

OBSERVATIONS ON LIVING FORAMINIFERA

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SUMMARY

Some foraminifers have been found living over *Anguinella palmata* van Beneden, 1841 (Bryozoa) or on green algae at the shore of Itanhaem State of São Paulo. The speed of movement was measured several times, and the formation of a new camera observed. The schizogonic phase of *Poroeponides lateralis* (Terquem) was followed to the embryonic formation of five chambers.

Near Itanhaem (50km W of Santos), São Paulo State, Brasil, living Foraminifera occur all the year round on the cystids of the Bryozoan *Anguinella palmata* van Beneden, 1845, which grows on the rocks exposed at low tid. The distribution of the foraminifers is somewhat erratic, and one must examine several colonies of *Anguinella*. After some time I learned to know where the bryozoans with numerous inhabitants occur. A powerful jet from a pipette is necessary to wash the rhizopods from the place where they have settled, as they adhere firmly to their substratum which is exposed to the agitated water around the rocks in the tidal zone. The capillary water between the tufts of Bryozoa protects the foraminifers against drying out.

I studied the following species: *Poroeponides lateralis* (Terquem) and *Massilina secans* (d'Orbigny) from *Anguinella*, and *Elphidium articulatum* (d'Orbigny), *Discorbina vilardeboana* d'Orbigny, and *Bolivina punctata* d'Orbigny from green algae.

In all these species one or two terminal chambers seem to be empty because they contain little protoplasm. The pseudopodia which I observed with the binocular microscope appear as delicate threads, sometimes bearing granules.

I tried to maintain the rhizopoda in Petri dishes with diatoms (*Navicula* sp.). The most delicate of my species, *Poroeponides lateralis*, lived at most for ten days; Jepps (1942) maintained *Polystomella* for two or three weeks in culture. For growing the diatoms the light of a window facing southwest was sufficient. The water was changed every day or every second day. The temperature of 21°C. was found optimal when I worked at the beach as well as in São Paulo. Myers (1960) found the same to be true in California. From the Bryozoa the foraminifers were separated under the binocular with a paintbrush. Then they were transferred two or three specimens to one dish, with a pipette. After this treatment the animals remained withdrawn in their tests, and as long as the water was agitated, the foraminifers did not attach to the substratum. A few minutes later, but some times only after half an hour the protoplasm emerges, and pseudopodia spread out almost all at once.

Poroeponides lateralis has reticular pseudopodia, narrow threads which ramify and anastomose, and usually bear lateral branches. In well fed specimens many small granules circulate towards the periphery of the pseudopodia until to the finest ends and then backwards to the centre. Some of the granules reverse their direction.

I did not observe any tendency of the animals to move in the direction of a moderate light. If such a positive phototaxis exists, which could lead the foraminifers to propitious feeding grounds, it seems to act extremely slowly, because I followed individuals crawling on the surface film for two days, where food is scarce. Jepps (1942) doubts that phototaxis exists in *Polystomella crispa*.

The pseudopodia of *Poroeponides lateralis* arise for the most part from the thin covering of cytoplasm which passes through the minute pores found all over the shell and through the big pores in its lower part. Some pseudopodia are also emitted from the inner protoplasm through the terminal aperture, and may extend across the last chamber straight, which is not filled by the protoplasm. The pseudopodia sometimes come out for a short distance, and after a few minutes form side branches which meet, fuse, and produce a net. Within half an hour this triangular net based on the shell spreads further bun-

dles of pseudopodia, which surround the shell more or less completely, or extend in two or three principal directions.

The pseudopodia of *Massilina secans* arise directly from the protoplasm inside the shell through the terminal aperture. The movements of the protoplasm were seen in the last chamber in this species and in *Bolivina punctata*. Also in *Elphidium articulatum* and *Discorbina vilardeboana* the pseudopodia extend from the terminal aperture.

The outer layer of the pseudopodia seems to be of mucous consistency. It contains hyaline, not very refractive granules of different sizes, which are moved by the stream of the protoplasm. Sometimes the smaller of these remain at the tip of the pseudopodia.

When any suitable object comes into contact with the pseudopodia it is carried towards the opening of the test. The movements of the protoplasm by which the particle is incorporated were watched through the shell. Sandon (1932) indicate flagellates, ciliates, and copepods as food of foraminifers.

