ARCTIC INSTITUTE OF NORTH AMERICA

TECHNICAL PAPER NO. 13

RADIOLARIA IN PLANKTON FROM THE ARCTIC DRIFTING STATION T-3, INCLUDING THE DESCRIPTION OF THREE NEW SPECIES

By

KUNIGUNDE HÜLSEMANN

PUBLISHED DECEMBER 1963

THE ARCTIC INSTITUTE OF NORTH AMERICA

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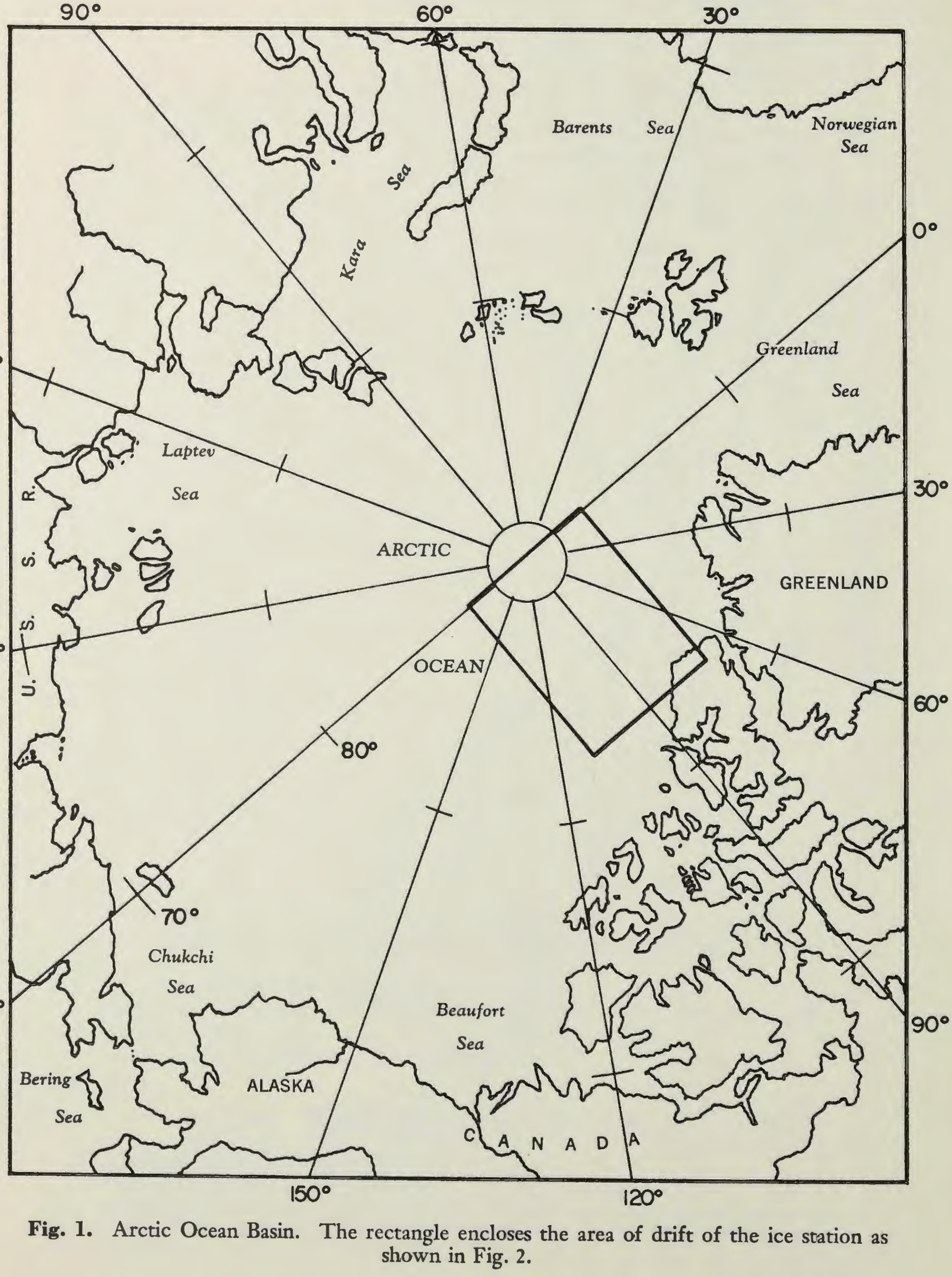

Fig. 1. Arctic Ocean Basin. The rectangle encloses the area of drift of the ice station as shown in Fig. 2.

RADIOLARIA IN PLANKTON FROM THE ARCTIC DRIFTING STATION T-3, INCLUDING THE DESCRIPTION OF THREE NEW SPECIES

Kunigunde Hülsemann*

Introduction

Little work has been done on the Radiolaria from arctic regions. Two factors are responsible for this: the inaccessibility of the area and the present neglect of this animal group by zoologists.

The first record from the Arctic is given by Brady (1878). His material came from bottom samples obtained in Baffin Bay and stations that extended to a latitude of 83° 19N., the most northerly point attained at that time. Unfortunately, the ten species of Radiolaria that Brady found have not been identified any further than to genus.

Since the turn of the century small expeditions have been made to collect plankton, mainly by Scandinavians (Jörgensen, 1900; 1905; Cleve, 1899; 1900a) and Germans (Borgert, 1901; Popofsky, 1905, 1907; Schröder, 1909; 1911; 1929), in the Greenland, Barents, and Kara seas – the seas that extend from the Atlantic Ocean. These expeditions resulted in a number of papers dealing with Radiolaria from subarctic and arctic waters.

The first collections from the Arctic Basin were taken by the Russians. Bernstein's (1932; 1934) material originates from collecting cruises in the Kara and Barents seas carried out in the years 1925 to 1929 from the icebreaker *G. Sedov,* and in the northern part of the Barents Sea (latitude ranging approximately from 76° – 80°N.) in the years 1930 and 1931 from the icebreakers *G. Sedov* and *Lomonosov.* Bernstein describes about a dozen species of Radiolaria which she interprets as being endemic forms from the Barents Sea or immigrants from the Arctic Basin.

Bogorov (1946a) describes ten species of Radiolaria from the plankton collections obtained during the drift of the icebreaker *G. Sedov* in 1937–40 while frozen into the ice pack. The collections covered an area ranging in latitude from 86° 38N. to 84° 47N. and in longitude from 73° 02E. to 28° 54E. Bogorov also used material from one station of the icebreaker *Sadko* (81° 11N., 137° 25E.). In his report on the plankton from the N-169 aircraft expedition to ice floes north of Wrangel Island, Bogorov (1946b) lists only one unidentified radiolarian.

In a report on the Russian North Pole 2 station of 1950–1 Somov (1955) lists the findings of Radiolaria for a number of stations, but to date only one species, *Porospathis holostoma,* has been identified.

