„ *7e.* The same still further developed and after the incorporation of some outer cæca.

„ *7f.* A section across the complete calicle with its twelve well-developed septa.

„ *7g.* The calicle as seen from the surface of the corallum.

Fig. 8*a–c.* ***Heliopora somaliensis***, n.sp. Turonian. Uradu, Somaliland. B.M., R4150.

„ 8*a.* Part of a horizontal section with two calicles. × 15 diam.

„ 8*b.* Part of a horizontal section showing circular and angular "cæca," the latter being in the upper portion, which is filled with quartz-grains. × 10 diam.

„ 8*c.* Part of a horizontal section, showing three calicles, with and without septal ridges. × 15 diam.

On the Structure of Coccospheres and the Origin of Coccoliths." By HENRY H. DIXON, Sc.D., Assistant to the Professor of Botany, Trinity College, Dublin. Communicated by J. JOLY, F.R.S., Professor of Geology, Trinity College, Dublin. Received February 3,—Read February 22, 1900.

[PLATE 3].

At the beginning of September last year, I visited Valencia, Co. Kerry. It occurred to me there that coccospheres might possibly be drifted in on the warm current of the Gulf Stream, which impinges on the south-west coast of Ireland, and as they float in would become entangled in the sea-weeds on the coast. With this idea, I gathered some of the finer marine algæ, such as species of Cladophora, Polysiphonia, and Plocamium, &c., from the rock pools in Valencia Harbour. Taking care to wash as little of the silt or sediment as possible from them, I fixed the mass in dilute formalin.

This method proved to be a most satisfactory way of collecting coccospheres and coccoliths. In the first sample of sea-weeds thus gathered at a venture, I obtained several hundreds of coccospheres, and of course innumerable coccoliths. In practice, the most convenient way of gathering coccospheres in abundance was found to be to collect the sea-weed, and there and then to wash the sediment from it in sea-water and formalin, or in alcohol, or in sea-water and osmic acid. The sediment which settles down in the fixing fluid will afterwards be found to contain large numbers of coccospheres. In preparations made from material collected in this manner, and mounted under a cover-glass 22 mm. × 22 mm., I have counted as many as fourteen coccospheres. Of course there are many other organisms present in addition to the coccospheres, *e.g.*, various crustacea, mites, worms, molluscs, foraminifera, infusoria, diatoms, peridineæ, &c.

I am indebted for most of the material from which the following

observations are made to Miss Delap and Mr. C. Green, who kindly gathered the algæ, the former at Valencia and the latter at Waterville, and posted them to me, to be then fixed in one or other of the fixing fluids mentioned above.

All the coccospheres found agree in their characters with Wallich's *Coccosphæra pelagica* and all the free coccoliths observed are apparently derived from that organism, all being oval and often possessing the characteristic D-shaped apertures. Throughout my search I did not find a specimen of *Coccosphæra leptopora* of Murray and Blackman, so that apparently this latter is absent from or very scarce in the ocean near our coasts.

The examination of fresh coccospheres in sea-water afforded no evidence as to whether these organisms were alive or dead when collected; no protoplasmic protrusions could be seen extending from the apertures in the coccoliths nor from the spaces between the coccoliths; nor could any spontaneous motion be observed in the coccospheres. In sea-water the coccospheres appear quite colourless, except for the bluish-green appearance of the covering coccoliths, due apparently to the fact that their refractive index is higher than the water in which they are immersed. No coloration due to the presence of an internal chromatophore nor any sign of such a body could in any case be made out.

The absence of the chromatophore, recorded by Murray and Blackman as occurring in *C. leptopora*, is not, I think, sufficient reason for concluding that all the coccospheres examined had been for some time dead, and so had lost their cell contents; for the coccospheres were in the great majority of cases quite perfect, and, as we will see later on, the presence of proteid material and probably of a nucleus in a large number of them was revealed by various stains and reagents. Some, however, were devoid of contents or possessed so little that their presence eluded detection.

External Characters.