No axial thread were seen in the pseudopodia of the specimens examined. The pseudopodia generally are straight and can extend through the water without any support for a distance three or four times the shell diameter.

When the pseudopodia are retracted from the substratum they become undulate like a thread cut under strain. Sometimes not all pseudopodia are withdrawn before movement begins again in the same direction.

At 21°C. the speed of four examined species is very different: *Poroeponides lateralis*, 120 mm/h.; *Massilina secans*, 20 mm/h.; *Bolivina punctata*, 6 mm/h.; *Elphidium articulatum*, 2 mm/h.

Poroeponides lateralis turned upside down recovers its normal position in 17 minutes. Some minutes after the animal has been turned over the pseudopodia are extruded. They are numerous on the ventral side where they spread and adhere to the bottom. Then the pseudopodia are shortened and lift the shell. Eight minutes after the beginning of the experiment the test forms an angle of about 45° with the substratum. The pseudopodia are withdrawn farther and become short and branched on the apertural side.

Long pseudopodia arise on the opposite side, and the shell stands at an angle of 90°. Then it begins very slowly to fall on to the apertural side. After an additional four minutes the animal has acquired its normal position and locomotion begins. The pseudopodia are like stilts supporting the weight of the shell, lengthening and shortening according to mechanical necessities.

After feeding small brown granules appear in the protoplasm. In *Massilina secans* and *Discorbina villardeboana* a digestive cyst is formed in a typical manner so as to cover the test completely in one or two hours. Inside the cyst the process of digestion goes on. The granules are eliminated from time to time and left behind in the mucous trail of the creeping foraminifer.

The cyst that begins the formation of a new chamber is called a growth cyst. The building of a new chambers was seen in detail in *Poroepionides lateralis*. Through the wall of the last chamber an unusually dense mass of radiating, closely anastomosing pseudopodia was extruded in the early evening. These pseudopodia collected all available particles and adhered to one another in a circular area delimited by a smooth covering membrane. They then form a semicircular cyst around the future chamber. The pseudopodia are thick and opaque, and appear as a semitransparent halo around the hitherto last chamber. Then they contract slightly and form a coherent white layer of protoplasm, the developing chamber. On the surface of the net formed by the sinuous and branched pseudopodia bright points indicate the appearance of crystals of calcium carbonate. These fuse and build a continuous layer of shell substance. It takes about 10 hours from the first appearance of the growth cyst to construct one of the large chambers of the test. Myers (1940) found 12 hours for *Discorbis patelliformis*; Le Calvez (1953), 8 hours for *Discorbis bertheloti*. The type of growth in the latter is similar to that in *Poroepionides lateralis* where the whole process takes place without a cover.

During my observations I had species living on *Anguinella palmata*. The animals were found attached to the substratum, and nearly all specimens of *Massilina secans* had the apertural region covered with mud. In Miliolidae such cysts are known and were completely studied by Hofker (1930).

In the last week of June 1961 I was able to keep eleven animals alive in Petri dishes. Several of them began to reproduce, but as only one continued normally, I preserved the others in incipient reproductive stages. The first indication of the beginning of this phase appears in the pseudopodia, which are abundant and form a narrow circular area around the shell, at first sight similar to the formation of a new chamber. I found the animal in this condition at 6:00 A.M. The sharply circumscribed area is formed by a cover of radiating and interlacing pseudopodia. As the pseudopodia are refractive, a semi-transparent halo, the "premonitory halo" of Lister (Heron Allen, 1930) is brought about. After some hours the protoplasm gradually withdraws from the peripheral parts of the outer whorl of chambers towards the terminal ones, which are gradually filled (2:35' P.M.). The protoplasm leaving the chambers is colored brown by the granules. Thin and diffuse radiating streaks form a successively more compact mass. At 6:00 P.M. nearly all pseudopodia have withdrawn and left branched lines of fine granules marking their most extended position. The protoplasm then emerges from the shell and the whole mass undergoes amoeboid changes of shape. Gradually light spaces develop free of brown granules. These regions increase in size and become better defined, but they are not stationary. The protoplasm in these areas is arranged radially. Later on (10:25' A.M. of the following day) spherules appear whose center consists of light granular protoplasm. Their diameter is 48μ . The plasma that had remained in the terminal chamber of the test divides there into spherical portions which according to Lister, (Heron Allen, 1930) also occurs, although uncommonly in *Polystomella crista*.