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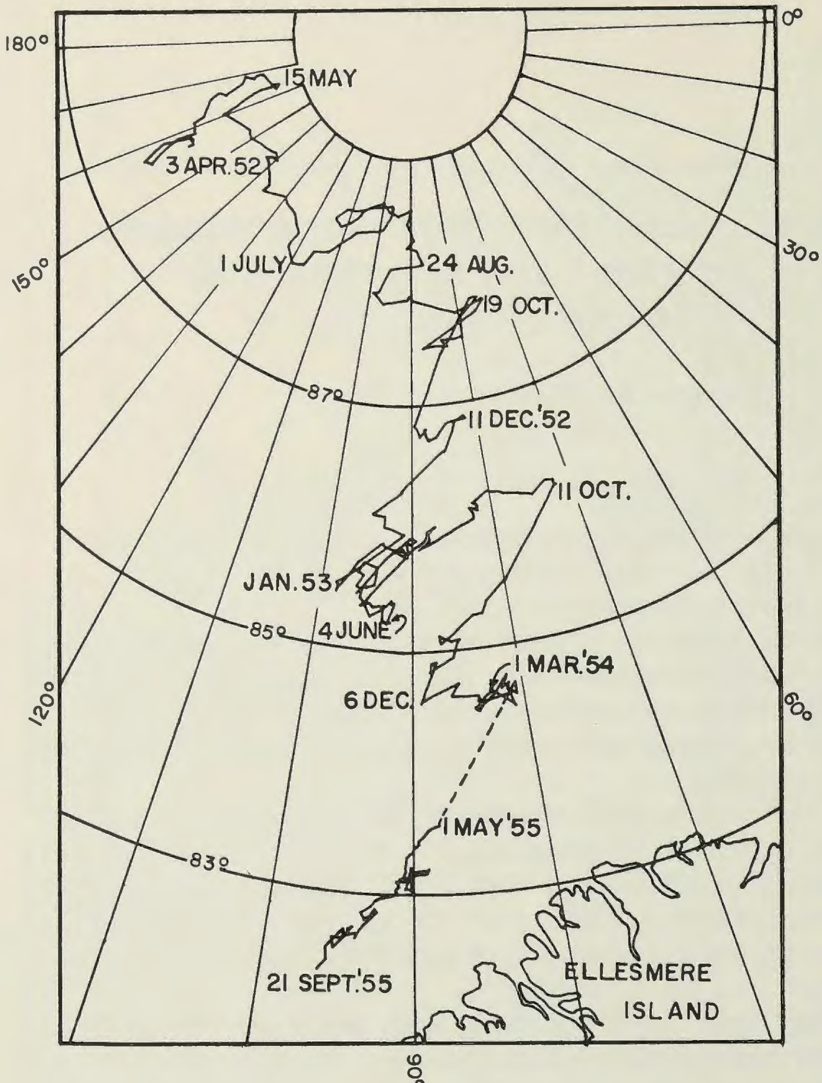


Fig. 2. Simplified track of Ice Island T-3.

Materials and methods

The Radiolaria considered here are part of the plankton collected by Charles Horvath in the years 1952–5 during three periods, totalling fourteen months, on Fletcher's Ice Island, T-3 (also known as Drift Station Bravo), making up nearly one composite year. The plankton was obtained at 26 stations in 116 tows in the Arctic Basin, about one-third of which were over the continental shelf north of Ellesmere Island (Figs. 1 and 2). The area covered ranges in latitude from 86° 53N. to 82° 40N. This is the first plankton collected from that area. Further studies are planned on systematic groups from the collection.

The tows were made vertically through holes in the ice with various types of plankton nets of a rim diameter of ½ m. (see also Mohr, 1959). A closing net was used only at stations 38, 73, 74, and 107. At most of the stations several hauls were made from various depths to the surface, generally from 200 m. to the surface and from a few metres above the sea floor (2500–430 m.) to the surface.

The plankton usually was preserved in formaldehyde and was stored in 70 per cent alcohol, to which some glycerine had been added. The Radiolaria were then sorted into vials. Permanent preparations were made of the small species (Nassellina and Spumellina) and of some representatives of the larger ones. In addition, after sorting, parts of the remaining plankton from six richer tows (stations 43.2, 46, 53, 60, 72, 87) were boiled in hydrogen peroxide to digest the organic matter and then boiled in hydrochloric acid to remove all calcareous contents. After careful washing in distilled water and settling or centrifuging, the residue was transferred to slides, dried, and mounted in Permount (see Campbell, 1954). This method added a number of smaller specimens to the ones already found by sorting. Obviously, the numbers recorded for animals found in digested samples only are unrepresentatively low.

The biological stations at which plankton tows were made are listed in Table 1. At all 26 stations radiolarians were found, though not in every haul. Fourteen hauls were brought up which did not contain any Radiolaria (12 per cent). In the quantitative considerations in this study only those 89 tows are included which contain radiolarians and for which full data are furnished (see Fig. 3). Nineteen of the tows (22 per cent) were taken with a closing net at various depth intervals; of the remaining 70 tows more than half (38 tows) were hauled from 200 m. or less, while 32 were hauled up from a few metres above the sea floor to the surface.

