oratorio—*Des Heiland's letzte Stunden*, known in England as *Calvary* or *The Crucifixion*—which was performed at Cassel on Good Friday 1835, and sung in English at the Norwich festival of 1839, under Spohr's own direction, with such unexampled success that he was accustomed to speak of this event as the greatest triumph of his life. For the Norwich festival of 1842 he composed *The Fall of Babylon*, which also was a perfect success. His last opera, *Die Kreuzfahrer*, was produced at Cassel in 1845. Of his nine symphonies the finest, *Die Weihe der Töne*, was produced in 1832. His compositions for the violin include concertos, quartetts, duets, and other concerted pieces and solos, adapted for the chamber and the concert room, and among these a high place is taken by four double quartetts,—a form of composition of which he was both the inventor and the perfecter. He was, indeed, very much inclined to explore new paths, notwithstanding his attachment to classical form, and his freedom from prejudice was proved by the care with which he produced Wagner's *Flying Dutchman* and *Tannhäuser* at Cassel in 1842 and 1853, in spite of the elector's opposition. Spohr retained his appointment until 1857, when, very much against his wish, he was pensioned off. In the same year he broke his arm, but he was able to conduct *Jessonda* at Prague in 1858. This, however, was his last effort. He died at Cassel on 16th October 1859. (W. S. R.)

SPOLETO (Lat. *Spoletium*), a city of Italy, in Umbria, placed in a commanding position near the Via Flaminia, between Rome and Perugia, is said to have been colonized in 240 B.C. (Liv., *Epit.*, xx.; Vell. Pat., i. 14), and is called by Cicero (*Pro Balb.*, 21) "colonia Latina in primis firma et illustris." After the battle of Trasimenus (217 B.C.) Spoletium was attacked by Hannibal, who was repulsed by the inhabitants (Liv., xxii. 9). During the Second Punic War the city was a useful ally to Rome. It suffered greatly during the civil wars of Marius and Sulla. The latter, after his victory over Crassus, confiscated the territory of Spoletium and reduced it to the rank of a military colony. Under the empire it again became a flourishing town (Strabo, v. p. 227; Plin., *H.N.*, iii. 14; Ptol., iii. 1, 54). Owing to its elevated position it was an important stronghold during the Vandal and Gothic wars; its walls were dismantled by Totila (Procop., *Bell. Get.*, iii. 12). Under the Lombards Spoleto became the capital of an independent duchy (from *c.* 570), and its dukes ruled a considerable part of central Italy. Together with other fiefs, it was bequeathed to Pope Gregory VII. by the empress Matilda, but for some time struggled to maintain its independence. In 1881 it had a population of 7969 (commune, 21,507), many of whom are occupied in the weaving of woollen stuffs. It is the seat of an archbishopric for the three dioceses of Spoleto, Bevagna, and Trevi.

The city contains many interesting ancient remains,—traces of an early polygonal wall, a Roman theatre, and parts of three temples, built into the churches of S. Agostino, S. Andrea, and S. Giuliano. Remains of a fine Roman bridge were found a few years ago buried in the former bed of a torrent, which now runs along a different line. These remains have recently been buried again under a newly made road. On the citadel, which commands the town, still stands an ancient castle, originally built by Theodoric. This castle was mostly destroyed by the Goths, but was afterwards rebuilt and enlarged at many different times, especially by Pope Nicholas V. The existing building contains work of many different dates. The cathedral of S. Maria Assunta dates partly from the time of the Lombard duchy, but was much modernized in 1644. Over the main entrance is a very interesting and large mosaic of Christ in Majesty signed "Salsernus," 1207; at the sides are figures of the Virgin and St John. In the choir and on the half cupola of the apse are some of the finest frescos of Lippo Lippi, representing scenes from the life of the Virgin. Lippo died in 1469, leaving part of the work to be completed by his assistant Fra Diamante. The fine stalls and panelling in the choir are attributed to Bramante. The church of S. Pietro is a fine early example of Lombard architecture, though much modernized. The façade is remarkable for its rich sculptured decorations of grotesque figures, dragons, and foliage. S. Domenico is a fine example of later Italian Gothic with bands of different coloured stones. The three-apsed crypt of the church of S. Gregorio is of great interest; it probably dates from the founding of the church in the 9th century. S. Niccolo is a beautiful example of Pointed Gothic.

The city is still supplied with water by a grand aqueduct (see vol. ii. pl. IV.) across the adjacent gorge; it has stone piers and brick arches, and is about 268 feet high and 676 feet long. It is said to have been built in 604 by Theodelapius, the third Lombard duke, and the stone piers belong probably to that time. The brick arches are later restorations.

SPONGES

THE great advance which has been made during the past fifteen years in our knowledge of the sponges is due partly to the vivifying influence of the evolutional hypothesis, but still more to the opportunities afforded by novel methods of technique. To the strength and weakness of the deductive method Haeckel's work on the *Kalkschwämme* (*6*)[1] is a standing testimony, while the slow but sure progress which accompanies the scientific method is equally illustrated by the works of Schulze (*20*), who by a masterly application of the new processes has more than any one else reconstructed on a sure basis the general morphology of the sponges. In the general progress the fossil sponges have been involved, and the application of Nicol's method of studying fossil organisms in thin slices has led, in the hands of Zittel and others (*24*, *35*), to a complete overthrow of those older classifications which relegated every obscure petrifaction to the fossil sponges and consigned them all to orders no longer existing. But, whilst many problems have been solved, still more have been suggested. An almost endless diversity in details differentiates the sponges into a vast number of specific forms; the exclusive possession in common of a few simple characters closely unites them into a compact group, sharply marked off from the rest of the animal kingdom.

[1] These numbers refer to the bibliography at the end of the article.

Structure and Form.