I stained five specimens in the first stage of reproduction but could not find any nuclei, although Lister (Heron Allen, 1930) found them, 10μ in diameter, in the clear protoplasm of the terminal chambers, when the protoplasm had begun to emerge.

By 9:30' P.M. of the second day the previously milky, semi-transparent halo appears transparent. Now the round bodies are milky and consist of two chambers each. At 2 00 A.M. the third chamber is added. By this time I saw eight embryos moving under the halo. The remaining protoplasm in the terminal chambers is divided into

spherules of 1-3 chambers at 2:35' P.M. The plasma of the parent is all used up in the formation of the broad, so that the shell becomes nearly empty. At 8:00 P.M. the halo was broken and the young animals with delicate pseudopodia were dispersed over a wide area. These juveniles had three chambers, and their pseudopodia had thrice the length of the test. Some of them remained in the empty parental shell.

The whole process from the first appearance of the halo to the dispersal of the offspring lasted about 60 hours at a temperature of 20°C. Lister (Heron Allen, 1930) found 12 hours for *Polys-tomella crispa*, where the process needs fresh sea water to be accomplished. I also changed the water several times.

On the next day at 2:10' A.M. all young animals had added a fourth chamber, hence 8 hours were necessary for its formation. This fourth chamber is flattened dorso-ventrally. Two further chambers were added in the course of the next 17 hours. Le Calvez (1953) found 24 hours for the addition of 2-3 chambers in young *Discorbis bertheloti*, and 8 hours in the adult.

The addition of new chambers increases the quantity of calcium carbonate in the old ones. The border of the third chamber is serrate and serves as base for the addition of a new one. Restricted areas with small perforations occur in the chambers of the young animals.

In ventral view the fifth chamber embraces the preceding one nearly completely, leaving only the perforate area free. This area shows that the animal can grow only in a restricted region, as the chambers are built over the imperforate parts of the test. The labiate aperture is median in the centre of the last chamber. In young animals with 5 chambers and with the mentioned perforate area large, irregularly distributed pores appear in the ventral wall of the last chamber.

In *Planorbulina mediterraneensis*, Le Calvez (1934, 1938) observed the embryos hatching a week after the formation of the fifth chamber. Some minutes after coming out the young animals stopped movement and added a sixth chamber. Hofker (1930) noted that the embryos of *Eponides repandus* hatch with 2 chambers. For *Discorbis orbicularis* 3 chambers are known, for *Discorbis bertheloti* 2-3, for *Discorbis vilardeboanus* 3-4, and for *Discorbis araucana* 2.

RESUMO

Alguns foraminíferos foram encontrados vivos sôbre *Anguinella palmata* van Beneden, 1841 (Bryozoa) ou sôbre algas verdes na região de Itanhaem, Estado de São Paulo. Foram realizadas medidas da velocidade de deslocamento, observada a formação de nova câmara e acompanhada a fase esquizogônica de *Poroeponides lateralis* (Terquem) até à formação de embriões com cinco câmaras.

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Explanation of plates

Plate 1

- Fig. 1. Living *Poroeponides lateralis*, attached to substratum.
Fig. 2. Pseudopodia of *Massilina secans*.
Fig. 3. Living *Massilina secans* on Bryozoon.
Fig. 4. Living *Poroeponides lateralis*.
Fig. 1. Living *Elphidium articulatum*.

