of the necklace of the natural size. B, a single disc of the same. C, portion of a disc magnified 50 diameters.

The second order of Echinodermata, the *Spinigrada* is composed of the *Ophiuridæ*, or Brittle Stars. These animals consist of a central portion, or disc, containing the organs of digestion, from which, as shown at *a* and *b*, in Fig. 106, radiate five or more solid jointed arms; in some species the arms are smooth, but more commonly, thickly covered with spines, and in the genus *Euryale*, the arms are divided into a number of branches. All the animals composing this order are brittle, whence their vulgar appellation; so that it is rare to find a perfect specimen, for unless some quick mode of killing them be adopted, the arms are sure to break. The plan usually recommended is to immerse them while living into a vessel of fresh water. These animals possess the power of reproducing the arms if broken off, and it is even stated that when a portion of the disc is left attached to an arm, the entire animal may be reproduced. The shelly covering of the *Ophiura* exhibits under the microscope a reticulated or areolar structure; the openings or areolæ in the reticulations are circular, and average about $\frac{1}{2000}$th of an inch in diameter; they are generally arranged in parallel lines, following the direction of the arms. The spines of this animal, as will be hereafter shown, are composed of the same reticulated structure; they are of conical figure, and their edges slightly serrated. The arms of the Ophiuridæ are covered with a contractile integument, which, acting on the joints, renders them capable of moving through the water with some rapidity. Within the disc is the stomach, which, like that of the *Actiniæ*, has but one orifice, as shown at *b*, in Fig. 106, and around the mouth is a series of small tentacula,

FIG. 106.



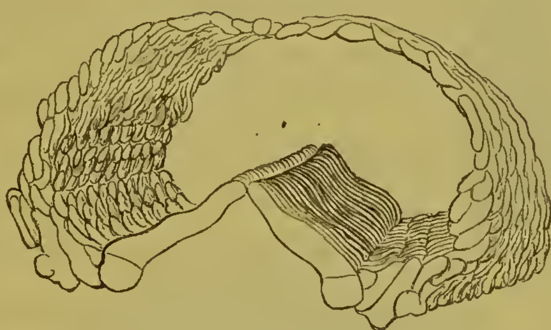
a, *Ophiura texturata*, or common Sand Star. *b*, under surface of the disc of the same (after Forbes).

probably employed in the prehension of food. If the under surface of the disc, after having been well cleaned and dried, be examined as an opaque object with a power of 20 diameters, it will be seen that those five portions of the skeleton which form the aperture of the mouth are provided with strong, sharp-pointed moveable spines, so arranged as to give the idea of their serving the office of teeth.

The third order of the Echinodermata, the *Cirrhigrada*, in which are included the *Asteriadæ*, or Star-fishes, differs from the *Ophiuridæ* in this essential particular, that whilst in the latter the arms are solid and attached to the central disc, in the former the rays are prolongations of the central portion; moreover, the rays of the Star-fish are tubular, and contain very important organs auxiliary to digestion and locomotion. In some families, as the *Urasteriæ*, the rays are five in number, in the *Solasteriæ* twelve or more, and in the *Goniasteriæ* and the *Asteriæ* they scarcely exist at all. The skeleton in our common *Asterias rubens*, is composed of a series of joints somewhat like vertebræ; these are arranged in the form of a triangle, and over them, as shown in Fig. 107, is a series of shorter and thicker pieces forming an arch; the whole is covered by a horny membrane, in which there is a distinct hexagonal network of calcareous matter. The outer surface of this horny covering is generally provided with spines, which in the great *Asterias echinites*, are as large as those of any British species of Echinus.

The largest segments of calcareous matter forming the skeleton are arranged around the mouth in an annular

FIG. 107.

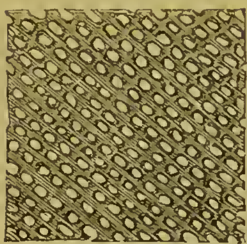


A vertical section of the skeleton of one of the rays of *Asterias rubens* (after Sharpey).

form; there is also in the Asteriadæ a small tubercle of calcareous matter called the "madreporeform tubercle," Figs. 135 and 136, with which is connected a canal to be noticed hereafter. The digestive system of the Asteriadæ consists of a stomach, occupying the centre of the body, which communicates with, or is prolonged by, a series of cœca, extending the whole length of the rays or arms; but on this I shall not now enlarge, as our attention is for the present confined to the structure of the skeleton.

Thin sections of the outer crust or shell of a common Star-fish, the *Asterias rubens*, are seen to be composed of a series of layers of calcareous matter of the usual characteristic reticulated tissue, as shown in Fig. 108, the meshes or areolæ being either round or oblong, and the walls exceedingly thick; indeed, all the parts of the skeleton, however massive, exhibit more or less of this same structure; a precisely similar appearance is found in sections of the madreporeform tubercle. Star-fish and Ophiuræ occur abundantly in the fossil state; the remains of Ophiuridæ are found in the lias limestone, and Asteriadæ are frequent in the chalk. Separate joints of the *Pentagonaster* are common in the latter, they consist of reticulations with a square outline, and a circular, or rather globular cavity. In these fossil specimens the square outline is not so decided as in the recent animal, and the cavities are filled with a granular matter, which forms the usual contents of cells in fossilized specimens.

FIG. 108.



A portion of the skeleton of a Star-fish, *Asterias rubens.*

On the external surface of the shell of *Asterias rubens,* as shown in Fig. 109, are numerous club-shaped spines, each surrounded by a ring of smaller ones, the interspaces between the spines being occupied by small bodies resembling minute mussel-shells mounted on a stalk, as shown at *a, a;* these are *Pedicellariæ,* which have been supposed to be parasites, but when carefully examined, are found to have a calcareous skeleton

FIG. 109.

Portion of the integument of *Asterias rubens. a a, Pedicellariæ.*

exhibiting the structure characteristic of the skeleton of the *Asterias*, and must be viewed as parts of that animal. They will be again alluded to when describing the Echini, in which they also exist. The spines of this Asterias are short and tuberculated, but those of the large *A. echinites*, as shown by *a, a, b,* in Fig. 110, are

FIG. 110.

A, *Asterias echinites* one-fourth of the natural size. *a, a, b,* spines o *A. echinites* of the natural size. *c,* a segment of a transverse section of a spine of a Star-fish of the genus *Astropecten*. *d,* a corresponding segment of a spine of *Asterias echinites*.

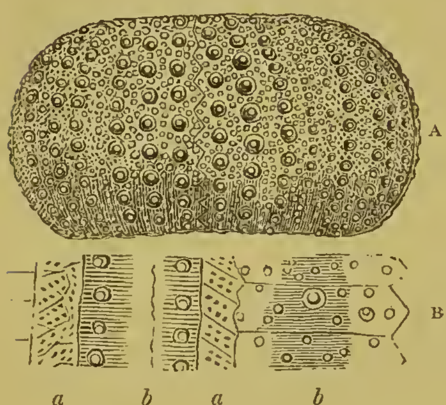
conical, and of sufficient size to be cut transversely. A segment of a transverse section, as shown at *d* in Fig. 110, exhibits a series of areolæ, or meshes, surrounded by thick walls of calcareous material remarkable for their rounded figure. In sections of spines of a species of *Astropecten*, shown at *c*, the reticulated structure is firmer, and the areolæ are arranged in radii, their size increasing gradually from the centre to the circumference; but the structure of these spines is very different from that of the Echini, which will be noticed in a future Lecture.

LECTURE XIII.

SKELETON OF ECHINODERMATA.

In my last Lecture I described the structure of the skeleton in the three first orders of the Echinodermata, viz.: the *Crinoideæ*, *Ophiuridæ*, and *Asteriadæ*, and I now proceed with the fourth order, the *Echinidæ*, the British species of which are divided by Professor Forbes into three families, the *Cidarites*, *Clypeasteriæ*, and *Spatangaceæ*. In the *Cidarites*, the skeleton, as shown in Fig. 111, A, is more or less globular, containing within it the organs of digestion and generation, while the external surface (Figs. 113 and 115) is covered with spines of variable form and size. The shell is composed of plates, usually of a square or oblong figure, some of them having smooth edges, others more or less indented. There are two sets of these plates, the ambulacral, *a*, *a*, Fig. 111, B, perforated with small openings through which the tubular feet project, and the interambulacral, *b*, *b*, which are not perforated, and they are all covered externally with tubercles to which the spines are articulated. The spines, however, as shown in Fig. 113, are generally so close together as to obscure the arrangement on the outer surface, but when the shell is divided vertically and viewed from the interior, the two sets of plates are seen to be disposed in alternate perpendicular columns, diminishing gradually in size from the oral to the anal pole of the spherical skeleton. Each plate being of a polygonal figure, elongated transversely, as shown at B, in Fig. 111; the margins of the columns present a serrated appearance, and form, when united, a very strong suture.

FIG. 111.



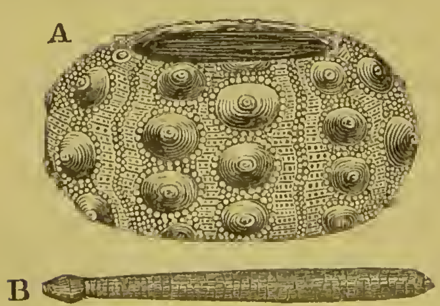
A, shell of *Echinus lividus*. B, portion of the shell *Echinus Flemingii*. *a*, *a*, ambulacral plates. *b*, *b*, interambulacral plates (after Forbes).

In the Echinus there are five double columns of ambulacral and the same number of interambulacral plates; the number of columns being determinate throughout this tribe, while the number of plates composing each column is extremely variable, according to the age of the animal. The interambulacral plates are much larger, but proportionally less numerous, than the ambulacral plates, and their whole surface is covered with tubercles for the support of the spines, while half of each ambulacral plate is pierced by oblique perforations for the passage of the ambulacral feet or suckers. The lateral edges of each of the plates form obtuse angles, which, by their apposition with the similar angles of the plates of the adjoining column, constitute a very regular serrated suture which greatly contributes to the strength of the entire skeleton. The adjoining edges of the ambulacral with the interambulacral plates are straight and minutely indented or serrated, and form a much finer suture than that between the two columns of similar plates, whether ambulacral or interambulacral. The plates around the oral and anal orifices differ from those in other situations; the genital plates around the anus—five in number—being heart-shaped and perforated for the five ducts of the genital sacs, while those around the oral, or inferior orifice, are large, and send inwards and upwards broad arched processes serving to give attachment to the muscles of the jaws.

In the Spatangi, the shell is always more or less flattened, and the plates of which it is composed are very variable in shape; the perforations of the ambulacral plates are generally arranged in the form of a star upon the upper surface of the shell, and in the centre of the star are seen the openings of the genital apparatus; but in the *Spatangus purpureus*, the position of the mouth is on the under surface of the shell, whilst the anus is on one side. The oral outlet is the largest, it is always situated on the under surface of the shell; with this, in most of the Cidarites, is connected a very complicated and beautiful dental apparatus, which was first accurately described by Aristotle, and by him compared to a lantern, hence this part of the shell is commonly called the "Lantern of Aristotle." It is composed of a series of pieces, all of which give attachment to muscles employed in the movement of five sharp-pointed teeth; some species have no teeth, the *Spatangus purpureus*, for example, is not provided with these organs.

The outer portion of the shell, as before stated, is covered with tubercles to which the spines are articulated; they are always of a convex figure, and in some genera—for instance, *Cidaris* and *Diadema*—the largest tubercles, as shown at A, in Fig. 112, have a depression in the centre, to which is attached one extremity of a round ligament like that of the hip-joint in the human subject, for the better security of the large spines. In the *Spatangi* the tubercles are very small, giving the surface a minutely granular appearance. The *Cidarites* are exceedingly numerous in a fossil state, especially in the chalk strata; it is more common, however, to find the siliceous casts of

FIG. 112.



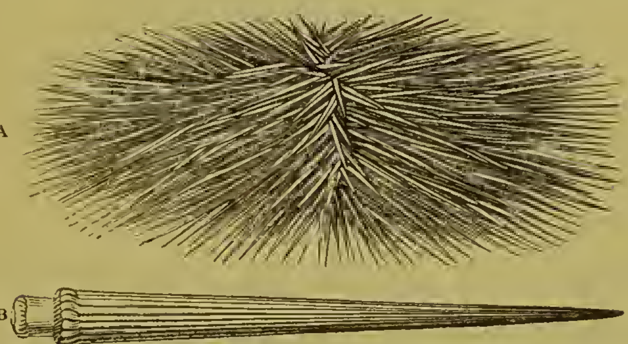
A, shell of *Cidaris papillata*. B, spine of the same (after Forbes).

the internal cavity of the shell among the flints of the chalk, than the shell itself, the latter having usually disappeared. The occurrence of these casts may be traced to the habits of these animals; their whole intestinal canal being generally filled with sand, and this attracting the silica contained in the water which filtrates through the strata, the whole internal cavity of the shell becomes gradually filled with solid flint, while the calcareous shell itself is slowly dissolved and disappears, leaving only the siliceous cast of its interior.

The minute structure of the shells of this order of Echinodermata, is precisely similar to that in the preceding orders. Horizontal sections of the inter-ambulacral plates of the *Echini*, for example, are composed of an areolar or reticulated tissue of hexagonal figure, but the size of the areolæ is not uniform: in some parts they are very large, in others very minute, and the framework much broader than the spaces it encloses. The differences in size of the reticulations are readily explained by other sections at right angles to the preceding, in which three kinds of reticulated structure may be readily recognized, so arranged as to give a great amount of strength and support to the tubercles. The first of these occupies nearly the entire thickness of the shell, forming a curved band extending from one side of the section to the other; external to this, in the middle line, is another curved band of very coarse network, formed by branching vertical eolumns, which support a very dense tissue eomposed of minute rctieulations, and upon this thc tuberele is situated. This external band is composed of the same tissue as the portion supporting it, but a dark line of separation is very perceptiblc between them. On either side of the dense tissue supporting the tuberele may be seen a band of fine retieular strueture, having its meshes arranged in a longitudinal direction; above this is a similar tissue, with its meshes disposcd at right angles to the former, presenting a eonvex margin, and forming the semi-eireular prominenee upon whieh the tuberelc is situated. Thc external, or artieulating surface of thc tuberele, is surrounded by a narrow band, or zone, differing somewhat in structure from that of any other portion of the tubercle.

Horizontal sections of the shell of the *Spatangus* exhibit a retieulated structure somewhat like that of the *Echinus*, but all the openings or areolæ are circular, and nearly uniform in size; the framework of the rcticulations, or the eell-walls as they may bc termed, are exeeedingly strong, and in some eases as broad as the arcolæ themselves. Some parts of the shell appear to be composed of laminæ, separated from each other by a series of minute pillars. The spines in this tribc of animals, as I have already statcd, are extremely variable, and are by no mcans propor-tionatc cither in size or number to that of thc shell. In one specics, *Echinus esculentus*, the shell is fully five inches in diameter, and the spines are not half an inch in length; other species, as, for instanee, *Echinus lividus*, Fig. 113, are so thiekly covered with spines

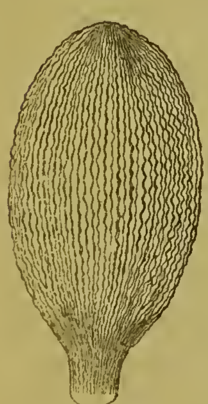
FIG. 113.



A, *Echinus lividus*. B, one of the spines magnified (after Forbes).

that no portion of the shell ean be seen between them, while in others again the spines are longer than the diameter of the shell. In some Eehini the spines are as mueh as five inches in length, and thin in proportion, while in certain fossil speeies of Cidaris, as in *C. glandifera*, Fig. 114, they are so short and thick as to assume an oval figure, and have, on more than one oeeasion, been taken for fossil fruits. The spines of most Eehinoderms are longitudinally grooved, as shown at B, in Fig. 113, others, as represented by B, in Fig. 112, have transverse grooves as well, so that the surfaee presents a beaded appearanee. In the Echini, as shown in Fig. 113, the spines on the greater part of the shell are tolerably uniform in size; but in the

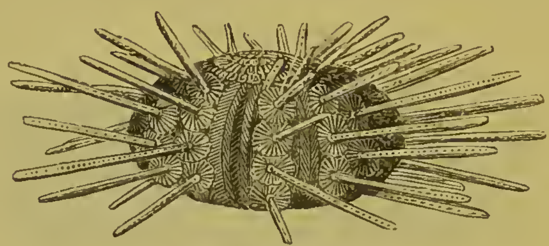
FIG. 114.



Spine of fossil *Cidaris*, *C. glandifera*.

genus *Cidaris* there are two kinds, as shown in Fig. 115; all those of large size having a series of smaller

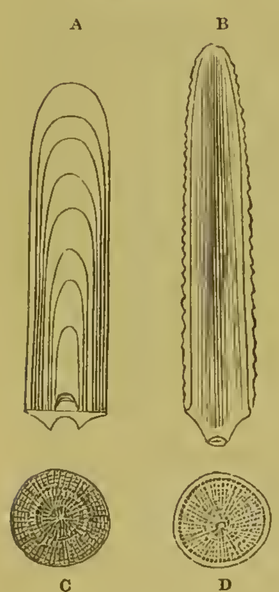
FIG. 115.



Cidaris papillata (after Forbes).

ones arranged in a radiated manner around their bases; other small spines are disposed in oblique rows on either side of the avenues for the cirrhi. It is, therefore, a very easy matter to distinguish a *Cidaris* from an *Echinus* at first sight; the spines themselves, as will hereafter be shown, also differ considerably in their minute structure.

FIG. 116.

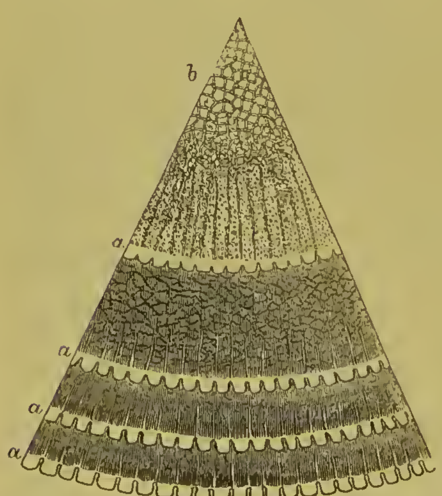


A, vertical section of a spine of an *Echinus*. B, vertical section of the spine of a *Cidaris*. C, transverse section of the spine of an *Echinus*. D, transverse section of the spine of a *Cidaris*.

In order to arrive at a correct knowledge of the mode of formation of these spines, it is necessary that both vertical and horizontal sections be examined. A vertical section of the spine of an Echinus, as shown at A, in Fig. 116, is composed of a series of cones arranged concentrically; a corresponding section of the spine of a Cidaris, as shown at B, exhibits no trace of cones, but merely a reticulated structure throughout, coated on its external surface with a thick layer of calcareous matter, generally more or less coloured, and penetrated by a series of tubes, to which I shall presently advert. Transverse sections of the spines of the Echini differ in structure according to their distance from the base of the spine; thus, a section taken near the apex will show only one cone divided transversely, whilst one taken near the centre will show four or five, and in one near the base, as represented by C, ten or twelve will be exhibited. In the Cidarites, on the contrary, there are no cones, and a transverse section, as shown at D, will present nearly the same appearance from whatever part of the spine it may have been taken. The densest part of the spine, is that which forms the socket for the reception of the tubercle, and sections made through this, differ considerably from those taken from any other part of the spine. A vertical section of a large spine of an Echinus, *E. mammillatus*, which has on its outer surface, near the top, two white lines or markings, shows that when the spine consisted of only one cone the white marks were then present, and the same will be seen in every succeeding cone. If a vertical section of one of these spines, made sufficiently thin to be transparent, be examined, and if that part which contains the greatest number of cones be placed in the centre of the field of view, it will be seen that the tissue of the base is much closer than that of any other part. The entire spine is made up of seven cones fitted, as it were, one over the other, each being indicated by a white structureless line, having on its inner side a purple streak; running up through the middle is a diverging column of reticulated tissue of a different structure from that composing the series of cones; the reticulations of the cones being so much smaller than those in the centre, and their direction being principally radiated, they are readily distinguished.

The cones in transverse sections are all represented by transparent, structureless annular bands, as shown at *a a a*, in Figs. 117 and 118; these are equal in number to the cones included in the section. Each cone has its outer edge slightly undulated, and in many specimens, as shown at *b*, in Fig. 117, the centre is occupied by a diverging column of reticulated structure differing from that composing the cones, the reticulations of which are smaller than those of the central column, and radiated.

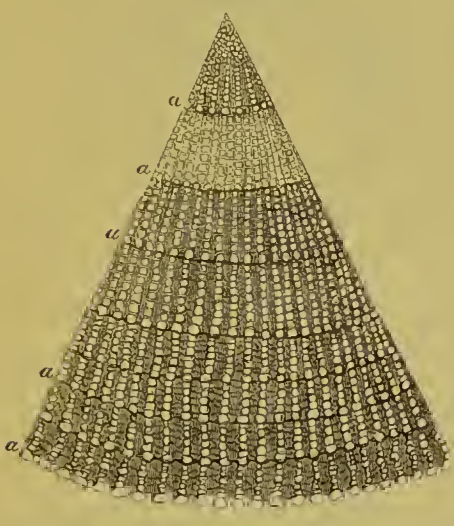
FIG. 117.



Segment of a transverse section of *Echinus lucunter*. *a*, *a*, *a*, divided cones with scalloped edges. *b*, reticulated structure in the centre.

The spines of some Echini, as, for instance, *E. lucunter*, Fig. 117, which are of large size, have a considerable space between the cones, and the centre, *b*, is occupied by the coarse reticulated tissue before noticed. In another species, *E. trigonarius*, the spines are very long, generally of triangular figure, and the cones very numerous. A segment of a section taken near the base is represented in Fig. 118; no less than nine cones have been divided, and it will be noticed that those near the margin are very close together. In order to understand the disposition of the cones, a spine should be selected, and sections taken at equal distances from the apex to the base; such has been done in the case of a spine of *Echinus miliaris*, a small species, and a section made just above the base, exhibits near the centre, a coarse reticulated tissue surrounded by a thin band with smaller meshes; this is again encircled by a zone of transparent structureless tissue indicating the innermost cone, then another zone of reticulated tissue, followed by another cone, and this structure is repeated according to the number of cones included in the section, until we arrive at the external part, which has little or no

FIG. 118.



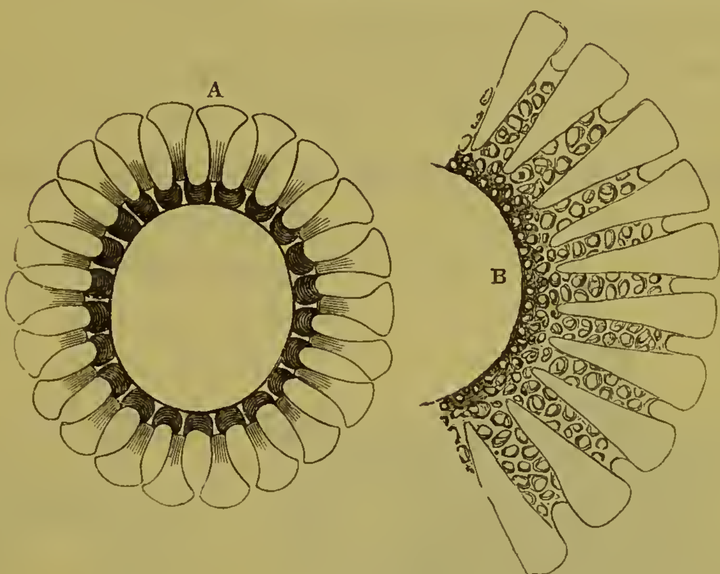
Segment of a transverse section of *Echinus trigonarius*. *a*, *a*, *a*, divided cones (after Carpenter).

structure, except that of the cones. In another section taken from the middle of the spine, the central reticulated arrangement occupies fully two-thirds of the breadth of the entire section, and on the margin there are three rows of cones having a slight trace of reticulated structure between them. In a third section, taken from near the apex of the same spine, the coarse reticulated structure is present in the centre, but the band surrounding it extends as far as the margin; this band, however, is composed of a row of transparent spots indicating the several parts forming the outer cone. The external surface of all the spines is more or less grooved, and therefore in making these transverse sections, although the margin is preserved entire, it will always present a series of indentations caused by the grooves, as shown at *a a a*, in Figs. 117 and 118.

A transverse section of a small brown spine of an *Echinus* taken from the base, was found to be made up of little else than concentric rings formed by the cones, except the margin, which was composed of a broad zone of very close tissue, like that of the vertical section already described; this arises from the section having been made through that part of the spine to which the ligament was attached.

Some species of Echini have hollow spines; in these the reticulated structure is very small in quantity, as shown at B, in Fig. 119, but sections may be made in which none of this structure is present, as represented at A. All the hollow spines examined by me have been very long and thin, and deeply furrowed on the

FIG. 119.



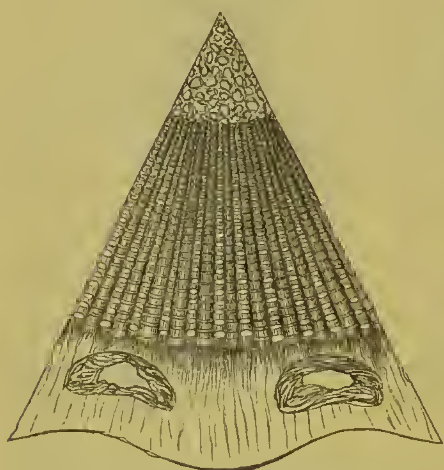
A, a transverse section of a hollow spine of an *Echinus*. B, a segment of a corresponding section of another hollow spine, exhibiting a small amount of reticulated structure.

external surface, and the base of each much larger than any other portion.

A vertical section of a spine of a *Cidaris*, as shown at B, in Fig. 116, exhibits no trace of cones; the base is composed of fine reticulated tissue disposed in a radiated form, the direction of the radii being from the centre towards the base. This fine structure ends abruptly in the centre of the spine, and forms a curved line from which numerous parallel columns of reticulated tissue arise, each being connected with its neighbour by broad transverse bands, the columns in the centre being stronger and differently marked from those near the circumference. On the margin, which is slightly undulated, is a coating of calcareous matter into which large tubuli pass, some of them projecting beyond the calcareous coating, in the form of spines.

In a transverse section of a small spine of a *Cidaris* of a beautiful brown colour, the central portion, as shown in Fig. 120, is composed of large reticulations, while the external part is made up of smaller ones, which are very minute near the centre, and gradually increase in size towards the margin, where they are disposed in a radiated manner. The marginal crust shows the tubuli before described; the edge is indented, and many large perforations occur at tolerably regular distances, midway between the margin and the reticulated structure. In a section of the spine of another species of *Cidaris*, the centre is composed of reticulated structure, but the marginal crust is very broad and transparent under a low power; being viewed with a higher power, the tubes are plainly seen running through it, and it is evident that they are continuations of what appear to be radii, passing from the centre towards the margin. Many of these tubes bifurcate within the crust, and a portion of

FIG. 120.

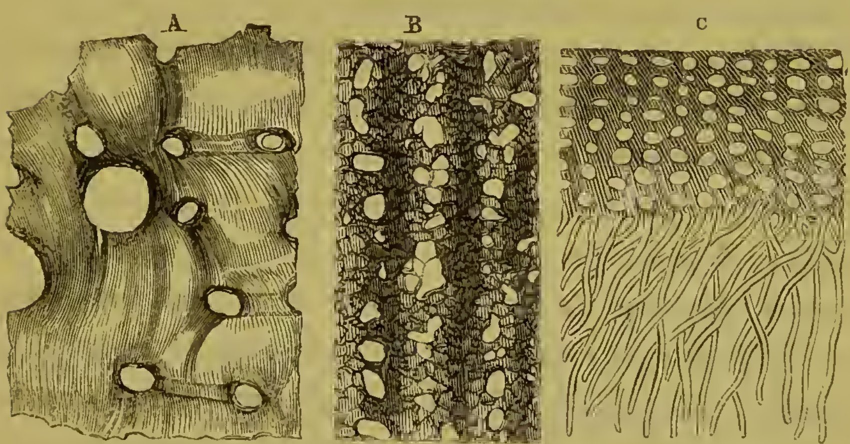


Segment of a transverse section of a spine of a small *Cidaris*.

the same spine, from which the calcareous matter of the crust has been removed, exhibits the tubes projecting like so many spines, as shown at C, in Fig. 121; they are connected with the last row of reticulations, and are evidently tubular, but what their precise office is, it would be difficult to determine.

Not only is the crust of some of these spines traversed by tubes, but the central shaft also: in Fig. 121, A, is shown a portion of the crust of a *Cidaris* spine, in

FIG. 121.



A, a portion of the crust of a spine of a *Cidaris* showing the tubes. B, part of the interior of a spine exhibiting tubes divided transversely. C, a portion of the margin of a decalcified spine showing the tubes of the crust.

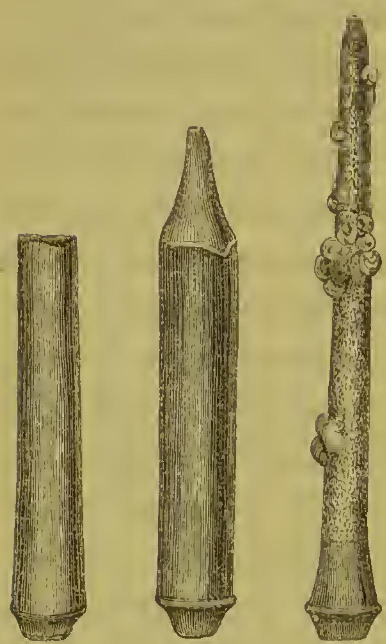
which there are numerous tubes of large size, and at B, a vertical section of another spine in which the tubes are divided transversely. Such an appearance as here represented, is very common in the spines of the Cidarites, but I have never yet seen anything at all like it in those of the Echini. There is also another curious point in connection with these spines that here requires mention, viz.: the faet of their being sometimes eovered with shells during the living state. I have met with very many speeimens of Cidaris in whieh some of the spines have had small shells attached to them, as represented by c, in Fig. 122, but I have never diseovered a shell upon a spine of an Eehinus; it would appear, therefore, that the ealeareous erust already notieed as being present in greater or less abundanee upon all Cidaris spines, performs the part of an insensible eutiele, and is in eonsequenee favourable to the attaehment of shells and other marine animals.

In most works on the anatomy of the Echinodermata, it is stated that all parts of the shell, as well as the spines, are eovered with a soft organie membrane, and that from this the ealeareous material is seereted; this tissue dips down between the edges of the plates of whieh the shell is formed, and it is supposed that the deposit of new matter and the formation of new plates during the growth of the animal, first eommenee in this membrane. The shell is eertainly eovered with an organie investment, but I eannot find any traee of it in the spines. I have taken spines that have never been dried, and have subjected them to the aetion of aeid, but have never yet sueeeeded in detaching anything like a eutiele or periosteum.

If an Eehinus spine be partially deealeified by acid, the eones of whieh it is built up may be distinctly traeed, and it is seen that the organic matter is very small in quantity, exeept at the base, where it is much more abundant; I am of opinion, therefore, that the vitality of the spine is chiefly sustained by this part, which is intimately connected with the organic investment of the shell. I have ascertained that these spines, like corals and shells, possess within themselves the powers of repair, as is exemplified by many specimens in the Museum of this College. The Echini, like most other creatures inhabiting the sea, have their natural enemies, which I believe to be principally fish, and I have lately found no less than eleven specimens of a small Echinus, *E. miliaris*, in the stomach of a Wolf-fish, *Anarrhicas Lupus*. In this instance the spines had all disappeared, but I have seen various specimens taken from the stomach of other fishes in which the spines were present, but detached and broken.

In a large species of Echinus, *E. lucunter*, from the Museum, many of the spines are broken, having the lower part still attached to the shell. This could only be effected by some cutting instrument, such as the strong teeth of fishes, for if the attempt were made to break the spine in any other manner, it would be detached from the shell rather than break, and on the attached extremities of some of these spines the marks of teeth can be plainly distinguished. Fractured spines, such as that shown at A, in Fig. 122, as well as others in various stages of the process of repair, are found on many Echini; some of these, as represented by B, are terminated by a blunt cone differing altogether in structure from the other parts of the spine, and indicating a new growth. These cones are of a brown colour, and entirely destitute of the striæ and markings observed in the normal structure of the spines. After I first noticed this peculiarity, I proceeded to make a vertical section of one of these spines, when the distinction between the old and new parts became very apparent—the old portion showing the cones and ordinary minute structure, while in the new part they were altogether absent and the line of fracture could be seen by the naked eye. When viewed with a power of 40 diameters, as shown at C, in Fig. 123, the distinction between the old and new structures is still more evident; the cones of the former, *a*, *a*, *a*, are green, while the new part, which is of a darker shade than the old, has no cones, and the line of fracture is, therefore, well defined.

FIG. 122.

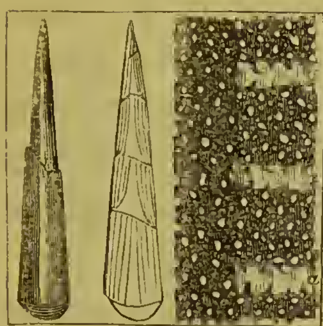


A B C

A, a fractured spine of *Echinus trigonarius*. B, a spine of the same *Echinus* in process of repair after fracture. C, a spine taken from a *Cidaris* having small shells attached to it.

Soon after I gave a description of these fractured spines in the first volume of the "Histological Catalogue," I was favoured by my friend Mr. Benjamin Tucker with two specimens, one of which, as represented by A, in Fig. 123, had been fractured and completely repaired. The new portion is an inch and a half in length, and of the same colour as the original spine, but the line of fraeture remains distinetly visible. The other speeimen on vertical seetion, as represented by B, clearly shows that four sueeessive fractures have been repaired, one of these being transverse, the others more or less oblique. It is evident then, that although these spines are unprovided with vessels, they possess within themselves the power of repair, as long as the animal is alive and the ligamentous matter entire. In the transverse seetions of some fossil spines of the Cidaris, the retieulated structure can still be distinetly recognized, but in others, all traces of it are lost, in eonsequence of the carbonate of lime having assumed a crystalline arrangement; the latter being the most eommon condition in speeimens from the ehalk strata.

FIG. 123.



A B C

A, a spine of an *Echinus* showing a fracture repaired. B, vertical section of another spine indicating four successive reparations of fractures. C, a section of a spine made in the line of fracture. *a, a, a,* portions of cones of the original spine; the part to the left of these is new matter, and shows no trace of cones.