Simple sponge

Description of a Simple Sponge.—As an example of one of the simplest known sponges we select *Ascetta primordialis* (fig. 1), Haeckel. This is a hollow vase-like sac closed at the lower end, by which it is attached, opening above by a comparatively large aperture, the *osculum* or vent, and at the sides by numerous smaller apertures or *pores*, which perforate the walls. Except for the absence of tentacles and the presence of pores it offers a general resemblance to some simple form of *Hydrozoon*. Histologically, however, it presents considerable differences, since, in addition to an endoderm and an ectoderm, a third or mesodermic layer contributes to the structure of the walls; and the endoderm consists of cells (see fig. 21*g*) each of which resembles in all essential features those complicated unicellular organisms known as choanoflagellate *Infusoria* (see PROTOZOA, vol. xix. p. 858). With this positive character is associated a negative one: nematocysts are entirely absent. The activity

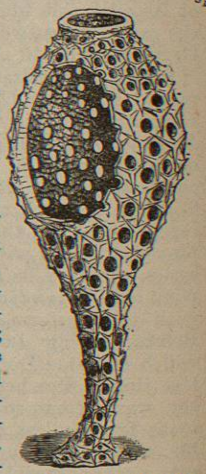

FIG. 1.—*Ascetta primordialis*, Hk. After Haeckel.

of the *Ascetta*, as of all sponges, is most obviously manifested, as Grant (*5*) first observed, by a rapid outflow of water from the oscule and a gentle instreaming through the pores,—a movement brought about by the energetic action of the flagella of the endodermic cells. The instreaming currents bear with them into the cavity of the sac (paragastric cavity) both protoplasmic particles (such as *Infusoria*, diatoms, and other small organisms) and dissolved oxygen, which are ingested by the flagellated cells of the endoderm. The presence of one or more contractile vacuoles in these cells suggests that they extricate water, urea, and carbonic acid. The insoluble residue of the introduced food, together with the fluid excreta, is carried out through the oscule by the excurrent water. New individuals are produced from the union of ova and spermatozoa, which develop from wandering amœboid cells in the mesoderm. The walls of *Ascetta* are strengthened by calcareous scleres, more especially designated as spicules, which have the form of triradiate needles. If we make abstraction of these we obtain an ideal sponge, which Haeckel has called *Olynthus* (*6*), and which may be regarded as the ancestral form from which all other sponges have been derived. To give greater exactness to our abstraction we should perhaps stipulate for the *Olynthus* a somewhat thicker mesoderm and more spherical form than a decalcified Ascon presents.

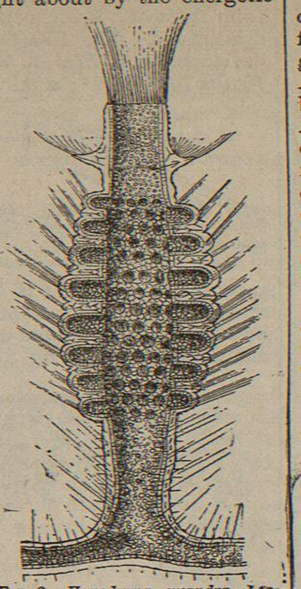

FIG. 2.—*Homoderma sycandra*, Lfd. One half cut away by a vertical median section. After V. Lendenfeld (×about 6).

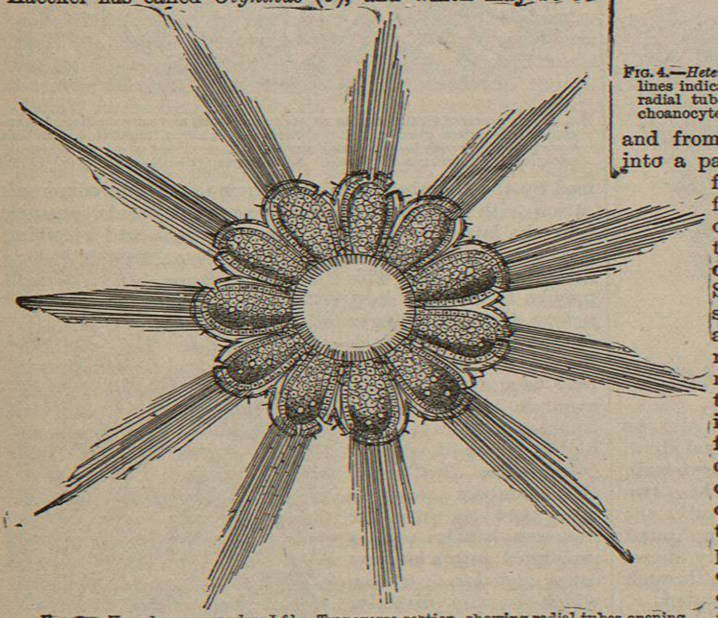

FIG. 3.—*Homoderma sycandra*, Lfd. Transverse section, showing radial tubes opening into central paragastric cavity. After V. Lendenfeld (×about 12).

Canal System.—We shall now trace the several modifications which the *Olynthus* has undergone as expressed in the different types of canal system.

Ascon type.

The simple paragaster of *Ascetta* may become complicated in a variety of ways, such as by the budding off from a parent form of stolon-like extensions, which then give rise to fresh individuals, or by the branching of the Ascon sac and the subsequent anastomosis of the branches; but in no case, so long as the sponge remains within the Ascon type, does the endoderm become differentiated into different histological elements. The most interesting modification of the Ascon form occurs in *Homoderma sycandra* (*12*), in which from the walls of a simple Ascon cæcal processes grow out radiately in close regular whorls, each process reproducing the structure of the parent sponge (figs. 2, 3). From this it is but a short step to the important departure which gives rise to the Sycons.

Sycon type.