As Murray and Blackman* point out, there is considerable variation in the size of *Coccosphæra pelagica*. Of about fifty specimens taken at random and measured, the largest had a diameter measuring 0·0294 mm., and the smallest 0·0199 mm. This variation is in part due to the inconstancy in the number of coccoliths on the coccospheres, and in part to the varying amount of overlap of the coccoliths over one another. The greatest number of coccoliths observed by me on one coccosphere was sixteen and the smallest six. Fig. 1 (Plate 3) shows a coccosphere captured in 1897 in Killiney Bay, having only six or seven coccoliths upon it. Fig. 2 shows a fragment of another coccosphere

* 'Phil. Trans.,' B, vol. 190 (1898), pp. 427—441.

equally small, taken in Valencia Harbour in 1899. It is difficult to estimate with certainity the number of coccoliths on the coccosphere while it is intact, and one is apt to under-estimate it. But it is possible to make sure of accuracy by crushing coccospheres mounted in glycerine jelly. The coccoliths are then sufficiently separated from one another to enable one to count them easily, while the viscidity of the mounting medium does not allow any of them to be lost. It was from coccospheres treated in this manner that the maximum and minimum numbers here stated were derived.

The variation in the amount of overlap brings it to pass that sometimes coccospheres with a small number of coccoliths upon them have an equal or even greater diameter than others which carry a larger number of coccoliths. To quote an example :—Two coccospheres were found, each measuring 0·021 mm. in diameter; one of these carried ten coccoliths and the other only seven.

The coccoliths, although they do not vary so much as the coccospheres in their dimensions, yet differ from one another considerably in size. From a large number of measurements of the long axis of the oval, it was found that the extremes deviated from the mean by as much as 20 per cent., the maximum being 0·018 mm. and the minimum 0·013 mm., while the mean was 0·015 mm.

This variation in size of the component coccoliths is in part but not, I think, to a large extent, responsible for the variation in the size of the coccospheres, as it is found that coccoliths of different sizes occur on one and the same coccosphere. It will be seen later that there is some reason to believe that the smaller coccoliths are formed in the early stages of the coccosphere's life history when it is itself small. It may be noted that the smaller coccoliths on a coccosphere are often, if not usually, without the transverse bar across the central perforation.

Some of the finer details of the structure of the coccoliths are more easily made out when these latter are examined *in situ* on the coccospheres, as then in the one field coccoliths may be examined in almost every position, and views from different directions may be carefully compared. Broken coccospheres, too, often afford valuable evidence as to the relations of the coccoliths to one another and their interlocking. This last point, as well as the shape of the body surrounded by the valves, is greatly elucidated by observations made on microtome sections of material embedded in paraffin. The most instructive preparations were obtained from sections 5μ—10μ thick; often those of 10μ are more satisfactory than the thinner ones, as, despite the support afforded by the paraffin, the coccoliths in the latter are so often badly shaken and cracked that the fine details of their structure are not so well seen as they are to the thicker sections.

When a coccolith is examined in actual or optical vertical section, it is

seen that the oval disc, which I shall call the body of the coccolith, forming the bottom of the central depression and carrying the single slit or two D-shaped holes, is of some considerable thickness (figs. 3, 4, and 5). Its inner surface projects very slightly inside the inner valve, and the slit or D-shaped perforations are enlarged towards its inner and outer surfaces. The whole coccolith consequently has the form of a very short, thick-walled, oval tube, with its outer extremity recurved to form the outer valve. The inner valve is a dished collar attached very close to the inner extremity of the tube. The projection of the tube-like portion, or body, inside the inner valve is very slight, and can only be made out either by sections or by very careful focussing.

An examination of the coccoliths in plan has also revealed a few points of interest. Where the body of the coccolith comes in contact with the depressed portion of the outer valve, there are to be seen a series of very minute punctations (fig. 6) corresponding, as far as could be ascertained, with the radiating grooves between the striations of the valve. It is possible that these punctations represent the ends of minute passages running down the outside of the body and inside the valves of the coccolith. Another point that may be noticed has reference to the material composing the transverse bar usually present, dividing the slit-like canal of the body into the two D-shaped holes. This bar is often obviously composed of somewhat different material from the rest of the coccolith, and this difference extends for some distance beyond the edges of the slit continuing the direction of the bar. In appearance the bar and its continuation are less highly refractive than the rest; and the difference of material is further manifested by the fact that it dissolves more rapidly in weak acids than the body of the coccolith, while this latter goes into solution more readily than the collar-shaped portion uniting the two valves. It must be borne in mind, however, that this difference in the rates of solution may be in part or completely due to a difference in the ease of diffusion round these parts. It will be seen later that the order of solution is the reverse of the order of development. The oldest parts of the coccolith are the last to be dissolved.

