The incompleteness of the observations is recognised, but on the whole it would appear that their suggestiveness justified the observer in devoting 15 seconds to making them.

The observed intensity of the bands, attributed to sky polarisation, is evidence of the quantity of light reflected by solid particles in the atmosphere. It seems not improbable that the unexpected brightness of the general sky and landscape during totality may have been connected with the amount of light reflected from the dust suspended in the atmosphere and illuminated by the sun-lit plains outside the moon's shadow. The light colouring of the plains, due to the dried herbage at that time of year, is very marked at Pulgaon, but it must not be forgotten that the "sun-lit plains" were in the moon's penumbral shadow for more than an hour both before and after totality.

The observations occupied the 15 seconds, ending 15 seconds before the end of totality.

About 30 seconds after the end of totality, polarisation was again looked for, but no trace could be detected near the sun in any position of the instrument.

"The Skeleton and Classification of Calcareous Sponges." By G. P. Bidder. Communicated by Adam Sedgwick, F.R.S.

Received May 6,—Read May 26, 1898.

I. *Skeleton.*

An element which seems to have been too little regarded in the physiology of sponges is the permanent tension of their walls.* The contours of the surfaces, particularly where they rise over projecting spicules, are alone sufficient to demonstrate that there is surface-tension between the protoplasm of the sponge and the sea-water. Both the outer and the inner surfaces of a cylindrical or of a spherical sponge unite, therefore, in exerting a force which tends to contract its diameter. In many sponges there would appear to be also some form of elastic matter in the tissue immediately underlying the collar-cells; since in teased preparations of the living sponge, fragments of the chamber-wall turn inside out and swim about like ciliate larvæ. While the collar-cells are active, these united tensions are resisted by the pressure of the water in the cavities they line. A broad generalisation of the mechanism of a sponge's currents shows that the velocity in the oscular stream (of comparatively narrow

* I have to thank Mr. G. T. Walker, of Trinity College, Cambridge, for rescuing me from some fallacies with regard to the effects of this tension, and Professor Lewis for most kind patience in mitigating my ignorance of crystallography, and much valuable information.

sectional area) is the manifestation of a pressure in the flagellate chambers (of broad aggregate sectional area); which pressure is maintained by the moving flagella, and resisted by a normal tension in the walls of the chambers or of the sponge.*

I therefore regard the contraction recorded by Minchin in *C. clathrus* (and undoubtedly occurring in unfavourable conditions, not only in this, but in many other sponges) as the passive result of permanent tensions in the sponge-walls, which are no longer counteracted by the comparatively inactive flagella.† It is with the advantage of preventing such contraction being a consequence of inactivity that a skeleton has been evolved in most sponges: whatever the substance of which it is composed, this skeleton tends to take in surfaces a triradiate [more rarely sexradiate] arrangement.

[If a uniform elastic membrane be extended by a star of rigid rods, the area extended is greatest in proportion to the material involved, when the star is equiangular and has either four or five rays; though there is comparatively little advantage for any number from three to six. Where, however, the rigid rods unite in a network, the triradiate (*i.e.*, hexagonal) arrangement is the most economical possible, and the triangular (or sexradiate) the most rigid. The square superficial network is less unstable but less economical than the hexagonal; it would seem rarely to occur except where—as in the Hexactinellida and in *Reniera*—a definite cubic mesh has been developed to support a frothy tissue of three dimensions (*cf.* Schulze (11)).—*July* 23, 1898.]

Minchin, after a most interesting account of the ontogeny of triradiate and quadriradiate spicules‡ in reticulate Ascons, writes (21, p. 549):—"Crystallisation cannot now be taken as an adequate explanation of the external form of the spicules . . . It is . . . clearly impossible that the triradiate system§ should owe its form,

* *Cf.* (18), p. 29. I still hope to write more in detail on this subject.

† The flask-like form of the ectocytes I still hold to have been "developed to expose the greatest possible surface to the medium from which the excreted" (or secreted) "substance is derived," (16), p. 480. The evidence appears to me still in favour of these cells being excretory; but whatever their secretion, it is important to the sponge, and did they not take this form on contraction of the sponge, their surface in contact with the parenchymal jelly would be disadvantageously reduced. I regard as an extreme case of this the spongoblasts [considering the fibre to be an invaginated tube of cuticle contracted by its own elasticity until it has become a solid rod.]