In the simplest examples of this type the characters of *Homoderma sycandra* are reproduced, with the important exception that the endoderm lining the paragastric cavity of the original Ascon form loses its primitive character, and from a layer of flagellated cells becomes converted into a pavement epithelium, not in any distinguishable feature different from that of the ectoderm. The flagellated cells are thus restricted to the cæcal outgrowths or radial tubes. Concurrently with this differentiation of the endoderm a more abundant development of mesoderm occurs. In some Sycons (*Sycaltis*, Hk.) the radial tubes remain separate and free; in others they lie close together and are united by trabeculæ, or by a trabecular network, consisting of mesodermic strands surrounded by ectoderm (fig. 4). The spaces between the contiguous radial tubes thus become converted into narrow canals, through which water passes from the exterior to enter the pores in the walls of the radial tubes. These canals are the "intercanals" of Haeckel, now generally known by their older name of *incurrent* canals. The openings of the incurrent canals to the exterior are called pores, a term which we have also applied to the openings which lead directly into the radial tubes or paragastric cavity; to avoid ambiguity we shall for the future distinguish the latter kind of opening as a *prosopyle*. The term "pore" will then be restricted to the sense in which it was originally used by Grant. The mouth by which a radial tube opens into the paragaster is known as a *gastric ostium*. In the higher forms of Sycons the radial tubes no longer arise as simple outgrowths of the whole sponge-wall, but rather as outgrowths

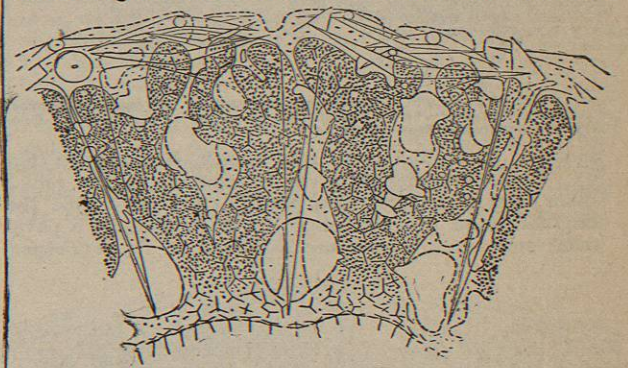

FIG. 4.—*Heteropegma nodus-gordii*, Pol. Part of a transverse section. The straight lines indicate spicules; the poriferous surface is uppermost; the branching radial tubes are rendered dark by numerous small circles representing choanocytes. After Polejaeff, "*Challenger*" *Report* (×50).

of the endoderm into the mesoderm, which, together with the ectoderm, exhibits an independent growth of its own; and this results in the formation of a thick investment, known as the *cortex* (fig. 5), to the whole exterior of the

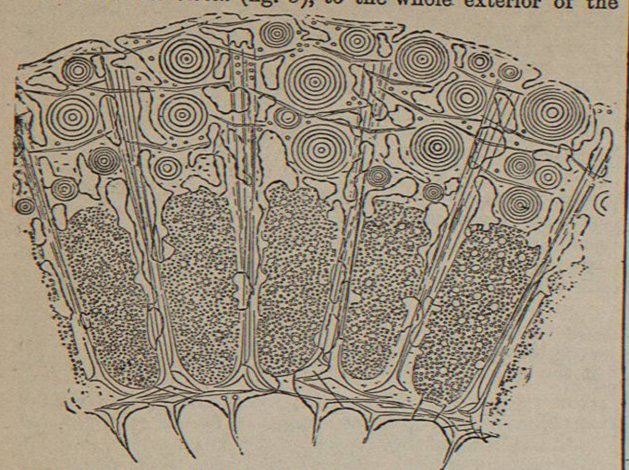

FIG. 5.—*Ute Argentea*, Pol. Part of a transverse section. The concentric circles, indicating transverse sections of spicules, lie within the cortex. After Polejaeff. "*Challenger*" *Report* (×100).

sponge. The radial tubes may branch, *Heteropegma* (fig. 4). If the branches are given off regularly, as the radial tubes were in the first plan, and if at the same time the original radial tube exchanges its flagellated for a pavement epithelium, a structure as shown in fig. 6 (*Polejna*

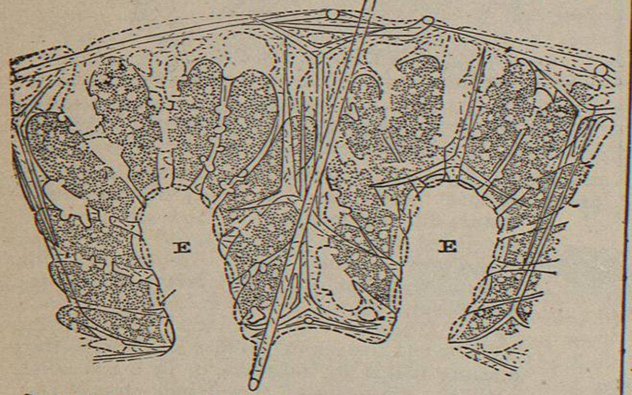

FIG. 6.—*Polejna connexiva*, Pol. Part of a transverse section. *E*, excurrent canals, into which the flagellated chambers open. After Polejaeff, "*Challenger*" *Report* (× 50).

connexiva, Pol.) will result. This form might also be brought about by unequal growth of the gastral endoderm leading to a folding of the inner part of the sponge-wall. Very little direct evidence exists as to which of these two plans has actually been followed. Phylogenetically the transition from a simple Ascon to the most complicated Sycon can be traced step by step; and ontogeny shows that such a Sycon form as *Grantia raphanus* passes through an Ascon phase in the course of its larval development.