In a previous note Dr. Joly* and I have already noticed that there is no evolution of free gas when coccoliths are attacked by acids. This is probably due to the fact that the amount of gas they generate is unable to overcome the cohesion of the liquid in which the reaction takes place. From this consideration it would appear that the absence of free gas under the action of acids is no objection to regarding coccoliths as composed in the main of calcium carbonate. To test the validity of this view I mounted some fine precipitated calcium carbonate in water, which had been boiled so that it thoroughly wetted the

* 'Nature,' September 16, 1897.

crystalline precipitate. While this preparation was under observation, dilute acid was introduced under the cover-glass, and it was found that gas bubbles were generated in connection with the larger crystalline aggregates only, while the smaller ones dissolved without any gas appearing in their immediate neighbourhood, even after the liquid was completely saturated, and contained much free gas. Crystalline masses having a diameter of 0·027 mm. dissolved in this manner without the formation of bubbles. In the case of the solution of the larger masses, an increase in size of the bubbles previously existing in their neighbourhood was observable. It seems quite probable that if greater care were taken to eliminate all free gas from the water in which the crystals were mounted and from the added acid, that much larger masses of calcium carbonate might be brought into solution without the evolution of bubbles, as then the cohesion of the liquid would have to be overcome before they could appear. To overcome this would require a force of many atmospheres. In any case the observation quoted shows that solid masses of calcium carbonate having the same diameter as a coccosphere (and consequently containing a great deal more calcium carbonate), dissolve without producing free carbon dioxide.

Besides their ready solution in weak acids, the behaviour of coccoliths towards picric nigrosine is very characteristic of calcium carbonate. While the coccolith is dissolving in this stain a dense, dark, but extremely fine precipitate or coloration is formed on its surface. The same reaction may be observed in the solution of small crystals of calcium carbonate. In the case of the coccolith the precipitate is most marked in the D-shaped holes, round the collar connecting the two valves, and along the radial striæ on the valves. It seems probable that the remaining parts of the valves do not possess sufficient material to render the reaction apparent in their case. Besides thus affording additional evidence as to the nature of the material forming coccoliths, this reaction makes several obscure points in their structure stand out with great clearness.

That the coccolith is not pure calcium carbonate appears from its behaviour towards a 1 per cent. solution of sodium carbonate. When mounted in this reagent the coccolith after a short time assumes a peculiar appearance. Its surface becomes lumpy and loses its clean-cut contour. Some coccoliths exhibit this change much more markedly than others, and all more plainly towards their periphery than at the centre. It is probable that the change is brought about by the solution of the organic basis remaining over in the coccolith. The completeness of the replacement of the organic basis by calcium carbonate would then determine the extent of the change.* The same change is

* Calcareous sponge spicules undergo a similar change when treated with this reagent.

noticeable, but to a much less degree, when coccoliths are treated with a 20 per cent. solution of sodium chloride.

On the coccosphere the coccoliths overlap each other to a considerable extent. The amount of overlap is not constant. It is usual for the outer valve of one to penetrate between the outer and inner valves of its neighbour, so far as to reach the collar uniting the two valves. (Figs. 7, 8, 9 and 4.) In this way the coccoliths on the surface of a coccosphere interlock with one another, and form a comparatively rigid shell. The bevelled shape of the coccolith is evidently necessitated by the overlapping on a curved surface. The rigidity of this form of structure is best appreciated from the examination of fragments of a broken coccosphere, which will preserve their curvature even when they are composed of only three or four coccoliths. Such a fragment is shown in fig. 2. Indeed the interlocking of the coccoliths is so complete that it seems impossible to break up a coccosphere without at the same time splitting the valves of several of its coccoliths. Some distortion in its shape is, however, possible without fracturing the coccoliths. This yield is possibly due to the give in the outer region of the valves, which appear to contain a considerable amount of organic material in their composition.