‡ I may mention that *Sycon compressum* has hair-spicules about $\frac{1}{10}\mu$ in thickness which are each formed by two cells, as Minchin describes for a ray of a triradiate in *Clathrina*; and the young giant club-spicules also show two formative cells. For such pairs of cells I suggest the name "adelphidia"; they were described by Lendenfeld (8) and Stewart (10) as sense-cells.

§ The "triradiate system" is a word used by Minchin to denominate the three rays of the triradiate spicule whether or not an adventitious fourth ray be added as a whole, to the action of crystallisation." If I understand my friend correctly, I differ from him essentially. I regard the spicules of calcareous sponges as being skeleton crystals of calcite. The direction of the optic axis is fixed (probably by the conditions of pressure and tension prevailing at the moment) when the spicule first makes its appearance. The formed material from which the calcite crystallises is commonly limited by biological conditions to a narrow interval between two similar surfaces. These surfaces may have the form of a comparatively wide cylinder, as in the case of *Clathrina clathrus* or *Leucosolenia Lieberkühnii*, a narrow cylinder, as in the case of the stalk of *Guancha blanca*, or a more complex irregular form, as in the afferent or radial canals of the Heterocœla. I suggest that the triradiate spicule is in all cases the skeleton of that region of a hexagonal prism, with the given optic axis, which is enclosed by the two surfaces which limit the formation of material.

It is impossible to profess, in a limited space, or indeed with the limits of our available knowledge, to give anything approaching a complete harmony of all known forms of spicules with the foregoing hypothesis. Treating of the simplest, the regular triradiates of *Clathrina clathrus* and *Guancha coriacea*, I have been led to the above conclusion primarily by observation of deformed spicules; of which I sketched all examples met with during many months examination of fresh preparations at Naples, and for which I have

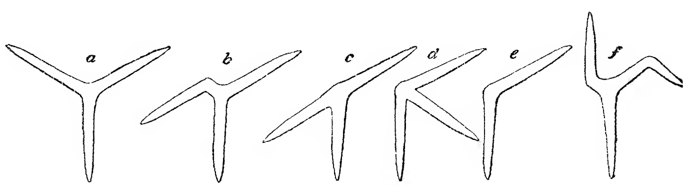

Fig. 1.—Spicules of *Guancha* (*Leucosolenia*) *coriacea* (Mont.) from Naples, × 120. *a* is normal, some hundreds of this type occurring for one of all the others. In this species and *C. clathrus* 26 or 27 deformed spicules were recorded. 15 belonging to type *b*, 6 to type *c*, 3 to type *d*, 1 to type *e*, and 1 to type *f*. In addition to these, a drawing was lost of a spicule of type *b*, but with the ray bent a second time to its original course, and Ebner gives a drawing of a plane quadriradiate X-shaped spicule (in *C. clathrus*), the four angles being alternately 120° and 60°. No other deformed spicule was observed in these species. [Ebner also draws a form resembling *f*, but with the two flexions symmetrical and in opposite senses.]

since carefully searched my permanent preparations. Drawings of all types met with, among some thirty examples, are given in fig. 1. It will be seen that they are all expressed in one statement,

perpendicular to them. I shall use the term "triradiate" where necessary with the same meaning.

that part or the whole of one ray deviates at an angle of some multiple of 60° from its normal course. That all deformities in these species should be reducible to this law appears to me inexplicable on the supposition that they are due to any biological variation of the formative cells; and it will be observed that the variation in which two of the angles between the rays are of 60° is wholly irreconcilable with the "honeycomb" theory of contiguous circles appealed to by Minchin. Ebner (12) has worked out the relations of many forms of spicule to the optic axis and the hexagonal prism: he sums up against regarding the spicules as mere crystals. I can only claim to have a little extended his observations, but that little is all in favour of exact obedience to crystalline laws.

Nitrate of potash has a crystalline form resembling almost to identity that of calcite. Fig. 2 is copied from Lehmann (13),

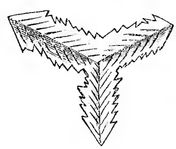

FIG. 2.—Nitrate of potash crystallising in caustic potash. (Copied from Lehmann (13), fig. 99.)

and shows the form taken by nitrate of potash crystallising in the presence of caustic potash. Fig. 3, placed near it for comparison,

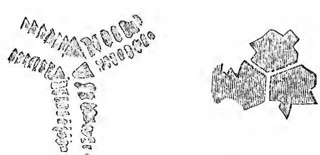

FIG. 3.—Last remains of spicules (× 1000) of *Guancha coriacea*, decalcified slowly in glycerin.