Returning to the ancestral form of sponge, *Olynthus*, let us conceive the endoderm growing out into a number of approximately spherical chambers, each of which communicates with the exterior by a prosopyle and with the paragastric cavity by a comparatively large aperture, which we may term for distinction an *apopyle*; at the same time let the endoderm lose its flagellated character and become converted into a pavement epithelium, except in the spherical chambers. Such a form, called by Haeckel "dyssycus," may be more briefly named a *Rhagon* from the grape-like form of its flagellated chambers, which differ from those of a Sycon both by their form and their smaller dimensions. The Rhagon occurs as a stage in the early development of *Plakina monolopha* (Schulze) and *Reniera fertilis* (*9*) (fig. 7); a calcareous sponge which appears to

FIG. 7.—Vertical section of a Rhagon, partly diagrammatic. *o*, oscule; *p*, paragaster. After Keller (× about 100).

approach it somewhat is *Leucopsis pedunculata*, Lfd. By the folding of the wall of a Rhagon, or by its outgrowth into lobes, a complicated structure such as that of *Plakina monolopha* (*20*) (see fig. 26 *f*) results. This is character-

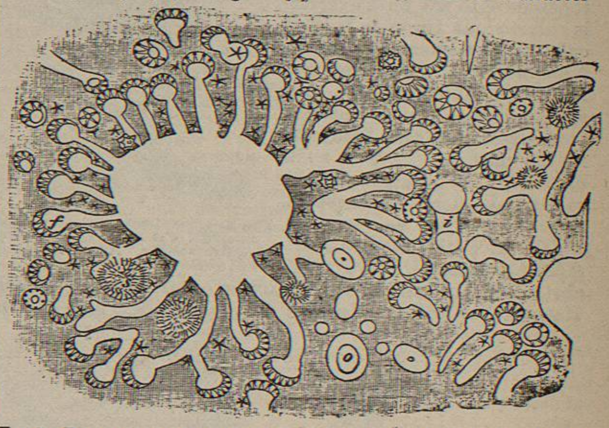

FIG. 8.—Transverse section across an excurrent canal and surrounding choanosome of *Cydonium eosaster*, Soll. *e*, excurrent canal; *f*, flagellated chambers communicating with it by aphodal canals; *i*, an incurrent canal cut across; *s*, a sterraster; *o*, an oxea cut across. After Sollas, "*Challenger*" *Report* (×125).

ized by the chambers retaining their immediate communication with the incurrent and excurrent canals, opening into the latter by the widely open apopyle and receiving the former by one or several prosopyles. This may be termed the *eurypylous* type of Rhagon canal system. The folding of the sponge-wall may be simple, as in the example given, or too complex to unravel. In higher forms of sponges (*Geodinidæ*, *Stellettidæ*) the chambers cease to open abruptly into the excurrent canals: each is prolonged into a narrow canal, *aphodus*, or *abitus*, which usually directly, sometimes after uniting with one or more of its fellows, opens into an excurrent canal. The prosopyles, now restricted to one for each chamber, may remain unchanged in character, or at the most be prolonged into very short

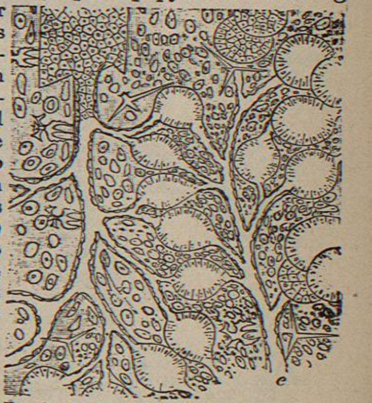

FIG. 9.—Diplodal canal system in *Corticium candelabrum*, O.S. *e*, excurrent canal; the incurrent canal is shown on the left-hand side, near its commencement in the cortex. After F. E. Schulze (× 200).

tubes, each a *prosodus* or *aditus* (fig. 8). This may be termed the *aphodal* or *racemose* type of Rhagon system, since the chambers at the ends of the aphodi radiating from the excurrent canal look like grapes on a bunch. As Haeckel, however, has used "racemose" in a different sense, we shall adopt here the alternative term. By the extension of the prosodal or adital canals into long tubes a still higher differentiation is reached (fig. 9). This, which from the marked presence of both prosodal and aphodal canals may be termed the *diplodal* type of the Rhagon canal system, occurs but rarely. *Chondrosia* is an example.

The following scheme will render clear the foregoing distinctions:—

1. Ascon type: simple, ex. *Ascetta*, Hk.; strobiloid, ex. *Homoderma*, Lfd.
2. Sycon type: simple radial tubes, ex. *Sycetta*, Hk.; branched radial tubes (cylindrical chambers), ex. *Heteropegma*, Fl.; chamber-layer folded, ex. *Polejna*, Pol.
3. Rhagon type: eurypylous, with several prosopyles to each chamber, ex. *Spongelia*; with a single prosopyle to each chamber, ex. *Oscarella*, *Thenea*; aphodal, aphodal canals well developed, ex. *Geodia*, Lmk.; diplodal, with both aphodal and prosodal canals well developed, ex. *Chondrosia*, O.S.

In the case of the calcareous sponges Polejaeff has argued forcibly that the eurypylous type arises directly from the Sycon and not from the Rhagon. It is therefore doubtful how far the Rhagon in other sponges is a primitive form derived directly from an *Olynthus*, or whether it may not be a secondary larval state resulting from the abbreviated development of a former Sycon predecessor. Whatever may have been its past history, the Rhagon serves now at all events as a starting-point for the development of the higher forms of canal system.