If coccospheres are dissolved in acid and subsequently or simultaneously stained, appearances are observed which seem to point to the existence of an extremely fine pellicle covering over the coccoliths and enclosing the whole sphere. The simplest method of demonstrating this pellicle is by mixing up in glycerine jelly a stain to which a trace of nitric or hydrochloric acid has been added. The coccospheres are then mounted in this medium, and the solution and staining go on simultaneously. Or again the material containing the coccospheres may be mounted in feebly acidulated jelly, and then a drop of the stain selected applied to the edge of the cover-glass. Either of these methods give good results (fig. 10) if the solution is sufficiently slow. The best results are obtained when the coccoliths take a fortnight or more to disappear. The stains I used were acid fuchsine and methyl green, fuchsine and iodine green, aniline blue, aniline green, and nigrosine.

After the solution of the coccoliths and staining it is seen (fig. 10) that the coccosphere is bounded by a pellicle of extreme tenuity. In the pellicle are a number of oval holes, corresponding in position and number to the central depressions of the coccoliths which have disappeared. The edges of the oval perforations are jagged, and from the irregular teeth extend radial striæ, which perhaps correspond to the striæ of the coccoliths. The striæ from two adjacent perforations are often continuous. The jagged teeth of the pellicle may often be made out by careful focussing of the surface of the coccosphere, even before it is attacked by acids and stained. Sometimes in dissolved

coccospheres there is a residue of stained material left in the central part of the holes, corresponding roughly in shape and position to the D-shaped perforations of the body of the coccoliths. This residue may possibly be the remains of protoplasmic filaments or protrusions once extending from the central region of the coccosphere. Similar granular slimy masses may frequently be seen in stained* and undissolved coccospheres occupying more or less of the central depressions of the coccoliths; but their irregularity of occurrence and shape make it impossible to say whether they are proteid material in connection with and derived from the central body of the coccosphere, or slime adventitiously deposited from the surrounding liquid.

Internal Structure.

By continuing the solution with acid, several points of the internal structure of coccospheres become apparent. The external pellicle gradually disappears, and only a number of disconnected, very minute granules persist to mark its position. The jagged edges of the holes persist the longest, but finally they also dissolve. If the coccosphere is stained in this condition it will appear that immediately within the external pellicle which has now disappeared there is a slimy proteid material, in which the inner valves and bodies of the covering coccoliths were embedded. Sometimes after treatment with nitric acid and staining with aniline blue this material has a homogeneous appearance, and is uniformly stained, while the positions once occupied by the coccoliths are colourless and transparent. More frequently, however, it is a finely and sparsely granular slime (fig. 9). It gives a faint orange coloration with nitric acid, followed by ammonia.

This slimy layer, in which the coccoliths are embedded, is bounded internally by a gelatinous, transparent, and sometimes slightly stratified membrane (figs. 11—14). There is usually no definite demarcation between the two, but the membrane passes imperceptibly into the slimy material outside. The internal valves of the coccoliths rest upon this membrame, and it is often seen to be drawn out into prominences corresponding with the position of the coccoliths on its outside. In optical section discontinuities are sometimes apparent in this membrane (figs. 13, 14), and it may be that these represent perforations corresponding with the perforations of the coccoliths, and through which the internal protoplasm communicates with the external surroundings. The membrane itself is difficult to stain, and it, like the

* I have found Bismarck brown, aniline blue, acid fuchsine, and methyl green useful stains for bringing out the structure of undissolved coccospheres. Delafield's hæmatoxylin sometimes gives very good results when precipitations do not occur. Material stained with the last mentioned is most satisfactory for microtome sectioning.

slimy layer, exhibits a slight orange coloration when treated with nitric acid followed by ammonia. With Schultze's solution it becomes amber-coloured.

Within this internal membrane in all my specimens but scanty protoplasmic contents were revealed, but in these there was often distinguishable a minute, more darkly staining body, presumably a nucleus. In several specimens this nucleus was double or hour-glass shaped (figs. 12 and 15). My specimens did not show the structure of the nucleus with precision, and nothing beyond its granular appearance and probable possession of a membrane could be made out. The aggregation of protoplasm in which the nucleus is situated occupies a lateral position, and is in contact with the internal membrane, and strands of protoplasm extend from it across the cavity of the sphere. In no case was a chromatophore, nor anything like one, seen in the protoplasm. In one case a colourless trilobed body was found in the cell; its nature is quite uncertain. Fig. 16 is drawn of it after its containing coccosphere was treated with *liquor iodi.* The unfavourable conditions of our coasts are, perhaps, responsible for the scantiness of the protoplasmic contents of the coccospheres obtained in the south of Ireland. But to these unfavourable conditions can scarcely be attributed the absence of the chromatophore, for the existence of which in *C. pelagica* we have no definite evidence.