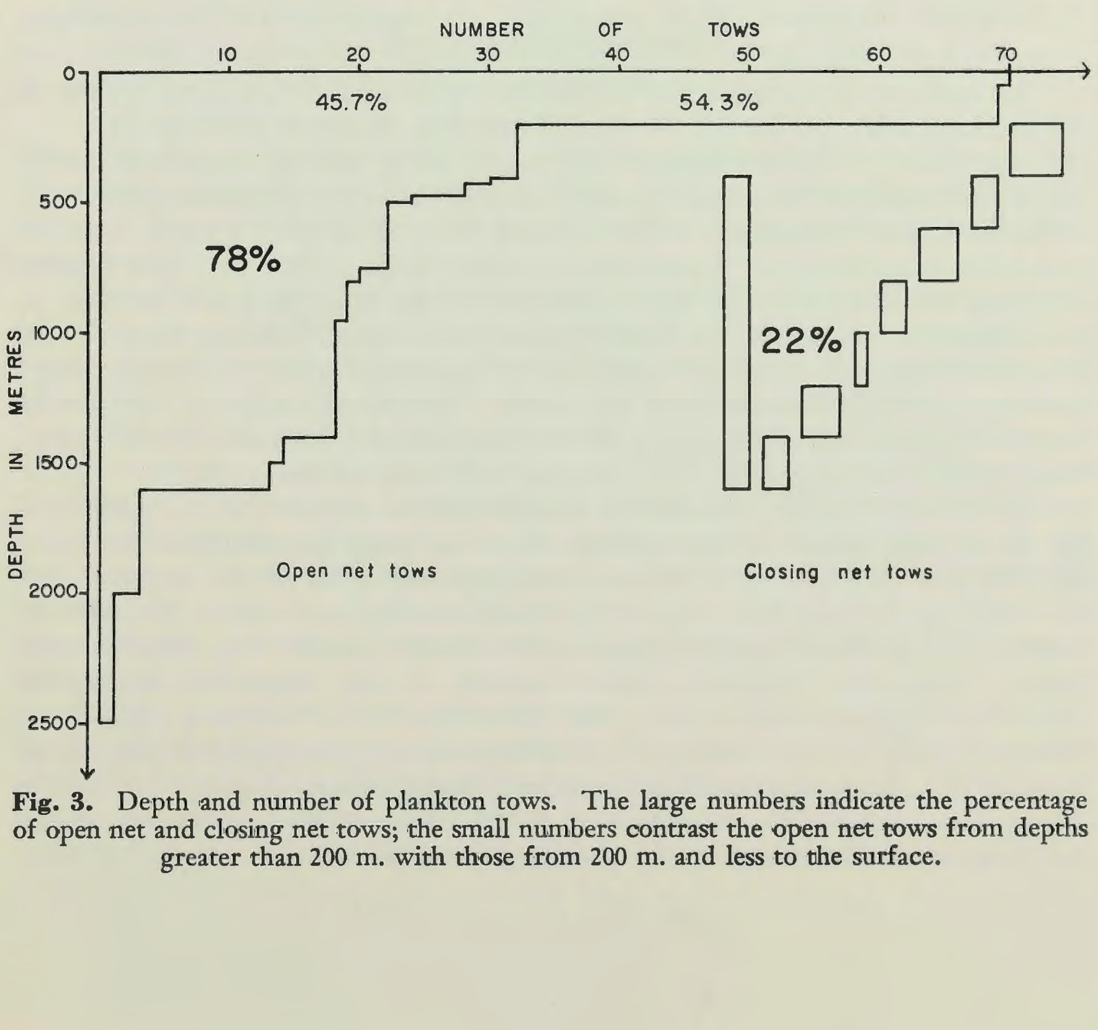


Fig. 3. Depth and number of plankton tows. The large numbers indicate the percentage of open net and closing net tows; the small numbers contrast the open net tows from depths greater than 200 m. with those from 200 m. and less to the surface.

In Table 2 the larger species are listed in relation to the depth of the tows from which they were obtained. For each species are given a) the number of individuals found, b) their percentage within the depth range, and c) the calculated number of individuals per tow. The table indicates clearly the exclusive or prevailing occurrence of some forms in greater depth (*Aulographis taumorpha, Porospathis holostoma, Coelodecas pygmaea*) or in the upper water layers (*Spongotrochus glacialis, Cannosphaera antarctica*). As might be expected, the greatest numbers of species per depth range are found in the longest water columns. This is true also for the numbers of individuals per tow, even if there is not a continuous transition from depth zone to depth zone.

Although samples were obtained in winter (December–January), in spring (April–May), and during summer (May–August), they are not easily comparable. It was only in the first period (winter), when the ice island was closest to the north pole, that hauls were taken from depths as great as 2000 and 2500 m. to the surface. In spite of these being the longest water columns sampled, they are the poorest in number of specimens. It was interesting that the poverty of the plankton in this area was also shown in the material collected with an automatic sampler during the cruise of the atomic submarine *Seadragon* under the polar ice (Grice, 1962). The spring and summer periods of plankton collecting from the ice island showed great improvement; the hauls did not, however, reach deeper than 1600 m. About one-third of these stations are situated above the continental shelf, a fact which has also been kept in mind when drawing the conclusions reported here.

Oceanographic setting

In order to understand the distribution of the species, a brief review of the oceanography of the area of this collection is necessary (see Fig. 1).

Sea floor. The area covered by the drifting station extends from the continental shelf off northern Ellesmere Island nearly to the north pole. The continental shelf continues for 100 km. out from shore with a water depth of about 500 m. at the edge. From there the slope drops to 1700 m. The increase of depth continues towards the deeper part of the basin to a low of 2700 m. In a distance of about 525 km. from shore a gradual rise of the sea floor to 1500 m. is followed by a relatively rapid one to the extensive Marvin Ridge, which has a rather abrupt escarpment to the north. This ridge is south of and parallel to the Lomonosov Ridge, from which it is separated by a valley about 50 km. wide (for details see Crary and Goldstein, 1957, and Green, 1959).

Currents. The drift of the ice island in the main followed the pattern of the surface currents. In this region a clockwise eddy extends from the Beaufort Sea probably almost to the pole, although velocities in the northern part are likely to be very low. A shallow current also flows north through the narrow Bering Strait into the Chukchi Sea where it mixes with Siberian shelf water. Occupying an upper stratum between 75 and 100 m., this Bering Sea water may be traced to the north pole (Brodskiy, 1956; Coachman and Barnes, 1961). Finally, one branch of the mighty submarine current, which carries most of the Atlantic water into the Arctic Basin, moves through our area in the region of the north pole on its way to the Beaufort Sea. Even there it still makes up a considerable part of the entire water mass.

Temperature. The temperature of the Arctic Ocean water in which the ice island drifted does not vary greatly, ranging between 0.52°C and –1.74°C. The Arctic Basin contains three distinct water masses: 1) The surface layers. Here the coldest temperatures were measured, and seasonal changes had little effect. Where present, the Bering Sea water could be recognized by a shallow temperature maximum, separating the cold surface water from the deeper Atlantic water. 2) The intermediate layer of Atlantic water, shown by positive temperatures, was found at a depth from about 244–818 m. 3) The bottom water with temperatures down to –0.41°C (Worthington, 1959) is also of Atlantic origin, but apparently forms only under special circumstances in the Norwegian Sea (see Coachman and Barnes, 1961).

Salinity. The salinity is uniform at all ice island stations below 500 m., being between 34.7 and 34.99‰ (Worthington, 1959). The salinity of the surface water is much reduced because of the influx of fresh water from the land masses surrounding the Arctic Ocean and from melting snow.

Light. During the summer months there is a considerable melting of pack ice which allows more light to penetrate the ocean. Consequently, there is an increase in phytoplankton followed by an increase in the amount of zooplankton (Shirshov, 1944, quoted by Green, 1959).

Ecology

Ecological considerations are given little room in earlier publications; most authors emphasize only the describing of the species collected. Although it is impossible as yet to determine the boundaries of the habitat for the species in our material, it is possible to give their geographical range, and this is indicated in Table 3 and discussed in the taxonomic section.