Subdermal cavities. In the higher Rhagons, as in the Sycons, further complications ensue, owing to an independent growth of the external ecto͜derm and the adjacent mesoderm. While the endoderm, with its associated mesoderm, is growing out or folding to form the excurrent canal system, the superficial mesoderm increases in thickness, and the ectoderm, extending laterally from the sides of the incurrent sinuses, burrows into it, parallel to the surface of the sponge. Thus it forms beneath the skin (*i.e.*, the layer of superficial mesoderm and investing ectoderm) cavities which may be either simple and spacious or be broken up into a number of labyrinthine passages by a network of mesoblastic strands (invested with ectoderm) which extend irregularly from roof to floor of the chamber. These cavities are known as *subdermal chambers*.

Ectosome, choanosome. With the appearance of subdermal chambers the sponge becomes differentiated into two almost independent regions, an outer or *ectosome* and an inner or *choanosome*, which is characterized by the presence of flagellated chambers. The ectosome forms the roof and walls of the subdermal chambers, and is in its simplest form merely an investing skin; but in a large number of sponges it acquires considerable thickness and a very complicated histological structure. It is then known as a *cortex*. The thickening which gives rise to a cortex takes place chiefly beneath those parts of the skin which are not furnished with pores. Beneath the pores—in this case collected into sieve-like areas—dome-like cavities are left in the cortex; they open freely into the subdermal cavities below and their roof is formed by the cribriform pore membrane above. In many sponges (*Geodia*, *Stelletta*) the cortical domes are constricted near their communication with the subdermal cavity (subcortical crypt) by a transverse muscular sphincter, which defines an outer division or *ectochone* from an inner or *endochone* (fig. 10), the whole structure being a *chone*. The endochone is frequently absent (fig. 10). The early development of the cortex has scarcely yet been studied. In *Stelletta phrissens* (Soll.), one of the "Challenger" *Stellettidæ*, an early form of the sponge (fig. 11), shows the choanosome already characteristically folded within the cortex, which forms a complete not-folded envelope around it. The roots of the incurrent sinuses form widely open spaces immediately beneath the cortex and are the rudiments of subcortical crypts. Again, in some sponges a part of the endoderm and associated mesoderm may likewise develop independently of the rest of the sponge, as in the *Hexactinellida*, where the choanosome forms a middle layer between a reticulation of ectosome on the one side and of endoderm and mesoderm, *i.e.*, *endosome*, on the other. Finally, the attached or lower half of a Rhagon may develop in an altogether different manner from the other or upper half, the endoderm not producing any flagellated chambers. In this case the upper portion alone is characterized by the flagellated chambers, which are the distinctive mark of a sponge, and hence may be

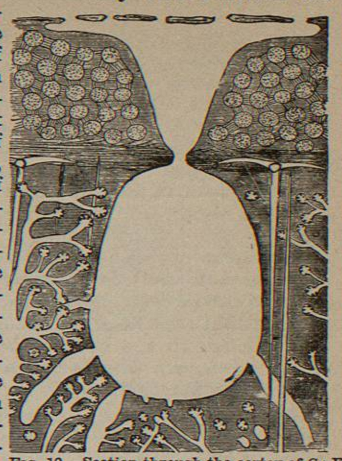

FIG. 10.—Section through the cortex of *Cydonium eosaster*, Soll., showing the pore-sieve overlying the chone, which communicates through a sphinctrate aperture with the subcortical crypt, lying in the choanosome with its flagellated chambers. The dotted circles in the cortex are sterrasters connected by fibrous strands. After Sollas, "*Challenger*" *Report* (×73).

Endosome.

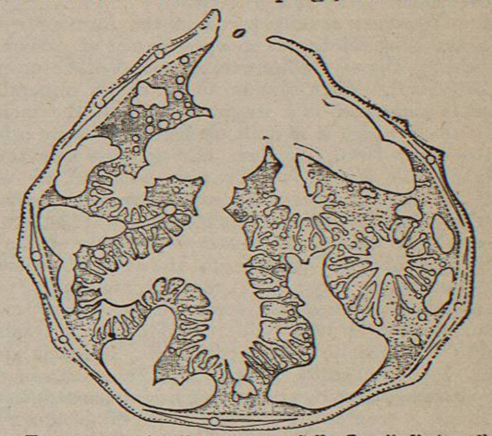

FIG. 11.—Young sponge of *Stelletta prissens*, Soll. Longitudinal median section, showing the choanosome folded within the cortex. *o*, oscule. After Sollas, "*Challenger*" *Report* (×50).

called the *spongomere*; the lower half, which consists of all three fundamental layers, may be called the *hypomere*.

The form and general composition of sponges are exceedingly various and often difficult to analyse, presenting, along with some important differences, a remarkable general resemblance to the *Cœlentera* in these respects. Like them, some sponges are simple, and others, through asexual multiplication, compound. The only criterion by which the individual sponge can be recognized is the osculum; and, as it is frequently difficult, and in many cases impossible, to distinguish this from the gastric opening of a large excurrent canal, there are many cases in which the simple or compound nature of the sponge must remain open to doubt. The oscule may also fail (*lipostomosis*) and so may the paragastric cavity (*lipogastrosis*); the problem then becomes insoluble. The loss of the oscule may in some cases be due to the continued growth of several endodermal folds towards the exterior, with a corresponding absorption of the mesoderm and ectoderm which lie in the way, till the folds penetrate to the ectoderm and open at the exterior, thus giving rise to excurrent openings which are not readily distinguishable from pores. At the same time the original osculum closes up and entirely disappears. Lipogastrosis, on the other hand, may be produced by the growing together of the roots of the choanosomal folds, thus reducing the paragastric cavity to a labyrinth of canals, which may easily be confounded with the usual form of excurrent canals. While in some sponges the original oscule is lost, in others secondary independent openings, deceptively like oscules, are added. This pseudostomosis is due to a folding of the entire sponge, so as to produce secondary canals or cavities, which may be incurrent (*vestibular*) or excurrent (*cloacal*), the opening of the latter to the exterior being termed a *false oscule* or *pseudostome*. The faulty use of the term oscule for what is neither functionally nor morphologically a mouth is here obvious, for in one sense the oscule is always a pseudostome; it would be better if the term *pseudoproct* could be substituted.