I now go on to a series of observations which seem to me to be of considerable interest, as throwing some light on the manner of growth of coccospheres, and on the origin and development of coccoliths. If entire coccospheres are examined in a medium of high refractive index, *e.g.*, balsam, or even glycerine jelly, it will be found that numerically about 80 per cent. of them contain an internal oval colourless body. Closer examination reveals that this body is in many cases a complete and perfect coccolith (fig. 17), in others it is a simple oval ring or shallow collar (figs. 3, 7, 8, 15). All stages of development connecting the collar-shaped body with the complete coccolith are found, so that it becomes evident that the coccolith arises as a ring of calcium carbonate within the coccosphere. At first the ring is a narrow band (fig. 3), it then deepens into a collar (fig. 8); on either end of the collar are then secreted oblique flanges (fig. 15), which, as deposition continues, are developed into the bevelled valves of the coccolith (figs. 7 and 17). The central body appears last, and only in its later stages is the transverse bar secreted, dividing its single aperture into two. The position of the internal coccolith within the coccosphere varies; generally speaking, in its earlier stages of development, it lies near the centre of the sphere, and in many cases it was found in contact with the nucleus (figs. 15, 17). When more mature it comes into contact with the inner gelatinous membrane, and when the coccosphere is intact, appears in close proximity to the external coccoliths

(fig. 18). It is presumably to be inferred that it is finally extruded between these latter, and takes up its position in the shell of the sphere.

The internal coccolith gives the same reactions as the outer ones. When a coccosphere is acted on by acids, the internal coccolith, if present, is the last (as we might expect) to dissolve (fig. 14), and in its solution its radial striæ are the last parts of it to disappear. Under treatment with picric-nigrosine, the behaviour of a coccosphere containing an internal coccolith is characteristic. First the external coccoliths darken, and their striæ and other details stand out with great clearness; as solution proceeds, a very dark coloration covers all the outer coccoliths, and when this clears away, their solution is all but complete. The internal coccolith then goes through the same phases as the outer ones; its striæ become clearer, it darkens, and, as it goes into solution, the whole cavity of the sphere becomes filled with a dark green coloration. The appearance of this coloration is sometimes very sudden; it disappears with less rapidity. When it is gone, the scanty protoplasm, nucleus, gelatinous and slimy envelopes stained with the nigrosine are all that are left of the coccosphere.

As a general rule, only one internal coccolith can be made out in each coccosphere; sometimes, however, one mature coccolith and one in a very early stage are found. In the coccosphere (fig. 16), which contained the central trilobed body alluded to above, so far as I could ascertain a ring-shaped coccolith was in contact with each lobe. But this observation is open to doubt, as the coccosphere was mounted in water, so that the internal coccoliths were only indistinctly seen, and unfortunately the solution of both internal and external coccoliths took place while they were not under observation.

In the case of internal coccoliths which have almost reached maturity, it is generally possible to perceive that they are somewhat larger than any of the coccoliths already in position on the sphere. It would appear from this that the coccoliths formed by a coccosphere in its earlier stages are smaller than those developed later in its life history. Indeed, measurements of coccoliths and coccospheres almost necessitate this conclusion. Thus coccoliths are often found with their longer diameter equal to 0·018 mm., while the internal measurements of some of the smaller coccospheres could not accommodate a coccolith of these dimensions. Again, it is found that the coccoliths with a simple slit-like perforation in their central body are, as a rule, smaller than those with D-shaped perforations; so that we may with some probability assume that the single perforation is the more primitive condition, and that coccoliths with it only are formed in the coccosphere during its earlier stages. The history of the development of the coccolith also points in this direction.