There yet remains a part of the skeleton of an Eehinus demanding examination. This is the Lantern of Aristotle, whieh I briefly alluded to in the first part of the present Lecture; it eonsists of a series of bones, all of which are connected with muscles destined to move five symmetrical teeth. Some of these picees are attached to the shell, whilst others can be readily separated from it when the soft parts have become dry. The pieces attached to the shell are five in number, they are generally perforated in the centre, and arched in form; they give origin to ten pairs of muscles, five of which are for the purpose of protruding the teeth, the other five for retracting them and enlarging the aperture of the mouth and œsophagus. The teeth are sharp-pointed and curved, as shown at A, B, in Fig. 124, each being composed of a dorsal plate having a fin-like process attached, for the purpose of strengthening it, so that a transverse section somewhat resembles in outline the letter T, as represented at C. Each of the teeth is enclosed in a triangular piece of bone, named the alveolus, or jaw, as shown in Fig. 125, two surfaces of which, as there represented, are composed of laminæ of calcareous matter; the thin edges of the laminæ project towards the œsophagus, so that it is by no means improbable that they may act as grinding surfaces. The curved levers seen on the upper part of this figure, are acted on by muscles arising from the arched processes attached to the shell. When the entire number of jaws—viz.: five—are present, the so-called Lantern of Aristotle is complete,

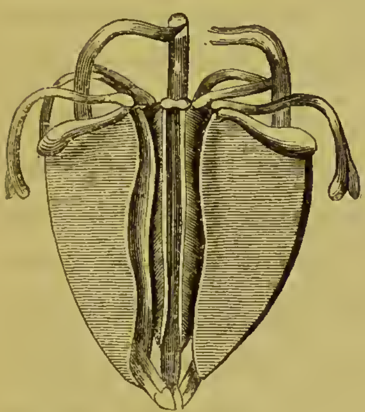
FIG. 124.

A C B

A, front view of a tooth of an *Echinus*. B, side view of the same. C, transverse section of a tooth of an *Echinus* magnified 12 diameters.

but this apparently complicated apparatus is very simple when dissected in the recent state, the combined action of all the muscles being to approximate the entire mouth to the oral aperture of the shell, as well as to cause the points of the teeth to protrude externally; or if the muscles act separately, as stated by Professor Rymer Jones, they can either draw the base of the lantern in any direction, or cause the laminated grinding surfaces of the jaws to work against each other.

FIG. 125.

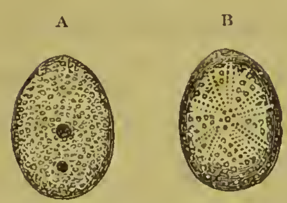


Three of the five jaws of an *Echinus*, enclosing a corresponding number of teeth.

The intestine of the Echini is of great size, and forms a spiral of two turns and a half, within the shell. When opened, it is found to contain a large quantity of sand, consisting chiefly of minute fragments of shell, which have been swallowed by the animal, and from which it extracts the organic matter for its nourishment. The Spatangus has no teeth, but the intestine is of very large size, and is always more or less full of sand. In the sand taken from the intestine of *Spatangus purpureus* I found a considerable number of specimens of *Echinocyamus pusillus*, or Green Pea Urchin, Fig. 126, which have been mistaken for young Spatangi, but as in these the anal pore is near the mouth, they must be a distinct species, and not the young of the Spatangus.

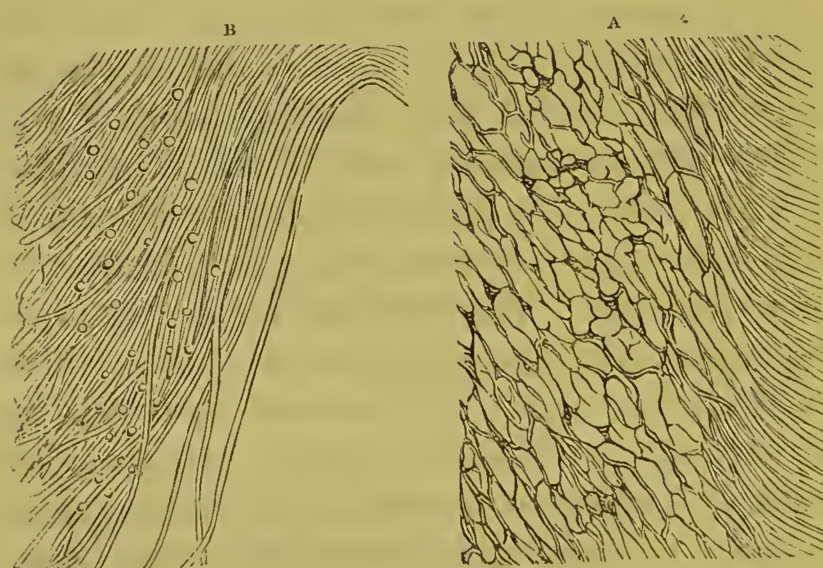
The structure of the teeth of the Echini is most interesting; in external appearance they very much resemble those of Rodents. Vertical sections show that near the point they are made up of super-imposed laminæ of a hard calcareous material, somewhat like enamel, whilst all the other parts, except the base, are softer, and contain numerous branching tubuli very like those of dentine, as shown at A, in Fig. 127; many of the tubuli are so much dilated at certain points as to form lacunæ,

FIG. 126.



Echinocyamus pusillus, or Green Pea Urchin. A, ventral, B, dorsal surface.

FIG. 127.



A, a portion of a tooth of an *Echinus* magnified 250 diameters, showing a tubular structure like that of dentine. B, the basal portion of the same tooth magnified 130 diameters.

or bone cells, but in others the branches are exceedingly minute, and run in parallel lines precisely like the tubuli of dentine. The base of the tooth is covered by a membrane, it is exceedingly soft, and always presents a fibrous appearance; the fibres are white and silky, and have not been unaptly compared to those of asbestos; they may be readily separated from each other, as shown at B. The teeth of certain Echini do not exhibit the tubular structure so well as the one represented at A; the distribution of the minute tubuli is not usually so apparent, and that of the coarser ones more nearly resembles the reticulated structure seen in the centre of many of the larger spines of these animals, so much so, indeed, that I have often doubted whether the structure is really tubular or not; but whatever may be its nature in other teeth, it is quite certain that the tubular structure existed in the tooth from which Fig. 127 was drawn.

The teeth of the Echini have been well described and ably illustrated by Valentin in a monograph forming one of the "Monographies d'Echinodermes" of Professor Agassiz, but there is no representation there given of the tubular structure, although all the other parts are well figured. I deem the presence of tubuli, and especially of lacunæ in the teeth of an invertebrate animal, a point of great interest, and one which, as far as I am aware of, has never before been described.

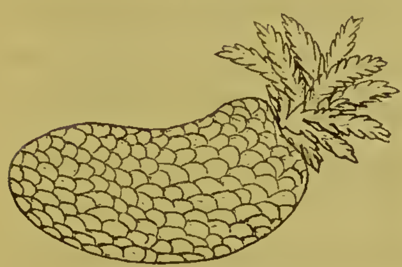
LECTURE XIV.

SKELETON OF ECHINODERMATA.

Having in the last Lecture concluded the description of the structure of the skeleton in four of the five orders of the *Echinodermata*, I now proceed to the fifth, or *Cirrhi vermigrada*, which is composed of a large tribe of animals—viz.: the *Holothuriadæ*, or Sea Cucumbers; according to Forbes, fifteen species at least are British. These animals, with few exceptions, possess only a mere trace of a calcareous skeleton, which is confined to the discs on the extremities of the suckers, or cirrhi, and to a framework supporting the dental apparatus. The skin is for the most part thick, leathery, and covered on the outside with tubercles, or spines; but in one species, termed *Holothuria squamata*, Fig. 128, the greater part of the body is enclosed in a bony case, the under surface is flattened, soft, and perforated by foramina through which the cirrhi are protruded, and on the dorsal surface the tentacula project from rounded orifices.

When I first saw this specimen, I took it for a species of *Doris*, one of the Gasteropodous Mollusca; but on examining a portion of the calcareous covering, I immediately recognized the reticulated tissue so characteristic of the Echinodermata, and I subsequently found, on referring to the "Règne Animal," that it was a true *Holothuria* of the species above named. This animal has cirrhi on the dorsal and abdominal surface, but there are some other Holothuriæ which have the cirrhi confined to one surface, generally speaking, however, they are either in five rows, or are scattered irregularly over the outer surface of the body. The cirrhi are like those of the Star-fishes and Echini, and I shall presently notice them more in detail. The Holothuria progress by means of their cirrhi and by the elongation of their bodies, like worms, and from this mode of progression the name of the order under which they are classed is derived. The largest animal of the kind found in the British seas is capable of elongating itself to as much as three feet. It was discovered by Professors Forbes and Goodsir, and the account of its capture, given by the former of these gentlemen in his work on

FIG. 128.

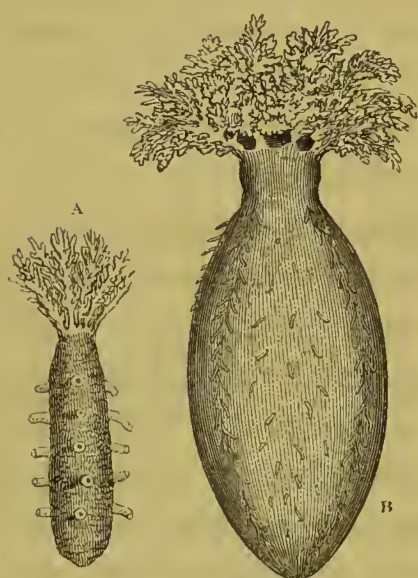


Holothuria squamata.

Star-fishes, is so interesting that I am tempted to quote it.

"The great Sea-cucumber, *Cucumaria frondosa*, Fig. 129, B, is the largest of all the known European species, and probably one of the largest *Cucumariæ* in the world, measuring, when at rest, fully one foot, and capable of extending itself to the length of three. He is the king of the Sea-cucumbers, and seems to have gathered the greater number of his subjects around him in the Shetland seas, where his majesty was first recognized as a native of Britain by Mr. Goodsir and myself in June, 1839. When he first came up in the hooks of the dreg—an instrument used by the Shetlanders as a means of procuring horse-mussels, *Modiola vulgaris*, called by them Yoags, for bait—he astonished us with his monstrous appearance."

FIG. 129.



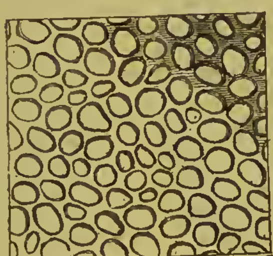
A, Sea Girkin, *Ocnus brunneus*. B, Great Sea Cucumber, *Cucumaria frondosa* (after Forbes).

The smallest of the Holothuriæ are termed Sea-girkins; one of these, *Ocnus brunneus*, Fig. 129, A, not more than three quarters of an inch in length, is not uncommon at Brighton. Around the mouth of these creatures the tentacula are arranged; they are either five or a multiple of that number, and are capable of being retracted within the mouth, and when this is done, both extremities of the body are nearly alike. The dissection of *Cucumaria frondosa* by Mr. Goadby in our Museum, displays these organs and the dental apparatus *in situ.* When caught, these animals, if not carefully managed, will eject all their viscera; but these, like the rays of the Star-fish and spines of the Echini, may be reproduced. A specimen in the Museum has been mounted expressly to illustrate the ejection of the viscera. The alimentary canal consists of a stomach and a long intestine, which is held *in situ* by a delicate mesentery; the intestine ends in a well-developed cloaca, and the mesentery is largely supplied with blood-vessels which communicate with a pulsatory vessel, or heart. The respiratory organs consist of beautiful ramified tubes opening into the muscular cloaca, from which water is forced into them. The ovary is composed of straight cœcal tubes, and in one of Mr. Goadby's beautiful preparations, these are admirably displayed.

John Hunter was well acquainted with the anatomy of more than one species of *Holothuria*, and he even succeeded in injecting the rich vascular system, as may be seen in Preps. 437 and 438 of the Physiological series of the Museum. The Holothuriadæ exist in great abundance in the Eastern seas, where they are called *Trepang;* they are collected with great eagerness by the Malays, for sale in the markets of China, where they fetch a good price. The Chinese employ them, says Mr. F. D. Bennett, in his "Account of a Whaling Voyage round the Globe," in the preparation of nutritious soups, in common with an esculent sea-weed, sharks' fins, edible birds'-nests, and other gelatinous substances.

The integument of *Holothuria squamata*, Fig. 128, which I have before stated was made up principally of calcareous material, when examined microscopically, is found to be composed of small angular plates exhibiting very beautifully the characteristic reticulated structure, interspersed with rows of larger plates of a circular figure and stellate margin, having the appearance of short spines. The structure of the calcareous framework of the dental apparatus of *Cucumaria frondosa* is precisely similar to that of an Echinus shell, the reticulations, as shown in Fig. 130, being well marked, although the framework itself is but sparingly developed even in the largest individuals.

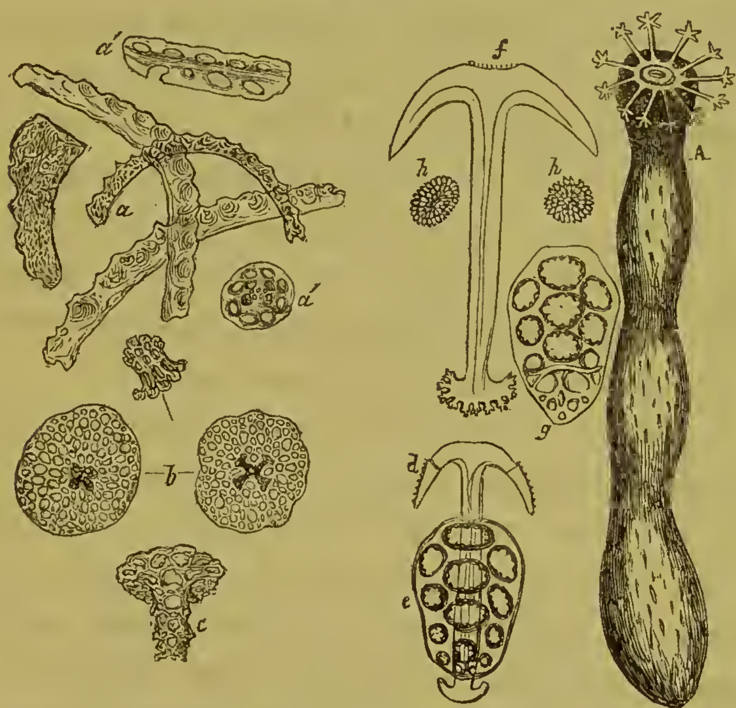
FIG. 130.



Portion of the bony framework of the mouth of *Cucumaria frondosa* magnified 250 diameters.

In some species of Holothuria there are numerous flattened spicula, either imbedded in the leathery tunic, or forming a coating to it; these vary considerably in shape; generally speaking, they are quite flat and fiddle-shaped, as shown at c, in Fig. 135, but occasionally, as represented at *b*, in Fig. 131, they are circular, and have a spinous process, *c*, projecting from the centre; but whatever their shape, the characteristic reticulated tissue is always present, and its diversity of arrangement, renders these spicula exceedingly interesting as objects for microscopic observation. Spicula of the shapes represented by *a*, in Fig. 131,

FIG. 131.



A, *Synapta*, or *Chirodota digitata* (after Forbes). *a, á, á*, spicula from oral tentacles of a *Holothuria*. *b*, flattened spicula from skin of a *Holothuria*. *c*, one of the same showing a spine. *d, e*, anchor-shaped spiculum and plate from skin of a *Synapta*. *f, g*, larger spiculum and plate from the skin of another species of *Synapta*. *h, h*, oval bodies from the same skin.

are sometimes found in the oral tentacula of Holothuriæ; in the specimen from which the drawing was made, there are several varieties, the greater number being more or less curved and having tubercles on the convex surface; amongst them were some few small ones, represented by *á, á*, in which the reticulated structure is well seen.

Allied to the Holuthuriæ are certain animals termed *Synaptæ*, the one represented by A, in Fig. 131, was discovered by Montagu on the coast of Devon, a few species occur in other parts of the globe; my reason, however, for introducing it here, is to point out the very peculiar shape of the calcareous plates and spicula composing its rudimentary skeleton. My attention was first directed to this subject by seeing two specimens, one of the skin, the other of the spicula, which had been mounted in Magdeburg, and formed part of a series of microscopic objects, said to be prepared for sale by an association of German *savants*.

A portion of the skin of a *Synapta* exhibits the peculiar compound spicula represented by *d, e*, in Fig. 131; one part is like an anchor, the other is in the form of an oval plate. The flukes of the anchor are serrated on the convex edge, and the opposite extremity is recurved, and appears to be connected in some peculiar way with the oval plate which lies upon it. This plate shows the ordinary characteristic reticulated structure, the inner margin of the reticulations being occasionally serrated. The plates and spicula can be easily separated; this, however, is better seen in the second specimen, in which the spicula have been detached from the skin. The spicula in this preparation are so different, both in size and shape, from those in the preceding, that it is probable the species from which they were taken was a different one; the flukes of the anchor are smooth, there being only a few very minute spines where they are connected to the shaft, as shown at *f*, the opposite extremity is recurved, and has a tuberculated convex edge. The plates are generally larger than those in the first specimen, and the inner edges of the seven large reticulations, as represented by *g*, are serrated. In addition to the peculiar spicula above described, there are in this preparation an immense number of the minute oval bodies shown at *h*, but in what part of the tunic they are situated I cannot say. From the great correspondence in structure between the oval plates of the *Synaptæ* and the flattened spicula of *Holothuriæ*, there is every reason to believe that the former are true Echinodermatous animals, and must be nearly allied to the latter.

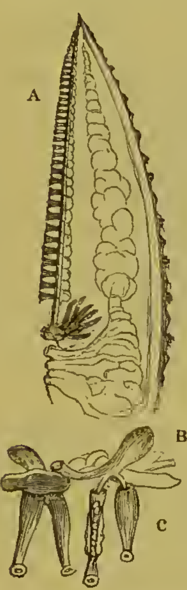
The only other portion of the body of the Holothuriæ in which calcareous matter exists, is at the extremities of the tubular feet, or cirrhi, of some species. If the free extremity of one of these cirrhi—of *Holothuria papillosa*, for example—be removed and laid flat, it will then be perceived that a circular plate or disc of calcareous material gives the shape to this part. This disc, as shown in Plate XIV, Fig. 12, of the first volume of the "Histological Catalogue," is composed of reticulated structure, and its margin is surrounded by a narrow zone or framework of spicula with dilated extremities, which are themselves built up of reticulated structure.

In some specimens the zone is complete, and exhibits the same structure as the disc, but in others the zone is imperfect, the remaining portion of the circle being formed by spicula with dilated extremities. If one of these discs be macerated in liquor potassæ so as to remove all the organic tissue, and afterwards dried and mounted in Canada balsam, the characteristic structure will be very plainly seen, and the disc itself will bear a very strong resemblance to a transverse section of the spine of an Echinus.

I have now described everything in the Echinodermata that can be properly designated a skeleton, but I cannot leave this part of my subject without alluding to certain other organs connected with the shell in these animals. When speaking of the skeleton of Star-fishes and Echini, I remarked that the ambulacral foramina, served for the passage of the Cirrhi or tubular feet, and that I should take another opportunity of describing these organs. The present is a fitting occasion, as I happen to have a living specimen of Echinus, in which both the Cirrhi and the Pedicellariæ are visible in active movement. The Cirrhi of the Star-fishes have been much studied, and as the mechanism connected with their motions is exceedingly beautiful, I must trespass on your patience a few moments whilst I describe it.

If a vertical section be made of an entire ray of a Star-fish through one of the rows of cirrhi, as shown at A, in Fig. 132, it will be found that these organs consist of two parts, one, B, contained within the ray, the other, C, external to it. The latter is tubular, lined with ciliated epithelium, and in some species tipped with a calcareous disc, and attached to the outer surface of the calcareous framework of the skeleton, while the former or internal portion of the cirrhus, is situated within the body, and consists of a bladder-like vesicle filled with fluid, which protrudes through the ambulacral hole in the shell, and extends into the tubular foot. When the vesicle contracts, it expels the fluid into the foot and protrudes it, but when the muscular end of the foot contracts, the fluid is forced back into the vesicle. The vesicles are supplied, not, as has generally been supposed, by a fluid secreted by them, but from a system of tubes carrying sea-water.

FIG. 132.



A, a vertical section of one of the rays of a Star-fish showing the Cirrhi. B, vesicular portion of one of the cirrhi. C, external portion of the same.

In the Star-fishes the cirrhi are confined to the under surface of the body, and are not capable of being protruded very far beyond the shell, but in most of the Echini, as shown at *a a*, in Fig. 133, they are situated upon the outer convex surface, and can be stretched beyond the spines, so that they are important instruments in progression. In *Echinus atratus*, the spines on the upper convex surface of the shell are mere flattened plates, as shown in Fig. 134, and are so close together that little or no interspace is left between them; there are no cirrhi on this part of the shell, but if we turn it so as to bring the mouth uppermost, we shall find them in great numbers. The spines around the outer margin are longer than the rest, and these creatures, when progressing—as they probably do very rapidly—must look not unlike small tortoises. Each of the cirrhi is tipped with a thin disc of calcareous matter, rather more like a section of one of the spines of the animal, than those I have already noticed as occurring on the tubular feet of the Holothuriæ. In *Echinus atratus*, each disc, as shown at A, in Fig. 135, has a central aperture, and is composed of five symmetrical pieces, the margin being slightly indented or scalloped. Sometimes a few bicurvate spicula are met with, scattered through the tissue in the neighbourhood of the disc, and may often be seen within the central aperture in some

FIG. 133.

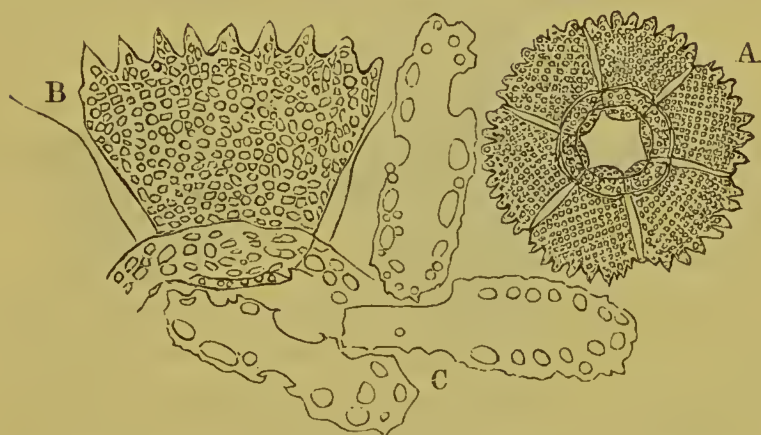
A, a portion of an *Echinus* showing rows of cirrhi between the spines. *a, a,* cirrhi. *b, b,* spines.

FIG. 134.

A, *Echinus atratus* showing the flattened spines on its convex surface.

specimens. In a preceding Lecture I spoke of my inability to detect anything like a cuticle or membrane

FIG. 135.

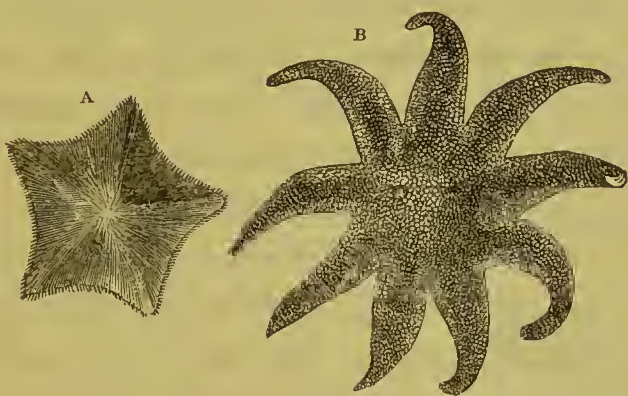


A, calcareous disc from extremity of one of the cirrhi of *Echinus atratus*. B, portion of the same more highly magnified. C, spicula from the skin of *Holothuria papillosa*.

investing the outer surface of the spines of the Echini, but, much to my surprise, I find it stated by Professor Forbes that Ehrenberg had discovered ciliated epithelium upon them. I have never been able to detect it, but during my stay at Brighton in the autumn I noticed on more than one occasion—when examining the surface of *Echinus miliaris* with a power of 40 diameters—a slight agitation in the water in the neighbourhood of the spines; but I subsequently found that this movement was owing to the presence of ciliated epithelium upon some of the neighbouring cirrhi. It was not, however, invariably present on all these organs, for many that I removed and examined with care presented no trace of cilia. The cirrhi, like the Pedicellariæ which I shall presently describe, may occasionally be useful in preventing foreign bodies from settling amongst the spines. You may remember that I have before mentioned the interesting fact of my never having seen any Serpulæ or other shelly parasites attached to the spines of living *Echini*, but on those of the genus *Cidaris*, as shown at C, in Fig. 122, they are not uncommon.

I shall next direct attention to a peculiar organ found in certain of the *Asteriadæ*, and called by Tiedemann a "Sand Canal." It may be recollected that when describing the skeleton of these animals, I noticed a small calcareous mass termed the "Madreporiform tubercle," always situated on the dorsal surface, at a little distance from the centre of the body. Connected with this tubercle is a column of the same material, which extends obliquely from its under surface downwards to the calcareous framework surrounding the mouth. This is termed the "Sand Canal," although no sand is ever found in it, its gritty feel depending entirely upon the calcareous framework of which it is chiefly composed. The madreporiform tubercle is very evident in *Asterias rubens*, and also in *Goniaster Templetoni* and *Solaster endeca*, represented by A, B, in Fig. 136. Under a power of 20 diameters, as shown in Fig. 137, the upper surface of this tubercle is very like that of a cerebriform madrepore, or "brain-stone;" but if a section be made sufficiently thin to be transparent, its structure will be found to be the same as that of other parts of

FIG. 136.



A, *Goniaster Templetoni.* B, *Solaster endeca* showing the madreporiform tubercle (after Forbes).

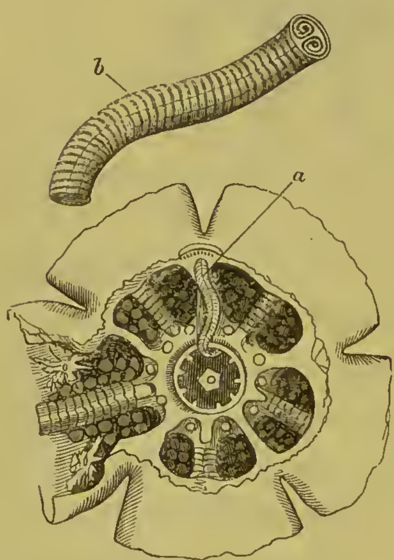
the shell. Tiedemann supposed that the canal secreted calcareous matter for the growth of the skeleton, while Dr. Sharpey, on the contrary, says it opens by a narrow orifice into the larger circular vessel surrounding the mouth, and which conveys fluid to all parts of the body, especially to the feet; but the more probable explanation of the nature of this canal, is that suggested by Dr. Coldstream of Leith, who believes it to be the rudiment or analogue of the stalk of the Crinoid Star-fishes. It is found in some of the Echini as well as the Star-fishes, but not in the *Ophiuridæ* or *Crinoideæ;* these may have possessed a stalk in their young state,

FIG. 137.

Madreporiform tubercle of a Star-fish magnified 20 diameters.

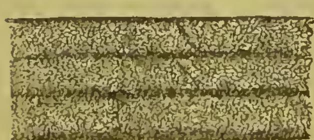
but the *Asteriadæ* and *Echinidæ* are always free. The column is composed of incomplete rings of the characteristic reticulated tissue, and if cut open and spread out, it will be seen that one edge is provided with a bundle of straight fibres of large size, like those of muscle. The canal itself somewhat resembles a tracheal tube, as shown at *a*, in Fig. 138, surrounded by incomplete rings. Dr. Sharpey says that the two ends of the rings are bent inwards, so that on a transverse section there is in some parts a trace of two canals in the interior, as represented at *b*. The outer surface, according to the same author, is invested with a strong membrane covered with a layer of ciliated epithelium. If a portion of the canal be treated with caustic potash to remove the animal matter, the calcareous framework, as shown in Fig. 139, will then be seen to have precisely the same structure as that of the other part of the skeleton.

FIG. 138.



a, "Sand Canal" of *Asterias rubens*. *b*, the same magnified (after Sharpey).

FIG. 139.



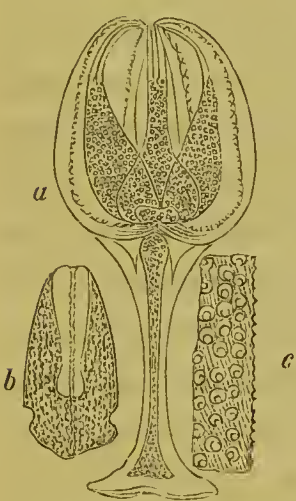
A portion of three of the rings of the "Sand Canal" of *Asterias rubens* magnified 50 diameters.

We now come to other organs found upon the external surface of some of the Echinodermata, and these are the curious bodies termed *Pedicellariæ.* They were first described by Muller the Danish naturalist, and have been since investigated by Sars, a Norwegian clergyman. Muller believed them to be parasites, whilst Dr. Sharpey and others, regard them as parts of the animal, which they undoubtedly are. On most Echini there are three kinds of Pedicellariæ; being considered as distinct animals, they have been termed *Pedicellaria tridens*, *Pedicellaria triphylla*, and *Pedicellaria globifera*, according to their form; but whatever this may be, each consists of a solid part, or skeleton, and a soft transparent flesh. The skeleton, as shown in Fig. 140, is composed of three calcareous jaws, having a sharp recurved tooth at the apex and an internal serrated edge, while the tissue surrounding the jaws is strengthened by minute bi-curvate spicula; it is seated on a cylindrical stalk placed in the centre of the fleshy stem.

All these parts, when highly magnified, present the characteristic structure of the shell of the animal; the soft tissue, on the contrary, is transparent, contractile, and, like that of the cirrhi, is capable of considerable elongation and flexion. While the Echinus is living, the Pedicellariæ are always in active movement from side to side, the jaws are continually opening and shutting, and if a small body be placed within them, it is held with tolerable force. They are attached to the soft fleshy covering of the shell by a dilated base, and are not confined to any particular part of the shell, but many may be seen on the thin membrane closing the oral aperture. The part which I have called the stalk, is somewhat dilated at each extremity; its structure resembles that of a small spine, and it is stated by Sars that each stalk, like a spine, is articulated to a minute tubercle, but of the truth of this I have never yet been able to satisfy myself, as in all cases after their removal the soft stem has been found to completely invest the whole of the calcareous matter.

If the Pedicellariæ be removed from the Echinus, they will continue in active movement for some time, and if one of them be touched with a needle or pin, those in the neighbourhood will all bend towards the one that has been irritated. In the Asteriadæ the Pedicellariæ are of a different form to those in the Echini, in the *Asterias rubens*, for example, in which they are very abundant, as shown at *a a*, in Fig. 109, the calcareous jaws are like the two valves of a mussel, as represented at *b*, in Fig. 140, two of the edges being serrated, whilst the other two, which are not closely approximated, have a semi-circular notch, leaving an opening between them when in apposition, and the stem is short and flexible, but not provided with a calcareous axis as in the Echinidæ. When magnified 130 diameters, as shown at *c*, the characteristic reticulated structure is exhibited. Mounted specimens taken from the outer surface of the shell of *Echinus miliaris*, as represented at *a*, in Fig. 140, show very distinctly the three jaws and the axis or stalk, but being in a state of contraction, the soft parts appear very short and puckered up, so that a species of neck is formed between the jaws and the axis; this, however, is not the case in living specimens. All the parts composing the skeleton of the Pedicellariæ exhibit the characteristic reticulated structure of the Echinodermata. The jaws are thin, flattened below, sharp above, and bent nearly at right angles, so as to form a tooth; the axis is about $\frac{1}{6}$th of an inch in length and dilated at both extremities, and in shape and structure is very like the spine of an Echinus. On either side of the jaws may be seen a row of small bicurvate spicula, somewhat resembling those in the disc of the cirrhi of the Echinidæ, but differing from them, as represented at *d*, in Plate XIV, Fig. 19, of the first volume of the "Histological Catalogue," in having more than one hooked process extending outwards from the point where the curved portion commences. Under a power of 40 diameters, as shown at *a*, in Fig. 109, numerous Pedicellariæ are distinctly visible on the upper dermal surface of *Asterias rubens*, even after having been dried, but as the soft fleshy stalk is very short and has no calcareous axis, little can be seen except the jaws. Pedicellariæ also exist in the *Spatangi*, but they are

FIG. 140.

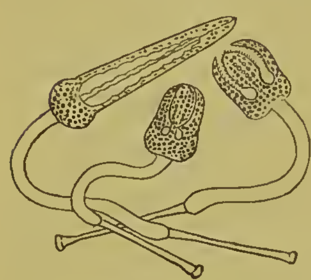


a, *Pedicellaria* of *Echinus miliaris*. *b*, skeleton of one of the *Pedicellariæ* of *Asterias rubens*. *c*, portion of the skeleton of the same magnified 130 diameters.

not so evident as in the Echini; the principal varieties found in *S. purpureus*, according to Forbes, are represented in Fig. 141.

The Pedicellariæ then, without doubt, belong to the animal on which they are found; they are not parasites, but it is difficult to determine their true office; they are probably useful in keeping the shell free from all intruders of a parasitic nature, and may be supposed to perform an analogous function to that of the so-called "Bird's-head processes" of the *Bryozoa*.

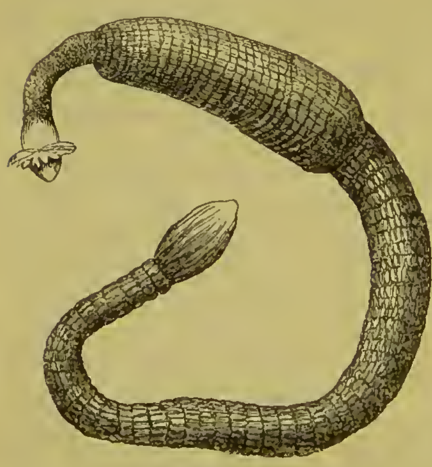
FIG. 141.



Pedicellariæ of *Spatangus purpureus*.

Little remains to be said on the structure of the skeleton of the last class of the Echinodermata, the *Vermigrada*, which contains the order *Sipunculidæ*; these animals, except in their internal anatomy, more nearly resemble worms than Echinoderms; they have no cirrhi or tentacula, and no rudiment of a calcareous skeleton, their outer integument being either fibrous or covered with spines or hooks. The British species, according to Forbes, are grouped under

FIG. 142.



Syrinx or *Sipunculus nudus* (after Forbes).

three distinct families, viz.: *Sipunculaceæ*, *Priapulaceæ*, and *Thalassemaceæ ;* in the former of these is included the *Syrinx*, represented in Fig. 142. The length of the body is stated to be six or eight inches, and the outer rough integument is composed of a tough leather-like substance, having both longitudinal and transverse rugæ. Many of the foreign species have the anterior portion of the body covered with brown nodulated tubercles, or spines, probably of a horny nature. I have examined very many species of *Sipunculi*, but have as yet entirely failed in making out any trace of a calcareous skeleton, which I believe to be almost universally present in the Echinodermata.

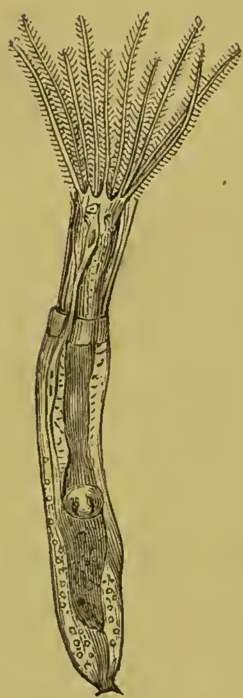
LECTURE XV.