Skeleton.—All sponges, except three or four genera belonging to the *Myxospongiæ*, possess some kind of skeletal structures. They may be either calcareous or silicious or horny scleres, the latter usually having the form of fibres, which sometimes enclose silicious needles (spicules) or foreign bodies introduced from without. Foreign bodies also contribute to the formation of the skeleton of some silicious sponges, and occasionally form the entire skeleton, no other hard parts being present.

Mineral spicules. Mineral scleres usually occur in the form of spicules. The spicules of calcareous sponges consist of carbonate of lime, having the crystalline structure and other properties of calcite (*29*). Each spicule, so far as its mineral component is concerned, is a single crystal, all the molecules of calcite of which it is built up being similarly oriented. On the other hand, its form and general structure are purely organic. Its surfaces are always curved, and usually it has the form of a cone or combination of cones, each of which consists of concentric layers of calcite surrounding an axial fibre of organic matter,—probably of the same nature as spongiolin or spongin, the chief constituent of the fibres of horny sponges. A thin layer of organic matter, known as the *spicule sheath*, forms an outer investment to the spicule and is best rendered visible as a residue by removing the calcite with weak acid. Silicious spicules consist of colloid silica or opal, and hence can be distinguished from calcareous by having no influence upon polarized light. Structurally the two kinds of spicules present no important difference. The spicules of different sponges differ greatly both in form and in size. They may be conveniently divided into two groups,—minute or flesh spicules, which usually serve as the support of a single cell only (*microscleres*), and larger or skeletal spicules, which usually contribute to the formation of a more or less consistent skeleton (*megascleres*). The distinction is not one that can be exactly defined, and must so far be regarded as of a provisional nature. There is usually but little difficulty in applying it in practice, except in some doubtful cases where large spicules do not form a continuous skeleton, or in others where flesh spicules appear to be passing into those of larger size. It is indeed highly probable that all large spicules have originated from flesh spicules (*12*).

(1) *Monaxon Biradiate Type* (*rhabdus*).—By far the commonest form is the oxea, a needle-shaped form pointed at both ends and produced by growth from a centre at the same rate in opposite directions along the same axis. It is therefore uniaxial and equibiradiate (fig. 12 *a*). (2) *Monaxon Uniradiate Type* (*stylus*).—By the suppression of one of the rays of an oxea, an acuate spicule or stylus results (fig. 12 *b*). (3) *Triaxon Triradiate Type.*—Linear growth

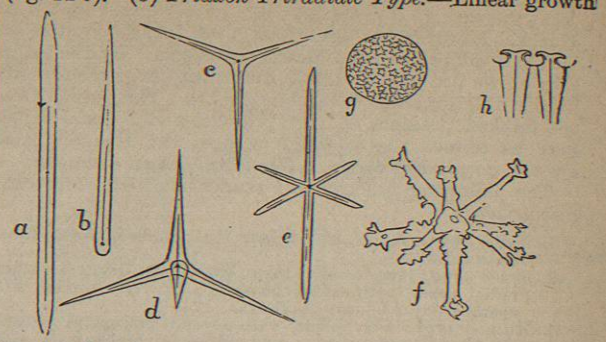

Fig. 12.—Typical megascleres. *a*, rhabdus (monaxon diactine); *b*, stylus (monaxon monactine); *c*, triod (triaxon triactine); *d*, calthrops (tetraxon tetractine); *e*, triaxon hexactine; *f*, desma of an anomocladine Lithistid (polyaxon); *g*, sterraster (polyaxon); *h*, radial section through the outer part of *g*, showing two actines soldered together by intervening silica, the free ends terminating in recurved spines and the axis traversed by a central fibre.

from a centre in three directions inclined at an angle of 120° to each other gives rise to the primitive form of triradiate spicule so eminently characteristic of the calcareous sponges, but by no means confined to them (fig. 12 *c*). (4) *Tetraxon Quadriradiate Type* (*Calthrops*).—Growth from a centre in four directions inclined at about 110° to each other produces the primitive quadriradiate form of the *Tetractinellida* and of some calcareous sponges (fig. 12 *d*). (5) *Sexradiate Type.*—Growth in six directions along three rectangular axes produces the primitive sexradiate spicule of the *Hexactinellida* sponges (fig. 12 *e*). (6) *Multiradiate Type.*—Extensions radiating in many directions from a centre produce a stellate form (fig. 12 *f*). (7) *Spherical Scleres.*—Concentric growth of silica about an organic particle produces the sphere, which occurs as a reduction of the rhabdus in some species of *Pœcillastra*, or as an overgrown globule (flesh spicule) in *Caminus*.

Uniaxial type. Usually conical, the spicular rays often become cylindrical; usually pointed (*oxeate*) at the ends, they are also frequently rounded off (*strongylate*), or thickened into knobs (*tylotate*), or branched (*cladose*). Their growth is not always rigorously confined to