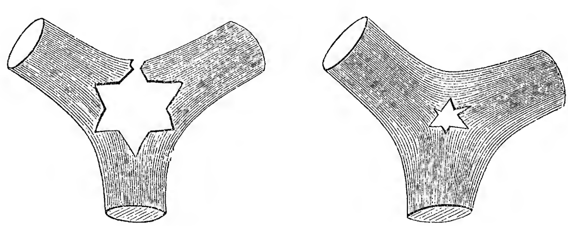

FIG. 4.—Spicules of *Clathrina clathrus* (× 1200) partly decalcified in glycerin. The sharp truncation is conventional, to show that only part of the rays is drawn.

shows the last rudiments of the spicule of *G. coriacea* slowly decalcified by the prolonged action of glycerin. Fig. 5 gives decal-

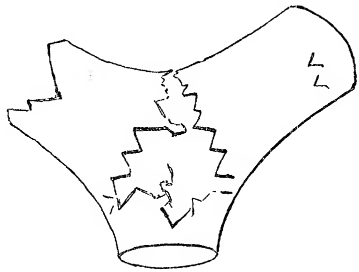

FIG. 5.—Spicule of *G. coriacea* (×1500), showing sculpturing by decalcification in Canada balsam. One ray is fractured and decalcified, the other two conventionally truncated.

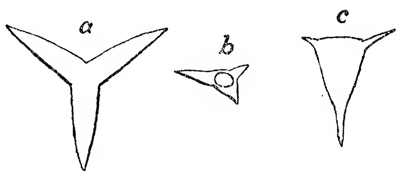

FIG. 6.—Young spicules (×1000). *a* of *C. clathrus*, *b* (an equiangular spicule in perspective) of *A. cerebrum*, *c* of *L. Lieberkühnii.*

cification figures on a spicule belonging to the same sponge under the action of Canada balsam, and fig. 4, spicules of *C. clathrus* attacked by glycerin. They appear to be generalisable, like those drawn and explained by Ebner for *Leucaltis solida*, into triangles whose angles are on the external face of the spicule opposite the rays, and intermediate to them on the gastral face; complementary, as are the edges on the opposing poles of a rhombohedron: the crystallisation is therefore closely comparable with that of Schiefer spar (a natural form of calcite crystallising in flat hexagonal plates), and still more with that of a specimen of dolomite (calcite with a little magnesium), No. 427 in the Cambridge museum, which is crystallised in flat triangular plates. The rays of the spicule are opposite the faces of the rhombohedron on the gastral surface, opposite the angles of the rhombohedron on what may be called the "dorsal" surface.*

* [The initial etchings by Canada balsam on the dorsal surface of the rays of *G. coriacea* frequently appear under the 2 mm. immersion lens to be small rhomboids, orientated so that lines bisecting their acute angles are parallel with the morphological axis of the ray. In some spicules of *C. clathrus* prolonged decalcification by glycerin yielded internal cavities of similar outline. The optic axis,

The fourth or gastral ray of a quadriradiate spicule is an acute rhombohedron which crystallises about the principal axis when the cellular conditions allow of material being deposited there, consequent (following Minchin's account) on the adventitious occurrence of another calcogenous cell on the gastral surface. That this crystallographic interpretation is correct is indicated by the frequently triangular section (fig. 7) of the fourth ray, the faces of the triangle

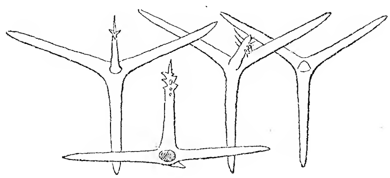

FIG. 7.—Three-spined quadriradiate spicules of *A. cerebrum* in perspective; the interior of the distant rays are in one spicule indicated by shading. The fourth spicule is drawn from above; it is not spined, but the apical ray shows a distinctly triangular section. All × 260.

being transverse to the rays of the triradiate, while a strong confirmation of the whole view is afforded by the thorns on the fourth ray in *Ascaltis cerebrum* (fig. 7). These, when viewed from above, are always seen to lie accurately over the rays of the triradiate,* either as definite minute triradiate spicules, or as three rows of thorns; and therefore crystallise on the three faces of the rhombohedron. The whole quadriradiate, with fourth ray and thorns, extinguishes simultaneously in four positions between the crossed nicols. I have verified on *G. coriacea* and *blanca* [and *A. reticulum*] Ebner's observation, that the optic axis of these equiangular spicules is perpendicular to their plane.