SKELETON OF MOLLUSCA—BRYOZOA AND TUNICATA.

Having in my last Lecture finished the description of the structure of the skeleton in the Echinodermata, I next proceed to that of the *Mollusca*. This sub-kingdom is now divided into the following classes:—*Bryozoa*, *Tunicata*, *Conchifera*, *Gasteropoda*, *Pteropoda* and *Cephalopoda*, the members of each class differing widely from those of the other classes. In the first, or *Bryozoa*, the individual animals approximate in character to the Zoophytes, and have until lately been classified with them, all being of microscopic minuteness, whereas among the *Cephalopoda*, some species are several feet in length; in fact, no one could classify these animals from their external characters alone, but so soon as the investing tunic is removed, traces of high organization are perceptible. In the first class, the *Bryozoa*, we may have animals either perfectly distinct, or connected by an investing tissue so as to form a colony.

When describing the Hydroid Zoophytes, I remarked that the polypes are continuations or developments from the soft animal matter occupying the centre of the horny tubular skeleton, and that the cell in which the polype is contained, is not a part of the body of that polype, but developed before the polype itself. Each polype was also stated to be provided with a series of arms, or tentacula, like the common fresh-water Hydra, for the prehension of food, which is conveyed by them to a globular stomach. Here, on the contrary, the horny or calcareous skeleton is a part of the body of the polype, and although the polype may be injured, the cell will be found to possess the powers of repair. The polype may be solitary, as in *Bowerbankia*, or several may be collected together in one polypidom, as in *Flustra*, *Lepralia*, or in clusters, as in *Laguncula*, but whatever the shape of the skeleton, the polype contained within it, differs in very many points from that of the true Zoophytes. Thus, for instance, the tentacula are provided with cilia, and are not employed in the prehension of food, this being brought to the mouth by the strong current produced by the vibratile movements of the cilia; the stomach is well developed, and immediately above it, is situated a muscular gizzard, and traces of a liver are also discernible. In *Bowerbankia*, as shown in Fig. 143, the skeleton is composed of horny matter, but in most of the others this tissue is consolidated by carbonate of lime. It may be remembered that when describing the skeleton of the polypes of the *Polyzoa*, I adverted to the *Anguinaria spatulata*, and mentioned that these animals were now removed from the *Zoophytes* to the *Bryozoa* in consequence of their having both a mouth and anus; but as some of them have striped muscular fibre, they properly belong to the *Articulata*. The *Bowerbankia*, as shown in Fig. 143, is of an elongated form, with ciliated arms protruding a long distance from the case, and under a power of 250 diameters the sheath or case which forms the skeleton is seen to be composed of a transparent material, like horn. The *Bowerbankia* has been accurately described by Dr. Arthur Farre in the "Philosophical Transactions" for 1837, and although considered by him as a distinct species, it is now generally believed to be the first stage of growth of *Valkeria imbricata*, or in that condition when it spreads over a plain surface, whereas, in the second stage, it rises up so as to form a distinct polypidom. The generic name, *Bowerbankia*, I need not tell you, was given in honour of one who has done

FIG. 143.



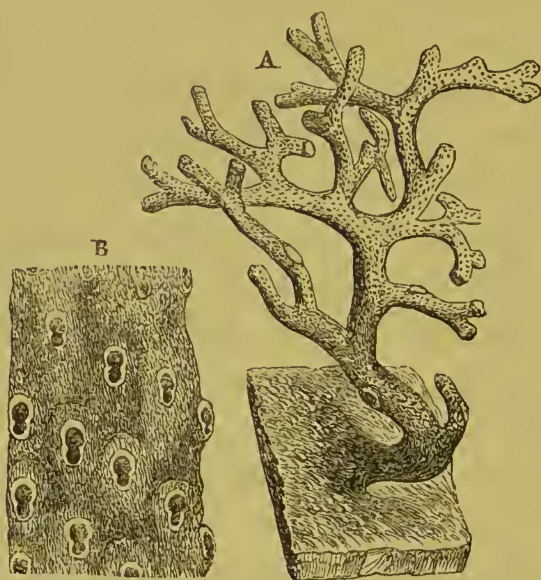
Bowerbankia densa (after Farre).

so much to promote the science of microscopical observation.

In the *Anguinaria spatulata*, represented at C, in Fig. 88, both the serpentine stalk and the tube supporting the polypes contain a large amount of calcareous matter, and in the *Notamia bursaria*, or Shepherd's-purse coralline of Ellis, shown in Fig. 89, the cells containing the polypes consist of transparent horn. Of this animal, as before stated in page 182, an excellent description is given by Mr. Busk in the second volume of the "Microscopical Transactions." The cells occur in pairs, they are of a somewhat triangular figure, and on the upper margin of each may be observed two projections—the "bird's-head" processes—which have been already alluded to as being in all probability the analogues of the Pedicellariæ of the Echinodermata. The polypes, as shown at D, in Fig. 89, are readily seen within the case, and at the lower and outer part of each cell some minute fibres pass inwards towards the polype, these are muscular, and if very carefully examined, transverse markings may be observed. Each of these fibres corresponds to one of the fibrillæ, or smallest filaments, into which the fasciculi or bundles of fibres of which the muscles of the higher animals are composed, is capable of being divided. This condition of the muscular tissue occurs in many of the *Articulata*, and it becomes a question whether the *Notamia* should not be removed to that sub-kingdom.

Some of the *Bryozoa*, as, for example, the *Eschara cervicornis*, represented at A, in Fig. 144, have a calcareous skeleton. This species is branched like a coral, the polypes reside in cells, some of which are well seen in the highly magnified portion B, and as soon as a polype dies, the cavity or cell which it occupied

FIG. 144.



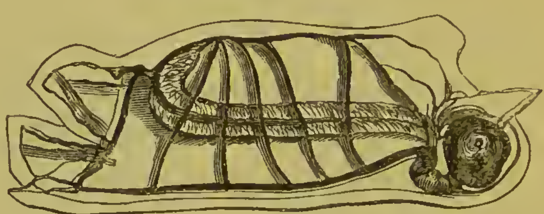
A, *Eschara cervicornis* of the natural size. B, portion of the surface magnified to show the cells for the polypes (from the "Règne Animal.")

is filled up by the inherent power of growth possessed by the skeleton. This animal is not considered to be a native of the British seas, but a species of *Cellepora* has often been mistaken for it; this last is not uncommon on the south coast of Devon.

The skeleton of the next class, *Tunicata*, so called from their possessing an outer tegument, or tunic, is in some species thin and transparent as glass, but in others thick, opaque, and tough as leather. There are many varieties of these animals in the Museum, but the most remarkable specimens for exhibiting the transparency of the tunic are those of the first order, termed *Salpæ*, which, like the Medusæ, are always floating near the surface and producing phosphorescent light. Some occur singly, as the *Salpa maxima*, Fig. 145, whilst others are aggregated together in chains many feet in length, as the *Pyrosoma atlanticum*, which is composed of upwards of a hundred individuals.

In the next family, *Ascidiadæ*, the individuals are solitary and attached to rocks by an expanded portion, or base, or mounted on a thin stem, as the *Boltenia*, Fig. 147, both being sessile or solitary. No one, at first sight, would imagine that these creatures belong to the animal kingdom, but if we examine their outer surface we shall find two large holes, as shown at A and B, in Fig. 146, the former being the oral, the latter the anal opening, and when divided vertically, the interior of the leathery tunic will be found to be inhabited by a highly organized animal, D, possessing a mouth, an œsophagus, a stomach, liver, and distinct circulating apparatus and a nervous system, which are invested with a well-developed muscular coating, as shown at A, B, C, in Fig. 146. These thick-skinned animals are termed solitary, or single Ascidians, but there are others which occur in colonies, and are known as compound Ascidians, or *Botryllidæ*, Fig. 150, and their skeleton is composed principally of calcareous matter in the form of stellate spicula. The animals are very minute, the colony forming a thin incrustation upon shells and sea-weeds, and they are commonly found on the expanded bases of many Gorgonias, and on the fractured edges of specimens removed from the Gorgonias the little cavities in which the animals were lodged may be distinctly seen. In all the individuals of this class the skeleton is a dermal one, and in *Salpa maxima*, Fig. 145, one of the largest species, it appears to

FIG. 145.

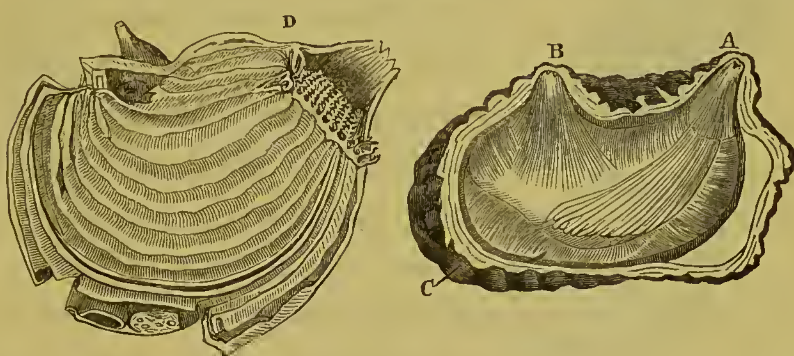


Salpa maxima; the dark circular mass on the right hand of the figure is the *nucleus* (from the "Règne Animal.")

be almost structureless, but according to the researches of Löwig and Kölliker, a number of peculiar star-shaped siliceous concretions composed of minute granules are present in the innermost layer of the tunic of this animal. One fact, however, I must not forget to mention, that Dr. Schmidt has discovered that the transparent tunic of *Salpa* contains *Cellulose*, an element hitherto supposed to be confined to members of the vegetable kingdom. The tunic is moved by muscles, and the stomach and liver are contained within the dark circular mass on the right hand of the figure, which is generally known as the *nucleus*.

In the *Ascidians*, as shown at C, in Fig. 146, the tunic is so tough, that unless the knife cuts exceedingly

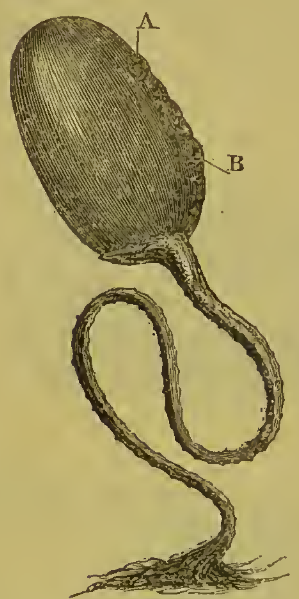
FIG. 146.



Ascidia microcosmus. A, mouth. B, vent. C, leathery tunic (in this figure the muscular coat is shown). D, visceral mass as seen after the removal of the muscular coat (from the "Règne Animal.")

well it is almost impossible to obtain a thin slice; but when obtained it is seen to be composed of exceedingly delicate, closely interwoven fibres. Hunter was well aware of the high position in the scale of creation occupied by these animals, for he called them soft-shelled Mollusca, and most of the specimens in the Museum of the College were prepared by him. In all the works on Comparative Anatomy, except those recently published, it is stated that there is no trace of a calcareous skeleton in these Tunicated animals, but this is incorrect, for when engaged in examining the structure of the skeleton of the invertebrata during the preparation of the first volume of the "Histological Catalogue," I investigated the structure of the coating of a sessile Ascidian, a species of *Boltenia*, Fig. 147, and discovered in the stem of this animal multitudes of minute calcareous spicula. These spicula, as shown in Fig. 148, consist of a central portion, or shaft, with trifid extremities, and are imbedded in the dense leathery tissue; they are most abundant in the stem, but some few may be met with in the dilated portions. They are partially dissolved by cold dilute hydrochloric acid, but if the specimen be boiled in the acid, they entirely disappear, and cavities are left in the horny tissue precisely corresponding to the spicula. If a section be treated with caustic potash, the horny matter is partially removed, and the spicula are rendered more apparent.

FIG. 147.



A sessile Ascidian, a species of *Boltenia*. A, the oral. B, the anal outlet.

We next come to those Ascidians which, from being made up of masses of similar individuals, have been named Compound Tunicata, of which the *Botryllidæ* are an important family. As a good example, I might mention the compound mass termed *Amaroucium proliferum*, represented in Fig. 149; they are generally of the consistence of wetted

FIG. 148.

Spicula from the stem of *Boltenia reniformis*.

leather, and so tough as to be torn with difficulty. Another animal of this class is the *Alcyonium Schlosseri* of Ellis, Fig. 150; like the preceding, it is found upon sea-weeds and portions of rock; its entire surface is covered with stellate figures, which indicate the presence of a number of individuals surrounding a common cloacal outlet. It is a remarkable fact that some of the smallest of the Compound Tunicata have the greatest number of calcareous stellate spicula. An animal of

FIG. 149.

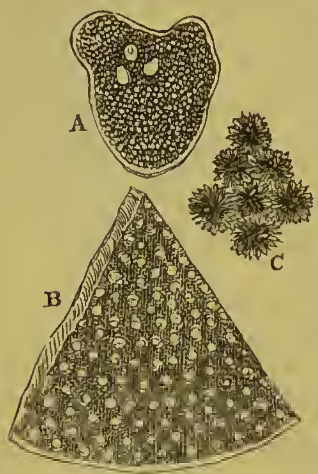
Amaroucium proliferum (after Milne Edwards).

FIG. 150.

Botryllus Schlosseri (*Alcyonium*, of Ellis) on a Fucus.

this kind, of very small size, found upon a Pinna-shell, was almost entirely composed of calcareous stellate spicula of the form represented by Fig. 152. Such animals are far from being uncommon upon Corals and shells, and whcn dried, look very mueh likc a mass of amorphous lime. Thc tunie of the eompound Ascidian, representcd in Fig. 151, which was brought from the China seas, at first sight I imagincd was a sponge, it contains a largc number of the calcareous stellate spicula shown at c, and is composed of a series of eells for the animals, each of whieh is surrounded by a number of black spots, these bcing the spicula in question; when isolated by boiling in caustic potash, they are found to be of stellate figure, and somewhat resemble those of the sponges of the genus *Tethea*, but the latter are always composed of silica, whilst these are ealcareous, and dissolvc in dilute acid with effervesccnce, leaving behind them an organic basis in the shape of a cell-wall. I am not aware that ealeareous stellatc spicula have ever bcen found in sponges; they appear indeed to be charaeteristie of the rudimentary skeleton of the Compound Tunicata. Upon eareful examination, scarcely a Tunieatcd animal, not even the transparent Salpæ, is to be found without possessing

FIG. 151.



A, a small compound tunicated animal. B, segment of the same magnified 12 diameters. C, calcareous stellate spicula.

FIG. 152.

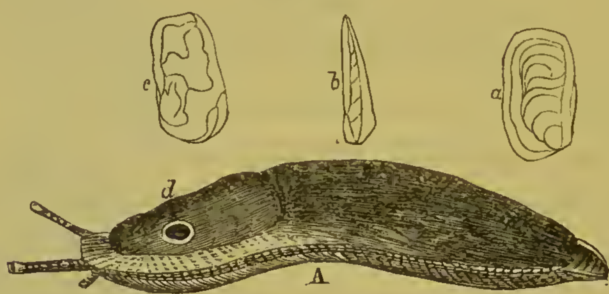
Calcareous stcllate spicula of a compound tunicatcd animal magnified 250 diamcters.

some rudiment of a skeleton in the form of stellate or acicular spicula. When we remember that *Cellulose*, an element belonging, as it was supposed, exclusively to vegetables, has been detected in the tunics of these animals, and that the spicula are mostly, if not all, contained in cells, the analogy between these bodies and raphides becomes very striking.

The third class of Mollusca, the *Conchifera*, are animals surrounded by a dense calcareous dermal skeleton, commonly designated *Shell*. Throughout this class the shell is formed of two more or less equal valves, which, with few exceptions, are external, and enclose the soft parts of the animal. The Conchifera are divided into the *Brachiopoda* and *Lamellibranchiata;* but before I enter upon the structure of the skeleton of these two divisions, I will give a brief description of Shell in general. For our knowledge of the minute structure of Shell, we are principally indebted to the labours of Mr. Bowerbank and Dr. Carpenter, the latter gentleman having published an elaborate paper on this subject in the "Transactions of the British Association." He divides it into two kinds, the cellular and the membranous, or in other words, into shell which retains its cellular character throughout life, and that which speedily loses it and becomes nearly homogeneous. When the first is decalcified, a cellular structure is left behind; but when the latter is subjected to the same treatment, the animal basis is in the form of a membrane either smooth or more or less lamellated.

The most simple form of Shell is that met with in the common Slug, *Limax rufus*, Fig. 153, A; it occurs

FIG. 153.



A, *Limax rufus*. *a*, *b*, *c*, the shell seen in various positions. *d*, shield on the back in which the shell is enclosed.

as a thin oval plate, imbedded in the shield *d*, situated on the back of this animal. When perfectly developed, as shown in *a*, *b*, *c*, it consists of a series of more or less concentric laminæ with a slight trace of cellular structure; but when examined in an earlier stage of growth, as represented in Fig. 154, it is found to be made up of cells which, from pressure, have become hexagonal in form, some of them being filled with transparent calcareous matter, whilst in others, as shown at *c*, in Fig. 167, this has assumed a crystalline appearance, the

FIG. 154.

A portion of the rudimentary shell of a Slug, *Limax rufus*.

latter affording an example of the crystallizing force overcoming the modelling power of the cell-wall. If the edge of the specimen be examined, cells may be seen in a state of formation; they are of small size, and imbedded in an intercellular substance, being developed in a plasma or blastema exuded either from the edge of the shell or mantle. On the outer surface the cells are small and distinct, but towards the centre of the specimen they become larger, and the intercellular tissue between them less and less, until they form a connected tissue, without any trace of intercellular substance.

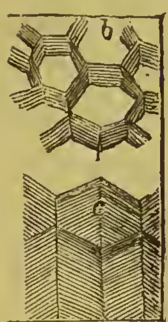
Soon after their development the cells begin to secrete carbonate of lime; many of them have a nucleus, or nuclei, which most frequently disappears soon after the deposition of the carbonate of lime, but not invariably, for in a transparent layer of the shell of an Oyster, as will hereafter be shown in Fig. 157, the nucleus is still present, although the cell is filled with calcareous deposit, and in this instance the carbonate of lime appears to have been deposited in concentric layers. The shell of all the Oysters of the genus *Pinna* is composed of a series of hexagonal cells filled with transparent calcareous matter as shown in Fig. 158. The greater part of the thickness of such a shell is made up of super-

FIG. 155.

A vertical section of a *Pinna* shell after decalcification, showing the mode in which the prisms will split up into layers of cells.

imposed layers of these cells, and it happens that in some instances, as represented in Fig. 155, the animal basis of the shell, after decalcification, will break up into laminæ, each composed of one or more layers of cells; occasionally, however, the outer layer of these shells will split up into prisms or columns, each of which, as shown at *b*, *c*, in Fig. 156, will be found to exhibit transverse markings, these being the indications of the thickness and number of the layers of cells composing such columns. This breaking up into prisms is certainly more rare than the division into laminæ, but in some old shells the prisms are very numerous in the outer layer, or crust, and the transverse markings indicating the cells of which the prism is built up, are very plainly visible.

FIG. 156.



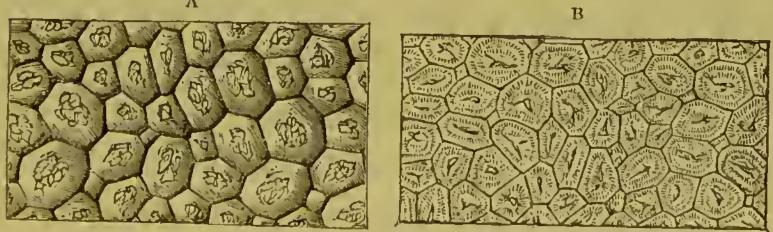
b, a portion of *Pinna* shell showing several layers of cells superimposed. *c*, parts of three prisms, or columns, made up of superimposed cells.

LECTURE XVI.

SKELETON OF MOLLUSCA—CONCHIFERA.

In the preceding Lecture I described the simplest form of shell as consisting for the most part of hexagonal cells. These cells are always nucleated in the earlier stages of development, and the nucleus, as shown at A, in Fig. 157, is sometimes persistent even after the cells are filled with calcareous deposit. In a thin layer of the shell of a small species of Oyster, some of the cells, as represented at B, in Fig. 157, exhibit a

FIG. 157.

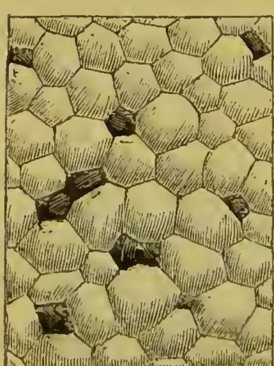


A, a portion of a thin layer of shell of a *Pinna* exhibiting cells, each containing a nucleus. B, nucleated cells from a thin transparent Oyster-shell.

transparent nucleus in the centre, around which there is a faint trace of a concentric laminated arrangement; these cells are full of lime, and if the section were decalcified, nothing would be left but the cell-walls, which are very strong and almost horny. When a thin section of shell composed of two or more layers of cells is decalcified by acid, nothing remains but the cell-walls; these are composed of a brownish horny material, and very much resemble a thin slice of vegetable cellular tissue.

The carbonate of lime contained in the cells of shell, possesses all the properties of the crystallized calcareous salt, it readily polarizes light; but in order to exhibit the colours to the greatest advantage, the shell should be mounted on a thin plate of selenite, as this adds very much to their brilliancy. The calcareous matter contained in the cells is generally of a pink hue, and is for the most part perfectly homogeneous; in some shells it presents a granular appearance. Certain shells of the genus *Pinna* have been described, both by Dr. Carpenter and myself, as having cells of an intense black colour; a section of *Pinna ingens* exhibiting this structure is represented in Fig. 158. It has been since ascertained that this blackness is not of uniform tint in all stages of adjustment of the focus, and as

FIG. 158.

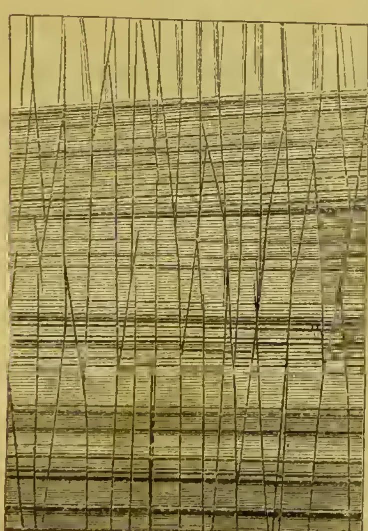


A horizontal section of the shell of *Pinna ingens* showing the so-called "black cells."

the cells having this appearance are generally smaller than the others in the neighbourhood, it is probable that the dark colour is due to the section having crossed one of the prisms near its pointed extremity, so that the conical part reflects most of the light, and a black appearance is produced. Dr. Carpenter believes that the blackness is owing to the presence of air in the upper part of the prism, the air occupying a portion of the cell, no lime being as yet secreted there. The black cells are almost always found in the superficial layers of the shell, and not in the deeper ones; but when a vertical section of such a shell is made, all trace of dark cells is lost.

In a vertical section of the shell of a *Pinna*, as shown in Fig. 159, the layers of cells are seen to be arranged one over the other to form prisms, and, however thick such a section may be, the prisms rarely extend from one surface of the shell to the other; they are generally pointed at one or both extremities, and every here and there may be seen a group of them in which the contents are more or less granular and coloured. It is in such cells as these, when cut transversely, that the granular condition of the lime, I have already mentioned, is observed. The prisms exhibit

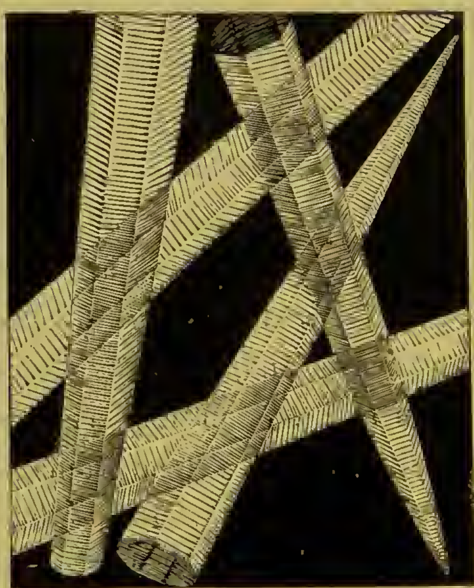
FIG. 159.



A vertical section of the shell of a *Pinna* showing the prismatic structure.

faint traces of transverse striæ, but these will be better seen in the outer layer of a *Pinna* of great thickness, remarkable as splitting up into prisms and not into laminæ, in consequence of the partial, if not total destruction of the organic cell-walls and the separation of the prisms from each other, like so many basaltic columns, as shown in Fig. 160. Some of the prisms exhibit very beautifully their pointed extremities, and all of them, more or less distinctly, the transverse striæ. Under very high magnifying powers the prisms appear indented, at points corresponding to the striæ; this is readily explained by the parts so indented being those occupied by the thickness of the cell-wall, which has probably been removed by decomposition previous to fossilization. The internal layer of the shell of the *Pinna* is not composed of hexagonal cells, but of a tissue somewhat resembling nacre, which possesses little or no brilliancy, but is always more or less coloured. It is this form of shell-tissue that Dr. Carpenter has named the *subnacreous* variety; the greater part of the thickness of the shell of the

FIG. 160.

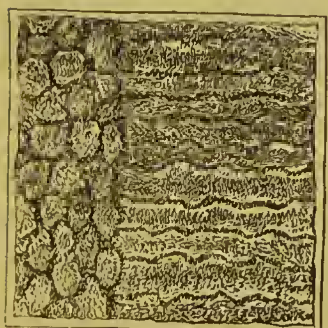


Separated prisms from outer layer of a *Pinna* (after Carpenter).

Oyster is composed of this tissue, it rarely exhibits any trace of development from cells, and when decalcified, the organic basis is found in a membranous form, hence it also has received the name of *membranous* shell-substance. In very many shells this layer is traversed by large tubes which take a sinuous course.

Although as a general rule the organic basis of the internal layer of shells exhibits no trace of cells, yet there are many in which such traces are very evident. A section of the shell of *Pholas cristata* shows a series of hexagonal cells, each having a nucleus in its centre; in some parts of the section, however, the only indications of the cell-walls are dark granular lines, but the nucleus is still perceptible. In a vertical section of the tooth of *Mya arenaria*, as shown in Fig. 161, hexagonal cells are visible on one part, but in others the cell-walls are partially absorbed, and a series of sinuous parallel lines result. It is in this way that the wavy lines found in shells are formed, a fact that must be borne in mind, as I shall again have occasion to allude to it. This subnacreous structure rarely possesses any brilliancy, but nevertheless there is a gradual transition from it to nacre, as for instance, many species of *Mytilus* have a subnacreous internal layer, whilst in others it is brilliant and nacreous.

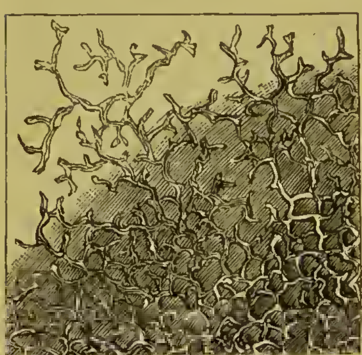
FIG. 161.



A vertical section of a portion of the tooth of *Mya arenaria* showing partial absorption of cell-walls and the production of laminæ.

I shall now speak of the subnacreous variety of shell exhibiting a tubular structure; this is very common in shells of the genera *Anomia*, *Lima* and *Arca*. The tubes sometimes run in a vertical direction, but more frequently horizontally, between or upon the laminæ of which the shell is composed; they are almost always of uniform diameter, and very frequently branched, so that some of them present very much the appearance of confervæ. That they are tubular and possess distinct walls may be readily seen by decalcifying a portion of shell containing them, as shown in Fig. 162, when they remain as distinct tubes, pervading the membranous organic residuum. Some of these tubes present a beaded appearance, indicating that they are made up of cells like the tubular fibres of many fungi. In a horizontal section of the shell of *Lima scabra*, Fig. 183, which is of the subnacreous variety, it will be found, as I have already stated, that the tubes are nearly all of uniform diameter and frequently branched. The tubes generally open upon the inner surface of the shell, as is beautifully seen in a small white shell, commonly called the Rice Shell, from its resemblance to a grain of that plant; these shells no doubt are familiar to most persons, as they are employed in

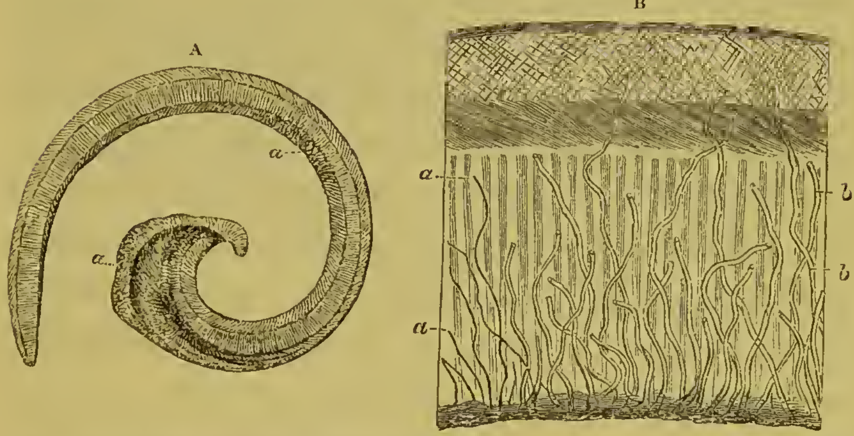
FIG. 162.



A portion of the shell of *Anomia ephippium* decalcified on one edge to show the tubular structure.

the manufacture of brooches and ornaments for the hair. In a transverse section of one of these little shells, as shown at A, in Fig. 163, a number of the tubes, *a a*, may be seen to commence on the inner

FIG. 163.



A, a transverse section of a Rice-shell showing the three component layers magnified 12 diameters; *a a*, tubes perforating the inner and outer layers. B, a portion of the same section magnified 130 diameters; *a a*, small tubes occurring in the inner layer; *b b*, larger tubes or perforations commencing in the inner layer and passing nearly through the shell.

surface of the first whorl, and pass nearly through it; others will be found in the outer layer, as represented in the thick part near the centre of the section.

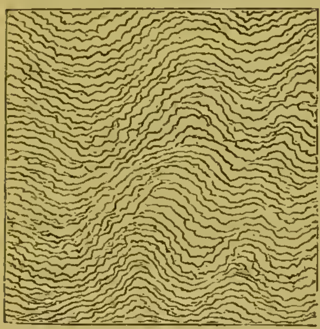
The nature and function of these tubes is but imperfectly understood; Mr. Bowerbank imagines them to be vessels, Dr. Carpenter believes that they are connected in some way with the nutrition of the shell; they may indeed perform a similar office to that of the tubuli of dentine.

In many shells there are two kinds of tubes, one much larger than the other; both are met with in some of the sections of the Riee Shell above alluded to, but the larger kind is not constantly present. On the inner edge of the section, shown at B, in Fig. 163, where the shell is thiekest there are a number of tubes, or tubular cavities, *b b*, much larger than those seen at *a a*, on the inner edge of the same, these, I believe, are either confervoid sponges, or the work of minute boring animals. It may be remembered that when speaking of the ealeareous axis of corals in page 152, I mentioned the faet that sponge-fibres and growths like confervæ are not uncommon in the polypidoms of these animals, and in Fig. 78 is shown a section in whieh, tubes similar to those oecurring in shell, are very abundant.

I shall now illustrate the strueture of the beautiful material termed *Nacre*, or "Mother-of-pearl," which lines the interior of all shells that exhibit an iridescent appearance. In some it forms but a thin internal layer, while in others—the Pearl Oyster, *Avicula margaritifera*, for example—it eonstitutes the largest portion of its thickness, that being the shell which furnishes us with the greater part of the Mother-of-pearl of eommeree. In the *Haliotis*, or Ear-shell, it is remarkable for the beauty of its colours, which are to a certain extent produeed by the development of a coloured horny substanee between the layers of naere. Like the other varieties of shell-tissue, this is evidently developed from cells, but in most instances a rapid partial absorption of the cell-walls has taken place, as in the ease of the

Mya before alluded to, so that nothing but wavy laminæ remain. These wavy laminæ were described by Sir David Brewster and Sir John Herschell as grooves upon the surface of Mother-of-pearl which produce the brilliant colours by decomposing the rays of light incident upon them. The iridescent colours of the shell of the *Nautilus* are well known, the epithet "pearly" being applied to the animal from this circumstance; horizontal sections of the shell, present in some parts a cellular, in others a lamellar structure. In a section of the nacreous layer of the Pearl Oyster viewed under the same power, nothing but fine lines are to be seen, which are either straight or more or less sinuous, in consequence of the parts completing the cellular structure having disappeared. The colours are still produced after the carbonate of lime has been removed by an acid; demonstrating that the decomposition of light depends, not on the calcareous matter, but on the arrangement of the organic basis which retains the striæ, and here and there gives evidence of cell structure.

FIG. 164.



A portion of the Nacre of *Haliotis splendens* magnified 500 diameters.

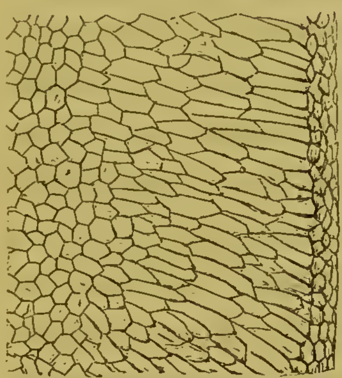
In the shell of *Haliotis splendens*, there are plates of coloured horny material occurring between the laminæ, which, like the laminæ themselves, are arranged in curves following the direction of those of the shell. When a portion of this shell is decalcified it splits up into laminæ, and the layers of horn, which generally communicate a greenish tinge to the acid solution, may be separated from the nacreous portion. The horny layers exhibit little or no structure, but the nacreous laminæ present the same gorgeous hues as in the natural condition. When examined with a power of 100 diameters, the membranous residuum, as shown in Fig. 165, exhibits a plaited or folded appearance, and if stretched by needles, the colours immediately disappear; proving, as was first pointed out by Dr. Carpenter, that the lines of mother-of-pearl are not attributable, as was supposed by Sir David Brewster and Sir John Herschell, to grooves in the substance, but to the plication of the organic membrane, which, as we shall presently find, is originally developed from cells, for even now traces of them may be seen in some parts of the shell.

FIG. 165.

A portion of the Nacre of *Haliotis splendens* decalcified; showing the plicated arrangement of the membranous residuum.