Table 3 shows that the majority of the species composing the radiolarian fauna is arctic or arctic-boreal. A somewhat smaller number is cosmopolitan. Four species are known to occur in both arctic and antarctic waters only. There is not enough information to place some of the species in these three categories.

The depth distribution of each species is reported in the taxonomic section of this study. Definite depth zones are indicated for most of the species. The upper layers (down to 200 m.) are inhabited by *Cannosphaera antarctica* and *Spongotrochus glacialis*, both of which are found in much smaller numbers from 400–200 m., and probably *Aulastrum spinosum.* The few findings of *A. spinosum* in this collection, which come from open net tows from various depths to the surface, do not indicate its living zone. However, information from earlier workers suggests that the species should be encountered in the upper zones. In the deep zone are found most of the *Aulacantha scolymantha, Aulographis taumorpha, Porospathis holostoma,* and *Coelodecas pygmaea.* The other species collected occurred in such small numbers that they could not be included in either group.

Riedel (1958) worked on bottom samples from the vicinity of the Antarctic continent and near the Kerguelen Islands. He correlated the frequency of occurrence and number of species with the increasing depth of the water at the respective stations. The number of samples available did not permit definite conclusions as to the ecology of the species; however, it was sufficient to permit suppositions that "(1) the majority of the species which are found consistently in the shallower samples are either restricted to Antarctic waters or have a bipolar cold-water pattern of distribution. . ." and "(2) many of the species which are apparently cosmopolitan are found only in the deeper samples . . ." (p. 222).

These hypotheses can equally be applied to the arctic species. Apparently there are two groups of species in the polar regions: one which lives in the cold upper layers, and the other, with a wider distribution in warmer oceans, which inhabits the slightly warmer layers of water at greater depth.

It is known that the density and viscosity of water increase with the depth. In less dense water there is reported to be a tendency for the forms to build small, spherical skeletons or long spines to enable them to keep afloat more successfully. In deep waters the forms, in turn, are believed to develop large skeletons and odd shapes (compare Haecker, 1908). This hypothesis may apply to some species from the upper water layers, including *Spongotrochus glacialis*, the nasselline radiolarians with long spines such as *Plectacantha oikiskos*, *Phormacantha hystrix*, and *Botryopyle setosa*, also *Cannosphaera antarctica*, which is more or less spherical. On the other hand, the majority of the deep-water nassellines and *Cadium melo* have compact and elongated shells. Thus, our findings do not fully support the hypothesis.

The size of eurythermal species appears to be smaller in the Arctic Ocean than in other, warmer waters. Among such species in this collection are *Sphaeropyle langii*, *Tetraphormis rotula*, *Aulographis taumorpha*, and *Cadium melo*; *Aulacantha scolymantha* was present exclusively as the delicate form *typica*. The only species larger than described earlier is *Tetraphormis triloba*. Popofsky (1908, p. 199) also mentions that antarctic animals of certain eurythermal species are frequently smaller than examples from warmer seas.

The present arctic planktonic fauna is composed of various elements. The influx of Atlantic and Pacific waters supplies the plankton of the central Arctic Basin with species mainly confined to these particular water masses and thus at characteristic depths. Although a particular water mass may become unrecognizable as such after moving for hundreds of miles, the species carried along may still be alive and intermingle with the local fauna. Our collections of the Radiolaria discussed below clearly show their relations to the adjacent oceans.

Taxonomy

In this report Campbell's (1954) system of radiolarian classification is followed except for the subfamily Spongopylinae Dreyer which is not separated here (see *Spongotrochus glacialis*). The type specimens of the three new species will be deposited at the Smithsonian Institution, United States National Museum, Washington.

Suborder Acantharina Haeckel, 1862

Acantharina were found in many plankton samples and usually occurred in numbers. Unfortunately they were not recognized at the beginning of the sorting because of their small size and their softness.

There were two species of *Acanthometron* J. Müller, 1855 (Astrolonchidae), and one species of *Litholophus* Haeckel, 1862 (Litholophidae). One of

Fig. 4. *Litholophus* sp. Distal end of spine.

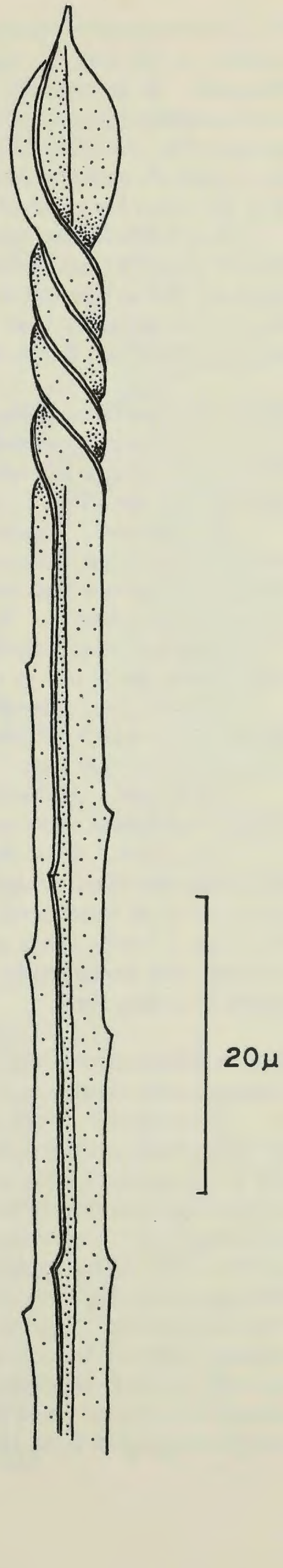
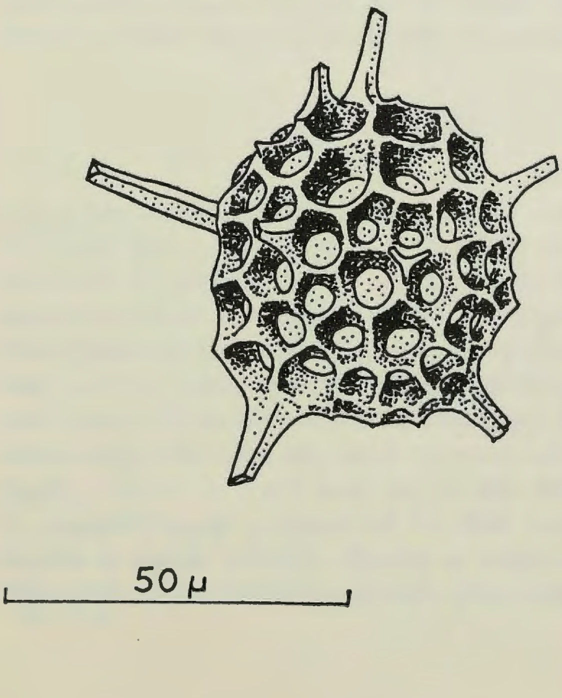


Fig. 5. *Haliomma* sp. The inner shell is not shown.



the *Acanthometron* species has very thin, long, smooth, cylindrical spines which appear to be soft; it may be identical with the cosmopolitan *A. elasticum* Haeckel. It is unlikely to be the very similar *A. pellucidum*, because the characteristic bifurcate distal ends of the spines were not observed. The spines of the other *Acanthometron* species are thicker, and the specimens may be identical with *A. cylindricum* Haeckel of the Central Pacific Ocean. This species was the most frequent of the three acantharians.