I suggest that the ancestors of these sponges had a skeleton consisting of organic rods, partially impregnated with carbonate of lime; that these rods united in a triradiate grouping and that—whether for cementation or merely for strength—the calcareous secretion increased to the point of crystallisation. The original triradiate form was due to an instinct, apparently acquired by the skeletogenous

with uniaxial optic picture, being vertical to the plane of the spicule, interpretation of these figures is not obvious.

Glycerin commonly first decalcifies the axial parts, presumably because the liquid enters most freely where there is greatest admixture of organic matter. Canada balsam (except where the sponge has been killed directly in chloroform) first attacks the surface, presumably because the more permeable regions are protected by consolidated balsam.—*July* 23, 1898.]

* I have once or twice recorded a twist of 5° or 10°; the thorns still being inclined at 120° to each other. This, if established, would form another resemblance with the crystalline forms of dolomite.

cells of all sponges, of placing themselves in the direction where the alternate thrust and tension, caused by expansion and contraction of the sponge, is maximal.* The carbonate of lime crystallised as calcite, in three-rayed stars, the optic axis being radial to the sponge, in the line of greatest pressure,—and Professor Lewis has shown me an example of calcite from Freiberg where the rhombohedra are etched and infiltrated in three-rayed stars, whose rays bisect the rhombohedral surfaces (fig. 8). These crystalline triradiates being them-

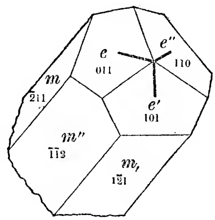

FIG. 8 (from a drawing by Professor Lewis).—Crystal of calcite infiltrated by opaque black matter (probably a metallic oxide), which forms a three-rayed star, shown by the strong short lines in the diagram. The rays bisect the angles made by the edges of the faces e, e', e'', and therefore lie in the planes of symmetry of the crystal. The black matter is in part underneath the faces, so that the reflecting surface can be seen to be uninterrupted over it. The specimen in the Cambridge Collection contains upwards of 120 crystals in which the star is conspicuously seen.

selves of the form advantageous for skeletal elements, the formative cells lost their directive instinct, and are now passively carried on the point of the growing crystal, showing no trace of individual character except in mere stalactitic modification of the crystalline contours. In the ancestors of *Leucosolenia*, *Sycon*, and *Leucandra*, crystallisation appears to have taken place while as yet only one cell (following Minchin) was concerned with the formation of the calcareous element. As in the reticulate Ascons, the optic axis lay in the line of greatest pressure, that is, vertical to the surface of the flagellate gastral cavity; but in the former case the principle of

* [The first combination of the primitively isolated spicules would be to form longitudinal spicule-fibres; since, on account of the open osculum, the surface-tension parallel to the axis of the cloaca is only in a slight degree opposed by internal pressure. To oppose the transverse strain, which would follow on variation in flagellar activity, such fibres must be united; this I conceive to have been effected in the simplest manner by two spicules, instead of one, applying themselves to the end of a fibre, and diverging to meet the circumferential stress. Thus would be produced longitudinal reticulations of branching spicule-fibre, resembling the skeleton which appears in many thin-walled Monaxonida; on this conception the triradiate represents phylogenetically the fork of a pair of branches.—*July* 23, 1898.]

the existing triangular grouping of the formative cells determined the crystallisation of the calcite in a flattened (pinacoid) form, extended transversely to the optic axis, as in Schiefer spar: the unicellular crystals appear as [elongated] rhombohedra [*cf.* Sollas (9) p. 389] which form the primitive acerates. The ontogenetic history of the triradiates of *Leucosolenia* is not yet known. It is possible that the rudiments originally form an acute angle with the morphological axis of the sponge, and that the formative cells repeat a change which has taken place in evolution, with the advantage of the production of a [gastral from an ectocytal] skeleton. The causes governing the direction of the optic axis in this and higher sponges are still not clear.*

Whatever the cause, the "alate" spicule (fig. 9), such as is typical of *Leucosolenia*, and very frequent in more complex sponges, is stated by Sollas (9) and Ebner to have its optic axis at an acute angle with the morphological axis of the unpaired ray, in a plane

* [The acicular spicules which clothe *S. raphanus* appear completely referable to law. In the body of the radial tubes the optic axis of the triradiates is nearly parallel with the axis of the tube; this we may ascribe to compression, radial to the sponge, due to tension of the cylindrical outer surface. On the free conical ends of the tubes the optic axis is nearly perpendicular to the surface; the large acicular spicules leave the surface tangentially, and can frequently be seen to be the extremely prolonged unpaired rays of triradiates (*cf.* Ebner and others); corresponding with these relations the optic axis makes an angle of nearly or exactly 90° with the morphological axis. The fine acicular spicules leave the surface nearly vertically, and the optic axis is correspondingly coincident with their length; like the gastral rays of quadriradiates in *Ascaltis* they are to be regarded crystallographically as extremely acute rhombohedra. This is the acicular form which we should expect to find in free crystallisation of calcite, and I have shown elsewhere (19)—though suggesting a teleological explanation—that the number and size of these fine spicules vary greatly with the condition of the water.