The same laminæ, corresponding to the supposed grooved structure, are seen in a horizontal section of the shell of *Haliotis*, as a series of undulating lines, but in some parts large pigmental cells are visible, which must form only a thin layer, as the undulating lines of the nacre may be readily recognized beneath them; each pigment cell has a stellate nuclear spot in its centre. If a similar section be examined with a power of 500 diameters, a cellular structure is very evident in certain parts, as seen in Fig. 166; a portion of the same shell decalcified shows, even to the naked eye, that the organic basis is gorgeously coloured. A preparation in the Museum of the College, made long ago by the late Mr. Hatchett, which consists of large flakes of the organic basis of shell, exhibits these colours even better than microscopic specimens. A very thin decalcified section, under a power of 250 diameters, proves that the plicæ of the laminæ are more numerous when the colours are most intense.

FIG. 166.

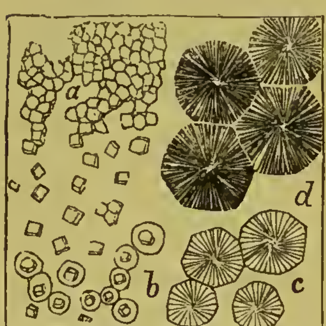


Nacre of *Haliotis splendens* exhibiting a cellular structure.

The nacreous, like the sub-nacreous variety of shell, is sometimes traversed by tubes, but this is not general; these tubes, however, are abundant in some specimens of *Haliotis*, and are best shown in vertical sections through the thickest part of the shell. In such a section, thin laminæ of horny matter are distinguishable by the naked eye lying between the layers of nacre, and when viewed with a power of 250 diameters, as shown in Fig. 197, dark lines may be seen passing across the layers of nacre at right angles to their length. These dark lines are tubes of uniform diameter throughout, and rarely branched; they might be mistaken for scratches, but are not confined to the surface of the section.

There is a very peculiar condition of the internal layer of the shell somctimcs met with in thc common Oyster, in which, instead of a subnacreous layer lining the whole interior of the shell, part of it is occupied by a thin lamina of brown horny material. This horny matter is not uncommon between the layers of prismatic structure on the outer surface of the shell, but I have never, until lately, seen more than three specimens in which it was situated on the inner surface. It is soft and flexible, and when examined with a power of 250 diameters, is found to consist of a thin layer of brown horn, which is thickly covered with, or has numerous minute rhombohedral crystals of carbonate of lime imbcdded in its substance, as shown at *a*, in Fig. 167.

FIG. 167.



a, crystals seen in the brown horny layer of the *Common Oyster*. *b*, crystals surrounded by a cell-wall. *c*, cells from the rudimentary shell of the common *Slug* in which the lime has crystallized. *d*, cells with crystalline deposit from the tooth of *Mya arenaria*.

When placed in dilute acid there is a copious effervescence, and if examined after all effervescence has ceased, the crystals are seen almost as plainly as before, but the parts which look like them would appear to be only the cavities in the horn which the crystals previously occupied. In some specimens, I have noticed whilst decalcification was going on, that each crystal seemed to be surrounded by a faint circlc likc a cell-wall, as shown at *b*, and such an appcarance, if constant, would induce the belief that this layer was onc in which the cclls wcrc not capablc of moulding the lime in a homogeneous form, but that the crystalline force had overcome the usual mode of deposition; the absence of the cellular character in all parts of the horn being a consequence of the speedy coalescence of the cell-walls, whereby a thin layer of structureless membranous substance is produced.

The inner or nacreous layer of shell is generally supposed to be formed upon the external surface of the mantle, whilst the outer layer is developed in connection with its margin. On many shells there is an outer brown coating or epidermis of horny material; this is met with in our common Mussel, and exhibits a cellular structure, but it is more abundant, and therefore more evident, in some of the univalves, as, for instance, certain species of *Triton* and *Conus*, where it forms a layer $\frac{1}{16}$th of an inch in thickness. This layer is termed *periostracum* by Conchologists, and our attention will be again directed to it when we consider the structure of those shells in which it is most abundant.

I have now described the general structure and the chief varieties of shell in the *Conchifera*; in the next Lecture I shall enter more minutely into the varieties peculiar to the orders into which this extensive class of animals is divided by Zoologists.

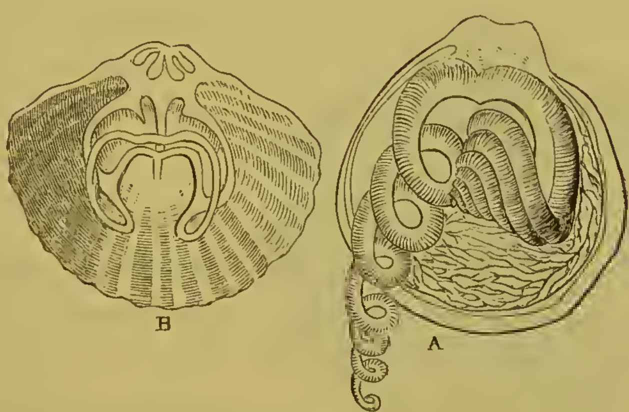
LECTURE XVII.

SKELETON OF MOLLUSCA—BRACHIOPODA.

In the present Lecture I shall apply our general knowledge of the structure of Shell, to the two primary divisions of the Conchifera, the *Brachiopoda*, or *Palliobranchiata* and the *Lamellibranchiata* That the *Brachiopoda*—so named from two arms said to protrude from the shell—were very numerous in our seas in the early geological periods, is made evident by the fact that upwards of six hundred species have been described as British; but at the present time we can enumerate only four living representatives of the order.

One species of *Terebratula* has been dredged up within the last few years on the coast of Ireland. I do not possess a British specimen; all that I have are from Australia and the Navigator's Islands, and were presented to the College by Captain Sir E. Home. They are of two species, the one a large white shell, the *T. Australis,* the other red, and named *T. rubicunda;* the former generally inhabit very deep water, being not unfrequently found at a depth of seventy or eighty fathoms; they are attached to each other, or to the rocks, by a short pedicle, which is capable of being protruded through a circular foramen in the larger valve of the shell; strong muscles are connected with this pedicle, the tendinous fibres of which are remarkable for their brilliancy. In the interior of the shell, and attached to the smaller valve, is a very beautiful framework composed of thin plates of shell substance, as shown at B, in Fig. 168, which, from its resemblance

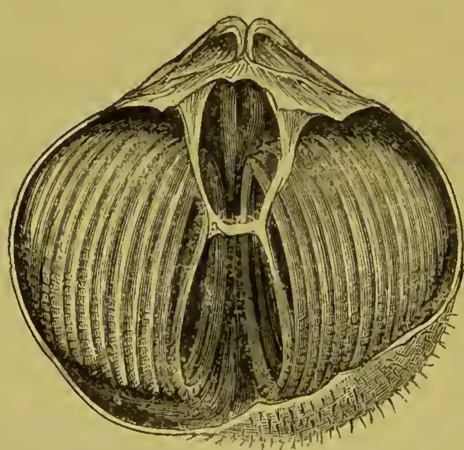
FIG. 168.



A, *Terebratula (Atrypa) psittacea* showing the arms, as formerly and erroneously represented. B, smaller valve of *T. Australis* exhibiting the carriage-spring framework.

to a coach-spring, has been called the "coach-spring" apparatus, and the shells themselves are commonly known as Coach-spring shells. This framework seems, at least in some species, to serve two purposes, the principal one being the support of the long spiral arms, as shown at A, the other probably, like that of the elastic ligament of the oyster, to keep open the valves of the shell. But, however beautiful this framework may be in the *Terebratula*, it is far surpassed by a similar apparatus in certain fossil Brachiopods of the genus *Spirifer*, which are very abundant in the Oolite, especially that of Ilminster in the county of Somerset. Here the framework occupies the greater portion of the shell, each spring, as it were, resembling a conical screw, and having as many as twelve spiral turns composed of flattened shelly matter fringed with minute spines along the lower margin, as shown in Fig. 169; this apparatus no doubt performed a similar office to that of the framework in the recent specimens. The arms, which we should suppose to be instruments of progression, are certainly not so, because the shells are firmly anchored by the short tendinous pedicle; they are clothed with cilia, and there can be no doubt that these produce currents in the water, by which food is brought towards the animal.

FIG. 169.



A magnified view of *Spirifer rostratus* showing the carriage-spring framework occupying the greater portion of the shell.

The arms in the *Terebratulæ* are said to be capable of being protruded from the shell, but in the Brachiopods existing in the earlier periods of the earth's history, the arms were attached to the carriage-spring framework, and were therefore incapable of being extended; in all probability such was the case in the Spirifers before noticed. A beautiful series of dissections of *Terebratula Australis* by Mr. Goadby, in which the entire anatomy of these interesting animals is displayed, may be seen in the Museum of the College. The mantle is shown lining the shell, and the arms folded upon the carriage-spring framework; the respiratory and digestive systems form only a small part of the animal, being confined to the minute space within the carriage frame-work; the shining fibres seen in one of the specimens are those of the tendons of the pedicle.

FIG. 170.

Shell of *Lingula anatina* with its pedicle.

Another existing Brachiopod I shall briefly notice is the *Lingula anatina*, Fig. 170. In this animal the shell is exceedingly thin, and of a green colour, whilst the pedicle is much larger than the shell itself, and not protruded through a hole in one valve of the shell, but attached to both equally. The *Lingula* is not found at such great depths as the *Terebratula*, being confined to parts nearer the surface; it is generally, but erroneously, represented as being provided with an extended arm on each side, but these arms have no carriage-spring framework for their support. There is another existing species of Brachiopod, the *Orbicula*, which has a horny shell, but of this I possess no specimen.

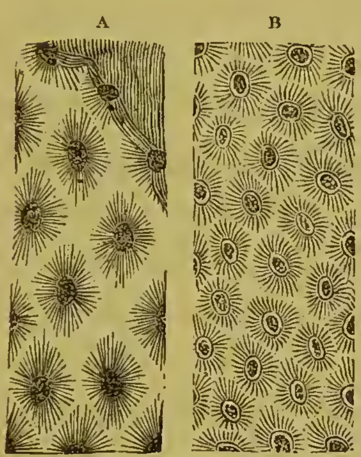
We will now proceed to examine the minute structure of the shell of the *Terebratulæ*, all of which will be found to exhibit one character so peculiar, as to enable a practised microscopist to determine the true nature of even the smallest fragment. This character, as shown in Fig. 171, is produced by a number of oval spots, or openings, of equal size, occurring in oblique rows equi-distant from each other, the tissue between the openings being sometimes fibrous or faintly cellular. When investigating the structure of the shells of *Terebratulæ*, during the preparation of the first volume of the "Histological Catalogue," I detected a series of radii around these openings which had evidently escaped the attention of Dr. Carpenter, as no mention is made of them in his "Report on the Structure of Shells," which contains almost all that is known on the shells of the Terebratulæ. The point to which I allude, is that each opening is surrounded by a series of

FIG. 171.

A portion of the outer surface of the shell of *Terebratula rubicunda* showing the perforations.

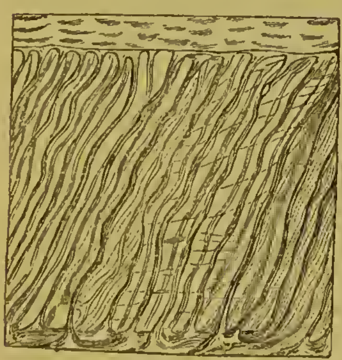
radiating lines, which are very evident in the shell of *Terebratula Australis*, as shown at A, in Fig. 172, and in that of *T. rubicunda*, represented by B. The entire thickness of vertical sections of these shells is traversed by large, more or less parallel, tubes or perforations, as shown in Fig. 173; the oval openings seen on the surface of horizontal sections are the mouths of these tubes, and it will be noticed that they are slightly dilated at both extremities, but as a general rule the openings upon the inner surface of the shell are smaller than those upon the outer surface. The tubes run either vertically or obliquely through the shell, and are very rarely branched; in some species of *Terebratulæ*, as for instance, *T. lenticularis*, Fig. 174, they are so much dilated on the outer surface of the shell as to be almost trumpet-shaped. In the living animal, long cœca containing granular matter occupy the tubes; these are readily

FIG. 172.



A, a portion of the outer surface of the shell of *Terebratula Australis* showing the radiated structure around the perforations. B, a portion of the outer surface of *T. rubicunda* showing the same structure.

FIG. 173.



Vertical section of a portion of the shell of *Terebratula rubicunda* showing the tubes or perforations.

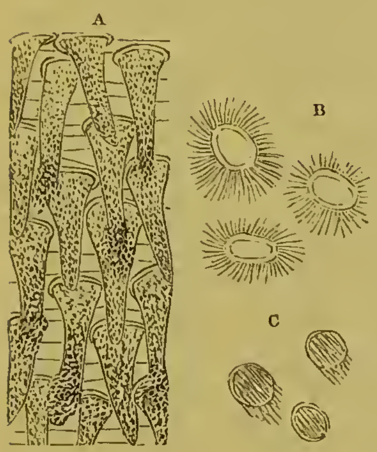
seen in decalcified portions of the shells that have been preserved in spirit with the animal entire. The upper or outer part of the cœcal tube is attached to a rim, or disc, in connection with the epidermis of the shell, whilst the inner opens upon the internal surface, but is quite distinct from the mantle; when highly magnified, the granular matter occurring in these cœcal tubes is well seen. In the decalcified shell of *T. Australis*, as shown at A, in Fig. 175, the cœcal tubes are attached to a structureless membrane, which is in all probability the epidermis, but this is not the case in all Terebratulæ, for in a small undescribed species, I succeeded in detaching an epidermis to which no cœca were adherent, nor was there any trace of them either upon the upper or under surface; but if portions of the decalcified shell-membrane were examined, the cœcal tubes were very abundant.

FIG. 174.

Vertical section of a portion of the shell of *T. lenticularis* showing tubes much dilated on the outer surface of the shell.

In a large specimen of *T. Australis*, I succeeded in separating the cuticle with the discs of the tubes attached, and I remarked that these had on their outer surfaces radiating filaments precisely corresponding to the structure just described as being visible around the mouths of the tubes upon the outer surface of the shell, and which resemble cilia, as shown at B. A radiated structure is very evident around the margin of the perforations in most, if not in all, the Terebratulæ, and was first noticed by me when investigating the structure of the shells of those Brachiopoda published in the first volume of the "Histological Catalogue." I imagined that the radii were tubular, but having once found that the discs could be detached from the tubes in the decalcified shells, I was induced to believe that they might be cilia, and if so, may not their office be that of driving currents of water or of secreted fluid through the cœcal tubes? This point, however, must be reserved for future investigation.

FIG. 175.

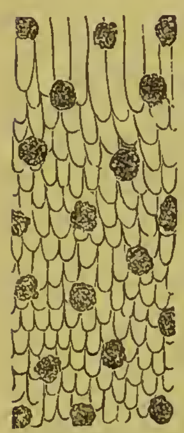


A, a portion of decalcified shell of *Terebratula Australis* showing the cœcal tubes. B, radiated or ciliated discs detached from the tubes. C, termination of the tubes on inner surface of the shell.

The internal surface of the shell of *Terebratulæ*, as shown in Fig. 176, also exhibits the openings of the perforations, but the intermediate shell-substance presents a cellular appearance; towards the outer margin, the cells are elongated, and assume the prismatic form. If, in making a section of the shell of a Terebratula, both the inner and outer surfaces be ground away, no other structure remains than elongated parallel flattened fibres, or cells, which are arranged in the same plane as the shell; the perforations are seen as oval holes, about $\frac{1}{400}$th of an inch in the long, by $\frac{1}{1000}$th in the short diameter, and the margins of these perforations are formed by a curvature in the flattened fibres.

The shell of *T. rubicunda*, which is so readily recognized by its red colour, exhibits the perforations as well as the long parallel prismatic fibres, all of which are curved opposite the perforations. This curving of the fibres, however, is better seen in fragments broken from the shell, some of which, as represented in Fig. 177, not only show the flattened fibres lying in a detached state, but the curvature of the parts forming the boundaries of the perforations. It is still a matter of doubt with microscopists, whether they are flattened fibres or elongated cells; it is true that they might be regarded as plications, but if the shell be decalcified, all traces of them disappear, and I am inclined to regard them as having a cellular origin. All the structures above indicated are seen in the carriage-spring framework, with the exception of the perforations.

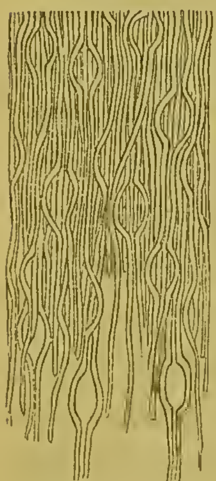
FIG. 176.



Inner surface of the shell of *Terebratula rubicunda* showing the cellular structure between the perforations.

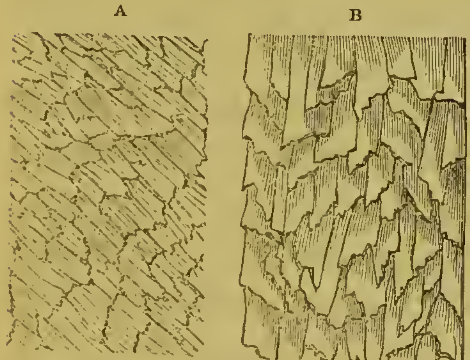
The *Terebratulæ*, as I have already said, are very numerous in the fossil state, and all the species of this genus, whether recent or fossil, are perforated with tubes, but the allied genus *Atrypa* presents all the other characters except the perforations. One species, *A. psittacea*, was formerly placed in the genus *Terebratula*, but no perforations being discoverable by microscopic examination of the shell, it is now removed to the genus *Atrypa*. The prismatic or fibrous structure is very evident in the shell of this animal, as shown at A, in Fig. 178; it is also plainly seen in a fossil species, *T. inconstans*, represented at B. Some of the fossil *Terebratulæ* are covered with delicate spines; these are very minute, and exhibit none of the characteristic structure of the shell, but are more like the large spicula found in the rachis of the *Pennatulæ*. The shell of another recent Brachiopod, the *Lingula anatina*, is also perforated by tubes of smaller size than those of the Terebratulæ. The shell is of a horny character, and presents two kinds of striæ, or tubuli, the one very minute — much more so indeed than those of dentine—which run in lines either parallel or nearly at right angles to the surface, the other much larger and less numerous, which

FIG. 177.



Elongated cells or fibres of the shell of *Terebratula rubicunda*, which are so curved as to form the margins of the perforations.

FIG. 178.

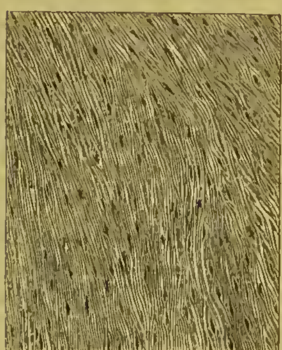


A, a portion of the shell of *Atrypa psittacea*. B, a chipping from the shell of a fossil Terebratula, *T. inconstans*, both being non-perforated.

are probably the analogues of the tubuli in the Terebratulæ; these take a sinuous course, and when divided transversely, appear as numerous round dots. The Lingula has been dissected by Mr. Goadby, and a series of beautiful preparations, mounted in the same way as those of the Terebratulæ, may be studied in the Museum.

In the second great division of the *Conchifera*, the *Lamellibranchiata*, the shells are all bivalve, the branchial organs well developed, consisting of four lamellæ, which are enclosed within the mantle. According to Dr. Carpenter, those of the Lamellibranchiata in which the lobes of the mantle are disunited, inhabit shells composed of prismatic cellular tissue, whilst those with the lobes either partially or completely united, consist of other kinds of structure, and their animal basis, instead of exhibiting a cellular appearance, is small in quantity, and made up of laminæ of delicate membrane. The Oysters and Pinnæ are examples of the former; the Cockles and Clam-shells, of the latter. The structure of the Pinna-shell has been already described in pages 269 and 272, and with the exception of the thin internal layer, all parts of any shell of this genus are composed entirely of the prismatic cellular tissue, the calcareous matter occupying the interior of

FIG. 179.



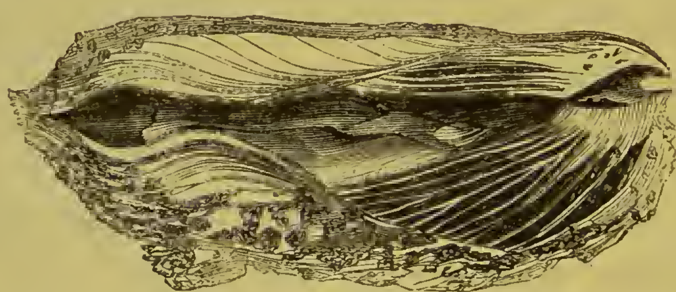
A portion of the shell of *Lingula anatina* showing the minute tubuli and the larger tubes divided transversely.

the cells being generally more or less pink and homogeneous. A horizontal section of the shell, as shown in Fig. 158, presents a series of hexagonal cells, averaging about $\frac{1}{500}$th of an inch in diameter; in a vertical section, on the contrary, these cells are arranged in vertical columns, or prisms, with one or both extremities pointed, and having a series of transverse markings indicating the individual cells of which each prism is composed, as represented in Fig. 159. In addition to the transverse lines on each prism, there are others much more evident, which run across the entire section, and indicate in all probability the successive stages of growth. The internal layer associated with this form of tissue is nacreous, or sub-nacreous, and when ground very thin, exhibits little or no structure, being composed of the membranous variety of shell-tissue.

The shell of our common edible Oyster, like that of the Pinna, is composed of two kinds of structure, the prismatic and the subnacreous, the former, more or less laminated, is external, while the latter forms the white internal layer. The distinction between these layers is very striking in old Oysters, and many specimens have been obtained from an Oyster-bed discovered some few years ago in the Channel, which on section, as shown in Fig. 180, exhibit this distinction in a very marked manner. In some of these, an imperfect formation of the prismatic layer, or the removal of this softer portion of the shell by boring animals, renders the distinction more evident;

such shells consist of a series of the internal, or nacreous layers separated by cavities from each other. The brown outer layer of the shell of the Oyster is composed of prismatic cellular tissue, which in the horizontal section, or when the prisms are divided transversely, appears to be made up of more or less regular hexagonal cells of uniform size, whilst the internal or subnacreous layer is almost structureless or minutely granular, exhibiting no trace of cells; but in some specimens this layer closely resembles nacre, the structure then being more or less sinuous, and in

FIG. 180.

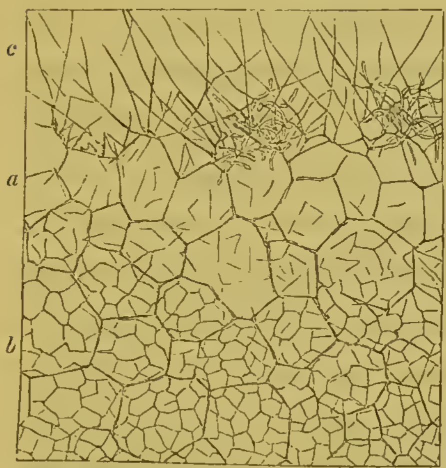


A vertical section of a shell of an old Oyster showing the course of the inner subnacreous layers and the destruction of a greater portion of the prismatic structure by boring animals.

certain oysters will be found traversed by tubes. In a horizontal section of *Perna ephippium*, the cellular structure is distinct, but the cells are much more minute, averaging $\frac{1}{1200}$th of an inch in diameter, whilst in most of the Pinnæ they are $\frac{1}{500}$th of an inch, and the internal layer of this shell is composed of true nacre.

The horizontal section of the shell of the Hammer Oyster, *Malleus albus*, shown in Fig. 181, evidently contains three kinds of structure; on the margin where the large hexagons are seen, the cells are about $\frac{1}{300}$th of an inch in diameter; beneath these there are other cells, forming a distinct layer so minute as $\frac{1}{2000}$th of an inch, whilst on the upper edge is seen the nacreous layer, in which not only wavy lines occur, but the greater part of its surface is traversed by numerous large branching tubes. If the shell be small and very convex, then, by grinding the horizontal section flat, the centre will be found occupied by the nacreous or subnacreous layer, whilst the margin is composed of hexagonal cells; such is the case in sections of the shell of a *Crenatula*, the centre of which exhibit the wavy lines characteristic of the nacre, whilst the margin is composed of hexagonal cells.

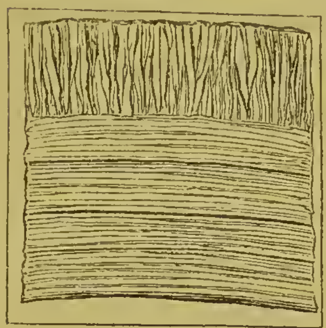
FIG. 181.



A horizontal section of the shell of *Malleus albus*. *a*, coarse prismatic structure. *b*, minute prismatic structure. *c*, nacreous layer with tubuli.

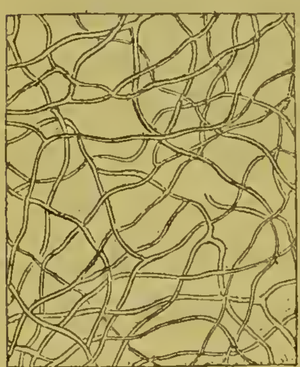
In vertical sections of the Pearl Oyster, as shown in Fig. 182, two distinct structures are evident, even to the naked eye; the outer is more or less brown, the lower truly nacreous; the former is composed of a series of short prisms, all of which show transverse markings, while the nacreous layer presents prismatic colours and distinct sinuous lines. The nacreous layer is very thick in this species, from which the principal part of the Mother-of-pearl of commerce is procured. Horizontal sections of the shell of *Lima scabra* are chiefly composed of the subnacreous tissue, traversed by large branching tubuli not arranged in any definite order, but crossing and re-crossing each other in every direction, as shown in Fig. 183. When the shell is decalcified, the tubes are still perfectly apparent, together with the rest of the organic matter. The office these tubes perform is still uncertain, most of them commence upon the inner surface of the shell, which must have been in contact with the mantle, and then pass towards the outer surface, their function, as I have said before, may probably be analogous to that of the tubes of dentine; they are generally found only in the subnacreous substance, but the beautiful nacre of the Haliotis is traversed by them, as shown in Fig. 197.

FIG. 182.



A vertical section of the shell of the Pearl Oyster, *Avicula margaritifera*, showing the prismatic and nacreous layers.

FIG. 183.



Portion of the subnacreous tissue of *Lima scabra* traversed by tubes.

LECTURE XVIII.

SKELETON OF MOLLUSCA—CONCHIFERA.

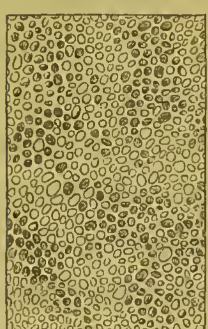
In a perfectly-formed Oyster-shell there is always a very perceptible difference between the structure of the outer and inner laminæ; the one is comparatively thick and soft, the other exceedingly thin and hard. In an old and thick shell which has been divided vertically, the two portions, as shown in Fig. 180, are very evident, the former being more or less calcareous, the other very thin. The calcareous portion is soft, containing scarcely a trace of animal matter, and is to a considerable extent destroyed by boring animals; but they have left the thin, internal layers untouched, probably in consequence of their hardness. In some parts of such a section, nearly the whole of the calcareous external layer has been removed, and the laminæ composing the inner layer alone remain, so that the shell in these parts has a cancellated appearance. A distinct cancellated structure is present in most of the shells of the genus *Spondylus*, the office of the cancelli being to render the shell lighter; the shell of *Spondylus gigas* is in some parts three inches thick, and if solid, would be very weighty, but if all the laminæ forming the cancelli were in close apposition they would form a stratum not much more than half an inch in thickness. It may be questioned whether the part corresponding to the outer layer, or that which in the Oyster filled up the spaces between the laminæ, ever exists in the Spondylus, or whether the laminæ, as we now see them, are really composed of two distinct kinds of shell-structure; this I shall endeavour to elucidate on another occasion.

The outer or calcareous laminæ of one of these thick oyster-shells, when ground as thin as possible, is still very opaque, except in some parts where the remains of prismatic structure may still be discovered. In the Pearl Oyster, *Avicula margaritifera*, the outer layer is generally very thin and coloured, the inner, thick and nacreous, and the flat valve is the upper one, as in the common Oyster. In a vertical section of this shell, shown in Fig. 182, the outer layer, which is of a greenish-brown colour, is composed of rows of prisms, whilst the whole of the inner layer is traversed by lines of growth; but when a portion of the same nacre is viewed under a much higher power, the sinuous structure is very apparent, and it is by such an arrangement that the colours of this beautiful substance are produced. When the whole of the calcareous matter of the nacreous lamina of the same shell is removed by an acid, the organic tissue is found to be a closely plicated membrane; these folds are closer and more numerous where the colours are most brilliant, but, on the other hand, where no folds exist, the colours are entirely absent. The inner layer of the common Oyster-shell exhibits no such colours, and when decalcified, the membranous residuum is so small in quantity as hardly to hold together. Many of the Mussels, as the *Iridina elongata*, have a nacreous internal layer, perhaps more brilliant than that of the Oysters, but these are all foreign species; the only British specimen at all resembling them is the *Unio margaritiferus* found in the rivers of Scotland, Ireland and Wales, which will be alluded to in a future lecture.

When Nacre or Mother-of-pearl was first examined, many years ago, by Sir David Brewster, he discovered on its surface a series of sinuous lines, which he imagined to be grooves, and they were compared by Sir John Herschell to the lines observed on a smoothly-planed piece of deal; they are not grooves, however, but plications of the animal basis of the shell. The same effect is producible by grooves, as was first shown by Sir John Barton on the principle of unequal reflection of light; but I shall reserve the consideration of this subject for a future occasion.

In all the shells I have now described of the Lamellibranchiate order, the lobes of the mantle are separate, and we have seen that the outer layer of the shell presents the prismatic cellular tissue, and the inner the nacreous or subnacreous. We have next to consider the structure of those shells in which the lobes of the mantle are either partially or completely united. In these shells the prismatic cellular tissue is very uncommon and the internal layer is generally subnacreous, sometimes presenting almost a crystalline appearance, and when decalcified, the organic basis is so small in quantity, that a fragment of the section will hardly retain its shape when deprived of its calcareous matter.

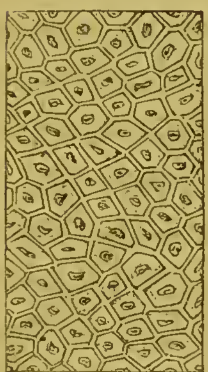
FIG. 184.



A portion of the horny epidermis of the Common Mussel, *Mytilus edulis*.

Many of the shells we are about to examine are provided with a horny epidermis, which is sometimes composed of cells like those of cuticle. The epidermis of our common edible Mussel contains traces of cellular tissue; Dr. Carpenter, however, believes that the epidermis of this shell is structureless, and that a layer immediately below it, which is cellular, is sometimes removed with it. In the specimen represented by Fig. 184, some of the cells had dark walls, others were black in the centre with transparent walls; these last were probably filled with air, the preparation being mounted in balsam. The periostracum of another shell, *Trigonia Lamarckii*, is undoubtedly cellular, each cell being hexagonal, with very thick walls, and containing a large central nucleus. The cells are not uniform in size, being smallest near the hinge and gradually increasing from this point to the margin of the valve. The beautiful periostracum, a portion of which is represented in Fig. 185, was first described by Mr. Bowerbank in a paper on the Structure of Shell published in the first volume of the "Transactions of the Microscopical Society."

FIG. 185.

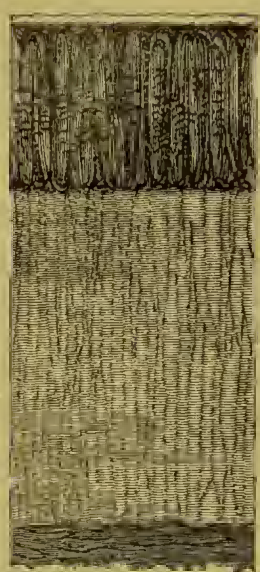


A portion of the periostracum of *Trigonia Lamarckii.*

In a vertical section of one of the valves of the common edible mussel, three distinct kinds of structure are discernible; one is prismatic, another more or less of a blue colour, whilst the third, which forms the inner layer of the shell, is white or greyish-white. In a horizontal section of the same shell, on account of the convexity of the shell and the process of grinding, these layers are all seen at one time in the field of view, but the blue-coloured layer predominates. On the margin of such a section there are faint traces of prismatic structure, towards the centre, where the blue colour prevails, there are no cells, but subnacreous tissue only, and in the very centre there is an almost colourless spot, which shows a slight indication of a nacreous layer. If this mussel had been one possessing a nacreous internal layer, the sinuous condition of the internal laminæ would have been more evident.

In Mussel-shells in which the internal layer is very brilliant—as, for example, the Pearl Mussel, *Mytilus margaritaceus*, Fig. 186—the nacreous layer, very thick and in some parts of a beautiful purple or violet colour, is covered by a thin prismatic layer with a still thinner cuticle. The horizontal section of the inner layer of the same shell presents the peculiar sinuous structure of nacre, differing entirely from that of the edible Mussel. The nacreous layer of shell occasionally exhibits a trace of tubular structure, and in the *Haliotis* long tubes are sometimes observed. Our common Cockle and Scallop-shells are principally made up of white subnacreous tissue, but the projecting ribs or ridges of the shell generally exhibit the prismatic cellular structure. In the Cockle, *Cardium cardissa*, the ridges are composed of prismatic structure, whilst the other parts are more or less fibrous; both layers, however, are traversed by small tubuli.

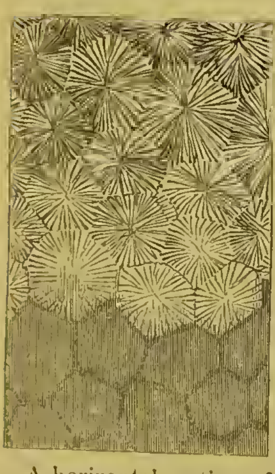
FIG. 186.



A vertical section of the shell of *Mytilus margaritaceus.*

The shell of *Mya arenaria* is principally formed of subnacreous tissue, but the horizontal section of this shell shows that all parts of the outer surface are distinctly cellular; the cells are very evident on the margin, but on tracing them towards the centre, the cell-walls become less and less evident, until at last, in the very centre of the field, nothing remains of them but the dark granular matter which occupied their interior. Immediately beneath this layer is the sub-nacreous tissue which is occasionally traversed by tubuli. One of the valves of this shell has a remarkable process near the hinge, called the tooth, which projects at right angles to the valve, and is generally half an inch in length; it is composed of short, broad prisms, which, in some specimens, are filled with calcareous matter in a radiating crystalline state. Dr. Carpenter possesses a specimen in which the carbonate of lime is in the form of radiating crystals, as shown in Fig. 187, and the section has not been unaptly compared to a specimen of the mineral Arragonite. A vertical section of the hinge of the same shell shows the length of the prisms in which the carbonate of lime is partially crystalline, and the direction of the crystals at an angle of 45° with the sides of the prisms. Other horizontal sections of the hinge of *Mya arenaria*, as shown in Fig. 161, beautifully illustrate the transition from a truly cellular to a perfectly membranous structure, by the partial absorption and coalescence of the cell-walls, for in these specimens we see the cell-walls very clearly in one portion, while in others they gradually lose the hexagonal outline,

FIG. 187.