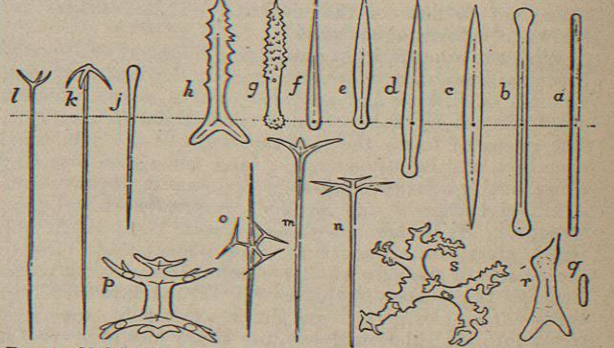

Fig. 13.—Modifications of monaxon type. *a*, strongyle; *b*, tylote; *c*, oxea; *d*, tylotoxea; *e*, tylostyle; *f*, style; *g*, spined tylostyle; *h*, sagittal triod (a triaxon form derived from the monaxon); *j*, oxytylote; *k*, anatriæne; *l*, protriæne; *m*, orthotriæne; *n*, dichotriæne; *o*, centrotriæne; *p*, amphitriæne (this is trichocladose); *q*, crepidial strongyle (basis of Rhabdocrepid Lithistid desma); *r*, young form of Rhabdocrepid desma, showing crepidial strongyle coated with successive layers of silica; *s*, Rhabdocrepid desma fully grown. The dotted line through the upper figures marks the origin of the actines.

a straight line: frequently they are curved or even undulating. They are also liable to become spined, either by mere superficial thickening or by a definite outgrowth involving the axial fibre (fig. 13 *g*, *h*).

The rhabdus if pointed at both ends is known as an *oxea* (fig. 13 *c*); if rounded at both ends as a *strongyle* (fig. 13 *a*); if knobbed

at both ends as a *tylote* (fig. 13 *b*); the tylote if pointed at one end is a *tylotoxea* (fig. 13 *d*); the strongyle similarly becomes a *strongyloxea*. These last two forms are with difficulty distinguished from the stylus, which is usually pointed at the end, and strongylate (fig. 13 *f*) or tylotate (fig. 13 *e*) about the origin. A particular case of the cladose rhabdus, but one of the most frequent occurrence, is the *triæne*; in this form one ray of a rhabdus ends in three branches, which diverge at equal angles from each other. The rhabdus then becomes known as the shaft or *rhabdome*, and the secondary rays are the arms or *cladi*, collectively the head or *cladome* of the spicule. The arms make different angles with the shaft: when recurved a grapnel or *anatriæne* is produced (fig. 13 *k*), when projecting forwards a *protriæne* (fig. 13 *l*), and when extended at right angles an *orthotriæne* (fig. 13 *m*). The arms of a triæne may bifurcate (*dichotriæne*) once (fig. 13 *n*), twice, or oftener, or they may trifurcate. Again, they may extend laterally into undulating lamellæ, or unite to form a disk, the triæne character of which is indicated by the included axial fibre. The shaft may also become trifid at both ends, *amphitriæne* (fig. 13 *p*), and the resulting rays all bifurcate, or the cladome may arise from the centre of the rhabdome, *centrotriæne* (fig. 13 *o*). Amongst one group of Lithistid sponges (*Rhabdocrepida*) the normal growth of a strongyle is arrested at an early stage; it then serves as a nucleus upon which further silica is deposited, and in such a manner as to produce a very irregularly branching sclere or desma (fig. 13 *s*), within which the fundamental strongyle can be seen enclosed. In such a desma no axial fibre besides that of the enclosed strongyle is formed.

Triradiate type. The chief modification of the triradiate spicule is due to an elongation of one ray, distinguished as *apical*, the shorter paired rays being termed *basal*, and the whole spicule a sagittal triradiate. The angle included by the basal rays is usually over 120° (fig. 14 *a*).

Quadriradiate type. Some or all of the rays of the primitive calthrops (fig. 14 *b*) may

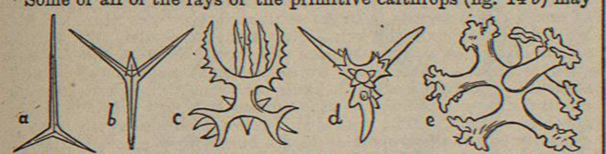

Fig. 14.—Modifications of the triaxon and tetraxon types. *a*, sagittal triradiate or triod; *b*, calthrops; *c*, candelabra (a polycladose microcalthrops); *d*, a spined microcalthrops; *e*, Tetracladine Lithistid desma.

subdivide into a number of terminal spines *candelabra* (fig. 14 *c*); or some or all of them may bifurcate once or twice and finally terminate by subdividing into numerous variously shaped processes; such a *tetracladine* desma (fig. 14 *e*) characterizes one division of the Lithistid sponges.

Sexradiate type. By the excess or defect of one or more rays a series of forms such as are represented in fig. 15 arise. In the oxea, which results from

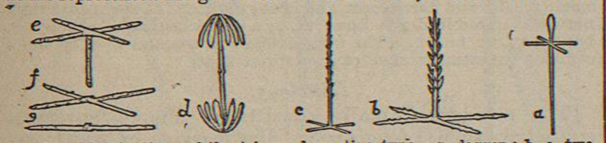

Fig. 15.—Modifications of the triaxon hexactine type. *a*, dagger; *b*, *c*, two varieties of pinnulus; *d*, amphidisk; *e*, pentactine; *f*, staurus; *g*, dermal rhabdus. After Schulze.

the suppression of all rays but two, the sexradiate character is sometimes preserved by the axial fibre, which gives off two or four processes in the middle of the spicule where the defective arms would arise. Let fig. 12 *e* represent a regular sexradiate spicule with its four horizontal arms extended beneath the dermis of its sponge; the over-development of the proximal ray and a reduction of the distal ray produce a form known as the *dagger* (fig. 15 *a*); the suppression of the proximal ray and the development of spines projecting forwards on the distal ray produce the *pinnulus* (fig. 15 *b*, *c*); the suppression of both proximal and distal rays gives the *staurus* (fig. 15 *f*), and the suppression of two of the remaining horizontal rays a dermal rhabdus (fig. 15 *g*). The suppression of a distal ray, excessive development of a proximal ray, and recurved growth of the remaining rays produce an *anchor*. In *Hyalonema* (glass rope sponge) anchors over a foot long occur, but their arms or teeth are not restricted to four, and the axial fibre gives off its processes before reaching the head of the spicule. Such a grapnel helps to support the sponge in the ooze of the sea-bed. Other character-