In *L. Lieberkühnii* the optic axis is often exactly at right angles to the acicular spicules, in other cases it makes with the long axis an angle of from 70° upwards. The figures of Schulze (*S. raphanus*) and Minchin (*L. variabilis*) suggest that the larval spicules are tangential when first formed, and that some are afterwards rotated outwards. It does not seem at present possible to account for the varying angles made by the optic axis to the morphological axis of acicular spicules, without reference to cellular directive power. The giant oxeotes of the young *Leucandra aspera* especially suggest that there has been cellular determination to form a divergent brush of protective spicules. To examine this question there is necessary greater knowledge as to the mode of ontogenetic development of the canal-system, as to the mechanical strains resulting in the various stages of such development, and as to the laws governing free crystallisation of calcite in acicular forms of which the greatest length is not parallel to the optic axis.

In the club-spicules of *S. compressum* the optic axis lies in the plane of the spicule, normal to the morphological axis at its point of greatest curvature. It must be noticed that, according to the observation recorded above, the acicular spicules of the adult sponge are in this species not unicellular in formation.—*July* 23, 1898.]

perpendicular to the plane of the spicule (fig. 10, *o.a.*). The curvature of rays has been adduced by Schulze (11) as an argument against

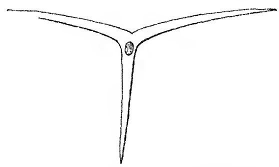

FIG. 9.—Alate spicule of *L. Lieberkühnii* (× 150).

FIG. 10.—Diagram of profile view of the spicule shown in fig. 9. The curvature is from measurement; the angle made by *oa*, the optic axis, is copied from Ebner's figure of a similar spicule, in *S. elegans.*

crystalline structure; but the form shown in fig. 9 is the trace on a cylindrical surface of three planes, which meet at equal angles in a line forming an acute angle with the axis of the cylinder, to which one plane is radial, two of them, therefore, cut the cylinder in ellipses, and one in a straight line. Investigation shows that the angle agrees with that given by Sollas and Ebner for the optic axis of a spicule of similar form.* *The alate triradiate of* Leucosolenia, *with curved rays, is therefore as accurately regular a skeleton-crystal as the equiangular triradiate of* Clathrina. Both follow the same law, that the calcareous secretion is limited by the form of the sponge to the surface of a cylinder, and crystallisation of the secretion takes place in the radial planes of a rhombohedron which are perpendicular to its three faces, the difference being only that in *Clathrina* the optic axis of the rhombohedron is radial to the cylinder, and in *Leucosolenia* it lies in a radial plane of the cylinder at an acute angle with the axis.†

* To fellow-naturalists my own method of investigation may prove helpful. Draw the spicule (fig. 9) two or three inches long on a sheet of paper; look at the diagram with the eye where the line *oa* (fig. 10) would come, and curve the paper so that it forms part of a cylinder the axis of which is parallel with the long ray. The diagram will then appear to be that of an equiangular spicule with straight rays.

† The fourth ray in *Leucosolenia* and allied sponges grows (perhaps most freely at right angles to the optic axis?) to an edge of the rhombohedron. It is often curved, a character possibly resulting from the suspension of the formative cell between it and the gastral surface. In *L. Lieberkühnii*, as observed by Minchin for *L. complicata*, its origin is on the unpaired ray. Unlike the apical ray

The young spicule of *L. Lieberkühnii* is not a skeleton, but a complete isosceles triangle (fig. 6), and the same is recorded by Breitfuss (22) for the adult spicules of his new genus *Sphenophorina*.

That natural selection has played a most important part in the arrangement of skeleton is shown clearly by the schemes in the Heterocœla, analysed by Poléjaeff (7) and Dendy (17). And if crystallisation of calcite had not been advantageous to the sponge, it would have assumed no more importance than crystallisation of urates among higher animals. But the strangely beautiful and elaborate patterns of calcareous spicules are truly crystalline, and their curves and angles, as they vary from one individual to another,* are not necessarily of appreciable advantage or disadvantage to the species in which they are found. And, in spite of the colloid nature of silica, Schulze's beautiful figures of Hexactinellid spicules prove to me that this substance has some property akin to crystallisation on the cubic system, to which the triaxon forms of siliceous spicules, and probably the tetraxon also, are to be ascribed. It remains to be shown whether the complex detail of a peacock's tail may not also be referable to a mathematical equation, rather than to the æsthetic nicety of ancestral hens. *De minimis non curat lex vitæ.*

[I find that in attempting condensation of statement I have not succeeded in completely explaining the position above advanced.