A horizontal section of a portion of the Tooth of *Mya arenaria* showing a radiated crystalline arrangement in the interior of each cell.

and merge into mere sinuous lines or folds. If the longitudinal lines were connected by transverse ones, the original cellular structure would reappear. These gradual transitions are the key to the formation of the sinuous lines in the nacre, but in true nacre the original cells are much more minute.

In the hinge-tooth of *Pholas crispata*, as represented in Plate XVI, Fig. 17, of the first volume of the "Histological Catalogue," a somewhat similar structure exists; the tissue is cellular, and the centre of each cell is occupied by dark granular matter; in some parts the cell-walls have disappeared, but the separate masses of granular matter indicate very clearly the position of the cells. In all the large shells, as the *Tridacna* and *Chama*, the tissue is prismatic and subnacreous; such shells are usually traversed by tubes which commence on the inner, and extend as far as the outer surface, and if this surface present any spines or ridges, the tubes are generally directed towards them.

In *Cleidotherus chamoides*, the outer layer of the shell is composed of prismatic cellular structure, while the internal is more or less nacreous, with numerous tubuli, which, as Dr. Carpenter has shown, form an irregular network parallel to the internal surface of the shell. From this network a series of straight tubes arise, which pass at right angles to the nacreous layer, at a considerable distance from each other, extending to the prismatic cellular layer, but terminating abruptly without entering it. In a section of this shell, for which I am indebted to Dr. Carpenter, the cellular structure is very evident, and occurs in all parts of the section appearing opaque to the naked eye; the transparent parts are nacreous, and exhibit the tubuli very plainly. Near the centre of the section is a triangular hole, and many of the tubuli commence on its margin, some of them are divided transversely, others ramify in the nacreous substance.

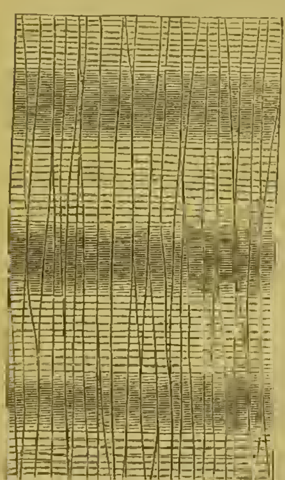
Before leaving the structure of the skeleton of the Lamellibranchiate Mollusca, I must notice a few points of interest in connection with the growth of shell. In some species of *Spondylus* the external surface is covered with large spines, usually of the same colour and minute character as those of the exterior of the shell, increasing in size with its growth. A series of hooks are developed on the external surface of the convex valve of the young shell of the Tree Oyster, *Ostrea folium*—so called from its adhering to the stems of trees, Gorgonias, &c.—by which the animal retains its position. These hamular processes increase by fresh deposits on their external surface, so that with the growth of the stem of the Gorgonia, their hold on it is strengthened.

An interesting example of the change of form in shells is afforded by an *Anomia* for which I am indebted to Mr. Baker of Bridgewater, who has kindly sent me several specimens illustrating the same fact. In these specimens the *Anomia* has attached itself to the upper strongly-ribbed valve of the common *Scallop ;* and the lower valve of the parasite, instead of being flat and thin as usual, is as much fluted as the Scallop itself.

The shells of this order generally consist of two valves connected by a hinge, either simple or composed of two or more teeth which interlock; within the hinge, or external to it, we find an elastic ligament, serving the purpose of opening the shell, and acting as an antagonist to the adductor muscle. While the animal is at rest and undisturbed, the adductor muscle ceases to act and the shell remains open, freely admitting food and water; but on the approach of danger, disturbance or removal from the water, the adductor muscle contracts with such force as not only to overcome the elasticity of the ligament, but to render it difficult to force apart the valves of the shell.

Shells of a rounded form, like the common oyster, have only one adductor muscle, and are termed *Monomyaria,* whilst those of an elongated form possess two adductor muscles, and are thence called *Dimyaria.* It is evident that a simple elastic tissue would suffice to open the shell, and that a piece of India-rubber might be substituted for the ligament, when this is internal to the hinge, but it would be inefficacious when the ligament is external to the hinge, because in the latter case the ligament must necessarily possess a true contractile power. The minute structure of this ligament was first investigated by my late brother, whose researches were published in the second volume of the "Transactions of the Microscopical Society." The ligament placed within the hinge he found to be composed of two different kinds of tissue, the external being nearly structureless, whilst the internal is fibrous, sometimes presenting a brilliant play of colours; the fibres take a vertical direction, they are crossed by transverse striæ, as in Fig. 188, and bear a perfect resemblance to the prismatic cellular structure of the shell deprived of its calcareous deposit; that this is its true character, is evident, and in some shells I have detected calcareous matter in the hinge ligament.

FIG. 188.



A portion of the elastic material from the hinge of *Cyrena purpurea.*

Whatever be the nature of this tissue, it must evidently be contractile, like muscle, and so powerful is its action and so extended its range, that in some of the Lamellibranchiate animals, as the Scallop, after division of the adductor muscle, the valves gape to the extent of three inches. This ligament must assist in the progression of the animal, for we are told that the Scallop is capable of moving rather quickly, by the rapid opening and shutting of its shell, and the Cockle can do more, for by means of its foot, aided I should imagine by the opening and shutting of its shell, it can perform a series of small leaps.

In many bivalve shells there is a peculiar collection of silken filaments called the *byssus*, extending from the extremity of the foot, by means of which the shells are firmly anchored to rocks or stones. A familiar example of the byssus is afforded by the common edible Mussel, and a still more striking one is that of the *Pinnæ*, which is often several inches in length. In *Tridacna*, when young, the byssus is so strong as to be cut with difficulty by a knife; but when the shell is older and heavier, no byssus is secreted. Examined microscopically, the byssus of the Pinnæ is found to be composed of filaments of a brown colour, without any trace of structure; in some species they are so long and silky as to be manufactured into gloves.

LECTURE XIX.

SKELETON OF MOLLUSCA—GASTEROPODA.

The animals comprising the class *Gasteropoda* are not only the most numerous, but the most typical of all the Mollusca; they have one remarkable peculiarity by which they can readily be distinguished; this consists in their being provided with a fleshy disc serving as a foot, upon which they creep. The foot is present in all the true *Gasteropoda*, as shown in Fig. 153, but there is a small class in which this organ is so modified as to form a vertical flattened fin, enabling the animal to swim rapidly through the water; to this class the term *Heteropoda* has been applied, and the *Carinaria*, represented in Fig. 207, is one of the best known examples. The back of a Gasteropod is covered with a cloak or mantle, in or upon which the *Shell* is secreted; the shell is usually spiral and *univalve*, but in the genus

Chiton, it is *multivalve*. In certain of the Nudibranchiate order it is either absent or represented by small calcareous spicula.

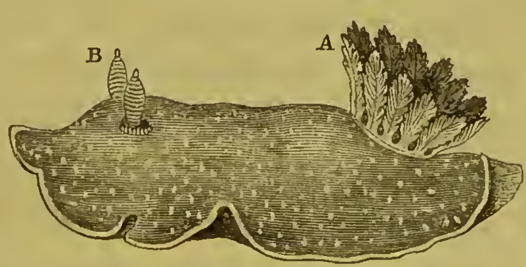
The shape of the shell of the Gasteropoda is more or less conical; in many genera, as in *Patella*, it is a simple flattened cone, in others the cone is elongated, and may be either straight, as in *Dentalium*, or in one plane, as in *Planorbis*, or forming a true helix, as in the common Snail. In many aquatic species the extremity of the foot is covered by a plate of horn, or of calcareous matter called the *Operculum*, which is considered by Mr. Gray as the rudiment of the second valve; its principal use appears to be that of closing the shell when the animal has retired within it. Most of you no doubt are familiar with the delicate membranous film by which the mouth of the common garden Snail is closed during the period of hybernation; this is a rudimentary operculum, but under certain conditions, as I shall hereafter show, it may become thickened and very opaque by a deposit of carbonate of lime in a granular form. Some of the shells are smooth, others are covered with long spines formed upon prolongations of the mantle; these are not constant either in size or number in the same species of shell, as the animal is not only capable of removing them when they have become old, but of forming new ones in other situations.

All the shells of this class of animals are remarkable for the small amount of the organic, compared with the inorganic element, so that they are not only extremely brittle, but their fractured surfaees have more or less of a crystallinc appearance; and to these shells the term *porcellanous* was applied by the late Mr. Hatchett in conscquence of the organic element being so small in quantity as only to be reeognized by its beeoming black when heated.

For our knowledge of the intimate strueturc of the shells of *Gasteropoda*, wc are principally indebted to the labours of Mr. Bowerbank, whose researches are published in the first volume of the "Transaetions of the Microscopical Society." As we proeecd with our examination of sections of shells of various genera, the strongest evidenee will bc afforded of the cellular origin of all the laminæ, howevcr erystalline some of them may at first sight appear.

The order *Nudibranchiata*, so named from the exposed condition of thc respiratory organs, as shown at A, in Fig. 189, in which thc shell is either absent

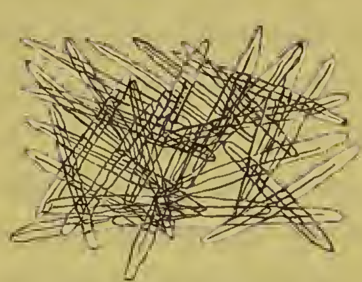
FIG. 189.



Doris Johnstoni. A, arborescent branchiæ. B, dorsal tentaclcs (after Alder and Hancock).

or only rudimentary in thc adult animal, must first claim our attcntion. The very important fact must however be borne in mind, that in the early stage of growth—the larval condition of the animal—a shell really existed, which was shed at an early age, and never reproduced except in the form of spicula. Our knowledge of the Nudibranchiate Mollusca has been of late greatly increased by the researches of Messrs. Alder and Hancock, and the splendid Monograph published by the Ray Society has been the result of their labours. In many of the species some rudiment of a skeleton in the form of spicula has been discovered; these spicula may be pointed at both extremities and nearly smooth, as in Fig. 190,

FIG. 190.



Spicula from the epidermis of a species of *Doris*.

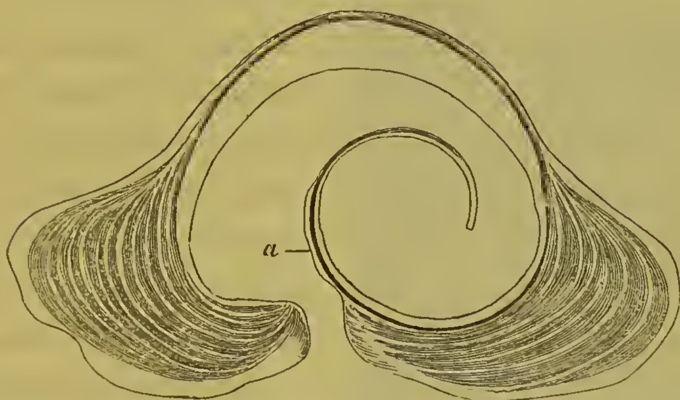
or covered with tubercles like those of the *Gorgoniæ*. According to Messrs. Alder and Hancock, in *Doris flammea* the cloak is fully developed and is covered with rather small, unequal, rounded, spiculose tubercles, which are large in the centre, and become less towards the margin. In *Doris Johnstoni* they are similar in shape to those represented in Fig. 190, but are so small as scarcely to be visible to the naked eye, although they occur in such numbers as to give the cloak a granular appearance. The spicula are situated in the epidermis; they are composed chiefly of carbonate of lime; but, like the inorganic element of shell in general, they contain a minute proportion of phosphate of lime. They may be separated from the soft tissue in which they are imbedded by means of caustic potash, and when treated with acids they dissolve with effervescence, and leave an organic basis, retaining to a certain extent the shape of the original spiculum.

The next order of Gasteropods, the *Pulmonata* of Cuvier, embraces our common Slugs and Snails, in the former of which, the shell is either absent in the adult state, or represented by a conical plate protecting the breathing organ. The shell of the Slug has been already described at page 268 as consisting, in its earliest stage, of a series of cells, which, in progress of growth, become filled with calcareous material. In *Limax rufus*, as shown in Fig. 153, the rudimentary shell is situated in the shield close to the head of the animal; but in *Testacella* the branchial apparatus is removed to the opposite extremity of the body, near the anus, and in this situation is found a small ear-shaped shell, but whatever be the shape of the shell, the cellular character is always more or less plainly visible on microscopic examination, especially in the newly formed parts. The garden Snail, *Helix pomatia*, belongs to the same family as the Slugs, but this animal is provided with a well-developed shell; when, however, it retreats to its winter quarters, it closes its shell with a transparent membranous operculum. Should it so happen that it be often disturbed, or be cognizant of the intrusion of foreign bodies, the thin membrane becomes thickened and cellular, and at length calcareous material is deposited in the cells, as will hereafter be shown.

The shells of all the Gasteropoda provided with a true shell, within which the animal can be wholly or partially withdrawn, almost always present a strong similarity in their minute structure, the most marked feature being the small amount of animal matter, owing to which, the original cellular structure is so very indistinct as to have led many Conchologists to suppose that the appearances presented on section are due to crystallization. Most of the shells, especially those of the *Pectinibranchiate* order, are composed of three layers, each consisting of innumerable plates, made up of prismatic cellular tissue disposed alternately in contrary directions, so that the row of cells in one layer intersects that below it, nearly at right angles. Mr. Bowerbank examined the structure of many univalve shells, and found them to agree so nearly that he was induced to select the *Cypræa mauritiana* as the type of the whole, there being in this shell so large an amount of colouring matter intermixed with its structures, as to render it the best for the examination of its fractured surfaces, when illuminated by means of the Lieberkuhn.

A section of a *Cypræa* is represented in Fig. 191; the coloured layers are well seen in the thick parts of the section, but all the other portions, however thin, exhibit three distinct layers. The section represented

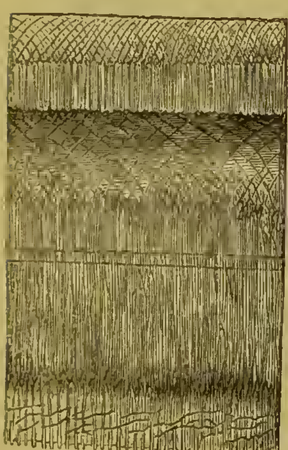
FIG. 191.



Vertical section of a Cowrie *Cypræa*. *a*, the portion from which Fig. 192 was drawn.

in Fig. 191 has been made sufficiently thin to be transparent in every part, and when one of the narrowest of the spiral portions, *a*, is examined with a power of 40 diameters, the structure shown in Fig. 192 is plainly exhibited; such sections, however, give but a faint idea of the remarkable arrangement of the cells of the middle layer. This layer, as pointed out by Mr. Bowerbank, is best seen in portions fractured in the vertical direction, or at right angles to the lines of growth in which the peculiar arrangement of the

FIG. 192.



A portion of the shell of a *Cypræa* marked *a*, in Fig. 191, magnified 40 diameters.

prismatic cells so faintly indicated in Fig. 192 is brought out in the manner represented in Fig. 193. The intimate structure of the three layers of the shell is the same, but the disposition of the laminæ is different in any two adjoining ones; in all cases, however, the rows of cells have the same direction in the inner and outer layers of the shell, and this may be either at right angles or parallel to the lines of growth, while in the middle layer they are always arranged so as to be at right angles to the other two layers.

FIG. 193.

Portion of the fractured surface of the middle layer of *Cypræa mauritiana* exhibiting laminæ of prismatic cells crossing each other at right angles (after Bowerbank).

The disposition of the cells in the three layers is very well seen in transverse sections of the shells of some of the smaller Gasteropoda, as the Rice Shell before alluded to at page 277. The section exhibited in Fig. 163, A, is about $\frac{1}{4}$th of an inch in diameter, and when slightly magnified, the structure of the three layers is distinctly visible; the arrangement of the cells is perhaps still better seen at B, which is a portion of the same section more highly magnified. These little shells almost always exhibit two kinds of tubular structure, one very minute, like that shown in *Malleus albus*, Fig. 181, the other much larger and probably due to boring animals, as in Fig. 163, *b b;* a faint indication of these tubes is shown at *a*, in the transverse section above mentioned. The elongated shells of the Gasteropoda, such as *Dentalium* and *Magilus*, exhibit nearly the same structure as those I have already described, the animal matter is very small in quantity, and the fractured surfaces have a crystalline appearance; the latter of these shells merits a brief notice in consequence of the peculiar manner in which its growth keeps pace with that of the coral mass in which it is imbedded.

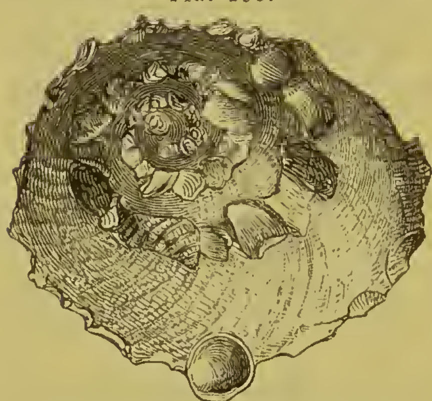
In the young state of the *Magilus* the shell is thin, differing very little in shape from that of the common Whelk, and of a spiral form. It is fixed amongst corals and madrepores, and were it to continue to grow in the spiral direction, the corals would soon cover it; to prevent this, it takes the form of a perpendicular tube, and the growth is sufficiently rapid to keep pace with that of the coral. The animal only occupies the upper portion of the shell, and as the new matter is added to the mouth, the cavity of the tube is solidified by the deposition of a glassy substance.

FIG. 194.

Elongated shell of *Magilus antiquorum* (after Woodward).

Some of the Gasteropoda have very thin shells; as for example, certain species of the genus *Trochus*, which live amongst rocks, and in order to resist the shocks to which they are constantly liable, strengthen the exterior surface of their shell by cementing to it, fragments of stone, or coral, and even valves of other shells. A specimen of Trochus, *T. agglutinans*, is represented at Fig. 195; the foreign bodies, it will be seen, have all been attached close to the mouth, and as the growth has proceeded, they are left in a spiral form corresponding with the convolutions of the shell. Some *Trochi* appear to make a careful selection of the foreign bodies, and arrange them in a regular spiral; these have been called *Masons*, while others seem to be indifferent as to the size and symmetrical arrangement of the strengthening materials, and these have been named *Carriers*.

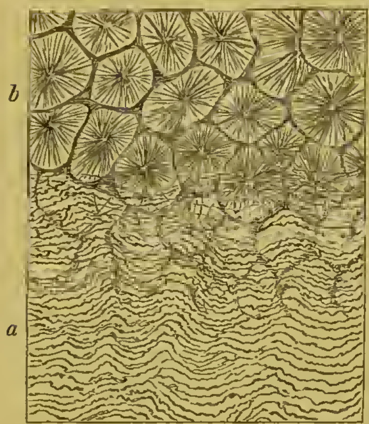
FIG. 195.



Trochus agglutinans having its shell strengthened by the addition of foreign bodies.

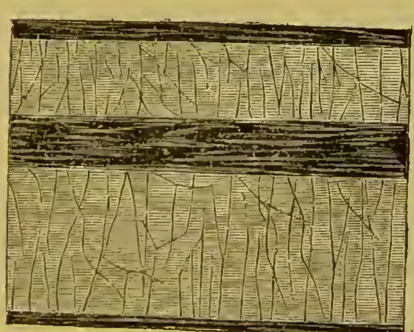
Certain genera of univalve shells, like some of the bivalves before noticed, have a very brilliant nacreous layer; of these, none is more beautiful than the *Haliotis*, all the species of which have more or less of a brown horny substance situated between the laminæ of calcareous material. A horizontal section of the shell of *Haliotis splendens* is seen to consist of alternate sinuous layers of a brown horny material, and *Nacre*; the latter may be readily distinguished from the former, not only by its colour, but by the peculiar undulating lines seen on the surface, as shown at *a*, in Fig. 196. In immediate connection with this nacreous layer may be seen the horny material, having its surface covered with hexagonal cells of various sizes, each being provided with a coloured spot of a stellate form in its centre, as shown at *b*. These cells form so thin a layer, that the nacre can be seen immediately beneath them. A vertical section of the same shell exhibits alternate bands of horny matter and of nacre, the former being on an average $\frac{1}{40}$th, whilst the latter is frequently $\frac{1}{10}$th of an inch in thickness. All the nacreous bands are traversed by minute tubes, as shown in Fig. 197, their direction being nearly at right angles to that of the striæ. When viewed with a power of 500 diameters, the nacreous layer of this shell exhibits a distinctly cellular structure, as before shown in Fig. 166, and when the same layer is

FIG. 196.



Vertical section of shell of *Haliotis splendens*. *a*, nacreous layer. *b*, horny layer covered with large hexagonal cells.

FIG. 197.



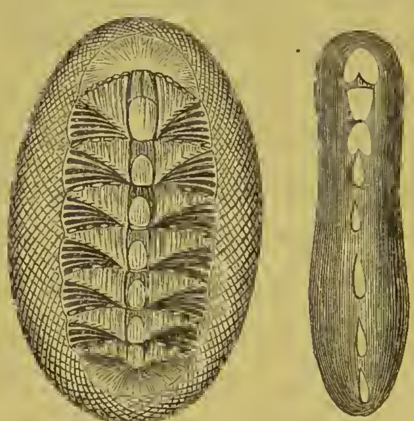
Vertical section of shell of *Haliotis splendens* exhibiting three dark bands of horny material and two of nacre, the latter being traversed by tubes.

decalcified, the beautiful iridescent hues will be found to depend upon the plications of the membranous basis, as first pointed out by Dr. Carpenter, and already described in page 301.

The most remarkable genus of Gasteropods is the *Chiton*, in which the shell is made up of several jointed plates so arranged as to bend like the skeleton of an articulated animal; in short, this animal would appear to connect the *Mollusca* and *Articulata* more closely than any other. The shell, as shown at A, in Fig. 198, consists of eight overlapping plates, firmly imbedded in a tough horny mantle, having its margins smooth or covered with minute plates, hairs, or spines. In the sub-genus *Chitonellus*, B, the shell is in a very rudimentary condition, but it will be noticed that it still consists of eight segments; the mantle is soft and velvety, and quite free from plates or spines. The structure of the shell of *Chiton* is very peculiar; the external layer is of a green colour, and is composed of a coarse fibrous material generally traversed by large canals. A vertical section of one of the plates A, Fig. 199; when magnified 40 diameters, exhibits large canals running

FIG. 198.

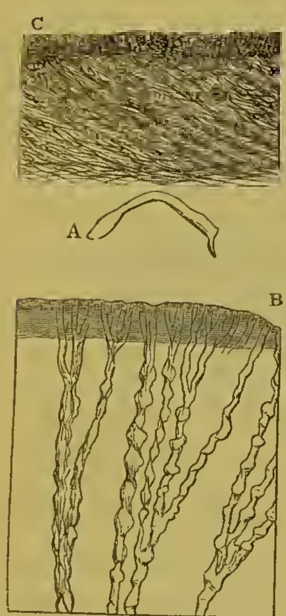
A B



A, *Chiton squamosus*. B, *Chitonellus fasciatus* (after Chenu).

through the entire thickness of the section sometimes presenting the moniliform appearance represented by B; but if the fibres are very strongly marked, the canals run between them in parallel lines, as shown at C; this is the common appearance at the base of the section. When one of the plates is divided horizontally, the fibrous structure of the outer layer is very plainly displayed, and the canals are then seen divided more or less transversely, as in Fig. 200; they are generally full of dark granular matter, but this is probably in great measure derived from the material employed in making the section. The canals do not always run through the entire thickness of the shell, but are generally confined to the superficial portion of the outer layer; while the deeper portion of this same layer presents a minutely cellular or prismatic structure. In the section represented by A, in Fig. 199, the coloured layer was absent in the centre, the entire thickness being formed by the inner layer. It was in this section that the branched and moniliform tubes represented at B occurred, extending completely through the shell, even through the outer

FIG. 199.



A, vertical section of one of the plates of the shell of a *Chiton*. B, a portion of the apex of the same exhibiting the branched and moniliform appearance of the canals. C, a portion of the base of the same section in which the canals are seen running in oblique lines.

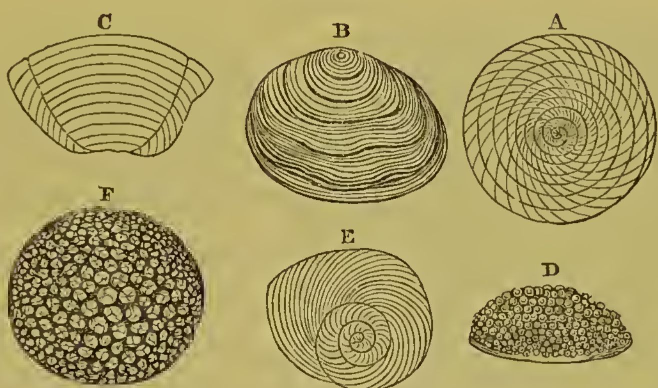
layer wherever that was present. The inner layer of some of these shells is eomposed of naereous material in whieh many small tubuli, like those of the *Haliotis*, frequently oecur, and when this layer is very thick, a trace of prismatie strueture is seen on the inner edge.

FIG. 200.

Horizontal section of outer layer of shell of a *Chiton* exhibiting a fibrous structure, and the canals divided more or less obliquely.

Many speeies of Gasteropoda, as before notieed, develope an *Operculum*, or lid, on a particular lobe of the foot; it may be eomposed either of layers of horn, or of dense shell-substance, the prineipal office of whieh is to elose the mouth of the shell when the animal retires within it. Mr. Gray eonsiders the Opereulum to be the analogue of the dextral valve of the Conehifera. It is developed in the embryo whilst within the egg and its starting-point is termed the nueleus; it always exhibits more or less of a spiral development, and in some eases the spirals are numerous and nearly eoneentric, as shown at A, in Fig. 201. In other eases, and these are the most eommon, the new matter is added prineipally on one side, and the nucleus, as shown at B and E, is then very excentrie. The surfaee attached to the foot in all the shelly varieties of Opereulum exhibits no traee of spirals, and is of eonvex figure, being generally smooth or eovered with a series of convex tubercles, Fig. 201, D and F. According to the Rev. H. Moseley, the number of

FIG. 201.

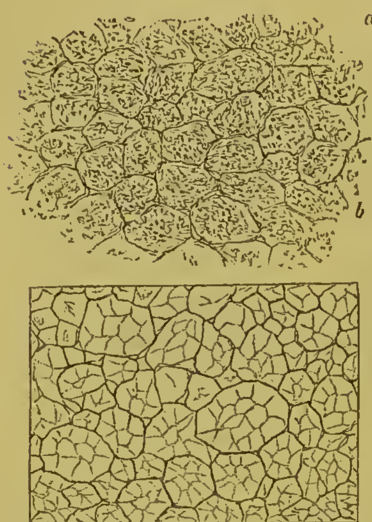


A, B, C, D, E, F, various forms of *Operculum* (after Chenu).

turns which the operculum makes is not determined by the number of whorls in the shell, but by the curvature of the opening and the necessity that the operculum should be developed with sufficient rapidity to completely close the enlarging mouth of the shell. The spirals of the operculum are invariably sinistral in dextral shells.

The most rudimentary form of operculum is that of the common Snail, which, generally speaking, consists of a thin membranous film formed during winter; occasionally, however, as in the present instance, observed by Mr. Warington, the thin transparent layer is rendered thick and opaque by a deposit of calcareous matter. When examined under a power of 130 diameters, as shown at *a*, in Fig. 202, the structure was found to be hexagonal, each hexagon exhibiting a minutely granular appearance from the deposit of carbonate of lime. When a portion of the same operculum was decalcified, as shown at *b*, the cellular structure could be easily recognized, but there was in some cases an indication that the larger hexagons represented at *a* were made up of several smaller ones. In the common Whelk the operculum is composed of horny material, and exhibits no structure; in most shells, however, it is made up entirely of shelly matter, and in certain species of *Turbo* it is nearly three inches in diameter. When rendered sufficiently thin to be transparent, all the sections have characters common to that of the shell to which they belonged, and like the shells of Gasteropoda generally, are remarkable for the small quantity of animal matter present, and for an almost total absence of the original cellular structure.

FIG. 202.

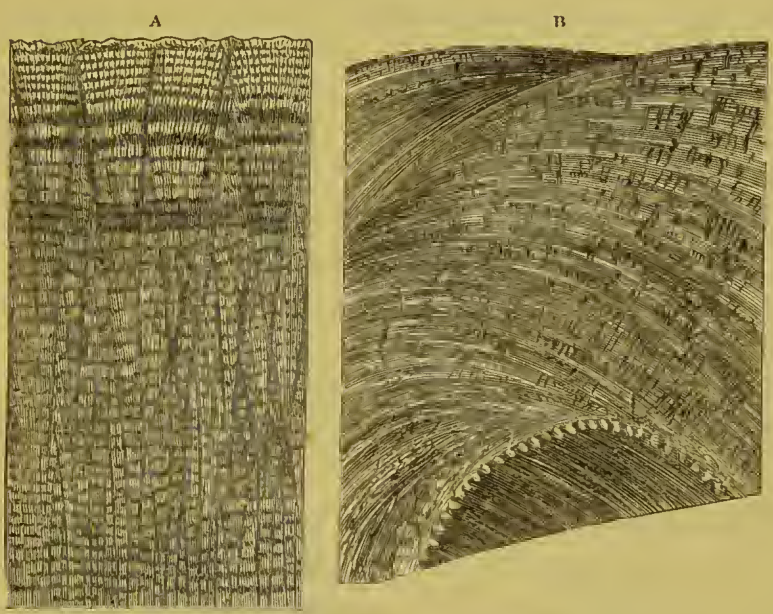


a, a portion of the thickened *Operculum* of a common Snail. *b*, the same decalcified.

A horizontal section of an *Operculum* of a large *Turbo* exhibits a prismatic structure, the contents of the prisms having a crystalline appearance; in some parts of the section the prisms are crossed by a series of curved lines, which are probably the lines of growth;

in others, especially on one edge, the prisms—Fig. 203, A, are arranged in a series of cones, each

FIG. 203.



A, horizontal section of the *Operculum* of a large *Turbo*. B, a vertical section of the same.

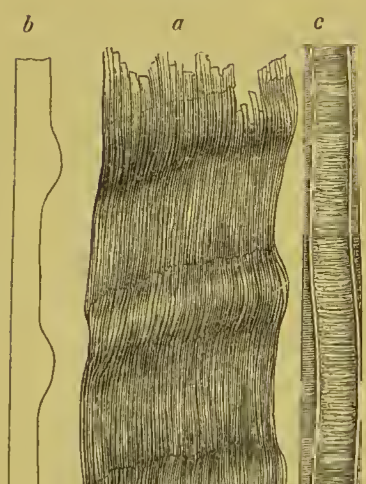
cone exhibiting a crystalline structure. In a vertical section of the same operculum, two curved rows of small foramina may be observed by the naked eye; one of these situated near the upper surface of the section, the other near the middle, as shown at B. The curved lines of growth are very evident in this section, and the shelly substance, especially in the neighbourhood of the foramina, exhibits traces of prismatic cellular structure agreeing in all these characters with those of corresponding sections of the shell.

LECTURE XX.

SKELETON OF MOLLUSCA—GASTEROPODA, HETEROPODA, PTEROPODA, AND CEPHALOPODA.

THE shells of most of the Gasteropoda are covered with an outer coat of animal matter, the *epidermis* or *periostracum*, which is sometimes the seat of the colour of the shell. In the Whelk it is brown and horny, and in one species of *Triton* it has been compared by Mr. S. P. Woodward to coarse cloth. A portion of the periostracum of a species of *Buccinum* is represented in Fig. 204; it consists of a series of horny laminæ, *a*, which precisely correspond to certain linear

FIG. 204.



Portions of periostracum of a species of *Buccinum*. *a*, laminæ showing the ridges. *b*, lamina seen edgeways. *c*, lamina magnified 250 diameters.

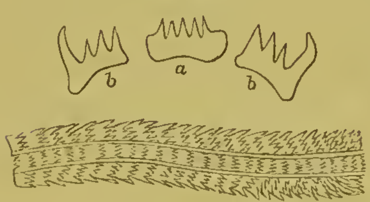
markings on the shell; each lamina is dilated at intervals, as at *b*; these dilatations lie over the spiral convolutions of the shell; and when viewed under a power of 130 diameters, as at *c*, each of the laminæ presents a minutely fibrous appearance. In the *Cowries* there is no epidermis, but the shell, from being always covered by the mantle when the animal is expanded, acquires a fine polished surface, and as the lobes of the mantle deposit the shell-substance, it often happens that when a small Barnacle or other parasite fixes itself upon the Cowrie, it is soon covered over with a layer of shell, as in the specimen represented in Fig. 205; this is a section of the shell of a Cowrie, *Cyprea Tigris*, on which a Barnacle has attached itself, but in revenge for this act of aggression, the Cowrie has enveloped all parts of its shell except the hole through which the cirrhi are protruded.

FIG. 205.

A vertical section of the shell of a *Cowrie*, the outer layer of which, *a*, has invested the shell of a parasitic *Barnacle*.

The Gasteropoda present all the leading characters of organization of the Mollusca in one or other of the genera, so that they are usually termed the types of the Mollusca. I have already made you acquainted with many of these characters; but there is one other to which I wish to allude before I pass to the next division of our subject, and this is the high state of perfection at which the dental apparatus has arrived in some of these animals. The destructive habits of the common Snail and Slug are universally known, but there are marine animals of this order whose boring operations even the hardest rocks and shells cannot withstand. I could not bring forward a better example of a boring Gasteropod than the common edible Whelk, *Buccinum undatum;* this animal is provided with a proboscis-like organ capable of extension, and having within it a muscular tongue armed on its free surface with a series of spines of peculiar form and arrangement, which have been termed *lingual teeth.* There are upwards of a hundred rows of these teeth (Fig. 206), each row composed of three pieces, the two lateral, *b*, *b*, having four teeth, all more or less curved, whilst in the central piece, *a*, they are smaller, straight, like incisors, and generally five in number. When the proboscis is opened in order to remove the tongue, the anterior extremity of this organ will be found curved upon itself, and to be of a brown colour for about the space of half an inch; the posterior extremity is soft, and its margins are brought nearly together, so as to form a tube. The curved anterior portion is placed in contact with the shell about to be bored, and by means of the curve, the points of the teeth are first brought into action. The teeth themselves are composed of silica, and are consequently admirably fitted for cutting the hardest shells.

FIG. 206.

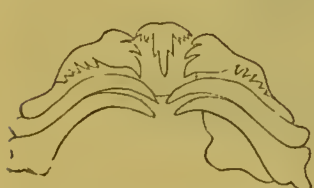


A portion of the tongue of a Whelk, *Buccinum undatum*. *a*, *b*, *b*, one row of teeth.

The small holes not unfrequently seen in the shells of Oysters are bored by the Whelk, and instinct leads the animal to select that part of the shell to which the adductor muscle is attached. This is the case in several shells in my possession, and in a valve of a large Pearl Oyster I have lately met with, there are no less than four holes all in this situation, one of which has completely penetrated the shell, the other three nearly so. The object of the Whelk in selecting this part of the shell is evident; when once the adductor muscle is wounded, the shell readily opens, and the fish then falls an easy prey to the voracious Gasteropod. In the *Limpet* the tongue is nearly three inches long; the teeth all of a brown colour, and more or less bent, but not being siliceous, they are only adapted for rasping a softer material than shell.