It appears that the extrusion of a coccolith to the surface must

lead to a readjustment of the coccoliths already in position. In order to effect this, they must slide past each other, and take up such relative positions with one another and the new coccolith as will change the curvature of the surface and increase the size of the sphere. The dished shape of the coccoliths and their oval outline are apparently adaptations to accommodate this peculiar method of growth. The oval form and the method of intercalating new plates in the skeleton, necessitates the overlap; but this expenditure of material is compensated by the great rigidity so obtained, and the complete protection of the organism.

It is evident that these observations on the internal origin and development of coccoliths dispose of those theories which regard the coccospheres either as reproductive bodies of the coccoliths or as independent organisms which aggregate coccoliths on their surface, as some Rhizopoda gather diatom skeletons. The observations also render improbable the view that the coccoliths are formed as precipitates in dead organic slimes, as has been suggested. The history of the development shows that the coccosphere is the organism which secretes the coccoliths as its skeleton, and it is probable that these latter only occur free in the water after the death and disintegration of the parent coccosphere.

Summary.

The following conclusions may be drawn from the foregoing observations:—

1. The body of the coccolith extends for a short distance inside the internal valve.

2. The coccolith is composed of calcium carbonate and a trace of some substance soluble in 1 per cent. of sodium carbonate.

3. Coccospheres are covered over with an extremely delicate pellicle, which is less readily soluble in dilute acids than the coccoliths within it.

4. The coccoliths on a coccosphere are partially embedded in a slimy proteid material.

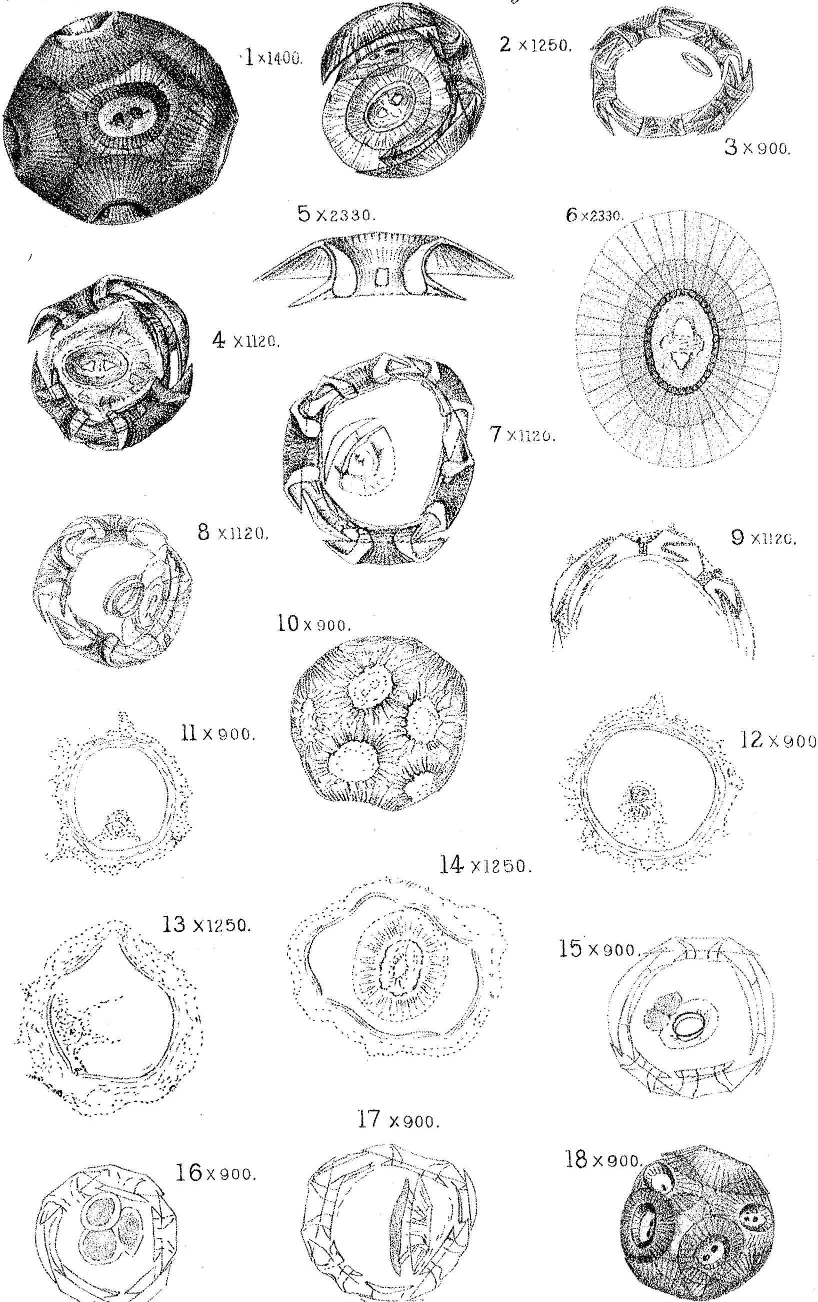
5. Within the slimy layer there is a somewhat stratified internal spherical membrane.