There is probably no group in which, more clearly than in the calcareous sponges, change phylogenetically progressive can be shown to result in progressive advantage to the organism, whether we consider the canal-system or the arrangement of the skeleton. It is not under dispute that, where the form of the spicule can appreciably affect the chances of survival of a sponge, there natural selection dictates to the necessary degree the form of the spicule. This it may do either directly, as appears probably the case in many acicular spicules, by developing a stubborn morphographic sense in the skeletogenous cells; or indirectly, by varying the chemico-physical conditions of the secreted fluid, so that the form of crystallisation changes. Such indirect action of selection in *A. cerebrum* may possibly explain the presence of thorns on the gastral ray, though irresponsible for their arrangement.

But, while granting fully that the most apparently unimportant variations may prove vital to the organism, it appears logically necessary that there must be variations which are unimportant, or unimportant compared with solid advantages with which they are necessarily concomitant. In the case of calcareous triradiates the solid advantage is that a mechanically useful skeletal element is

of *A. cerebrum*, its crystalline position tends to give it a laminate rather than an acicular form.

* In *Sycon raphanus* this is most markedly the case.

attained by the passive submission of a solution of carbonate of lime to forces of crystallisation; thus, with economy to the organism, very simple secreting cells produce a result similar in effect to that which would be attained by morphographic skeletogenous tissues of far more complex heredity. It would appear from comparison of the spicules of *Sycon* and *Leucascus*, *Anamixilla* and *Heteropegma* (*vide infra*), that in calcareous sponges this advantage completely outweighs any possible profit or loss resulting from slight change in angle or substitution of curved for straight rays.

It is difficult to believe that the equiangular spicule with which *Heteropegma* and *Leucandra australiensis* support their tubes, alike has induced their survival, and would cause death to the *Sycon* that should imitate them. Nor, on the other hand, can the spicule forms of *S. raphanus* be ascribed to a rigid atavistic heredity; for between individuals self-sown in the same tank, the striking differences of homologous spicules proclaim their form to be most variable. The explanation of the exact geometrical figure observed in any one case is to be sought in crystallography, and not in physiology; in the laws which we recognise as governing form in dead matter, that is, those that are apparently independent of any forces in the dimension of memory.

So far as can be judged, it seems that the change in form, which, through influence on the direction of the optic axis, results from change of stress, renders the spicule less well adapted to bear that stress; a predominant longitudinal tension placing the paired rays nearly transverse to its own direction. *A priori*, where one character in an organism is physically a function of another character in the organism, the variation of one only can be exactly correlated to the needs of the organism. If both are important, the adaptation of neither can be perfect; according as either is predominant, the other exhibits phenomena which do not conduce to survival of the variety in which they are noted.

The calcite crystal may be compared to a symbiotic organism; its characters within certain limits of saliency are subordinated to the needs of the organism within whose tissues it finds a welcome. But the number of mesenteries in *Adamsia* is dictated by its own history, and not by the mode of life of the crab which carries it; so the angles of a triradiate calcareous spicule are dictated by the properties of calcite, and, within a considerable range, would appear neither to influence nor be influenced by selective mortality in the species among which it occurs. To hold that this view is unjustified it seems necessary to suppose that individuals of *A. cerebrum*, in whom gastral thorns were not parallel to the facial rays of the spicule which bears them, have consequently perished and been unable to procreate their race.—*July* 23, 1898.]

II. *Classification.*

Minchin, in 1896 (20) and 1897 (21), recorded that the larva of *L. variabilis* is an amphiblastula, as shown by Metschnikoff for *L. Lieberkühnii*; and that that of the species *coriacea*, *cerebrum*, *reticulum*, and *contorta* (*sensu* Bwk.) is a parenchymula, as shown by Miklucho-Maclay (1) for *blanca* (confirmed by Minchin), and by Schmidt (2) and Metschnikoff (6) for *primordialis* and *clathrus*. He pointed out that the first spicules to appear in the amphiblastula larva are acerates, in the parenchymula larva triradiates. He found that in *L. botryoides*, *variabilis*, *complicata*, and *Lieberkühnii* the nucleus of the collar-cell is distal, as in *Sycon*; in the species with parenchymula larvæ it is basal.*

On these important observations he divides the Homocœla into two families.