The *Cowries* are carnivorous, they generally inhabit shallow water near the shore, and Zoophytes constitute their principal article of food. They are provided with a long tongue, covered with several rows of teeth which, according to Löven, take the form represented in Fig. 207. The central one is single, but on each side there are three, one of which is provided with serrated edges, the other two taking the form of recurved spines. The upper jaw of the common Snail is provided with a horny cutting instrument, opposed by a flattened

FIG. 207.

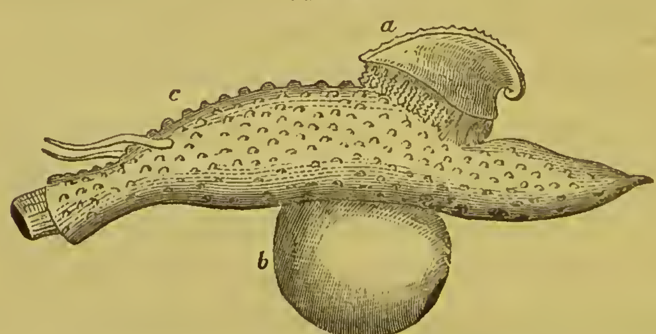


A single row of lingual teeth of a Cowrie, *Cypræa Europæa*, (after Lovèn).

tongue covered with a pavement of minute teeth; and the same form of dental apparatus occurs in all our land Snails; but in the most highly organized *Mollusca*, as will hereafter be shown, there are two horny mandibles, moving vertically like those of a bird, in addition to a tongue covered with recurved spines.

The next division of the Mollusca, the *Heteropoda*, is one which, although usually included in the Gasteropods, should, I think for many reasons, be separated from them, and form a distinct Class. As stated before, the foot of these creatures is placed upon the upper surface of the body in the position usually taken by the animal in swimming, and is converted into a fin-like organ. There are, however, a few species in which a rudiment of a foot is found in the form of a small sucking disc placed upon the upper edge of the fin, by means of which it is said they adhere to floating seaweed. One of the most striking representatives of the class, is the *Carinaria cymbium*, Fig. 208, an inhabitant of the

FIG. 208.

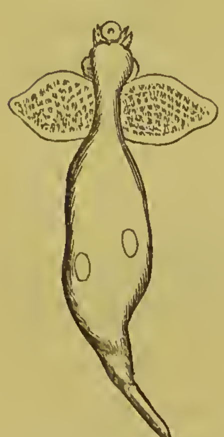


Carinaria cymbium. *a*, shell enclosing the branchiæ, liver, &c. *b*, fin-like foot. *c*, tentacula.

Mediterranean. The body is of elongated form, having the mouth at one extremity and a fin at the other; it is composed of a jelly-like material, as transparent as the finest glass, which is almost wholly invested by a muscular tunic sufficiently transparent to allow of the alimentary canal being seen through it. The mouth, as in the Gasteropoda generally, is furnished with a horny tongue upwards of half an inch in length, having three rows of brown teeth, used for rasping the harder kind of seaweed upon which it is said to feed. The alimentary canal runs from the mouth to the centre of the lower part of the body, where all the other important organs are collected into a mass very like that of the nucleus of the *Salpa*, page 262. In the species under consideration this mass is protected by a thin, delicate, boat-like shell, *a*, very much resembling that of the Arganaut. Within this shell the branchial organs, the heart, liver, and generative apparatus are contained, and from this circumstance the order *Nucleobranchiata* has been founded by certain modern authorities. The shell is the undoubted skeleton of the *Carinaria*, and as such, requires our more immediate attention; its shape is exceedingly elegant, being somewhat like that of a helmet, and when dried, it presents an opaline appearance, but is thin and brittle, like the finest glass. Under the highest powers of the microscope, the shell of *Carinaria vitrea* presents no trace of cellular structure; it is not, however, clear and transparent like glass, but in every part exhibits a minutely granular appearance. When the inner surface of the shell is examined, certain circular markings may be observed which occur in parallel rows, and at nearly equal distances; they are very small, not more than $\frac{1}{4000}$th of an inch in diameter; and at first sight they may be mistaken for foramina, but on more careful examination, they are found to project slightly from the surface of the shell. Their office is probably to assist in attaching the delicate skeleton to the soft parts of the animal.

The next class of Mollusca, the *Pteropoda*, includes only a few genera, and of these, the species most commonly known is the *Clio borealis*, which is said to form the principal food of the great Whalebone Whale. The peculiar sieve-like apparatus formed by the plates of whalebone and their fringed inner margins serve the purpose of detaining the small Mollusca, while the water taken into the mouth with them is ejected.

FIG. 209.

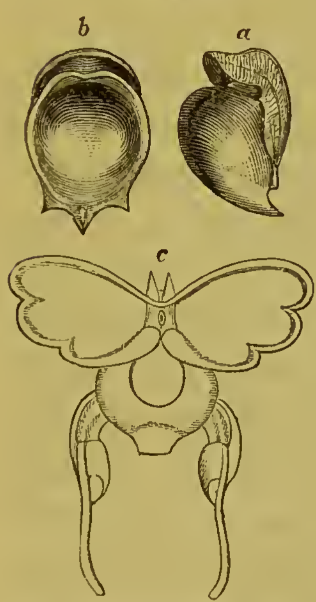


Clio (after Chenu).

The term Pteropod is derived from two wing-like appendages attached to the side of the neck, as shown in Fig. 209; by means of which the animal swims rapidly through the water. There are two species of *Clio* described, the one found in the northern regions being termed *C. borealis*, whilst the other, confined to the south seas, is known as *C. Australis*. Both species occur in the greatest abundance, and voyagers have stated that, in very fine weather and towards evening, ships often sail through shoals of them extending for several miles.

The *Clio* has no rudiment of a shell, but there are other genera in which this protective exo-skeleton is sufficiently large to contain nearly the whole of the soft parts of the animal. The most remarkable of these is the *Hyalæa*, represented of its natural size, with the fins extended, at *c*, in Fig. 210. The shell is exeeedingly thin, delieate, and somewhat boat-shaped; it looks at first sight like a bivalve, but the parts between which the hinge might be supposed to exist are firmly joined together. The soft parts of the animal are protruded from two fissures, one in front of the shell, as shown at *b*, the other at the side, as seen at *a*. In the genus *Cleodora* the shell takes the shape of a flattened funnel, is very transparent, and marked with curved lines. In *Criseis* it is elongated and conical, but in *Limacina* the cone is convoluted. I have examined the structure of the shell of one or more species of the genera *Hyalæa*, *Cavolina*, *Clione*, *Creseis* and *Triptera*; in most of them it is as

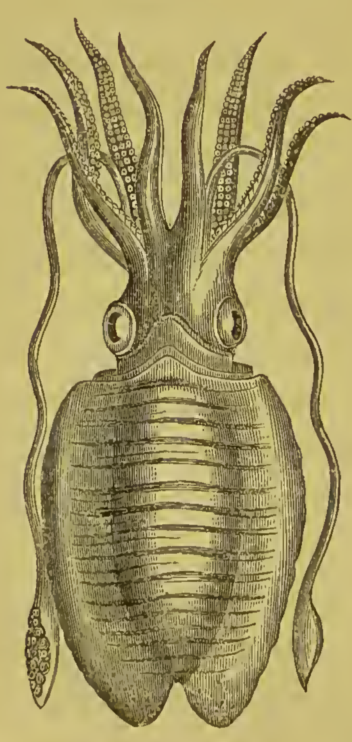
FIG. 210.



a, *Hyalæa globulosa*, side view of the shell. *b*, front view of the same. *c*, animal with fins expanded.

transparent as glass, and almost structureless; but in a large species of *Creseis* it was found to be composed of two layers, the outer opaque and minutely granular, the inner somewhat fibrous, the fractured edges in most cases exhibiting portions of fibres which extend beyond the outer granular layer. Most of the shells, especially those of *Hyalæa*, have the curved lines of growth very strongly marked, but I have never been able to detect the least trace of prismatic cellular structure in any specimen.

FIG. 211.



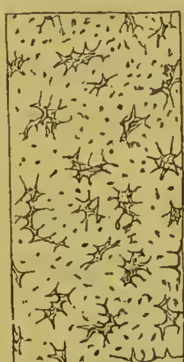
Common Cuttle Fish, *Sepia officinalis*, (after Woodward).

The highest class of the Mollusca, from the disposition of their principal locomotive organs around the head, as shown in Fig. 211, have received the name of *Cephalopoda.* They are not only the most highly organized of the Mollusca, but many species resemble the lowest of the Vertebrata—the Myxinoid Fishes, for example—in having a cartilaginous internal skeleton, supporting and protecting the nervous centre and the organs of vision and mastication. In addition to this cartilaginous skeleton, many of the Cephalopoda, as for instance, the Nautilus and Argonaut havc a perfectly developcd shell; in others, as the Cuttle-fish, the shell is reduced to a calcareous plate termed the "cuttle-bone," but in the Calamary the shell is represented by a horny pen, or *gladius*, and in the Oetopus, or Poulpe, it exists in its most rudimentary form as a cylinder of horny matter termcd a *style;* in other species it is altogether absent. It will thus be seen that the skeleton of this elass as a whole does not present a single constant character; therefore our description must be confined to eaeh form separately.

The Cephalopoda have been divided by Professor Owen into two prineipal orders—viz.: *Di-branchiata* and *Tetra-branchiata*, aecording to the number of the branchial organs: the animals included in the order *Di-branchiata* have no external, ehambered shell, their bodies being soft and naked, and as a eompensation for this seeming deficieney, they are providcd with an "Ink-bag," from which a black pigment termed *Sepia* can bc disehargcd so as quickly to render thc surrounding water opaque and enable them to escape from their enemies. In this order are ineluded the Cuttle-fishes, Calamaries, the Argonaut, Spirula and Belemnite, all being provided with feet, or tcntaeula, eight or ten in number, whieh arc arranged in a radiating manner around the mouth; the speeies are very numcrous, but in the order *Tetra-branchiata*, on the contrary, only thrce specimens, and these of one genus—viz.: *Nautilus*, remain, although in the earlier periods of the earth's history they were most abundant —more so perhaps than any other family of the class Mollusca.

The structure of the internal cartilaginous skeleton of one of the commonest members of the Di-branchiate order, the Cuttle-fish, *Sepia officinalis*, has already been described in the first volume of these Lectures; I shall therefore only briefly allude to it again, as exhibiting cells of a peculiar figure, somewhat like the bone cells of many fishes: they are imbedded in a semi-transparent matrix, as shown in Fig. 212; the same structure exists in the cartilage of most of the soft Cephalopods, but in some species a fibrous tissue is mixed up with the cartilage.

FIG. 212.



Cartilage from the cranium of *Sepia officinalis*.

I shall now proceed to describe the structure of the rudimentary shell in some of these animals, and will first take that of the *Octopus*, or Poulpe, in which it exists simply as a horny *Style*. When this is divided transversely, it is found to consist of concentric laminæ of brown horny material; in some specimens the centre of the section is much more consolidated and of a darker colour than the outside. The *Pen* or *Gladius* of the Calamary, *Loligo vulgaris*, as shown in Fig. 213, is very like a quill in shape; when divided transversely it also exhibits a laminated structure like that of the *Octopus*, but when that part which corresponds to the plume of the quill is carefully examined, a very faint trace of hexagonal cells, like those shown in Fig. 214, has been observed; from these markings not being noticed in the transverse sections, I am induced to believe that they belong to a cuticular layer, and do not enter further into the structure of the horny gladius.

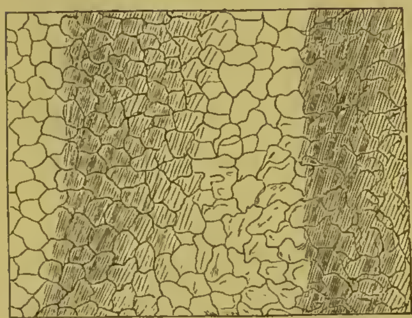
FIG. 213.

The Horny-pen or Gladius of a Calamary, *Loligo vulgaris.*

In the Cuttle-fish, *Sepia officinalis*, the "bone," or *Sepiostaire*, as shown in Fig. 215, is usually considered as a rudiment of a chambered shell, one chamber of which, and this the last or outer one, has been developed unilaterally. The "bone" is usually as long and as wide as the mantle in which it is imbedded; the outer surface is convex and shelly, the inner concave and chalky; on the edges is a brown horny substance which is very broad at the lower portion of the bone, and in the median line terminates in a pointed process termed the *mucro*. In former times this rudimentary shell was employed in medicine as an "antacid," but its principal use now, is either for tooth-powder or for "pounce."

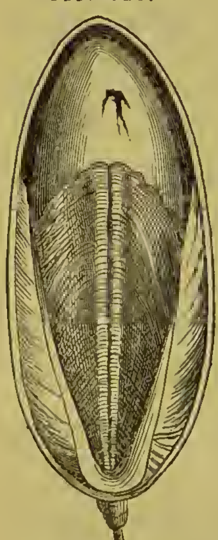
The outer shelly portion of the *Sepiostaire*, when rendered sufficiently thin to be transparent, exhibits a coarse hexagonal structure, as shown at F in Fig. 216; each hexagon has an oval nucleus in the centre, from which a series of radii proceed towards the margin; in many parts of the section the radii very much resemble the crystals before described as occurring in the tooth of *Mya arenaria*, Fig. 187. The soft internal portion of the same specimen exhibits a totally different structure. On transverse section, as shown at D, in Fig. 216, it will be found to be composed of a series of curved laminæ, *a a*, separated from each other by thin wavy partitions, or pillars, of transparent calcareous material, each of which, when highly magnified, as shown at E, exhibits a series of fine transverse markings, somewhat like those seen in the prisms of the *Pinnæ*. In consequence of the laminæ being curved, those portions of the pillars which are attached to the concave side of each, are much broader than those attached to the convex side, as may be readily seen on referring to Fig. 216, D. When a portion of the Sepiostaire is divided longitudinally, the pillars will be found to project from the laminæ, and being viewed edgeways, their true nature can be easily ascertained; they may

FIG. 214.



A portion of the *Gladius* of a *Calamary* exhibiting a cellular external layer.

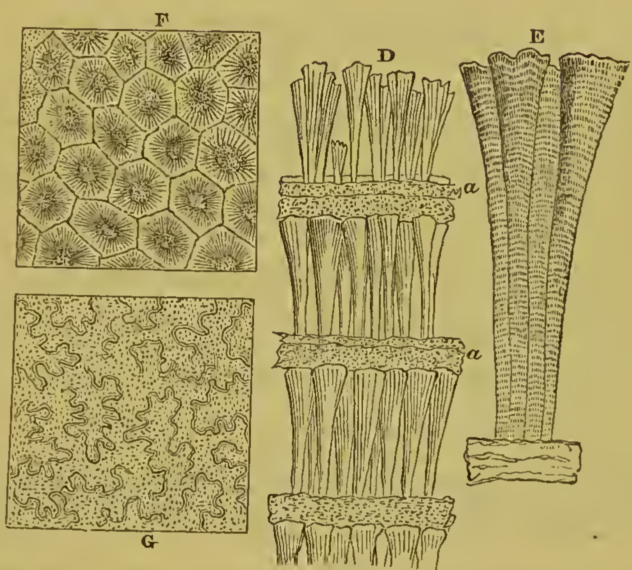
FIG. 215.



The *Sepiostaire*, or cuttle-bone of *Sepia officinalis*.

therefore be described as consisting of a thin layer of calcareous material folded or bent upon itself like a

FIG. 216.



D, a portion of a transverse section of Cuttle-bone; *a a*, laminæ between the pillars. E, one of the pillars magnified 95 diameters. F, portion of the outer shelly substance of the Cuttle-bone. G, concave inner surface of one of the laminæ.

frill. When separated from the laminæ, they leave an impression of their exact shape upon them, as shown at G, which is a representation of one of the laminæ having its concave surface uppermost. It will thus be seen that there must be a considerable part of each lamina not occupied by the pillars; all these spaces therefore may be considered as so many cavities in, and as diminishing considerably the weight of, the mass. The structure of the laminæ is minutely granular, and the calcareous material of which it is composed is far more opaque than that composing the pillars.

LECTURE XXI.

SKELETON OF MOLLUSCA—CEPHALOPODA.

The *Argonaut*, or Paper-sailor, belongs to the same order as the Cuttle-fish. The animal very much resembles the *Octopus* in shape; it has eight arms, two of which are provided with expanded extremities, and perform the function of a mantle in secreting and protecting the delicate shell. The Argonaut was formerly described as having the power of coming to the surface of the sea in fine weather, and spreading its thin sail to catch the breeze, but I need hardly tell you that this is not the case; it progresses as the Octopus does, by ejecting the water from its funnel; it also is able to crawl over rocks and stones by means of its arms, the shell being reversed like that of the Snail. The attachment of the animal to the shell is very slight, and when preserved in spirit, unless care have been taken to keep its expanded arms in contact with the shell, it will drop out, if the shell be turned with its mouth downwards. There is a specimen in the Museum, presented by Madame Power, a lady who has paid very great attention to the habits of these beautiful creatures, exemplifying the manner in which two of the expanded arms completely invest the delicate shell; two other specimens, presented by the same lady, have been prepared by Mr. Goadby in order to show how the animal is able to crawl with its shell reversed like that of the Snail. The Argonauts provided with a shell are invariably females, and one of the principal uses of this skeleton is to protect the ova, which are very numerous and occupy the hollow portion of the spire. The males are very minute and shell-less, that of the common Argonaut, *Argonauta Argo*, not being more than seven lines in length; it has often been found attached to the female by its suckers, and was at first considered as a parasitic worm; the researches of Costa and of Kölliker prove that it is undoubtedly the male of this species.

Of the minute structure of the shell of the Argonaut I have little to say; it is very brittle, and exhibits no trace of cellular or prismatic tissue; under the highest powers, every part presents a minutely granular appearance.

The next example of the order *Di-branchiata* I shall notice, is the remarkable animal denominated *Spirula;*

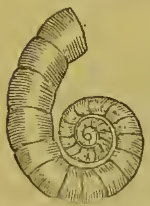
the shell has been long known, being found in abundance on the shores of New Zealand and of the Atlantic; not a few specimens, according to Woodward, "are yearly picked up on the coasts of Devon and Cornwall, supposed to have been brought thither by the gulf stream." The animal belonging to this shell was originally described by Péron and Lesueur, and more recently by De Blainville; but a perfect specimen, obtained by Mr. Percy Earl on the coast of New Zealand, was dissected by Professor Owen, and its anatomy given by him in the "Zoology of the Voyage of the 'Samarang.'" By some authorities the shell was supposed to belong to an animal like the Nautilus, and to be external to the soft parts; but the researches of Péron and others indicated that it was an internal one, and that the soft parts resembled those of the Cuttle-fish, as represented in Fig. 217. Professor Owen has shown that the animal possesses eight short arms covered with suckers and two elongated tentacles, and is also provided with that peculiar apparatus termed the ink-bag. The shell, which is of a spiral form, as shown in Fig. 218, is situated at the lower part of the body, and enclosed between two lobes of the mantle; it consists of a series of chambers which are formed by transverse septa, each being perforated by a small calcareous syphonic tube on the inner or concave

FIG. 217.

Animal of *Spirula* (after Woodward.)

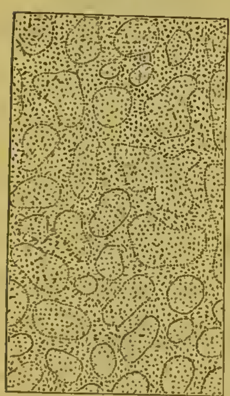
margin of the shell. The septa are likc a watch-glass in shape, the concave surface being situated towards thc mouth of the shell; in full-grown specimens they are upwards of twenty in number. The outer surface of the shell is rough and opaque, and when examined microscopically, exhibits a coarse reticulated tissue, as shown in Fig. 219, the reticulations being slightly raised above the general surface, the interspaces being usually of a brown colour, and presenting a granular appearance. The internal surface of the shell is much smoother than the external, and under a power of 250 diameters exhibits a minutely hexagonal structure, as secn in Fig. 220; the septa are coated with nacre, both on their anterior and posterior surfaces, and on microscopic examination, present all the wavy markings characteristic of that beautiful material.

FIG. 218.



Shell of *Spirula Australis* natural size.

FIG. 219.

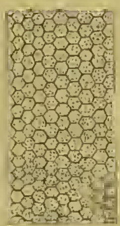


A portion of the outer surface of the shell of *Spirula Australis* magnified 50 diameters.

We now arrive at the last family of the Di-branchiate order, the *Belemnitidæ*, animals which formerly existed in thc greatest abundance in the secondary strata of the earth's surface, so much so that ncarly a hundred species have been found in a fossil state. Nothing very certain was known of thc soft parts of these animals, until the year 1842, about which time, cuttings being made through the Oxford clay in thc ncighbourhood of

Chippenham, Wilts, by the Great Western Railway Company, a great variety of Belemnites were discovered.

FIG. 220.



Portion of the internal surface of the shell of *Spirula Australis* magnified 250 diameters.

These were found to consist of two principal genera, one termed *Belemnites*, the other *Belemnoteuthis ;* of the former genus very few remains of the soft parts occurred, but those of the latter were in so perfect a state of preservation that a very good idea could be formed of the shape of the animal. Most persons are familiar with a conical dart-shaped fossil found in the secondary deposits formerly termed *thunderbolts* or *Belemnites* by Geologists ; the larger end having a conical cavity occasionally occupied either by sand or the remains of a chambered shell. This was all that for many years was known of the Belemnite, and Zoologists were induced to classify it with the Ammonites. Mr. Miller was the first to attempt a restoration of the animal; he conceived that the fusiform fossil, or guard above described, was an internal skeleton, and placed it in the body of a Calamary; a few years afterwards Drs. Buckland and Agassiz examined specimens in which the fossil ink-bag was preserved in the last chamber of the shell occupying the conical cavity of the guard, and confirmed to a certain extent Mr. Miller's ideal restoration. About the year 1842, the wonderful specimens discovered in the Oxford clay set the question at rest; in that formation, the perfect animal, represented in Fig. 221, and named by the late Mr. Channing Pearce of Bath, *Belemnoteuthis antiquus*, was found. The soft parts of the Belemnite proper have not yet been discovered, the most perfect specimen being that represented in Fig. 222, which was collected by Mr. Buy, of Chippenham, and described by the late Dr. Mantell in the "Philosophical Transactions" for 1849, and is now to be seen in the British Museum. It consists of theguard, *a*, into the upper conical cavity of which was inserted the siphunculated internal chambered shell, *b*, termed the *phragmacone;* this last was provided with a pointed process on each side, like that shown at *c*. According to Dr. Mantell, all these parts were invested by a horny coating or integument, so as to form a receptacle for the viscera of the animal. At the time I am now speaking, no other portion of the soft parts of the true *Belemnite*, such as the arms, fins, &c., have I believe been discovered, but of the *Belemnoteuthis*, on the contrary, every portion of the animal, even to the muscular fibres of the arms, has been wonderfully preserved in

FIG. 221.

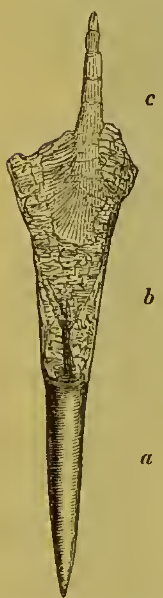
Belemnoteuthis antiquus from Oxford clay, Christian Malford, Wilts, ⅓rd the natural size (after Mantell).

the Oxford elay, as may be shown by thc specimcns now before you. The greater part of these were prescnted to the Museum by the late Marquis of Northampton, for others the College is indebted to Mr. S. P. Pratt; they have all been described by Professor Owen in the "Philosophical Transactions" for 1844. The most perfect of thesc specimens is the *Belemnoteuthis* of Pearce, the *Belemnites Owenii* of Pratt; the arms are eight in number, and each provided with a double series of (what were once, no doubt) horny hooks similar to those found in existing Calamaries of the genus *Onychoteuthis;* there were also two long tentacles, but it is generally supposed that the animal was not provided with a horny beak, like our eommon Cephalopods, as no trace of them has yet been discovered; but there is undoubted evidence of the preservation of such remains in other Cephalopods, by fossils termed *Rhyncholites*, whieh are nothing more than the beaks of these animals.

The skeleton of a *Belemnoteuthis* eonsists of a short blunt "guard," the interior of whieh is oceupied by a chambered shell termed the *phragmacone;* it is provided with a siphuncular tubc, not situatcd in the eentre, but on onc edge; abovc this is the ink-bag. Thc part known as the Belemnitc or guard, therefore, is very rudimentary, or may be said hardly to exist in this animal, the shelly skeleton consisting essentially of the phragmaeonc; there is, however, abundant evidence to prove that this was covered by a thin eoating of shelly matter.

The skeleton of the *Belemnite,* however, is very different; it consists of the long *spathose guard, a,* surmounted by the conical chambered *phragmacone, b,* from the upper sides of which two sword-like processes, like that seen at *c,* proeeed. An external eapsule, probably of a horny nature, invested the whole of these parts, and as it extended upwards, it formed a receptaele for the principal portions of the viseera of the animal. The phragmaeone is composed of a series of shallow eoneave cells of a nacreous material, having a siphuneular tube passing through them: the cells are frequently found of very large size in the lias; some specimens I have seen have measured nearly two inches in diameter.

FIG. 222.

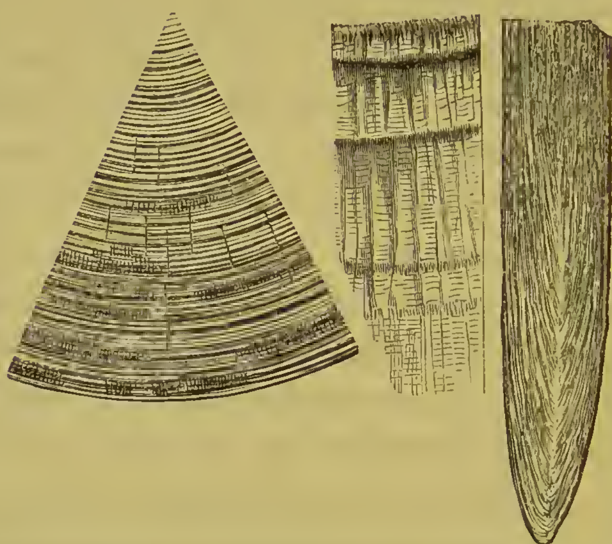


Belemnites Puzosianus from the Oxford clay, Christian Malford, Wilts, (after Mantell).

The shelly covering of the "guard" and of the phragmaeone is too opaque to enable the microscopist to make out mueh of its minute strueture; it appears to resemble naere more nearly than any other substanee. The "guard," however, is sufficiently firm to allow of sections being made in every direetion; when divided transversely, as shown at A in Fig. 223, a concentric laminated arrangement is visible under a power of 10 diameters, some of the laminæ being more strongly marked than others; but when a higher power is employed, and if the section be a favourable one, a

FIG. 223.

A B C

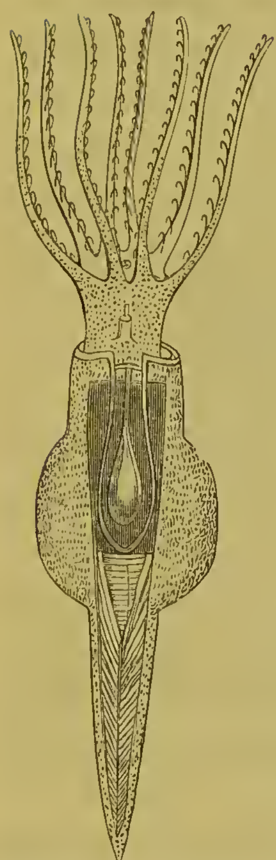


A segment of a transverse section of the guard of a *Belemnite*. B, portion of the same magnified 95 diameters. C, vertical section (nat. size.)

radiated prismatic structure, like that of many of the larger shells, as exhibited at B, will be faintly observed. When divided vertically, as shown at C, the strong lines of growth, consisting of a series of cones one within the other, are very visible to the naked eye, but when examined with a power of 100 diameters, an intermediate faintly cellular structure may be observed. Many "guards" exhibit little or no structure, the animal basis having been destroyed, and a crystalline homogeneous mass occurring in its place.

In Fig. 226 is given a representation of the Belemnite according to Professor Owen, from which it will be seen that the animal was provided with eight arms, two tentacles, an ink-bag, a funnel, and two lateral fins. Since the publication of Mr. Owen's paper in 1844, many

FIG. 224.



Belemnite, restored (after Owen).

Palœontologists have been induced to believe that none of the soft parts of a true Belemnite—that is, an animal possessing a long conical *guard*, such as that shown at *a*, in Fig. 222—have ever been discovered, and that all the specimens described in the paper above mentioned under the head of *Belemnites Owenii* really belong to the genus *Belemnoteuthis* of Pearce; it matters not, however, for our present purpose to which of the two genera the specimens are referred, our principal concern having been that of directing attention to the minute structure of the most durable part of the skeleton—viz.: the "guard."

So perfectly preserved have been some of these specimens, that even the muscular fibres of the arms are visible to the naked eye; the minute structure of these fibres, as seen under a power of 500 diameters, is shown in Fig. 225; those of a recent *Onychoteuthis* have been described with them by Professor Owen, in the paper above alluded to.

FIG. 225.

Fossil muscular fibres of *Belemnites Owenii*.

To the second order of the Cephalopoda, the *Tetra-branchiata*, belongs the Pearly Nautilus, *Nautilus pompilius*, which is one of three existing representatives of a long-lost tribe of Cephalopods having a chambered siphunculated shell by which the greater portion of the animal was protected. Upwards of 1000 fossil species belonging to this order are now known by their shells, but of the existing genus *Nautilus*, only three species have been found; the shell of *N. pompilius* is exceedingly common in collections, but of the animal inhabitant very few specimens have ever been brought to Europe. This College is fortunate in possessing two of these; the first was captured off the New Hebrides by Mr. G. Bennett, and is the subject of the splendid Monograph by Professor Owen, for the second the College is indebted to Sir Edward Belcher; a specimen has also been acquired lately by the British Museum.

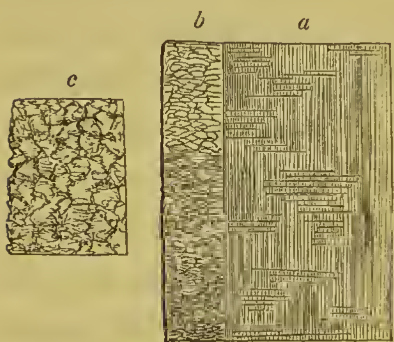
The animal inhabits the last chamber of the shell as shown in Fig. 227; it has no connection with the other chambers, except by means of the siphuncle *a a*, through which a tubular portion of the mantle passes, and is protected in part by a short tube of shell, arising from each septum; according to Professor Owen, a small artery and vein accompany this prolongation of the mantle, the object being to nourish the chambered portion of the shell, as the septa and walls are each lined by a delicate membrane, the vitality of which no doubt is maintained by such a direct connection with the vascular system of the animal. The use of the siphuncle in chambered shells has been said to be that of enabling the animal either to sink or float at pleasure; the common opinion, even now, is that the animal has the power of injecting water into the siphuncular tube, by which the specific gravity of the shell is increased, and it gradually sinks to the bottom; at the will of the animal, the water can be forced out of the siphuncle by the compressed air of the chambers, as in the philosophical toy named the Hydrostatic paradox, and the shell, being thus rendered lighter than the water, again comes to the surface. If such a theory as this were applicable to the Nautilus, it certainly could not be to other shells found in the fossil state—as for instance, that shown in Fig. 228, the siphuncle of which is entirely composed of shelly matter; hence the idea entertained by Professor Owen of the use of the siphuncle, is, no doubt, the correct one.

FIG. 226.

Vertical section of the shell of *Nautilus pompilius*, showing the siphuncle, *a a*, and the situation of the animal in the last chamber.

We now proceed to the examination of the skeleton of the *Nautilus pompilius*, which we shall find well deserves the epithet pearly. The shell itself is so well known that I only think it necessary to point out that there are three distinct varieties of colour on its outer surface, each forming a very thin layer, the greater part being of an opaque white, the others of a reddish-brown and black. When divided vertically, as shown in Fig. 227, the greater portion of the section, as seen at *a*, consists of nacreous material, whilst the superficial layer, *b*, exhibits more or less of a cellular structure, and when magnified 500 diameters, presents the appearance represented at *c*. If a fragment of the nacreous lining be decalcified, it will show perhaps quite as plainly as any other shell, that this beautiful material is made up of cells.

FIG. 227.

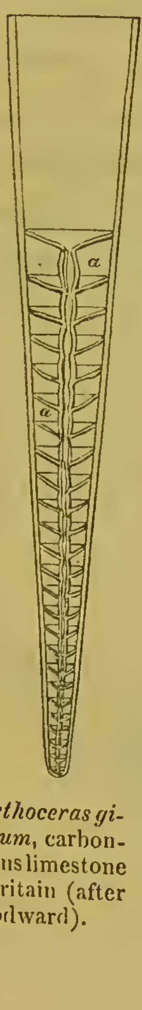


Vertical section of shell of *Nautilus pompilius*. *a*, nacreous layer. *b*, superficial layer. *c*, portion of superficial layer magnified 500 diameters.

Of the structure of the remaining members of the *Tetrabranchiate* order I have very little to say, as they are only known to us by their fossil remains. They were, however, so numerous in the palæozoic and secondary strata, that they appear to have been the principal representations of the carnivorous Mollusca at that period of the earth's history.

The type of the shell in all the fossil species is that of a cone, and this may be either straight or more or less convoluted, as in the Ammonite; between these two forms a great many varieties occur, and the shells in consequence have been named, *Orthoceratites*, *Baculites*, *Turrulites*, *Hamites*, &c., but whatever the shape, every variety is characterized by possessing a series of *septa*, by which the shell is divided into a number of chambers, and the last is occupied by the animal. The outer shell is most frequently absent, and the curious zig-zag markings observable on the exterior of *Ammonites*, are the edges of the *septa*. In the *Nautilus pompilius*, as shown in Fig. 226, the septa are concave; this is their condition also in the *Orthoceratite* represented in Fig. 228. During life, the chambers, like those of the Nautilus, are empty, but in most fossil specimens, as may be seen in horizontal sections of Ammonites, they are filled with sparry crystals. Of the structure of the shell of these remarkable fossils I have little to say; the nacreous layer of the *Ammonite*, which I frequently find to be the only one left, exhibits precisely the same characters as that in the recent *Nautilus*, but the *Ammonites* are interesting in another point of view, as we have abundant evidence to prove that the mouth of the shell was more or less closed by an *operculum* either composed of horn or of shelly material. According to Woodward, in one group (*Arietes*) the operculum consists of a single piece, and is horny and flexible, but in others it is shelly and divided into two plates by a median suture, the external

FIG. 228.



Orthoceras gigantum, carboniferous limestone of Britain (after Woodward).