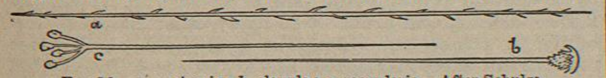

Fig. 16.—*a*, uncinaria; *b*, clavula; *c*, scopularia. After Schulze.

istic spicules belonging to sponges distinguished by sexradiate spicules are the following:—the *uncinaria* (fig. 16 *a*), a spinose oxea with the spines all pointing one way; the *clavula*, a tylotate form with a toothed margin to the head (fig. 16 *b*); the *scopularia* (fig. 16 *c*), a besom-shaped spicule with tylotate rays, which vary in number from two to eight; the *amphidisk* (fig. 15 *d*), a shaft terminating at each end in a number of recurved rays. When the sexradiate spicules of the *Hexactinellida* unite together in a manner to be described later, the rays may be bent in a variety of ways out of the triaxial type, so that the sexradiate character alone remains.

Multiradiate Type.—The rays of an aster as of other spicules may be spined or tylotate. In one remarkable form known as a *sterraster* (fig. 12 *g*, *h*), and characteristic of the family *Geodinidæ*, the rays are almost infinite in number, and coalesced for the greater part of their length; the distal ends, however, remain separate, and, becoming slightly tylotate, are produced into four or five recurved spines, which give attachment to connective tissue fibres by which adjacent sterrasters are united together.

In one aberrant group of Lithistid sponges (*Anomocladina*) the skeleton is formed of desmas, which are multiradiate, each presenting a massive centrum (with an included cavity) produced into a variable number (4 to 8) of rays, which rays terminate in expanded ends (fig. 12 *f*).

Microscleres. It is doubtful whether a distinction between megascleres and microscleres can be maintained in the calcareous sponges, unless the minute oxeas which occur in *Eilhardia schulzei*, Pol. (*16*), are to be referred to this group. They are widely distributed throughout the silicious sponges, and by their different forms afford characters of the highest importance in classification.

One of the simplest forms is the *sigmaspire* (fig. 17 *a*, *b*); it looks like the letter C or S, according to the direction in which it is

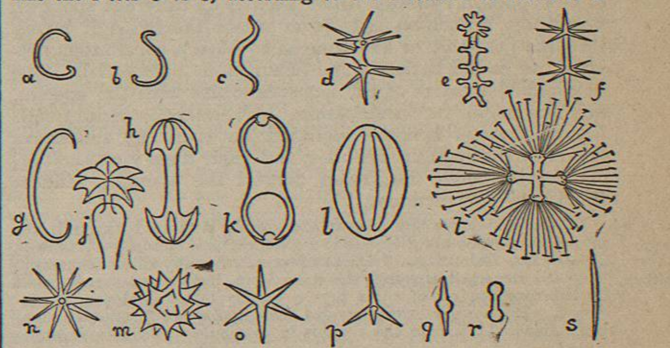

Fig. 17—Microscleres. *a*, *b*, sigmaspire viewed in different directions,—*a*, along axis, and *b*, obliquely; *c*, toxaspire; *d*, spiraster; *e*, sanidaster; *f*, amphiaster; *g*, sigma or cymba; *h*, cymba, with three ptera at each end,—the central one a proral pteron and the lateral, pleural ptera; *j*, one end of another form of cymba, showing seven ptera; *k*, monopteral cymba,—proral ptera only, developed at ends, tropidial ptera much enlarged; *l*, oocymba, in which proral and pleural ptera have grown towards each other and coalesced; *m*, spheraster; *n*, oxyaster; *o*, the same, with six actines; *p*, the same, with four actines; *q*, the same, with two actines (a centrotylote microxea); *r*, microtylote; *s*, microxea (*q*, *r*, and *s* are reduced asters); *t*, rosette.

viewed, its actual form being that of a single turn of a cylindrical spiral. A turn and a part of a turn of a spiral of somewhat higher pitch than that of a sigmaspire gives the *toxaspire* (fig. 17 *c*); a continued spiral growth through several revolutions gives the *polyspire*. The sigmaspire becoming spined produces the *spiraster* or *spinispirula* (fig. 17 *d*); this, by losing its curvature, becomes the *sanidaster* (fig. 17 *e*), and by simultaneous concentration of its spines into a whorl at each end, the *amphiaster* (fig. 17 *f*). By reduction of the spire the spiraster passes into the *stellate* or *aster* (fig. 17 *n*). A thickening about the centre of the aster produces the *spheraster* (fig. 17 *m*), allied to which is the sterraster. By a reduction in the number of its rays the aster becomes a minute calthrops, from which, by increased growth, the skeletal calthrops may very well be derived; by further reduction to two rays a little rhabdus or microrabd results, and of this numerous varieties exist, of which the oxeate microrabd is the most interesting, since it only differs in size from the commonest of all skeletal spicules, the oxeate or acerate rhabdus. The sigmaspire is formed as a superficial spiral thickening in the wall of a spicule cell or scleroblast; as superficial deposits also the next group of spicules, the so-called *anchorates*, arise. Take a hen's egg as the model of a scleroblast, draw round it a broad meridional band, interrupted only on one side, for 30° above and below the equator; this will represent a truly C-shaped spicule, which differs from a sigmaspire by the absence of spiral twist. It may be termed a *cymba* (fig. 17 *g*). The back of the "C" is the *keel* or *tropis*; the points are the *prows* or *proræ*. Now broaden out the prora on the eggshell into oval lobes (*proral pteres*); and from each pole draw a lobe midway between the prora and the tropis (*pleural pteres*), and a common form of anchorate, the *pterocymba*,