(1) *Clathrinidæ* (*Clathrina clathrus*, *coriacea*, *cerebrum*, *reticulum*, *contorta*, and *Ascandra falcata*) with reticulate external form, equiangular triradiate systems, collar-cells with basal nuclei, parenchymula larva, and triradiates the first spicules to appear.

(2) *Leucosoleniidæ* (*Leucosolenia botryoides*, *complicata*, *Lieberkühnii*, *variabilis*, and *Ascyssa* (?)) with erect or arborescent form, sagittal triradiate systems, collar-cells with terminal nuclei, amphiblastula larva, and monaxon spicules the first to appear. Such Sycons as *S. raphanus* he derives from the Leucosoleniidæ, but leaves it an open question whether some Heterocœla may not be derived from the Clathrinidæ.

I propose to emphasise very considerably the lines he has indicated, and particularly the suggestion (originally made by Keller (5)) that *Leucosolenia* is closely allied to the Sycons. The classification of sponges according as they are homocœl or heterocœl, is a physiological classification by the most essential and active organ of the sponge; I have always regarded it as no more satisfactory than classifying higher animals according to whether they walk, swim, or fly. Dendy has already pointed out the close resemblance of his Leucascidæ with the reticulate Ascons ((17) pp. 166, 190, 249, &c.); I find† that *Heteropegma nodus Gordii* of Poléjaeff has basal nuclei to the collar-cells and that the optic axis is perpendicular to the plane of the triradiates, while *Anamixilla* is opposed to it in both these characteristics. [I have also confirmed on *L. Lieberkühnii*, Minchin's observation as to the distal nuclei in *Leucosolenia*.] There is perhaps

* It may be remembered that I stated to the Society, in 1892, that "the nucleus of Homocœla is generally basal, whereas in the Heterocœla, contrary to current statement, it is almost always distal" (16), p. 479; *cf.* also (19), p. 21.

† I owe to the kindness of Dr. Vosmaer and Dr. Poléjaeff the opportunity of investigating type-slides of the "Challenger" sponges.

little reason for supposing *Calcarea* to be a natural class; but retaining it provisionally I propose to divide as follows:—

Class.—CALCAREA.

Sub-Class I.—*Calcaronea*, nov.

The nucleus of the collar-cells and of the flagellate cells of the larva is distal, and the flagellum arises from it directly. The larva is an amphiblastula. The first spicules to appear are oxea, generally (always ?) lance-headed, the triradiates are typically alate* and the optic axis is rarely perpendicular to the plane of the spicule. The pylocyte is annular† and generally lies at the bottom of a funnel-shaped depression or afferent canal. Branching of the sponge takes place typically nearly at right angles to a growing axis, giving rise to stolonate and arborescent forms. The gastral fourth ray of a quadriradiate spicule rarely rises perpendicularly from the meeting point of three rays. Lance-headed oxeotes are frequently present in the adult. The sponges never show a coral-red or sulphur-yellow colour.

Order 1. *Asconida*, H. (s.m.). The central cavity is in the adult lined with collar-cells and communicates with the exterior directly by pylocytes in its walls.

Fam. *Leucosolenidæ*, Minchin. Genus 1. *Leucosolenia*, Bwk. *emend.* Minchin. Genus 2. *Ascyssa*, H.

Order 2. *Sycettida*, nov. The central cavity is in the adult not lined with collar-cells and does not communicate with the exterior directly by pylocytes in its walls.

Fam. 1. *Sycettidæ*, Dendy.
,, 2. *Grantidæ*, Dendy.
,, 3. *Heteropidæ*, Dendy.
,, 4. *Amphoriscidæ*, Dendy (s.s.).

Sub-Class II.—*Calcinea*, nov.

The nucleus of the collar-cells and (? ?) of the flagellate cells of the larva is basal, and the flagellum does not arise from it directly. The larva is a parenchymula. The first spicules to appear are triradiates, the triradiates are typically equiangular and the optic

* *I.e.*, with paired angles, from the resemblance of the oral rays of such spicules to the two wings of a flying bird. [I propose the corresponding term "caudate" for equiangular sagittal spicules.]