The *Litholophus* species has about fourteen quadrangular spines, two of which are 0.785 and 0.920 mm. long and 0.004 mm. wide. Distally the very ends of the spines are twisted and slightly thickened (Fig. 4); the edges of the spines seem to bear scattered small wings. The conical central capsule encloses the basal 0.015–0.020 mm. of the spines.

Suborder Spumellina Ehrenberg, 1875
Family Astrosphaeridae Haeckel, 1882
Genus Haliomma Ehrenberg, 1838
***Haliomma* sp.** (Fig. 5)

Description. There are two concentric shells, the outer one of which is thick-walled with hexagonally-framed circular pores of slightly different size. The inner sphere has small roundish pores. The two spheres are joined by slender radial beams. Eight three-bladed radial spines are irregularly distributed on the outer shell. These spines originate from nodal points on the outer shell, probably as continuations of the beams connecting the two shells.

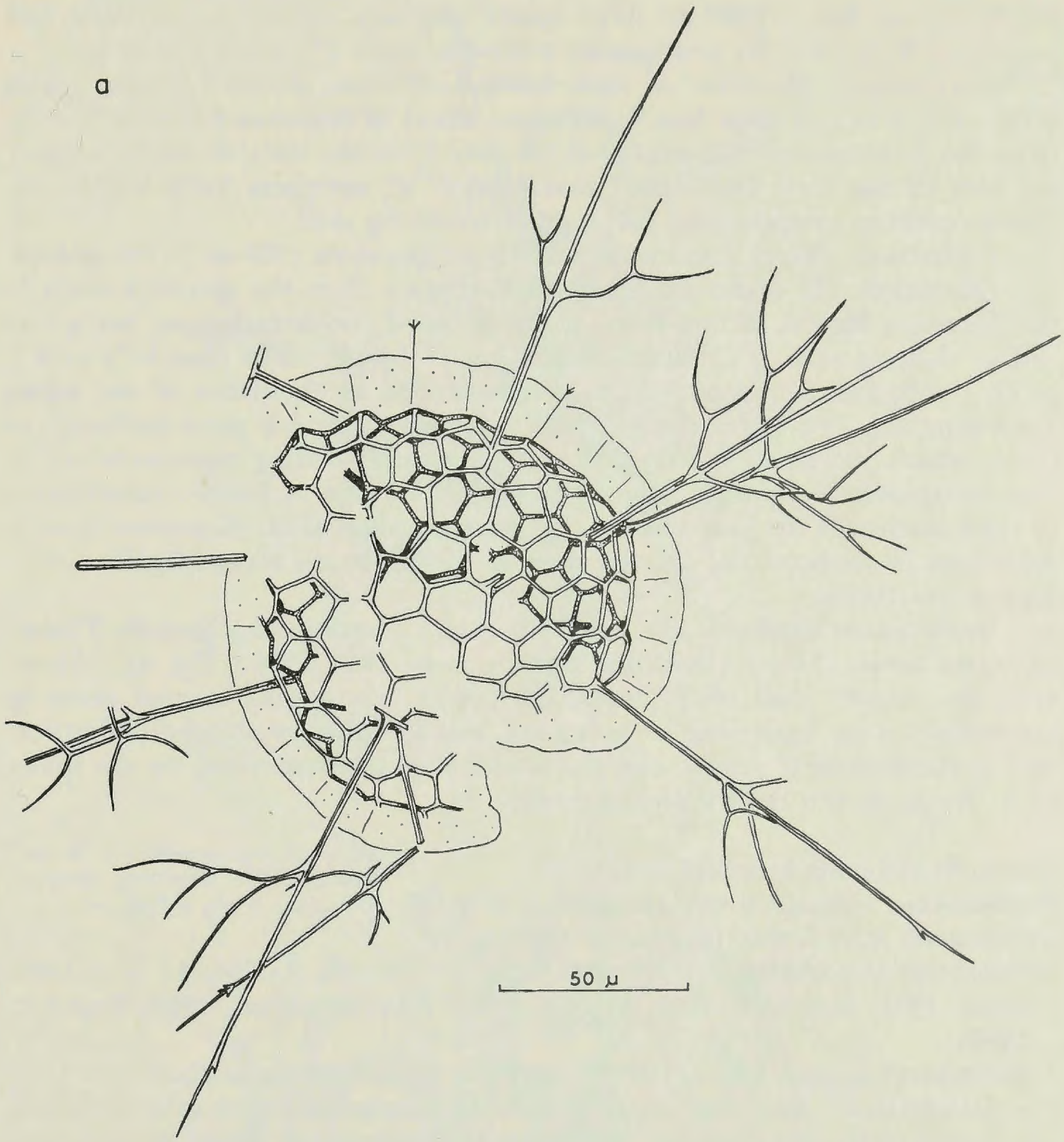
Dimensions. Diameter of outer shell 0.045 and 0.048 mm., of inner shell 0.016 mm.; width of pores in outer shell 0.003–0.007 mm.; basal breadth of spines 0.005–0.007 mm.

Collection. Arctic Ocean, station 31; one specimen, 1400 m. to the surface. The radial spines were broken short.

Discussion. The dimensions of this specimen correspond with those of *H. minutum* Mast, which has 12 spines (outer shell 0.04 mm., inner shell 0.02 mm., pores in outer shell 0.004 mm.; Mast, 1910). However, the arctic specimen has a fairly thick outer shell the round pores of which are funnel-like, sunken, and hexagonally framed, whereas *H. minutum* has only simple round pores in a thin shell.