6. The specimens of coccospheres examined contained no chromatophore.

7. In many instances the presence of a minute internal body, presumably a nucleus, was demonstrated.

8. Coccoliths are secreted internally in close proximity to the nucleus; the collar uniting the valves is first formed, then the valves are developed, and finally the central body of the coccolith is secreted.

9. The coccolith, when complete, is probably extruded to the surface, and takes up its position among its predecessors. Its valves



A. S. Huth, Lith[r]

become interlocked with those of its neighbours. By this intercalation an increase of the volume of the sphere is provided for.

10. The oval and dished form of the coccoliths are adaptations to allow of the rearrangement of the older coccoliths on the extrusion of a new one, and of suitable interlocking on the spherical surface.

EXPLANATION OF PLATE 3.

All the figures are drawn by means of a *camera lucida* from specimens obtained at Valencia and Waterville, Co. Kerry, except Fig. 1.

Fig. 1.—Coccosphere, × 1400, drawn from a fresh specimen captured September, 1897, in Killiney Bay.

„ 2.—Fragment of small coccosphere composed of four interlocking coccoliths. × 1250.

„ 3.—Microtome section of coccosphere, showing an early stage in the development of an internal coccolith. × 900.

„ 4.—Microtome section of coccosphere, showing coccoliths in section. × 1120.

Figs. 5 and 6.—Single coccolith in section and plan.

Fig. 7.—Microtome section of coccosphere, showing mature internal coccolith. × 1120.

„ 8.—Microtome section of coccosphere, with partially developed internal coccolith. × 1120.

„ 9.—Microtome section of coccosphere after solution of coccoliths and staining with Delafield's hæmatoxylin. × 1120.

„ 10.—Outer pellicle remaining over after the coccoliths of a coccosphere are dissolved in acid glycerine jelly and stained in aniline blue. × 900.

Figs. 11 and 12.—Coccospheres after prolonged action of picric nigrosine, × 900, showing the slimy layer, stratified membrane, and the nucleus within the latter.

Fig. 13.—Same as 12. × 1250.

„ 14.—Coccosphere partially dissolved in picric nigrosine, showing the internal coccolith in early stages of solution.

„ 15.—Optical section of a coccosphere, × 900. Within the external coccoliths are seen the constricted nucleus and a nearly mature coccolith in contact with the nucleus. The specimen is stained with aniline blue soluble in alcohol.

„ 16.—Optical section of a coccosphere after treatment with *liquor iodi*. × 900. Inside the coccoliths is seen a problematical trilobed body.

„ 17.—Optical section of a coccosphere, showing nucleus in contact with a completely developed internal coccolith, stained in aniline blue soluble in water. × 900.

„ 18.—A coccosphere showing an internal coccolith immediately beneath the external coccoliths. × 900.