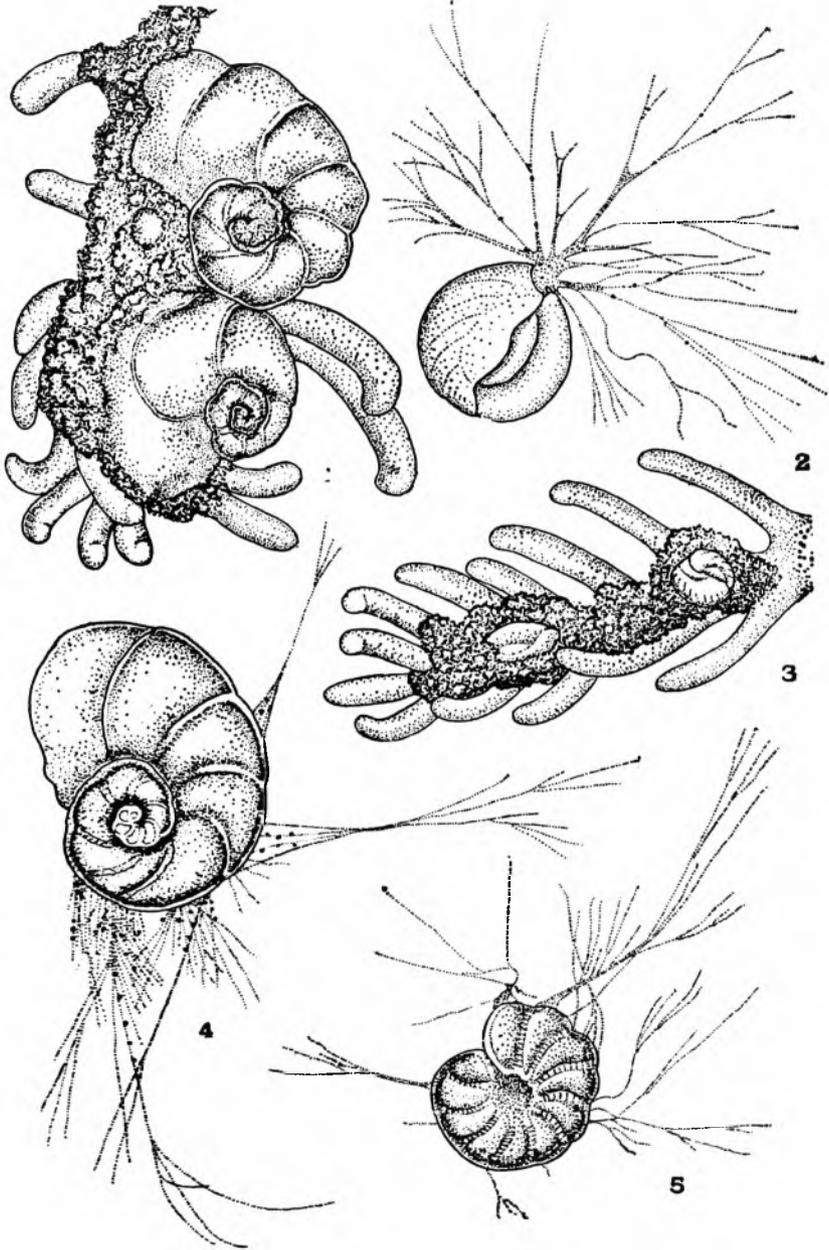


Plate 2

Fig. 6, 7, 8, 10. *Feroeponides lateralis*, successive stages of asexual reproduction.

Fig. 9. Living *Poroeponides lateralis*.