† "Pylocyte" = the cell surrounding a prosopyle, leaving "porocyte" = the cell surrounding a pore. I have observed this in *Leucosolenia Lieberkühnii*, *Sycon raphanus*, *Sycon compressum*, and *Leucandra aspera*. *Cf.* Dendy on *Leucosolenia stolonifera* ((14), p. 25), and *Granlessa intusarticulata* ((17), fig. 30), and Poléjaeff on *Grantia tuberosa* ((17), pl. 3, fig. 7).

axis is generally perpendicular to the plane of the spicule.* The pylocyte has as yet only been investigated in homocœl species, it is there amœboid, and perforates the entire sponge-wall without any afferent funnel-shaped depression lined by other ectocytes. Branching of the sponge is typically dichotomous or umbellate, with frequent anastomoses, giving rise to reticulate growths supported on solid stalks often of obvious length in the adult. The fourth ray of a quadriradiate spicule generally (or always) rises perpendicularly from the meeting point of three rays. Lance-headed oxeotes are rarely (or never) present, either in larva or adult. Most species show varieties which are coral-red and sulphur-yellow.

Order. 1. *Ascettida*, nov. No quadriradiate spicules are present.

Fam. 1. *Clathrinidæ*, Minchin (s.s.). There is no distinct pore-bearing dermal membrane.

Genus 1. *Clathrina*, Gray. With knobbed ends to the spicules. Sp.: *C. clathrus*.

Genus 2. *Guancha*, M.M. With pointed ends to the spicules. Sp.: *G. blanca*, *coriacea*.

Fam. 2. *Leucascidæ*, Dendy. A distinct pore-bearing dermal membrane is present.

Genus 1. *Leucascus*, Dendy.

Order 2. *Ascaltida*, nov. Quadriradiate spicules are present.

Fam. 1. *Reticulatæ*, Dendy (s.s.). The radial arrangement of the flagellate tubes is only pronounced near the cloaca.

Genus 1. *Ascaltis*, H. (s.m.) The flagellate epithelium is not pouched deeply into the wall of the sponge. Sp.: *A. cerebrum*, *A. reticulum*, *A. primigenia* (*Leucetta primigenia*, H.=*Leucosolenia ventricosa*, Dendy ?).

Genus 2. *Ascandra*, H. (*sensu* Minchin). The flagellate epithelium is pouched deeply into the wall of the sponge. Sp.: *A. falcata*.

Fam. 3. *Heteropegmidæ*, nov. The flagellate tubes are completely radial in arrangement.

Genus 1. *Dendya*, nov. The ends of the branches, even when united, are distinguishable as separate prominences on the external surface, and there is no true dermal membrane or cortex. Sp.: *Dendya tripodifera*, (= *Leucosolenia tripodifera* (Carter) Dendy (14)).

* [In a specimen of *G. blanca* I find the optic axis at the base of the cup 9° below the external perpendicular on the spicule-plane, while on the solid stalk it rises 33° above the perpendicular. This would seem to be consonant with the probable direction in these parts of the line of maximum thrust, and to account for the abnormal "horn" spicules described by Metschnikoff (5) and Poléjaeff (7)]

Genus 2. *Heteropegma*, Pol. The external surface is a cortex with dermal skeleton, and the ends of the branches are indistinguishable as separate prominences. Sp.: *Heteropegma nodus gordii.*

(From Dendy's illustration it would seem that his *Leucandra australiensis* ((17) Fig. 17) should form the type of a third genus in this family, with a dermal membrane but no cortex.)

It is impossible to estimate the degree of relationship between Calcaronea and Calcinea until the histology of siliceous sponges is better known. The fact that the skeleton is in both groups composed of calcite seems little evidence of common origin; since the researches of Ebner and Minchin suggest that they separated before the calcite took the form of spicules. The mode of attachment of the flagellum would seem necessarily perfected so soon as the mode of nourishment by aquiferous canals was established for the race; on this reasoning it would seem not improbable that the phylum Sponges may be composed of two classes, the Basinucleata and the Apicinucleata; or the Hexactinellida may be a third class of equal value. The Spongillidæ and Spongida are the two groups among Demospongiæ which would appear to offer themselves for union with the Calcinea, as having basal nuclei to their collar-cells and larvæ completely flagellate; for the Apicinucleata we know of distal nuclei in the Calcaronea, *Halichondria* (18) and probably (reasoning from Schulze's figures) *Chondrosia* (3), *Corticium* (6), *Halisarca* (3).

The Spongillidæ and Spongida are both anomalous groups, and the Demospongiæ would be rather more homogeneous if they were removed, and scarcely more heterogeneous by the admission of the Calcinea. But our knowledge is as yet too imperfect to propose such a classification.

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