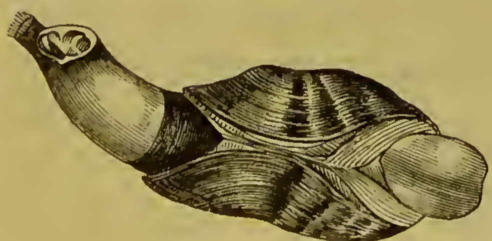
surface being smooth, the internal showing the lines of growth. These bodies were called *Trigonellites* by Parkinson in 1811, they have since been described by Meyer as bivalve shells under the generic name of *Aptychus.* M. Deshayes believes them to be calcareous plates belonging to the gizzard of the animal, but the prevailing opinion in this country is that they are opercula. I am indebted to Mr. Woodward for the specimen I now show you. When sections are examined microscopically, the shell-structure is very evident. The *Aptychi* are found either in the last chamber of the Ammonite, or in the matrix near to it. Mr. Moore of Ilminster has a very large collection of them, and to a paper of his, lately published in the "Transactions of the Somersetshire Archæological and Natural History Society" I would beg to refer you for much valuable information concerning them.

LECTURE XXII.

SKELETON OF MOLLUSCA—PEARLS.

BEFORE leaving the structure of the skeleton of the *Mollusca*, there are a few species which offer such peculiarities either in their habits or their internal anatomy as to require a brief notice. Many of the bivalve Mollusca are "boring" animals—of these the most remarkable are the *Pholas* and *Teredo;* the first, Fig. 229, bores in wood or clay, and two principal theories have been started by naturalists to explain the *modus operandi;* the one that the shell is employed in the process, the other that an acid liquid is excreted which acts as a solvent. The view

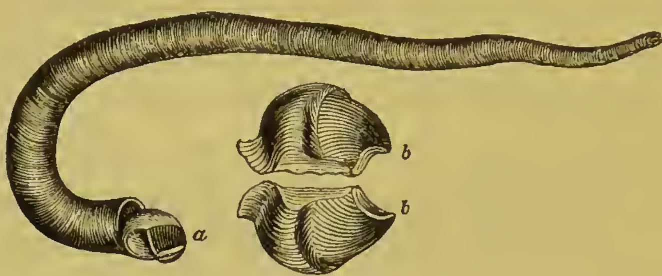
FIG. 229.



Pholas crispata.

now, however, generally entertained, is that a fleshy organ, either the foot or mantle of the animal, is solely engaged in the work of destruction. The *Teredo navalis*, or "ship-worm," Fig. 230, is known to most

FIG. 230.

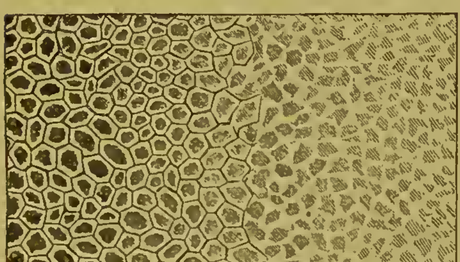


Teredo navalis. *a*, valves covering the foot. *b*, *b*, valves magnified.

persons; it bores into wood always in the direction of the grain, unless diverted from its course by the presence of a knot, or the tube of a neighbour, for they never bore into each other's tubes. The shelly portion of this animal consists principally of two valves, *a*, which cover the foot, and two dart-like processes termed *palettes*, situated at the opposite extremity; the body is soft and fleshy, nearly destitute of shell; but the wood through which the animal has bored is lined with shell as it progresses. The valves, as shown under a magnifying power at *b*, *b*, are covered with rows of small spiny projections, like those of the shell of *Pholas*, and it was until lately believed that by means of these the boring was effected; but on examination, I find them invested with a soft horny cuticle totally unfit for the purpose; the end of the foot is said to be the instrument employed, being provided with strong muscles and its free surface covered with sharp gritty particles probably composed of lime or silica.

Many of the Mollusca not having a lingual dental apparatus, possess, like the lobsters, a gizzard armed with spines or plates of shell. In the *Aplysiæ* there are several rows of horny plates, but in the *Bullæ*, especially *B. aperta*, which I now show you, there are in the gizzard two calcareous plates nearly $\frac{3}{4}$ths of an inch square; these serve the purpose of crushing the shells of other Mollusca. Dr. Carpenter has shown that these plates exhibit a cellular structure; those of *Bulla aperta*, as represented in Fig. 231, do so in a remarkable degree, but the cells are not constant in all parts of the section, the cell-walls having disappeared, the dark spot which is commonly found in the centre of each cell alone remaining to indicate its position.

FIG. 231.

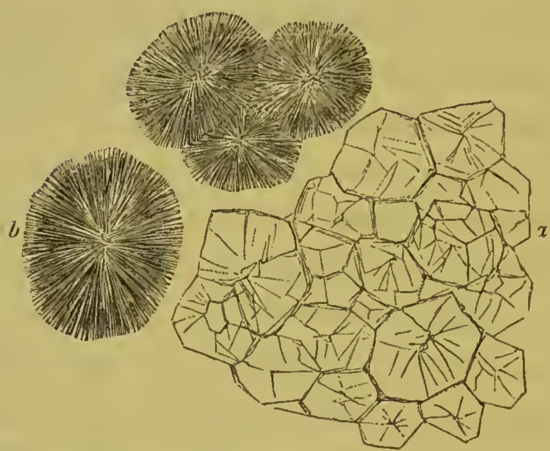


Horizontal section of shelly matter from the gizzard of *Bulla aperta*.

I cannot leave the skeleton of the Mollusca without briefly noticing certain oval or globular masses, either wholly or partially composed of nacreous material, which are commonly known as *Pearls*. They occur in the soft parts of Mussels and Oysters, either in connection with the mantle or firmly attached to some portion of the internal surface of the shell, and are more common in shells from certain localities than from others; the finest specimens are said to be obtained from the fisheries of Ceylon and of Olmutz, on the Persian Gulf. Next to diamonds, Pearls are perhaps the most highly prized as objects of adornment, and from the earliest times have been eagerly sought after. Those of the Oyster, *Meleagrina margaritifera*, are by far the largest and most brilliant, and this is the species fished for, in the localities above noticed. Our own rivers are not devoid of Mollusca in which Pearls of considerable value are frequently found; the Conway in Wales, and the Tay in Scotland, may be mentioned as examples; in the former river a fishery exists to this day. Some idea may be formed of the number and value of Scottish Pearls from a statement in the recent work on Conchology by Dr. Johnston of Berwick-upon-Tweed, who informs us that "between the years 1761 and 1799, pearls to the amount of £10,000 were sent from the Tay and Ila to London." The British Pearls are found in the fresh-water Mussel, *Mytilus margaritaceus;* similar bodies are also occasionally met with, in our edible Mussels and Oysters, but are entirely valueless as ornaments, although their structure, as will hereafter be shown, is very interesting.

Before entering upon the growth of these bodies, I must give you a brief account of the mode of formation of shells generally. It is a well-known fact that the shell of a mollusc is developed within the egg, and appears to commence with the earliest stages of growth of the embryo, as may be readily seen in the eggs of many of our smaller fresh-water species. There are three parts of the animal more or less concerned in the development of shell; the first is the edge of the mantle, which is always more or less thickened, and, according to Dr. Carpenter, forms the outer layer; the second, the broad surface of the mantle upon which the inner layers are formed; and the third, the foot, which I believe with Dr. Johnston (who appears to have been the first to notice the fact) is an important organ of secretion, as may be evidenced by the development of the operculum in many species. The formation of shell has been most carefully studied by Mr. Bowerbank in the young cartilaginous lips of the common garden Snail, *Helix aspersa*, and in the thin edge of the shell of a half-grown Oyster; I myself have studied the growth of the rudimentary shell of the common Slug. The earliest stage of the process appears to consist in the exudation from the surface of the mantle of a *plasma*, within which cells are developed; these, when first formed, are transparent and nucleated, but very soon carbonate of lime is secreted from their inner surfaces. In their isolated condition the cells are of globular figure, but by pressure during growth they generally assume the form represented by *a*, in Fig. 232. In most shells the lime is clear and transparent, but occasionally, as in Fig. 202, it is granular; in a few instances, as shown at *b*, in Fig. 232, it is in the form of radiating crystals. The walls of the cells may either remain or they may coalesce and form laminæ. In the thin edge of the shell of the Oyster,

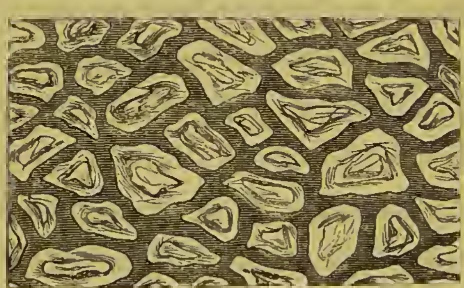
FIG. 232.



Shell of Slug in process of growth. *a*, cell becoming hexagonal by pressure. *b*, cells filled with radiating crystals.

Fig. 233, the cells are well seen; they are nucleated, and very much resemble those of cartilage, being imbedded in a horny matrix generally of a brown colour. The growth I have now described as taking place upon the edge of the shell, according to Dr. Carpenter, is due to the margin of the mantle, and produces the outer layer of shell, but at the same time the whole inner surface of the mantle is exuding a plasma or epithelium from which the inner layer is formed.

FIG. 233.



Cells seen on the thin edge of the shell of a young Oyster (after Bowerbank).

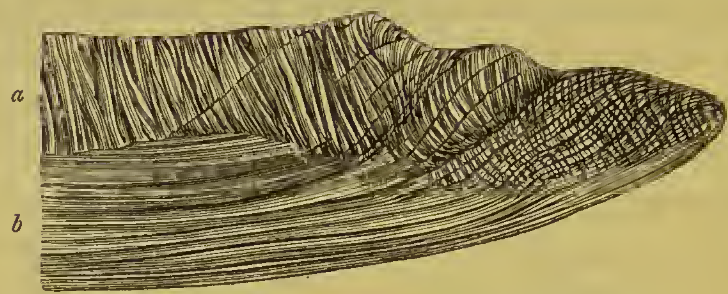
The above remarks will apply to the growth of shell generally; but as Pearls are most commonly developed in Oysters and Mussels, what I shall have further to say on this subject will relate principally to the shells of these animals. In the ova of many of our fresh-water Snails the hexagonal structure of the rudimentary shell may be seen investing the soft parts. In Oysters during the months of June and July, I have frequently found the young fry provided with a thin transparent bi-valve shell, as represented in Fig. 234. About the middle of July the young fry may be observed in an active state of movement produced by large cilia attached to a portion of the margin of the shell, as shown at *a*. The movement of the shell by means of the powerful cilia can be seen by the naked eye; and as they soon disappear, I regard them as organs of locomotion, their use being that of enabling the young to make their escape from the shell of the parent.

FIG. 234.

Young fry of the oyster, nearly ready to escape from the shell of the parent. *a*, cilia attached to the shell.

If a vertical section of the lip of the shell of the Pearl Oyster be examined, as shown in Fig. 235, two distinct kinds of structure will be evident; the upper, *a*, corresponding to the outer layer of the shell, will exhibit a prismatic cellular arrangement, whilst the lower, *b*, is nacreous; both, it will be observed, are traversed by dark lines indicating the successive

FIG. 235.



Vertical section of the lip of shell of the Pearl Oyster.

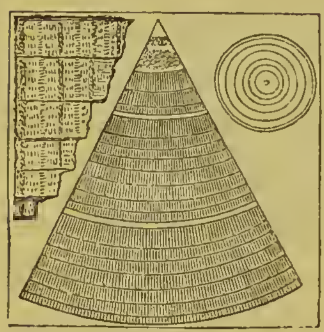
stages of growth; it will also be seen that every layer of nacre has its free extremity covered with one of prismatic cellular tissue. According to Dr. Carpenter, "every new production of shell consists of an entire lamina of nacre, which lines the whole interior of the old valve, and of a border or margin of the prismatic layer which thickens its edge. So long as the animal continues to increase in dimensions, each new interior layer of shell projects so far beyond the preceding, that the new border, composed of the outer layer, is simply joined on to the margin of the former one; so that the successive formations of the outer layer scarcely underlie each other. But when the animal has arrived at its full growth, the new laminæ cease to project beyond the old; and as each is still composed of a marginal band of the external substance attached to the edge of an entire lamina of the inner, these bands must now underlie each other, being either quite free, as in

Ostreæ, or closely united to each other, as in *Unio* and most other bi-valves."

Having now given a brief account of the formation and growth of shell, I will in the next place point out how a knowledge of these facts may lead to the understanding of the development of Pearls. In the first volume of the "Histological Catalogue" you will find that I have classed Pearls under four heads, as follows:—1st, Pearls exhibiting prismatic cellular structure; 2nd, those in which there is no trace of prismatic structure, being wholly composed of subnacreous tissue; 3rd, those composed entirely of naere (true Pearls); and 4th, those composed of nacre and prismatic cellular structure. The first kind, it is evident, must be formed on the edge of the shell, where the prismatic cellular strueture is being developed—as, for instance, at *a*, in Fig. 235—and no doubt owes its origin either to the presence of a foreign body or to some injury to this part of the shell. The second kind is developed in the soft parts of the animal, and within the shell of such Mussels or Oysters as have no true nacreous lining, whilst the third variety is developed in corresponding situations in Mussels and Oysters in which the nacreous layer is most brilliant. The fourth variety is a compound one; such Pearls, there is every reason to believe, commence growth on the edge of the shell, and when they have arrived at a certain size, eneroaeh more or less upon the mantle, and from it receive a partial coating of nacre.

Pearls of the first variety, when divided horizontally, as shown at A, in Fig. 236, exhibit a series of laminæ arranged concentrically around a nucleus, which in the present instance is a mass of brown horny material, like that found upon the edge of the valve of a mussel from which the specimen was probably developed. Under a power of 50 diameters, a segment, as shown at B, exhibits a prismatic cellular structure, the striated character of the prisms being better shown under a higher power at C. In this Pearl two bands of horny matter occur between the prisms, as indicated by the white lines in the segment B; these would tend to prove that for a short space of time the formation of shell-structure must have ceased, and the Pearl was more or less coated with horny matter. Pearls exhibiting the prismatic cellular structure are always of a dark-brown colour, and may be readily recognized; they are of no commercial value. The second variety includes all those Pearls which are composed of sub-nacreous tissue, being developed in the soft parts of our common edible Mussels and Oysters, their colour and brilliancy being derived from the same source as that of the internal layer of the shell; all such Pearls vary in colour from purple to dull white, and when

FIG. 236.



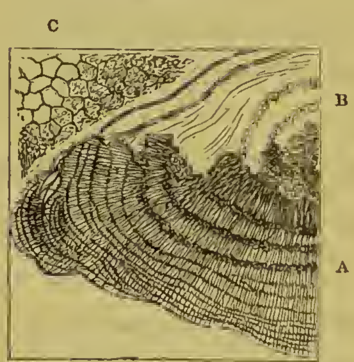
A, a horizontal section of a Pearl. B, segment of the same, exhibiting prismatic cellular structure. C, portion magnified 250 diameters.

divided horizontally and rendered sufficiently thin to be examined microscopically, always exhibit a minute laminated arrangement, but no trace whatever of prismatic cellular tissue; such Pearls, like those of true nacre next to be described, are generally formed upon a nucleus, but if attached to the shell, it has been said that they are developed in order to resist the attacks of boring animals.

To the third class belong all Pearls that are valuable as ornaments; they are formed most probably in the same way as those last described, but always in shells having a true nacreous interior. The quality of a Pearl depends upon its size, roundness, and brilliancy; in order to possess all these qualifications it must be developed in the soft parts of the animal; those attached to the shell are always more or less irregular in figure, whilst those formed upon the edge are rarely entirely coated with nacre. When thin, transparent, horizontal sections of true Pearls are examined microscopically, they always exhibit more or less of the iridescence common to the shell, and should the section traverse the centre, the nucleus will probably be seen.

The last class I shall speak of, is that in which both prismatic cellular tissue and nacre occur; such Pearls appear to be first formed on the edge of the shell, and as they increase in size, they project between the valves, and become coated with nacre. I have every reason to believe that these Pearls may become detached from the edge of the shell and be wholly or partially covered with nacre, and if of small size are capable of forming the nuclei of true Pearls. A segment of one of these compound Pearls is shown in Fig. 237; at A is represented the prismatic cellular structure, and at B the nacre; this last is traversed by two or three brown horny bands in which traces of cellular structure, as shown at C, are very evident. This section would tend to prove, that after a portion of the surface had received a coating of nacre, there was a disposition to cover this again with a layer of prismatic cellular structure.

FIG. 237.



A segment of a horizontal section of a Pearl exhibiting at A the prismatic cellular structure, and at B nacre. C, cellular structure occurring in a band of horny material.

I have now to say a few words upon the nucleus of Pearls. Sir Everard Home was of opinion that the nucleus consisted of a blighted ovum, but I have examined numerous sections of Pearls exhibiting nuclei, and have never yet seen any trace of an ovum; the substance found is generally something foreign to the animal. Some of the nuclei that have been discovered in my investigations are so very peculiar as to merit a slight notice. In Fig. 238, A, is shown a section of a large and brilliant Pearl, the nucleus of which consisted of a black granular substance, like a mass of clay. A Pearl from an Oyster, represented of its natural size at B, has a small particle of flint as a nucleus, but the most remarkable specimen of all is that shown at C, also from the oyster, and the nucleus is

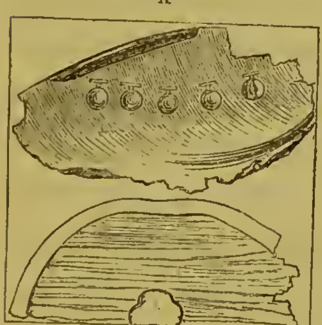
FIG. 238.

A, a section of a true Pearl, showing a nucleus, probably of clay. B, section of a Pearl having a particle of flint as a nucleus. C, section of an Oyster-Pearl, having as a nucleus a piece of steel.

a piece of steel looking like the end of a knife or chisel, which no doubt was employed at sea to open the oyster, but was broken in the attempt, and the oyster again committed to the deep; in process of time the steel has received a coating of shelly matter, and a pearl has been the result.

Pearls may be formed artificially, a fact that was well known to the ancients, and the immortal Linnæus, we are told, suggested a way of

FIG. 239.



A, a portion of a valve of a Mussel, in which five pearls have been formed artificially. B, section of one of the pearls, showing the thin coating of nacre and the hole through which the wire passed.

making them at will by puncturing the shell with a pointed wire. A more perfect plan of forming pearls has been adopted by the Chinese, who introduce into the shell certain anchor-shaped pieces of silver wire, upon each of which a rounded mass of mother-of-pearl, said to be turned in a lathe, is fixed; the animal gives these masses a coating of nacre, and so a pearl is formed. In the Museum you will find a valve of a Mussel in which five nearly equal-sized pearls as shown at A in Fig. 239, have been developed in this manner. A section of one of the pearls is shown at B; the thin layer is nacreous, and in the centre of the mass of mother-of-pearl is seen the hole through which the wire passed. Pearls formed in this way could never be drilled and strung as beads, and therefore their value must be much less than those developed in the ordinary manner.

When speaking of the structure of the skeleton of Zoophytes and Echinoderms I brought forward instances in which fractured portions had undergone the process of repair: if such power were possessed by the tissues of animals so low in the scale of organization as these, we should naturally expect that it would be greater in animals having a special organ for the development of shell. Hunter was fully aware of the reparative power of the Mollusca: the valve of a common fresh-water *Anodon* which has been fractured and repaired is placed in the Pathological series under this head. Nothing is more common than to find shells of the common garden-snail which have been repaired after injury: the researches of Madame Power have proved that the Argonaut is not only the true inhabitant of the shell in which it is found, but that it is capable of repairing its frail tenement with the same material, and after the same pattern as that composing the other parts of the shell.

LECTURE XXIII.

SKELETON OF ARTICULATA—ENTOZOA, ROTIFERA, ANNELIDA, AND MYRIAPODA.

The animals composing the sub-kingdom *Articulata* are characterized by having the body enclosed in a tunic or integument consisting of a series of rings, segments, or joints "articulated" together by a flexible membrane. The segments are disposed in longitudinal rows, and, in some of the orders presently to be described, are nearly of the same form throughout the body, whilst in others every segment is dissimilar to the one preceding it. In some of the animals classed with the Articulata, as for instance the Cystic Entozoa, the firmest portion of the body, or that which might be termed the skeleton, is nothing more than a pellucid membrane: in the Insects however, it is composed of a horny material, whilst in the higher forms of Crustacea and the Cirrhipeds, it is made up of shelly tissue very like that before described as characteristic of the Conchiferous Mollusca. In modern times the articulate sub-kingdom has received two or more accessions to the number of the classes of which it was formerly composed, there now being eight, which by Dr. Carpenter are arranged as follows: *Entozoa*, *Rotifera*, *Annelida*, *Myriapoda*, *Insecta*, *Crustacea*, *Cirrhipoda*, and *Arachnida*. At first sight you will no doubt wonder how animals differing so much in external form and structure could be classified together, but when you take the Entozoa, which certainly includes a great number of species exhibiting no trace of articulations, you will find, nevertheless, that the highest members of this class really are "articulated" animals, and it is on this account that they are placed in so elevated a position.

The *Entozoa* are divided into four orders, viz.: *Cystica*, *Cestoidea*, *Trematoda*, and *Nematoidea*; and the skeleton, if such can be said to exist, certainly belongs to the dermal class. In the Cystic order the structure of the tegument or wall of the cyst is minutely granular, but in its highest state of development, as in *Cysticercus*, it consists of fibrous tissue.

In the genus *Cœnurus* the cyst is granular, but in *Echinococcus*, the young frequently found within the cyst or body of the parent are each provided with a crown of hooks of peculiar figure: the same kind of hooks, but on a larger scale, are met with in adult individuals of the genus *Cysticercus* and *Cœnurus*.

In the *Cestoid* order, which includes the "Tape worms," the body consists of a series of joints, each of which is composed of a fibrous tissue, and encloses a distinct vascular, digestive, and generative apparatus. The head of the *Tænia solium*, or common Tape worm, is surrounded with a crown of hooks, but, although larger, they are not so numerous as those of the young of the *Echinococcus*.

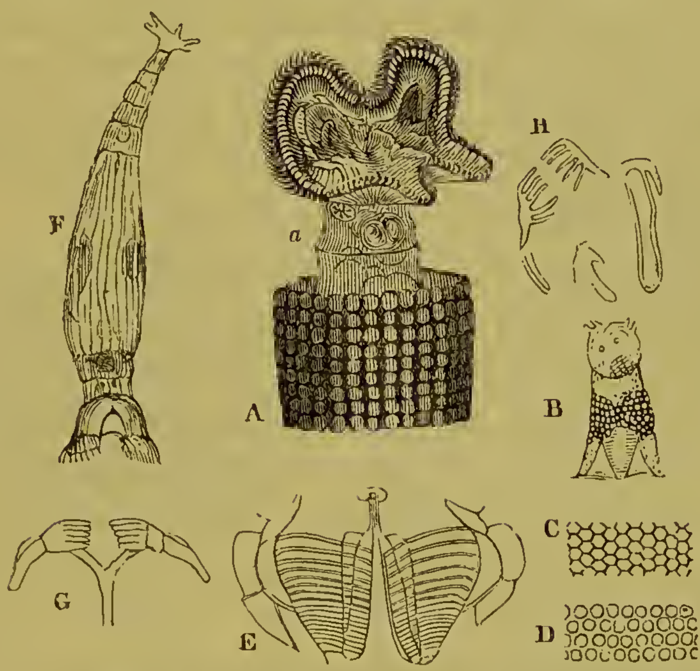
In the order *Trematoda*, which may be represented by the Fluke inhabiting the ducts of the liver, the external tegument is principally composed of a soft fibrous structure sufficiently transparent to allow of some of the viscera being seen within. In the *Planariæ*, which resemble the *Distoma* in external form, the integument is capable of considerable elongation.

In the last order *Nematoidea*, in which the "articulated" character arrives at its highest state of perfection, we have also a well-developed dermal skeleton: in some of the large round worms, such as the *Ascaris lumbricoides*, the integument is of a horny nature, and when viewed under a power of 250 diameters, is found to consist of a series of rings or bands of transparent elastic material, exhibiting short fibres crossing each other at various angles; so elastic is it, that when every trace of muscular tissue is removed, there is an evident tendency in it to resume the cylindrical form it originally occupied.

In the next class, the *Rotifera*, the skeleton is also a dermal one. The common Wheel Animalcule, *Rotifer vulgaris*, Fig. 240, F, (so named from the ciliated apparatus around its mouth being disposed in the form of two wheels), has a jointed tail and a body or case composed of a transparent flexible material, through which the movements of the gastric teeth are readily perceived. The structure of these teeth, as shown at G, is very peculiar; they are partly composed of a hard substance like silica, and are by far the most durable part of the creature. In some of the more highly organized Rotifera, as the *Stephanoceros*, the skeleton is in the form of a shield or case, which is separated from the body, and is composed of a transparent horny substance: the greater part of the body of the animal can be withdrawn within it. In other genera, as for instance that of *Melicerta*, the case or dermal skeleton is made up of rounded masses of foreign substances, which are generally of equal size and disposed in parallel rows.

One species of *Melicerta*, *M. ringens*, Fig. 240, A, has been described by Ehrenberg, who supposed that the rounded particles by which the case was strengthened were composed of excrementitious matter, he having noticed that they first escaped from some part of the body of the creature, and were subsequently employed to strengthen the case. Within the last few years much attention has been paid to the structure and habits of many of the more highly organized Rotifera by Mr. P. H. Gosse, and the species now under consideration has formed the subject of a very interesting communication to the 3rd volume of the "Transactions of the Microscopical Society." After alluding to the description of the animal given by Ehrenberg, and his notion that the case was strengthened by particles of a gummy substance

FIG. 240.



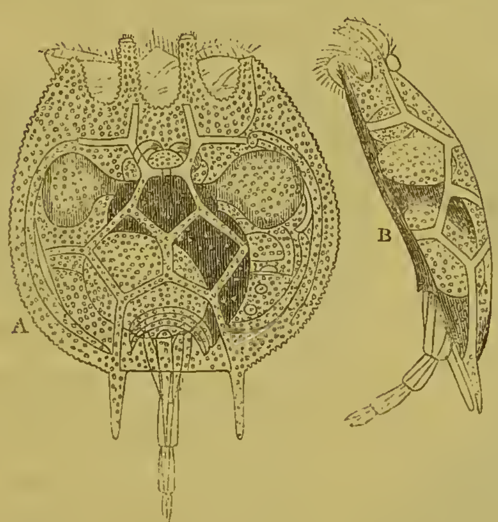
A, *Melicerta ringens*, showing the ciliated hood and part of the dermal skeleton or "case." B, a young individual, the "case" only partly formed. C, D, portion of the "case" in different species of *Melicerta.* E, gastric teeth. F, *Rotifer vulgaris*. G, gastric teeth of the same. H, gastric teeth of another *Rotifer*.

separated from the intestine, Mr. Gosse observes that the animal was known to Leeuwenhoek, and that he even discovered the fact of the augmenting its case by the deposition of rounded particles. Mr. Gosse, however, noticed a peculiar rotating organ seen at *a*, in Fig. 240, which he compares to one of the circular rotating ventilators commonly placed in kitchen windows to cure a smoky chimney. When the animal was fed with carmine, Mr. Gosse found that the larger particles passed into this rotating organ, and were there made into a round pellet. When completed the head of the animal was bent forward, the pellet escaped from the rotating organ, and was speedily deposited upon the edge of the case. The time occupied in making and depositing a pellet, was found by Mr. Gosse to be from two and a half to three and a half minutes; the pellets made of carmine being readily distinguished from the others by their red colour.

The development of the young of *Melicerta* has been carefully studied by Professor Williamson of Manchester, and he has noticed the mode in which the case is formed. The pellets are first arranged in a ring round the middle of the body, as shown at B, in Fig. 240, and new ones are added both to the upper and lower layers. After a time the case is, as it were, pushed down, and cemented to the plant to which the animal has attached itself, and, lastly, new pellets are added to the free surface only as already noticed. The shape of the pellets, according to Professor Williamson, is hexagonal at the base of the case, as shown at C, but at the free extremity they are spherical, as represented at D. The gastric teeth of *Melicerta* which form the splanchno-skeleton of the animal, have also been described by Professor Williamson, and are shown at E. They consist of two principal portions, viz., two plates acting as crushers, and a series of levers or transverse bars which serve the purpose of transmitting the muscular power to the crushers.

Some of the higher forms of Rotifera, as for instance *Noteus quadricornis* and *Anuræa Testudo* of Ehrenberg, the former of which is represented in Fig. 241, have the entire body invested with a shell-like envelope very much resembling that of certain *Entomostraca:* the dorsal surface A, B, is convex and exhibits coarse hexagonal markings, the ventral is flattened and the hexagonal markings are absent. The shell itself is entirely covered with minute rounded tubercles.

FIG. 241.

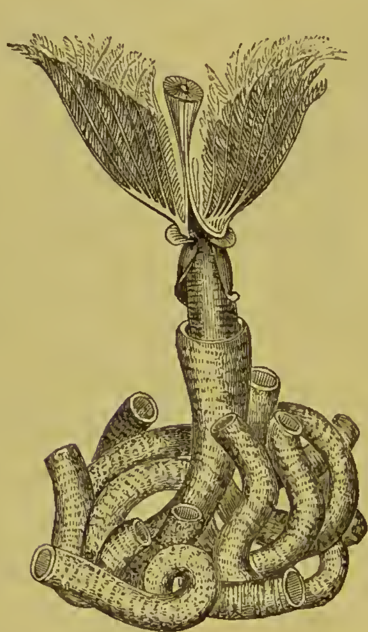


Noteus quadricornis. A, dorsal view. B, side view. (after Carpenter).

The next great division of the *Articulata* is that known as the *Annelida*, or worm-like animals, having a body made up of a series of rings. They have red blood and a well-developed respiratory apparatus. The class is usually divided into three orders, viz.: *Tubicolæ*, *Dorsi-branchiata*, and *Abranchiata*, the first name being derived from the circumstance of most of the species being inhabitants of tubes; the second from the position occupied by the respiratory organs; whilst the third have no apparent branchiæ.

Many of the *Tubicolæ*, as for instance, *Serpula contortuplicata* represented in Fig. 242, inhabit calcareous tubes, which differ in no respect in their mode of formation and minute structure from the shells of some of the Mollusca, being made up of calcareous material exuded from the external surface of the body of the creature. These tubes are always more or less rough externally, but very smooth internally; the animals are readily taken out of the tubes, there being no muscular attachment to them. When thin sections of the tube of a *Serpula* are examined microscopically, they exhibit all the characters of the shell of many of the *Gasteropoda*. The transverse section generally consists of a series of concentric laminæ, made up of radiated prisms: occasionally the prisms of the inner layer cross each other, as in the *Cypræa mauritiana*, represented in Fig. 193; vertical sections exhibit the prismatic structure more plainly, and very frequently branching tubuli occur in great abundance amongst the prisms.

FIG. 242.



Serpula contortuplicata.

Many *Tubicolæ* inhabit tubes composed of horny material, others render the horny matter more solid and durable by cementing to it particles of mud, clay, and sand, fragments of shell, and a variety of other foreign substances; and it is wonderful to see in some cases how beautifully uniform in size all the particles are. In Fig. 243 is shown a portion of the tube of an Annelide, which is composed of grains of transparent silex firmly cemented together: the size of the grains in some parts of the case is so uniform that the specimen very much resembles a transverse section of the prismatic structure of shell.

FIG. 243.

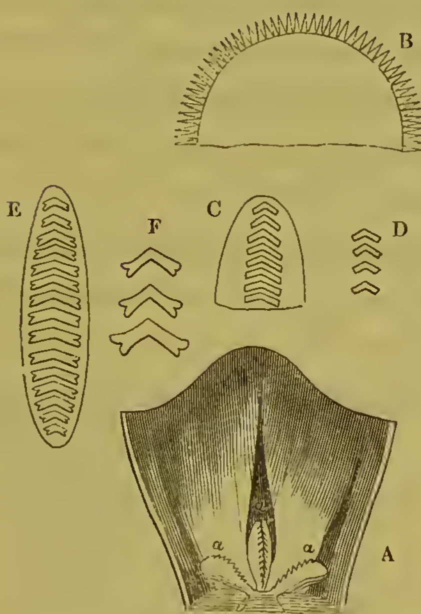
A portion of the tube of an Annelide composed of grains of sand firmly cemented together.

In the order *Dorsi-branchiata*, the skeleton is also a dermal one; it is always more or less soft, and occurs either in the form of distinct segments, or of transverse folds of the integument. Each segment is provided with a series of iridescent bristles or *setæ* upon the sides, which answer the purpose of feet, and enable the animals either to crawl on the ground, or to progress rapidly through the water. A few species burrow in the sand, and most of you, no doubt, are familiar with the common sand worm, *Lumbricus marinus*. The sea-mouse, *Aphrodita aculeata*, also belongs to this order, and is remarkable for the splendid hues of its hairs; the back of this creature has two rows of broad plates or scales, not always very plainly seen, being eovered by a hairy substanee very mueh resembling tow; these seales form the dermal skeleton, and eonsist of a semi-transparent horny material exhibiting a minutely granular strueture. The integument of the *Nereides* eonsists of a thin strong irideseent membrane, whieh eompletely invests the segments, and, no doubt, eommunieates the gorgeous hues to the jointed eirrhi as well as to the tufts of setæ; it is eomposed of a finely striated fibrous strueture, and, when viewed with a power of 250 diameters, is always more or less eoloured.

To the order *Abranchiata* belong the earth worms and the leeches; the former have a thin eutieular investment, provided with a series of small spines or *setæ*, which are employed in loeomotion; they have no external respiratory apparatus, that funetion being probably performed by the entire surfaee of the skin. The Leeehes have an internal respiratory apparatus but no setæ, the dermal skeleton eonsisting of a very thin fibrous strueture, whieh is eovered by a transparent eutieular layer, exhibiting in some eases distinet traees of the epithelial eells of which it was originally formed. But the most durable part of the Leeeh is the peeuliar dental apparatus, which, as we well know, is employed so sueeessfully by them in piereing the skin.

When the anterior or oral sueking dise of the Medicinal Leeeh is laid open, as shown at A, in Fig. 244, three semieireular jaws *a a*, *a*, are brought into view: they are composed of a horny tissue, and eaeh has its free eonvex edge provided with eighty or ninety inverted V-shaped teeth. When the jaw is seen sideways, as shown at B, the teeth appear as so many incisors, but if viewed from above, their shape will resemble that represented by C and D, the latter having been detached from the jaw. The food of the Medicinal Leech is blood, but the common Horse Leech is a much more voracious creature, being capable of swallowing individuals of its own species with great ease: the dental apparatus, as might be expected, differs from that of the medicinal varieties in the shape and number of the teeth, there rarely being more than fifteen in each jaw. They are more like molars than incisors, and are larger than those of the medicinal species, as may be seen by comparing E and F with C and D in Fig. 244, both being magnified precisely to the same extent. The teeth are composed of calcareous material, and by maceration can be easily separated from the jaw to which they were attached.