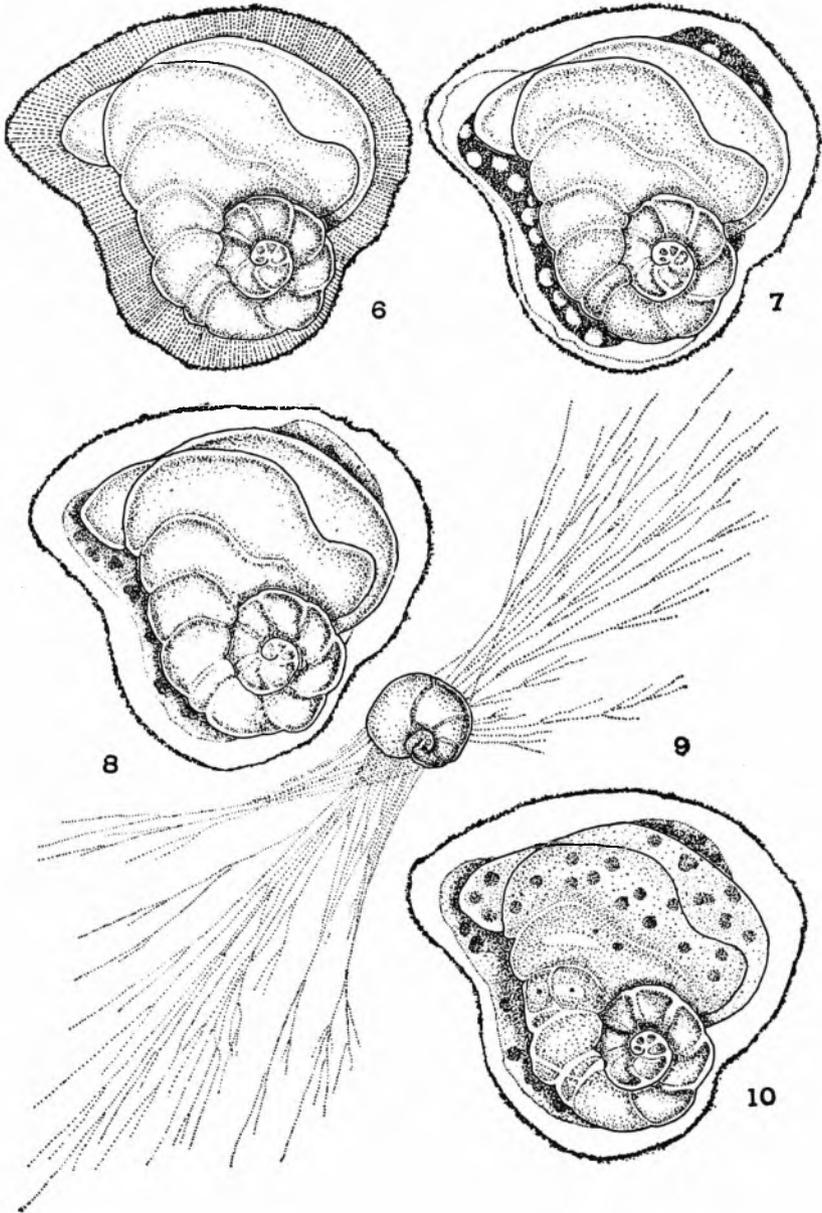


Plate 3

Fig. 11. Three-chambered stage just after hatching.

Fig. 12. *Poroeponides lateralis*, asexual reproduction, young leaving parent's test.

Fig. 13. Same, general view.