Genus Cladococcus Müller, 1856
***Cladococcus leptus* sp.n.** (Figs. 6 a, b)

Description. Very delicate form. The spherical lattice shell is composed of polygonal, mostly hexagonal meshes of slightly different size, not rounded off at the corners as in other members of the genus. The bars of the shell are cylindrical and mostly straight. There are 8 (–10) straight three-bladed main spines, evenly distributed over the shell, each one originating at a nodal point of the shell. The spines taper gradually and end as fine points. At the base of each spine the three edges continue for a short distance on to the three bars that meet there. About one-third of the distance from the base of a spine three slightly curved branches diverge from the edges and form a whorl. Each branch divides dichotomously at about half of its length. In a distance of about four-fifths from the base of a spine a whorl of three dents is found originating again from the edges. Short, very fine by-spines stand in the nodal



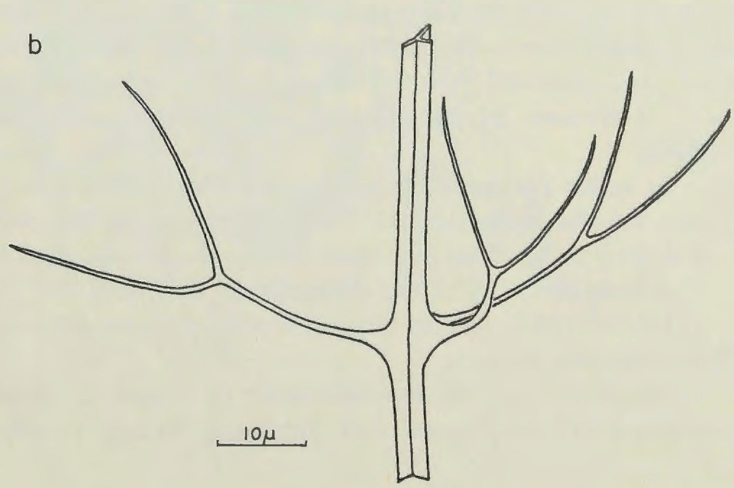


Fig. 6.
Cladococcus leptus sp. n.
a) Entire animal; b) Part of a spine with whorl of branches.

points of the shell where no large spines originate. They are straight and project little beyond the protoplasm, ending in three (?) small branches.

Dimensions. Diameter of shell 0.090–0.100 mm.; length of main spines 0.128 mm., width of their base 0.003 mm.; whorl of branches 0.040–0.050 mm. from the shell; second whorl 0.103–0.109 mm. from the shell; width of tangential bars of the shell 0.002–0.003 mm.; length of by-spines 0.020–0.022 mm. The protoplasm extends about 0.015 mm. beyond the shell.

Collection. Arctic Ocean, station 39; one specimen, 1400 m. to the surface.

Discussion. C. leptus is clearly distinguished from the species known in the literature by the dichotomous ramification of the branches on the spines and its delicate shell. This new species has to be placed in Haeckel's (1887, p. 225) subgenus *Cladococcodes* which is defined as "branches of the spines again ramified. Pores regular . . . similar form". There is some similarity to forms which Jörgensen (1900) described as possibly young representatives of *Arachnosphaera dichotoma.* But since there is no sign of further ramification of the branches of the new species, and since the shell of *A. dichotoma* is only 0.060 mm. in diameter, the one specimen in the collection is not identified with Jörgensen's forms.

Some distant similarity also exists between *C. leptus* and a juvenile *Thalassoplegma tenuis* (Mast) (Hollande and Enjumet, 1960, Pl. 50, Fig. 6). However, the (inner) shell of *T. tenuis* has round, hexagonally-framed pores in comparison with hexagonal or polygonal meshes built by slender cylindrical bars in the shell of *C. leptus;* also the branches of the first whorl on the spines of *T. tenuis* do not ramify dichotomously.

Genus Echinomma Haeckel, 1862

***Echinomma leptodermum* Jörgensen** (Fig. 7)

Echinomma leptoderma Jörgensen, 1900, p. 57

Echinomma leptodermum Jörgensen, 1905, p. 116, Pl. 8, Figs. 33 a–c; 1907; Gran, 1902; Schröder, 1909; Mielck, 1911; 1913; Bernstein, 1934; Bogorov, 1946a

? Actinomma borealis Cleve, 1899, p. 26, Pl. 1, Figs. 5 a, b (*non idem* c)

Description. The shell consists of three concentric lattice-spheres, which are connected by radial beams. The two outer spheres are spherical, the innermost is somewhat irregular. The outermost shell is thin walled with roundish polygonal pores of very uneven size. Beginning with the second sphere, the 8–15 radial spines are three-bladed, about as wide inside as outside the third shell, and pointed. In addition, on the outer sphere there are three-bladed, pointed shorter by-spines; they are less numerous and seem sometimes to be lacking.

In some (young) specimens the outer shell is indicated by transverse processes on the radial spines. The specimen in Fig. 7 is in a somewhat further developed stage than Fig. 33c (Pl. 8) in Jörgensen (1905).

Dimensions. For the dimensions see Table 4.

Collection. Arctic Ocean, station 53; one adult and one juvenile specimen, 200 m. to the surface.

Distribution. E. leptodermum is found in northern moderate and cold waters, south to Faeroe and Shetland islands, in the Greenland Sea, and the

Fig. 7. *Echinomma leptodermum.* Juvenile specimen.