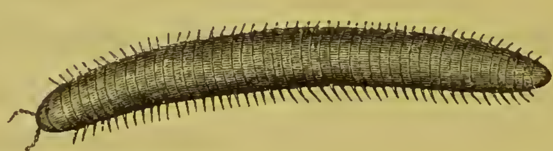
FIG. 244.



A, Mouth of the Medicinal Leech, *a, a, a* jaws. B, side-view of one of the jaws, showing the teeth. C, portion of a jaw seen from above. D, teeth removed from the jaw. E, jaw of the Horse Leech seen from above. F, teeth detached from the same jaw.

The animals composing the next class of the Articulata, the *Myriapoda*, were formerly considered as Insects, but although they resemble them in many points they differ from all true Insects in having more than six legs. The body of a Myriapod consists of a number of joints or segments, each of which generally bears two pairs of feet: the joints increase in number with the age of the animal, and in some species they even exceed fifty. The *Myriapoda* are commonly divided into Millepedes and Centipedes: the dermal skeleton or skin of both is of a horny nature, and in many species is strengthened by a slight admixture of calcareous material. In most Millepedes the skin is frequently shed, and with it the cuticular lining of some parts of the alimentary canal, as in the Crustacea; at each moult one or more joints and feet are added. The animals composing the genus *Iulus*, Fig. 245, have a rounded body, and all the

FIG. 245.

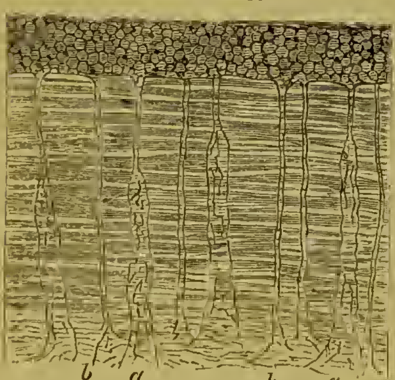


Iulus, or Gally-worm.

larger species are of a dark brown colour; when at rest they roll themselves up into a spiral form. The *Scolopendræ* or Centipedes have a flattened body with a single pair of legs to each segment; the dorsal and abdominal portions of the segments are more dense than the connecting pieces at the sides, whereby a free movement of the body is obtained.

The structure of the dermal skeleton of *Iulus fuscus*, one of the largest of the Millepedes, has been carefully examined: it consists of upwards of fifty segments of a dark brown horny-looking material, which, when divided transversely, or at right angles to the length of the body of the creature, exhibits a fibrous structure, the fibres being arranged in the direction of the section, and occasionally traversed by short tubuli. A section made in the direction of the long axis of the body presents a minutely granular appearance, the granules being the divided extremities of the fibres noticed in the preceding section. The sections, in order to be transparent, must be made exceedingly thin, more so, indeed, than if they consisted of horny material only; on this account I was led to treat them with acetic acid: a copious effervescence then took place, proving the presence of some carbonate: when this was removed a better view of the arrangement of the entire section was obtained, and a distinct cuticular layer composed of minute hexagonal cells was brought into view; the tubuli were few in number, and always presented more or less of a brown colour.

FIG. 246.



A vertical section of the integument of *Scolopendra gigas*, magnified 250 diameters. *a*, tube with dilated extremities; *b*, small tube.

Sections of the horny skeleton of a large Centipede, *Scolopendra gigas*, present better-marked characters; the brown external layer is composed of a series of hexagons, on an average $\frac{1}{2000}$ of an inch in diameter; occurring amongst them, at certain regular distances, are two kinds of circular spots, which I find are the mouths of tubes. A vertical section of the same segment, as shown in Fig. 246, exhibits the depth of the coloured cellular layer, the principal thickness, which is about $\frac{1}{20}$ of an inch, being due to a white fibrous structure, traversed at tolerably regular distances by two sets of straight tubuli, one set *b* being of the same diameter throughout, the other *a* large at the base, and becoming less almost abruptly; both kinds end upon the free surface of the hexagonal layer in the same way. In some specimens the tubes seem more solid than in others, so much so that I am almost induced to consider them as hairs, which have never grown beyond the free surface.

LECTURE XXIV.

SKELETON OF ARTICULATA—INSECTA, CRUSTACEA, CIRRHIPEDIA, AND ARACHNIDA.

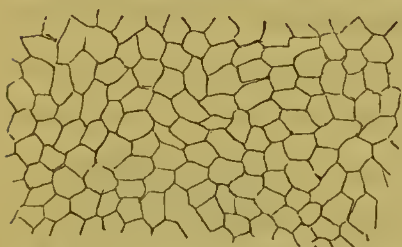
The class *Insecta* is not only far more extensive than any other included in the animal kingdom, but is said to contain nearly as many species as all the other classes put together. The whole tribe of Insects are now usually divided into eleven orders, among which the Myriapods were formerly included, but as these have more than six legs, and the body is not divided into head, thorax, and abdomen, they have been placed in a separate class.

The orders are: *Thysanura*, *Parasita*, *Suctoria*, *Coleoptera*, *Orthoptera*, *Hemiptera*, *Neuroptera*, *Hymenoptera*, *Lepidoptera*, *Rhipiptera*, and *Diptera*. Of these the *Coleoptera*, or Beetles, not only contain by far the greatest number of species, but the skeleton in this order, arrives at its maximum of development; it is strictly a *dermal* one, and said to be composed of a peculiar animal principle, termed *chitine*, which is of a horn-like appearance, but differs from horn, nails, and all other cuticular appendages, in very many points; principally, however, in being insoluble in boiling caustic potash. In some Insects the skeleton is soft and membranous, as is the case in many of the *Diptera;* in the parasitic Insects, and in almost all larvæ, it is also very thin and soft. In changing from the *pupa* to the *imago* state, the skeleton of an Insect very soon becomes hardened, especially if exposed to solar light: in an hour or two it is sufficiently firm for the insect to move about, but in the course of a day it is perfectly rigid.

Entomologists are now in the habit of describing the skin of an Insect as consisting of three layers, viz.: an *epidermis, rete mucosum*, and *corium;* the first two are exceedingly thin, the bulk of the skeleton being formed by the corium or third layer. The *epidermis* is described as being thin and structureless; the *rete mucosum* as consisting of two layers, one smooth, attached to the epidermis, and variously coloured, and superimposed on the second, which is always black or brown. The *corium* is said to be composed of several layers of fibrous structure, crossing each other at various angles: it is occasionally traversed by tubes, and in it the bulbs of the hairs are imbedded. It must not be imagined, however, that all these layers, nor even the principal ones, can be distinguished in every insect; the examples are far from numerous in which the three layers are not, to all appearance, blended into one.

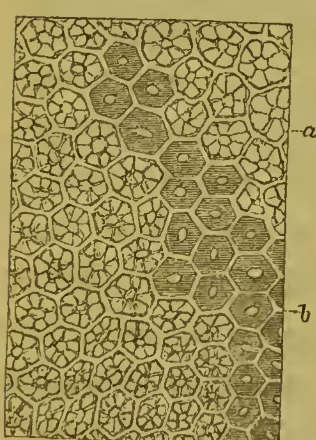
The intimate structure of the skeleton is cellular; in most insects this is retained as a permanent character, but in many others the cells have become so fused together that all appearance of them is lost. The hexagonal structure is well seen in the small parasitic insects, in the skins of larvæ, and in the thinner parts of Beetles. In the Red Ant, *Myrmica domestica*, the entire body exhibits the structure represented in Fig. 247; it is hexagonal, the average diameter of the cells being $\frac{1}{2000}$ of an inch; the tissue itself has no other trace of markings, and is of a rich brown colour. The cast skins of Myriapodous insects, and in fact the articular layer of the Centipede, as before noticed, all exhibit a similar hexagonal structure. The larva of a large Water Beetle, *Hidröus piceus*, appears to be entirely made up of a series of thick-walled hexagonal cells, on an average $\frac{1}{800}$ of an inch in diameter: each, as shown at *a*, in Fig. 248, has a tuberculated structure internally. Amongst

FIG. 247.



Portion of the body of a Red Ant, *Myrmica domestica*, exhibiting a cellular structure.

FIG. 248.

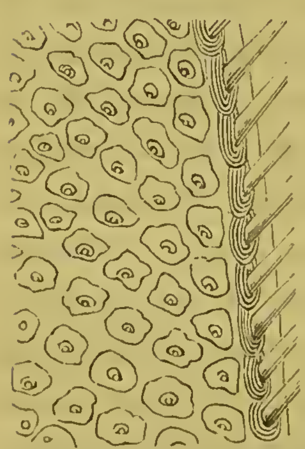


A portion of the skin of the larva of *Hidröus piceus*. *a*, cells with tubercles; *b*, cells with a central nucleus.

these cells are others in which the tuberculated character is absent, but a nucleus of circular figure, as seen at *b*, occupies the centre of each. A trace of this nucleus is visible in the tuberculated cells, but in most cases is obscured by the tubercles.

The antennæ of the Male Cockchafer, *Melolontha vulgaris*, are interesting to the microscopical observer, for, independent of their beautiful leaf-like shape, their intimate structure is very remarkable. Each antenna consists of a jointed pedicle, from which, seven, thin, oval leaflets are given off: the leaflets are very transparent when mounted in Canada balsam, and under a power of 250 diameters exhibit a cellular structure; but the cells, instead of being of hexagonal figure and so close together as to form a confluent network, are more or less oval, and situated at a slight distance from each other, as shown in Fig. 249. The wall of the cells is sometimes very faintly seen, but the nucleus, with its contained nucleolus, which reminds one of a small projecting spine, is always very evident. Each leaflet is composed of two layers of precisely the same structure, but it generally happens that the cells in one layer are not placed exactly over those in the other, so that when cursorily examined under a low power, the entire leaflet may

FIG. 249.

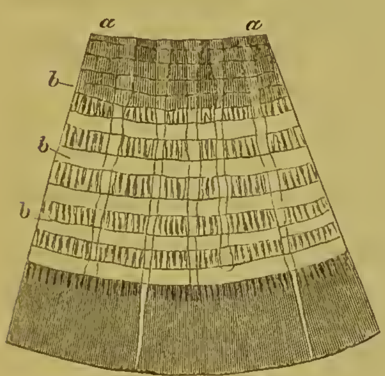


A portion of one of the leaflets of an antenna of *Melolontha vulgaris*.

be supposed to be wholly made up of a series of cells of hexagonal figure.

The skeleton attains its maximum of development in the order *Coleoptera*, or Beetles, and in proportion to the thickness of the horny matter, the hexagonal structure either entirely disappears, or only occurs as a thin cuticular layer. In Fig. 250 is shown a segment of a transverse section of the upper mandible of the great Hercules Beetle, *Dynastes Hercules:* it consists of a series of concentric bands of various widths as shown at *b b b;* these are traversed at right angles by large radiating tubuli, seen at *a a;* the band forming the circumference of the section is the thickest; some of the others exhibit a minutely striated structure, as if made up of prisms, whilst a few are, comparatively speaking, structureless. Other sections of the skeleton of the same beetle sometimes exhibit traces of hexagonal structure, the cells being on an average less than $\frac{1}{2000}$ of an inch in diameter: some of the cells contain a number of granules, which are probably composed of earthy material, the phosphates both of lime and magnesia having been described as hardening elements of the insect skeleton.

FIG. 250.

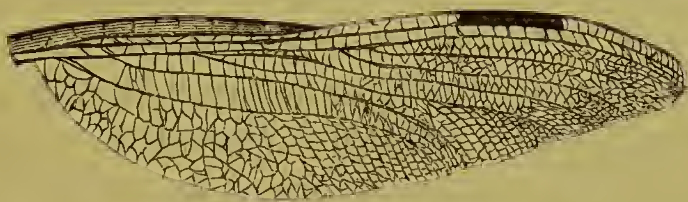


A segment of a transverse section of the upper mandible of *Dynastes Hercules*. *a a*, tubes passing through the laminæ. *b b b*, concentric horny laminæ.

Scetions taken from thc cranial portions of othcr Coleoptcra cxhibit nothing more than a scries of parallel laminæ, and whenever large tubereles are developed from the inncr surfacc, the laminæ always follow the direction of the outline of the tuberele. Sections of the elytra of beetlcs present ehannels or eavities through some of whieh large traeheæ pass; others are said to be reservoirs of nutritious juiees: all such sections elearly show, that an elytron, whieh is nothing more nor less than a modified wing, is made up of two principal layers, separatcd from eaeh other by vertical pillars, and by this arrangement channels for traeheæ and other purposes are left.

When spincs, hairs, scales, &e., are found on the external surface of insects, they must be eonsidered as developments from the eutieular layer, as in the higher animals. Thc varied hues displayed in the eovering of the Lepidoptera are not all produced by pigment, but many of them are the result of light, deeomposed by falling upon grooved surfaces at partieular angles. However thin the wings of flies and the sealy eovering of moths may appear to be, they are nevertheless all eomposed of two layers of membrane, between whieh the ribs or nervures and the pigment are cnelosed; such delieate structurcs are even preserved in the fossil state. At Aix, in Provcnee, a marl is found in whieh the rcmains of inscets abound; many of them are as perfcet as if they had but recently bccn cntombed. In thc Oolitc and Lias of this eountry, inseets are also found in great quantities; in the Lias from the ncighbourhood of Warwick, occurred the wing of the Dragon-fly, represented in Fig. 251, which is said by some of

FIG. 251.



Fossil Wing of Dragon-fly; from the Lias of Warwickshire (after Mantell).

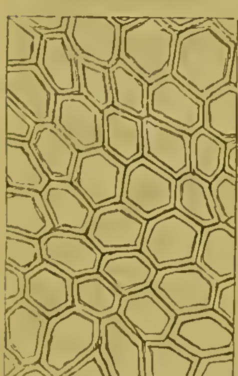
the highest authorities to resemble closely that of a recent species of *Æshna*. Large collections of fossil insects from the Lias and Oolite have been formed by the Rev. Mr. Brodie, by Mr. Binfield, and Mr. Moore, and there is hardly a structure or tissue, however delicate, that has not been detected by these gentlemen. To Mr. Moore I am indebted for the beautiful specimens I now have the opportunity of showing you.

The next class of the Articulata, and one in which the skeleton, being strictly dermal, arrives at its greatest stage of density, is that known as *Crustacea*. Nearly all the members of this class are aquatic, and provided with well-developed organs for aquatic respiration; it is divided into two principal sections, viz.: *Entomostraca*, and *Malacostraca*, both being named from the structure of the integument—the first, from its resemblance to that of Insects; the second, because the shell is considered softer than that of the Mollusca. The *Entomostraca* are very abundant in our fresh waters, and most of them are of microscopic minuteness: the *Monoculus*, *Cyclops*, *Daphnia*, are amongst the commonest examples. The greater number of the species have a bivalve shell, composed of very transparent horny material, and, when examined microscopically, generally exhibits an hexagonal structure. This condition of shell is well seen in *Daphnia pulex*, which is so abundant in some seasons as to communicate a reddish tinge to the water, when they come to the surface towards evening. The hexagonal structure of the skeleton or shell is also present in some of the larger Entomostraca, as, for instance, in *Branchipus stagnalis*, which is occasionally met with in the little pools of water in the neighbourhood of Blackheath. A few years since, only a small number of Entomostraca were described, and these principally by writers on the microscope; the British species are exceedingly numerous, and a valuable monograph of them, by Dr. Baird, of the British Museum, has lately appeared, as one of the series of volumes published by the Ray Society.

The skeleton of the *Malacostraca* varies considerably in density; in some of the small Crabs it is almost as thin as it is in the Entomostraca, but in the chelæ of the large edible crab it is nearly half an inch in thickness. Dr. Carpenter, M. Lavalle, and others, have described the skeleton of the higher forms of Crustacea as consisting of three layers; first, an outer one composed of horny material, quite structureless; second, a thin, cellular layer, to which the pigment is exclusively confined; third, a thick calcareous *corium*, exhibiting a tubular structure like that of dentine. These layers are said to vary in thickness not only in different animals, but frequently in different parts of the same animal. My investigations, however, have led me to believe that in the higher Crustacea the outer layer is essentially composed of hexagonal cells, as in Insects, and that there is rarely such a layer as a distinctly pigmental one, exhibiting cellular structure; the colouring material being diffused throughout a certain thickness of the outer surface of the shell.

In the Glass Crabs, *Phyllosomæ*, the skeleton is composed of horny material, exhibiting no trace of structure; in some species the segments bearing the legs have minute tubercles developed from their upper surface. Most of the small British Crabs, of the genus *Portuna*, are exceedingly transparent, but the entire thickness of the Carapace is made up of hexagonal cells, having thick walls, as shown in Fig. 252. Other Crabs exhibit the hexagonal structure very plainly, but it is principally confined to the surface, for all the thick parts, as shown in Fig. 253, present a granular appearance in addition to the cellular layer. When tubercles are present, the cells do not always cover them, but extend

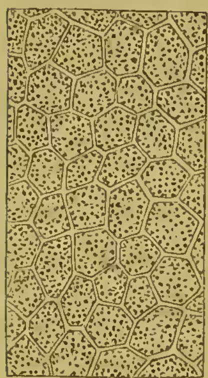
FIG. 252.



Hexagonal structure exhibited by the Carapace of a Crab of the genus *Portuna*.

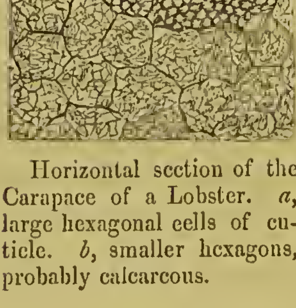
as far as the base, and there terminate in a well-defined line. If the carapace be coloured, the colouring matter is usually spread uniformly over the surface, and in many of these small Crabs, the first trace of the thick, calcareous corium of the larger Crustacea is the granular structure above mentioned. In the Shrimp tribe, the hexagonal cuticle is rarely present, but the calcareous element of the skeleton is generally arranged in the form of concentric rings. In the Prawns large stellate pigment cells occur; their skeleton is frequently shed, and the exuviæ are interesting subjects for examination. In the Cray-fish and Lobsters, a distinct hexagonal layer, as shown at *a* in Fig. 254, is found; beneath this, there is frequently a much smaller hexagonal net-work, not uniformly diffused, but occurring in patches: some of the hexagons are so opaque as to appear like rhombohedral crystals, as seen at *b*. If the section be taken from an unboiled lobster, a tolerably uniform blue tint will be noticed in every part; but if the section be exposed to heat, the colour will change to red; occasionally, however, patches of cells, probably of

FIG. 253.



Portion of the Carapace of a small Crab, showing the granules co-existing with the cellular layer.

FIG. 254.

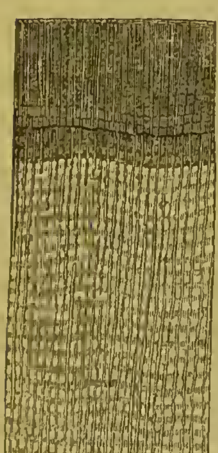


Horizontal section of the Carapace of a Lobster. *a*, large hexagonal cells of cuticle. *b*, smaller hexagons, probably calcareous.

pigment, may be noticed beneath the cuticular layer. When vertical sections of the same shell are made, the hexagonal layer may be seen at the surface, and below this, the thick corium, exhibiting a series of parallel laminæ, crossed by vertical striæ or tubes, somewhat like those described in the corresponding layer of Insects. The upper edge of the section always exhibits either a red or a blue structure, but in no other respect do the two layers differ. When the calcareous matter is removed by acid, the organic basis retains all the characters of the original section. The shell of the large Cray-fish, *Palinurus*, and of the edible Crabs, presents somewhat similar characters; when divided vertically, the hexagonal cuticle is found in every part, and the thick calcareous *corium* is always more or less coloured on its upper surface.

A vertical section of the shell of a large Cray-fish is represented in Fig. 255: the upper margin is red for about the space of $\frac{1}{40}$ of an inch, the remainder is either transparent or of an opaque white colour, and exhibits both vertical and horizontal striæ, with here and there the appearance of a large column or tube passing through all the layers; the vertical striæ are considered to be tubes, the horizontal ones lines of growth; the pigmental layer differs very slightly except in colour from the deeper portion of the section, and not unfrequently is the thicker of the two. Horizontal sections of the

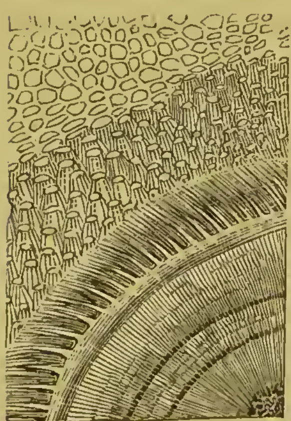
FIG. 255.



Vertical section of the Shell of a large Cray-fish, *Palinurus vulgaris*.

shell of the edible Crab, *Cancer pagurus*, when rendered sufficiently thin to be transparent by grinding away the under layer only, always exhibit a series of white tubercles, slightly elevated above an hexagonal groundwork of a pink colour. The tubercles are composed of a semi-opaque granular substance, and are evidently raised portions of the corium: they exhibit two or more concentric bands having both circular and radiating markings like those of vertical sections of the Cray-fish. On the circumference of the tubercles there are elongated cells arranged in the form of radii, whilst all the spaces between the tubercles exhibit hexagonal cells of equal size, as shown in Fig. 256; they are similar to those forming the cuticular layer in the Cray-fish and Lobster, but their walls are rather thicker. Beneath the hexagonal cells, and in some cases appearing within them, there are in certain situations a series of granules arranged somewhat in a hexagonal form without any cell-wall around them, as shown at B, Fig. 257, but in other parts, where the granules are less diffused, the cell-walls are apparent. A uniform red tint will be found to pervade every part of the section except the tubercles, upon which there are no hexagonal cells. The ends of the chelæ, or large claws of the Crab, are quite

FIG. 256.

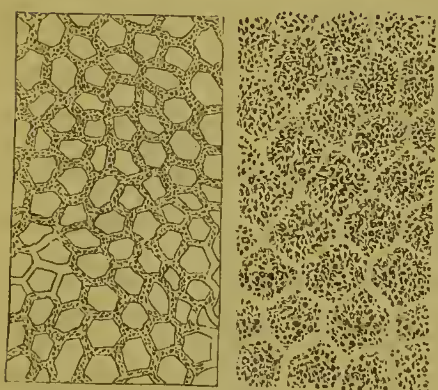


Horizontal section of Shell of the common Crab. *a*, portion of tubercle. *b*, radiated cells on margin of the tubercle. *c*, hexagonal cells of cuticular layer.

black: upon these, few tubercles occur; the colouring matter is extensively diffused throughout the upper layers of the *corium*, and is of a dark brown colour, being blacker around the base of the tubercles than in any other parts. Horizontal sections of the large claws of Crabs and Lobsters exhibit the characters of the shell better than any other parts: in them a distinctly tubular structure is evident; the tubes measure on an average $\frac{1}{12000}$ of an inch in diameter, and run from the inner to the outer surface of the shell; they are crossed by concentric lines, which, like those of the shell, probably indicate successive stages of growth; and in some specimens, as shown in Fig. 258, there is an appearance as if some of them gave off transverse branches. When cut at right angles to their length, as shown in Fig. 259, they present a central cavity precisely like tubes of dentine, to which they were compared by Dr. Carpenter, who was the first to describe them: the principal points of difference between these and dentinal tubes are, that in the former the size of the tube diminishes as it proceeds from the centre towards the circumference of the tooth, and terminates in a series

FIG. 257.

A B



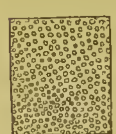
A, portion of the cuticular layer of the common crab magnified 250 diameters. B, granules arranged in hexagons magnified 500 diameters.

of branehes; whereas in the latter they are of the same size throughout. Tubuli, as before stated, exist in nearly all parts of the shell of the higher Crustacea, but in no situation can they be so well seen as in the black portion of the large Claws, as in them the intertubular tissue is more transparent than in the shell itself.

FIG. 258.

Branching of Tubuli seen in a transverse section of a large Claw of a Crab.

FIG. 259.

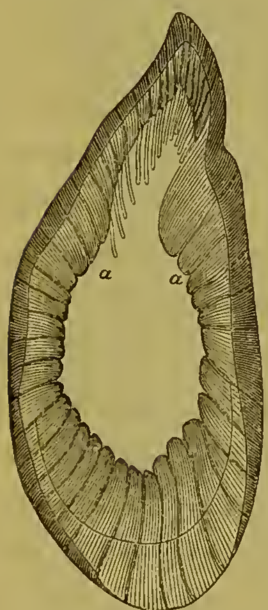


Tubes of the Claw of a Crab divided transversely.

The claws of the King Crab, *Limulus Polyphemus*, when divided transversely, exhibit a structure very like that of a Lobster or Cray-fish deprived of its earthy matter; the colouring material, which is brown, is eonfined to an outer layer, as shown in Fig. 260, but the entire thickness of the seetion is traversed by large tubes, some of which occur at eertain regular distances; others, near the pointed extremity, are more abundant, and, as shown at *a a*, hang loose in the cavity oecupied by the museular substance of the animal: a similar tubular strueture may be observed in the horny extremity of the large claws of the Cray-fish, and of the Land Crab of the West Indies, but they bear no relation whatever to the smaller tubes oecurring in the ealeareous portions of the shell: some of them appear like hairs.

The shells of Crustaeca, unlike those of the Mollusca, do not keep pace with the growth of the animal, but are occasionally shed: this happens generally once a year in the Crabs and Lobsters, and also in the little fresh-water Cray-fish. The old shell splits down the back, and with it all the cuticular parts, even of the stomach, are cast off: but prior to the removal of the old shell, a new one has been developed, as may be seen in a series of preparations of the Cray-fish in the Museum. In Crabs, there are occasional exceptions to this annual shedding of shell: upon a Crab lately sent to the Museum, are several oysters, which from their size must be at least three years old, which prove that during their habitation upon the shell, it could not have been changed. In the first volume of the Histological Catalogue, I have described the structure of the new shell of the Cray-fish, and to that work I would refer those who may be further interested in the subject.

FIG. 260.



Transverse section of a Claw of a King Crab, *Limulus Polyphemus*. *a a*, tubuli passing through both layers of the section.

The next great class of Articulated animals is the *Cirrhipedia*, which consists of those remarkable animals termed *Barnacles*, formerly regarded as Mollusca. The class is divided into two principal groups, viz.: *Pedunculata* and *Sessilia*, names derived from their mode of attaching themselves to foreign bodies; the first are usually termed *Lepadidæ*, and are provided with a long fleshy peduncle or foot-stalk for this purpose, whilst the second, or *Balanidæ*, are attached at once by an expanded shelly basis.

The animals themselves are imperfectly divided into segments, and from every segment a pair of short feet arises, from each of which, two, long, jointed, flabelliform appendages or *cirrhi* are given off. The cirrhi are furnished with cilia, and by their motion, both food and fresh water are brought to the animal. The skeleton is a strictly dermal one, and is composed of many pieces or valves; in the Pedunculated tribes or *Lepadidæ*, which attach themselves generally to floating bodies, such as ships' bottoms and logs of timber, the shell, in most species, consists essentially of two valves, somewhat like those of a Mussel, and of certain accessory pieces. In the common Goose Barnacle, *Lepas anatifera*, there are five valves in the *capitulum*, or that part supported by the peduncle; the two largest being named by Mr. Darwin, *Scuta*, the next two *Terga*, and the fifth, a single one, termed the *Carina*, or "keel valve." The peduncle in this species is soft and naked, and is occasionally two feet in length; it is, however, capable of being shortened by muscular contraction.

In the genus *Pollicipes*, according to Mr. Darwin, the valves vary from eighteen to a hundred in number, as shown in Fig. 261, and the peduncle, which is short, is covered with calcified scales, varying slightly in shape and arrangement in the different species. The valves of the *Pedunculata* are always more or less strongly marked with curved lines, indicating the successive stages of growth; but when sections are examined microscopically, no trace of prismatic or cellular structure is evident. The most remarkable character exhibited by every specimen I have yet examined, is the presence of wavy tubuli, which generally occur at certain regular distances apart. In a horizontal section of a valve of a *Pollicipes*, given to me as *P. villosus*, they present the appearance shown in Fig. 262. They are about $\frac{1}{25}$th of an inch distant from each other, and the shelly matter surrounding them is more transparent than it is in other parts. The direction of the tubuli is always opposite or at right angles to that of the lines of growth; but it is very difficult to trace them through their entire course.

FIG. 261.

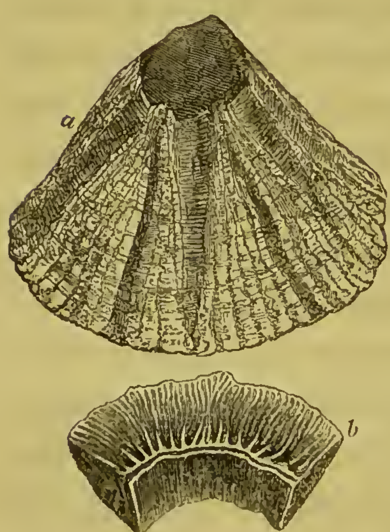
Pollicipes.

FIG. 262.

Horizontal section of valve of *Pollicipes villosus*, showing tubuli.

In the *Balanidæ*, or sessile group, the shell is sufficiently large to contain the entire animal; it is composed of twelve conical plates, or valves, six of which, as shown at *a*, in Fig. 263, are thicker than the rest, and placed with their bases below and apices above; the other six are thinner, and their bases form the principal part of the mouth, whilst their apices reach nearly to the common base of the shell. All these plates are crossed by transverse markings, which indicate the successive stages of growth, and are most evident in the valves forming the principal part of the base of the shell. Some Barnacles have the base of the shell covered by shelly matter; to these the generic name *Balanus* has been given; they generally attach themselves to wood and stone, whilst others have no solid base, and are most commonly found on living animals, especially the Whale; to such the name *Coronula* has been applied. The mouth of the shell is closed by an operculum, consisting of two or four triangular plates attached to the soft parts of the animal. The plates are moveable one upon the other, and readily admit the cirrhi to pass out through a slit-like orifice between them; although when brought together, they completely close the shell.

FIG. 263.

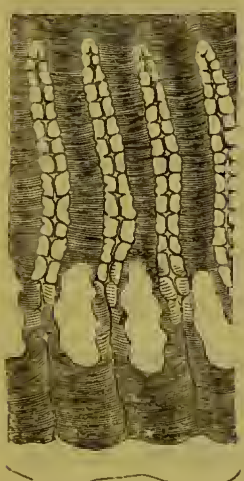


a, entire shell of a *Balanus*, showing the two sets of plates; *b*, portion of the base of a *Coronula*, exhibiting the cancellated structure.

When divided transversely, the shell is found to be composed of two layers between which a cancellated structure, as shown at *b*, in Fig. 263, exists; the solid parts never exhibit the least trace of prismatic or of cellular tissue, but always present more or less of a granular appearance;

and, however much the shelly matter may be involuted to form the cancellated structure, I have always been able, in some part or other, to detect a series of tubuli passing through it. The tubuli are well seen in a horizontal section of the base of one of the large valves of *Balanus tintinnabulum*, as shown in Fig. 264. One margin of this section exhibits a laminated arrangement of the shell tissue, but on the other, there are a series of small involutions of the laminæ, and through the centre of each, a branching tube passes; four of these tubes are represented in Fig. 264. They all commence on the outer surface of the valves, and pass inwards; the shell tissue around them is very often as transparent as that shown in the figure: in this particular the tubes correspond with those of *Pollicipes*, before described.

FIG. 264.



Horizontal section of the base of a large valve of *Balanus tintinnabulum*, exhibiting branching tubuli passing through the cancellated structure.

Several species of Barnacles attach themselves to the skin of Whales; they are principally *Coronulæ*, and they sometimes attain a diameter of three or four inches: the shell is always flattened, and has a cancellated base: imbedded in the skin of the whale is also frequently found another Cirrhiped, termed *Tubicinella*: it is of cylindrical form, and, as it increases in length, it descends lower and lower into the skin: its entire surface is strongly ribbed and marked with transverse lines of growth. In the genus *Otion*, the shell is rudimentary, consisting of two small valves, the remainder of the tegument being composed of a material resembling horn or cartilage, or like that which joins the different valves in some of the *Pedunculata*.

The last and most highly organized class of the Articulata is known as *Arachnida;* in it are included the Spiders, Scorpions, and Mites, which differ from Insects in having eight legs; and instead of the body being divided into three parts, viz.: head, thorax, and abdomen, as in Insects, the two first, in the Arachnida, are joined together, and have received the name of *cephalo-thorax:* to it, the legs are articulated.

The Arachnida are divided into two orders: *Trachearia* and *Pulmonaria*, so named from the structure of their organs of circulation and respiration: in the first, which includes the *Mites*, there are tracheæ, as in Insects, but no distinct vascular apparatus; in the second, on the contrary, there are pulmonary cavities, and a well-developed circulating system. The skeleton of the *Trachearia* requires only a brief notice; it rarely exhibits any trace of the hexagonal structure so common in Insects, but appears to be composed principally of a fibrous tissue: such is its condition in the *Sarcoptes scabiei*, or Itch insect; and in the *Demodex folliculorum*, a parasite infesting the sebaceous follicles of the human skin.

In the *Pulmonaria*, on the contrary, the skeleton is in some species very dense. In the Scorpions, and in the cephalic portions of the larger Spiders, it is as thick and horny as in Beetles, but in the abdomen of the latter it is comparatively soft. When the cephalo-thorax of a Spider is divided vertically, it will be found to consist of a series of laminæ, the superficial layer being of a darker colour than the rest: these layers in some species are traversed by stout hairs. The free surface exhibits every here and there a hexagonal structure, but the hairs are often so numerous as to obscure the view: horizontal sections, under a power of 250 diameters, show that the horny matter has a minutely granular appearance. The abdomen is composed of a beautiful wavy fibrous structure, with short stout hairs projecting from them; in some of the large Bird-catching spiders the form of these hairs is extremely beautiful, as has been shown by Mr. Shadbolt.

The Skeleton of the Scorpions is very dense, and is said to be composed of *chitine*, as in Insects: vertical sections of the mandibles exhibit a series of laminæ of a brown colour; these are traversed by tubes precisely in the same way as the corresponding parts of the Centipede, Fig. 246; some of the tubes resemble abortive hairs, they never appear above the surface. All the other parts of the body are made up of a thinner and softer material, and an outer coloured layer can be readily separated from a deeper one; the former exhibits the hexagonal structure as in insects, but it is not so well-marked as in the Centipedes, whilst the latter is white and minutely granular. By the employment of reagents I have failed to detect any trace of a calcareous strengthening ingredient, as occurs in some of the Iulidæ.

I have now, Gentlemen, in conclusion, to thank you for the kind and patient attention with which these Lectures have been honoured. The minute structure of the skeleton of Invertebrate Animals is a new subject, and one which has never before, I believe, occupied an entire course of Lectures; I must therefore crave your indulgence if I have failed in making it as intelligible as I could have wished. I can only assure you, that I have learnt more of the secret workings of Nature from its investigation than from any other subject which has engaged my attention. In the hope, therefore, that you also may have derived at least some interest, if not instruction, from the numerous facts that have been, not only orally, but visually, brought forward, I bid you farewell.

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