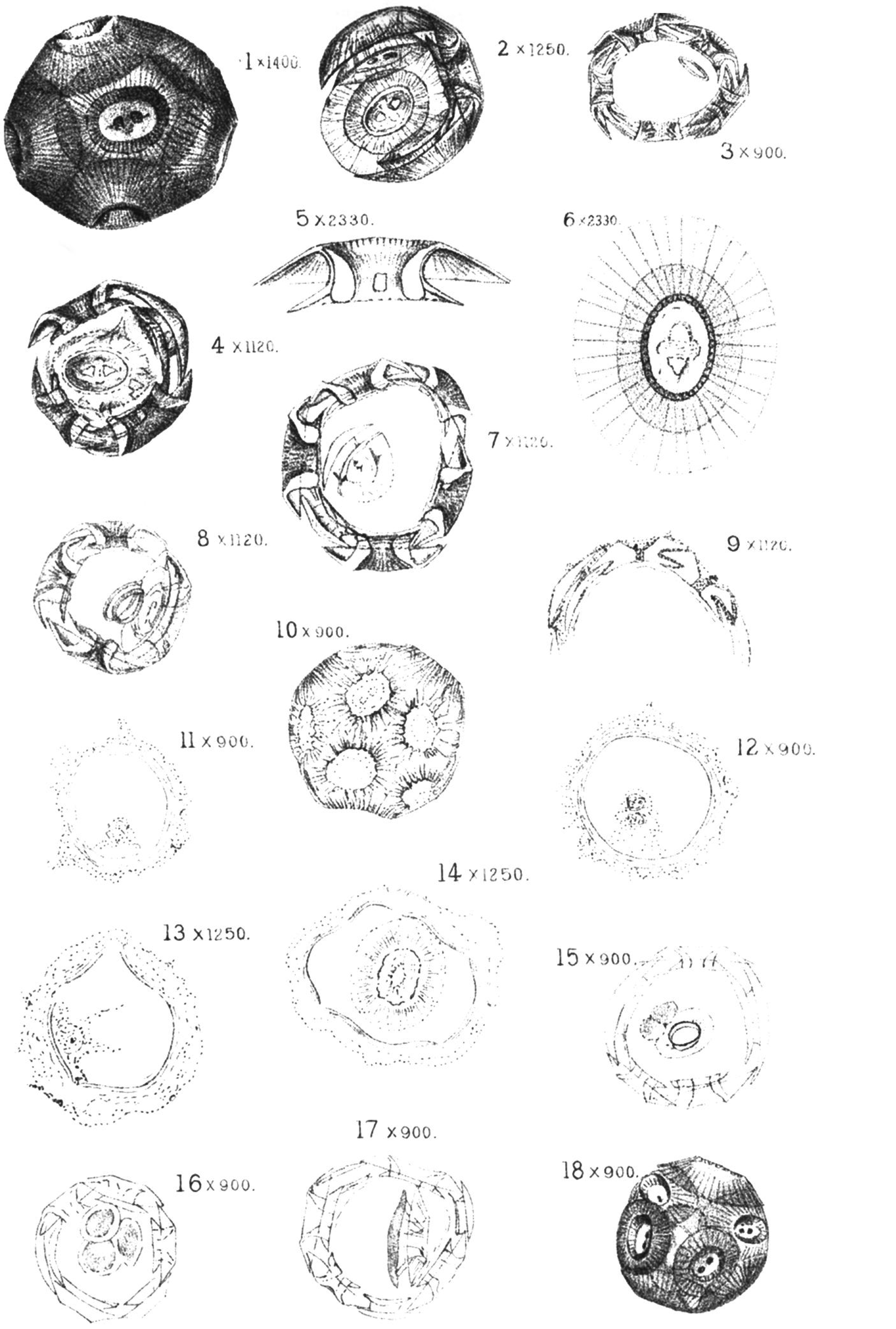


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Fig. 1.—Coccosphere, ×1400, drawn from a fresh specimen captured September, 1897, in Killiney Bay.

„ 2.—Fragment of small coccosphere composed of four interlocking coccoliths. ×1250.

„ 3.—Microtome section of coccosphere, showing an early stage in the development of an internal coccolith. ×900.

„ 4.—Microtome section of coccosphere, showing coccoliths in section. ×1120.

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Fig. 13.—Same as 12. ×1250.

„ 14.—Coccosphere partially dissolved in picric nigrosine, showing the internal coccolith in early stages of solution.

„ 15.—Optical section of a coccosphere, ×900. Within the external coccoliths are seen the constricted nucleus and a nearly mature coccolith in contact with the nucleus. The specimen is stained with aniline blue soluble in alcohol.

„ 16.—Optical section of a coccosphere after treatment with *liquor iodi*. ×900. Inside the coccoliths is seen a problematical trilobed body.

„ 17.—Optical section of a coccosphere, showing nucleus in contact with a completely developed internal coccolith, stained in aniline blue soluble in water. ×900.

„ 18.—A coccosphere showing an internal coccolith immediately beneath the external coccoliths. ×900.