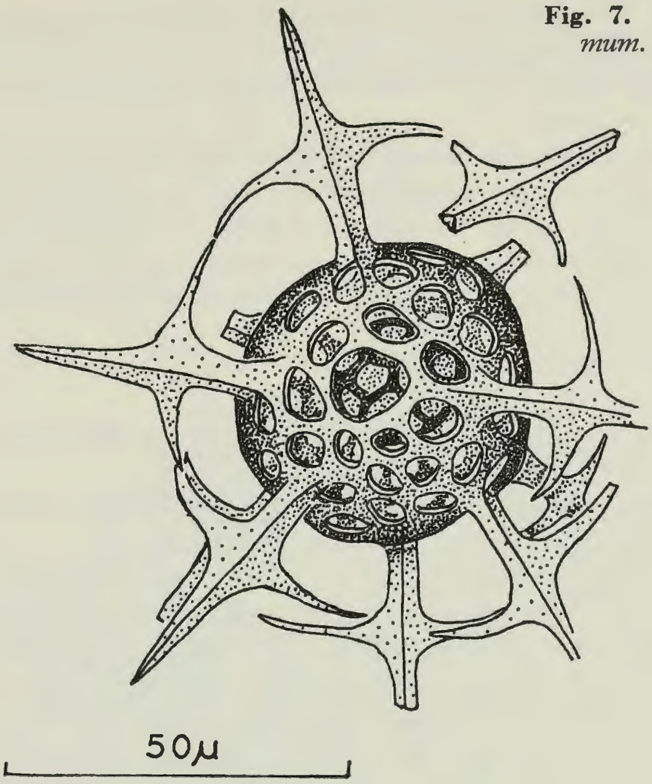
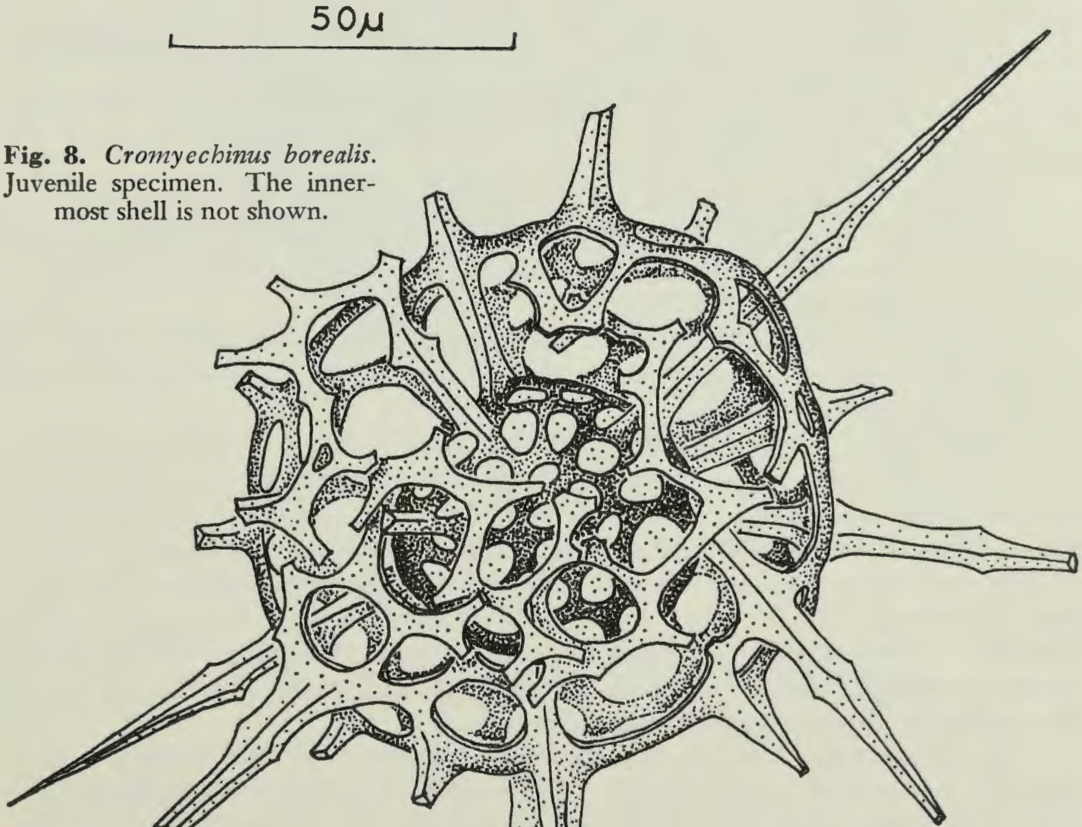


Fig. 8. *Cromyechinus borealis.* Juvenile specimen. The innermost shell is not shown.



northern Kara Sea. Bernstein (1934) found it at moderate depths, down to 420 m., in the northern Kara Sea; she concluded that the species was an immigrant from the Arctic Basin. This view was supported when Bogorov (1946a) found it in the Arctic Basin.

Discussion. As Jörgensen remarks, a specimen consisting of two shells and only a vestigial third one might equally well be assigned to the genus *Actinomma* (without by-spines on the third shell) or *Haliomma* (with only two shells). However, its measurements, which correspond to the description of the species, may justify a classification as *Echinomma leptodermum.*

Genus Cromyechinus Haeckel, 1882

***Cromyechinus borealis* (Cleve)** (Fig. 8)

Actinomma boreale Cleve, 1899, p. 26, Pl. 1, Fig. 5c (*non idem* a, b); 1900

Chromyomma boreale Jörgensen, 1900, p. 59; Gran, 1902

Chromyechinus borealis Jörgensen, 1905, p. 117, *partim*, Pl. 8, Fig. 35, Pl. 9, Figs. 36, 37 a, b (*non idem* c, d); Mielck, 1911; 1913

Cromyechinus borealis Schröder, 1909

Description. The shell consists of four concentric lattice-spheres connected by radial bars. The outermost shell is very delicate. It may, however, be indicated only by transversal processes on the radial spines of the third shell (Fig. 8). There are both three-bladed, pointed mainspines and by-spines in the third shell as well as on the fourth shell. The dimensions of the second and third shell are very close to the corresponding ones of *Echinomma leptodermum.* The pores of the fourth shell are usually small and roundish like those of the second shell. The pores of the third shell are very uneven, roundish and oblong.

Dimensions. For the dimensions see Table 4.

Collection. Arctic Ocean, station 46, one incomplete specimen; stations 60, 72, each one adult specimen; 1500 and 1600 m. to the surface. This is the first record from the Arctic Ocean.

Distribution. *C. borealis* was reported earlier from deep Norwegian and Spitsbergen waters and from near surface waters on the American side of the Atlantic (Jörgensen, 1905).

Discussion. Jörgensen describes two series of forms in *C. borealis*: one has shorter, broader spines, the other one longer, more slender spines and a pylome in the outer shell. A pylome is a considerable opening on one side of the outer shell where the nearest spines and by-spines are particularly long. Within each series there are many variations, and Jörgensen considers that there may be several closely allied species. Evidently he was not familiar with Dreyer's (1889) study on pylomatic radiolarians. According to this paper the series with pylome should be placed in the genus *Sphaeropyle* Dreyer within the subfamily Sphaeropylinae (see *S. langii*).

The forms Riedel (1958) identified as *Actinomma imperfecta* are probably very closely related to *C. borealis.* He includes two-shelled specimens with only indications of a third shell and four-shelled specimens in this species. Both his Fig. 5 (Pl. 1) and the dimensions of *A. imperfecta* suggest that at least the four-shelled forms—and those three-shelled ones with a beginning fourth shell—were identical with *C. borealis.* However, Riedel specifies that the spines of the fourth shell represented "prolongations of at least some of the rods connecting it with the third shell." In other words, there are less spines on the outside of the fourth shell than bars on its inside. In the specimens from the Arctic, there are more spines with every shell, including the fourth shell.