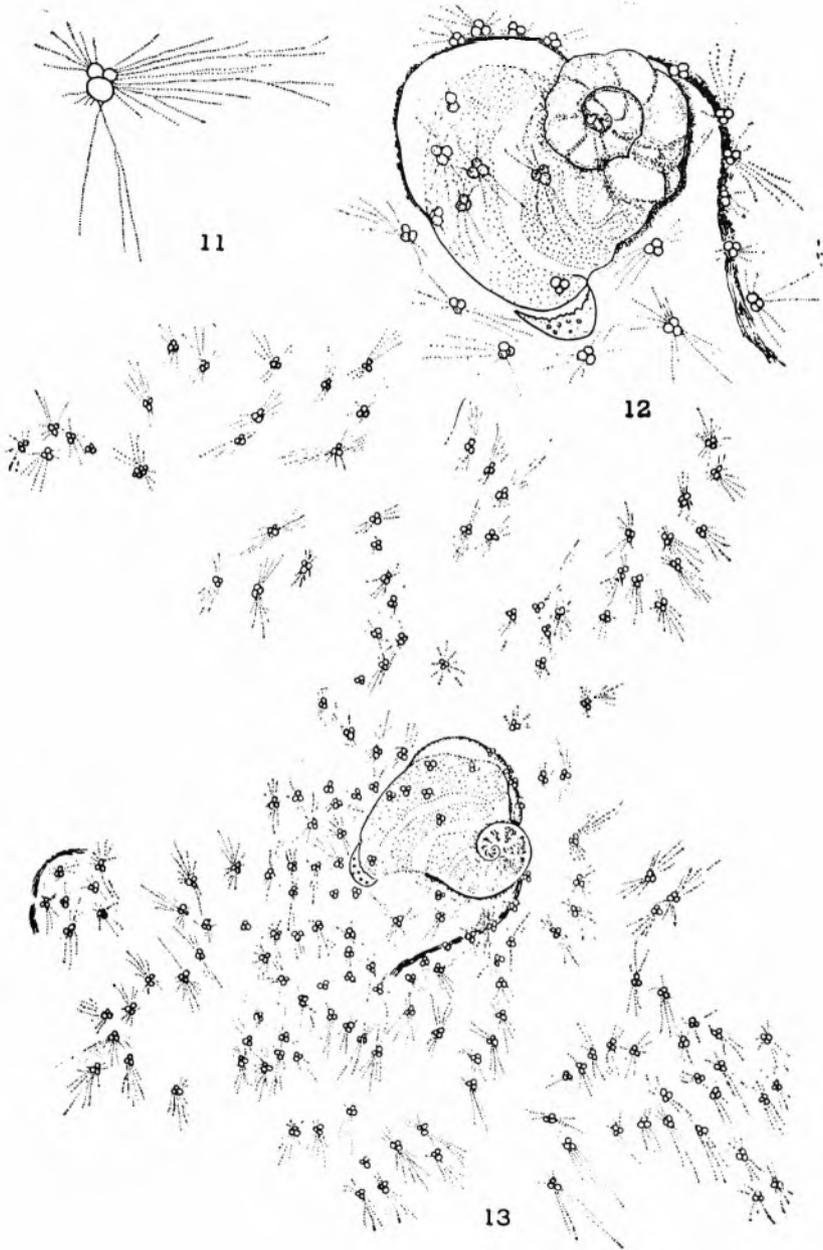


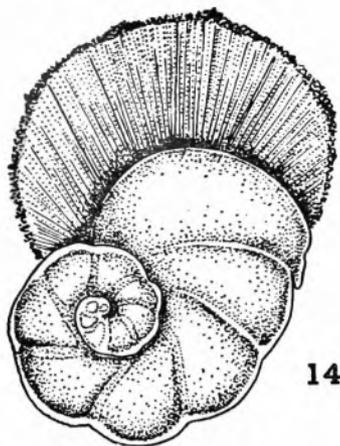
Plate 4

Fig. 14, 14, 16, 17. *Poroeponides lateralis* successive stages of formation of new chamber.

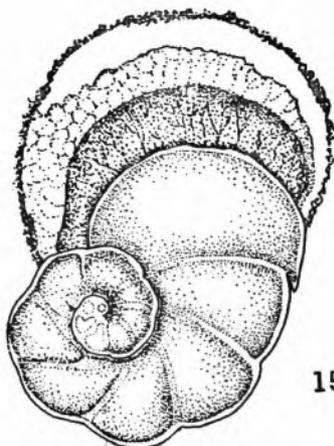
Fig. 18. Five-chambered stage of *Poroeponides lateralis*.

Fig. 19. Final stage of formation of 5th. chamber.

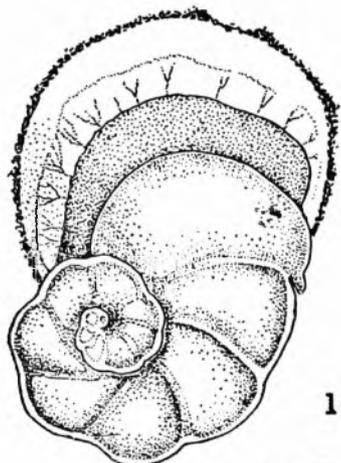
Fig. 20, 21, 22, 23. Different stages of formation of 4th chamber.



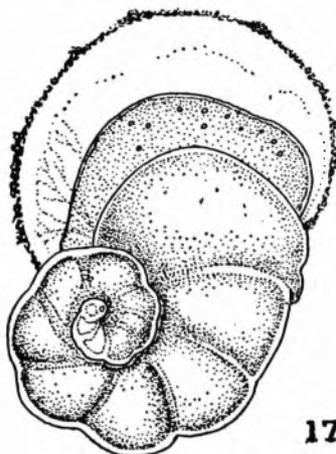
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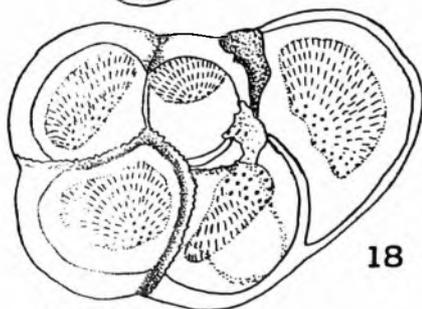
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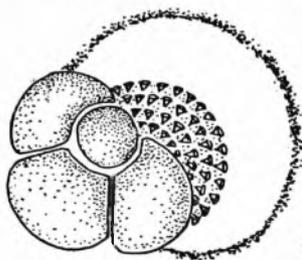
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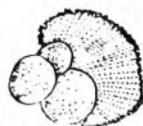
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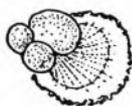
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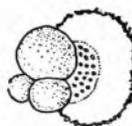
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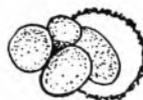
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23