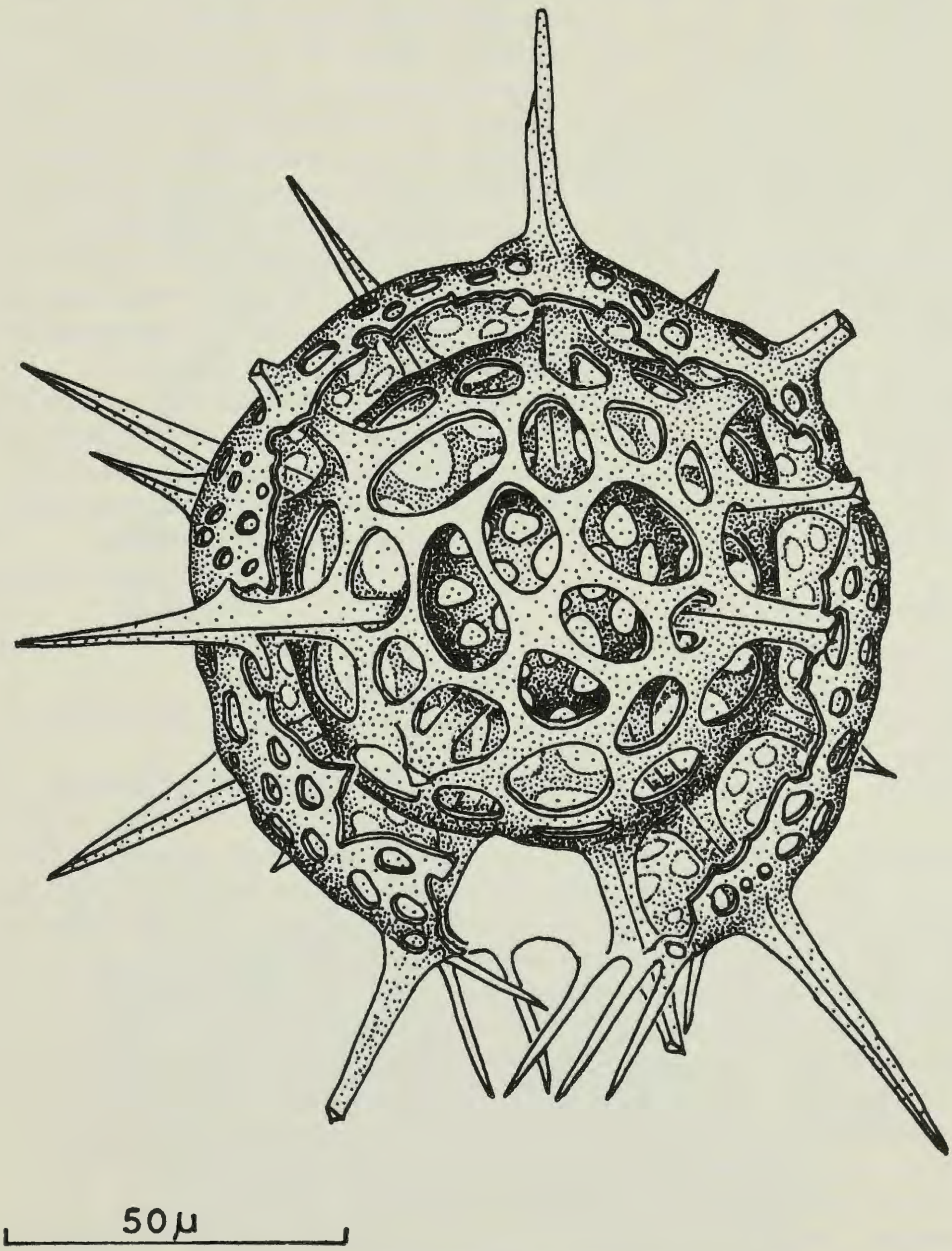


Fig. 9. *Sphaeropyle langii.* The innermost shell is not shown.

Genus Sphaeropyle Dreyer, 1889

Sphaeropyle langii **Dreyer** (Fig. 9)

Sphaeropyle langii Dreyer, 1889, p. 89, Pl. 9, Fig. 54

Chromyechinus borealis Jörgensen, 1905, p. 117 *partim*, Pl. 9, Figs. 37 c, d (*non idem* a, b, Pl. 8, Fig. 35, Pl. 9, Fig. 36)

Description. As *Cromyechinus borealis,* except that the fourth shell has a pylome (Fig. 9).

Dimensions. For the dimensions see Table 4.

Collection. Arctic Ocean, station 96; one specimen, 200 m. to surface. This is the first record from arctic waters.

Distribution. The specimens of Dreyer (1889) come from the sea floor of the Central Pacific and the southern North Pacific from depths of 2300 and 2900 fathoms. Jörgensen's (1905) material is from Norwegian waters.

Discussion. Jörgensen describes under the name of *Chromyechinus borealis* two series, one of which has a pylome in the fourth shell (see also *C. borealis*), ignoring Dreyer's (1889) classification of pylomatic forms as *Sphaeropyle* Dreyer. The only four-shelled *Sphaeropyle* of Dreyer (1889) is *S. langii.* By-spines are neither mentioned in his description nor in his Fig. 54 (Pl. 9); mainspines are only very few. There are hints in the figure that the spines are also three-bladed. Jörgensen (1905) says, however, by-spines were rare in his material. The diameter of both the third and fourth shells of our specimens are larger than in Jörgensen's description of *C. borealis* (see Table 4).

Although the descriptions of one of the series of *C. borealis* and *S. langii* do not correspond completely, both are united here as *S. langii.* The separation of the pylomatic forms as a systematic group might be disregarded as is proposed in this paper for *Spongotrochus glacialis.* However, as only one specimen of *Sphaeropyle langii* was found it is better to postpone a decision.

Family Spongodiscidae Haeckel, 1882

Genus Spongotrochus Haeckel, 1860

***Spongotrochus ? glacialis* Popofsky** (Figs. 10, 11)

Spongotrochus glacialis Popofsky, 1908, p. 228, Pl. 26, Fig. 8, Pl. 27, Fig. 1, Pl. 28, Fig. 2; 1912

Spongotrochus ? glacialis Riedel, 1958, p. 227, Pl. 2, Figs. 1, 2, Text-Fig. 1, *partim*

Description. The lenticular-discoidal shell is of spongy structure. The disc has a coarse surface, built of circular or subcircular meshes of different size. On the margin and in most specimens on both sides of the disc there are irregularly distributed solid spines of varying length between which are considerably smaller spines. In some specimens there are very few or no small spines. The disc can occur with or without pylome.

Dimensions. The dimensions of the arctic specimens of *S. glacialis* measured (90 animals) are recorded in Table 5, which also includes the measurements given by other authors. It will be seen that the measurements of the arctic specimens show a greater variation than those given by Popofsky (1908) for antarctic ones, probably because of the larger numbers collected.

Collection. Arctic Ocean, stations 5–107; more than 2,000 animals. In the tows up to the surface the animals occurred in rather regular numbers. In the closing net tows a preference for the upper water layers down to 400 m. is evident; at depths below 400 m. only single animals were taken.

Distribution. S. glacialis has been reported from antarctic waters and the South Atlantic at depths from 400 m. to the surface and in bottom samples.

Discussion. S. glacialis was the most abundant species in the arctic material. The specimens were present in all stations except station 3, the first at which plankton was collected. In that haul the only radiolarian was a *Porospathis holostoma*, and I suspect that the poor contents were the result of poor techniques rather than a real absence of other animals.

Fig. 10. *Spongotrochus ? glacialis*. Abnormal spines.

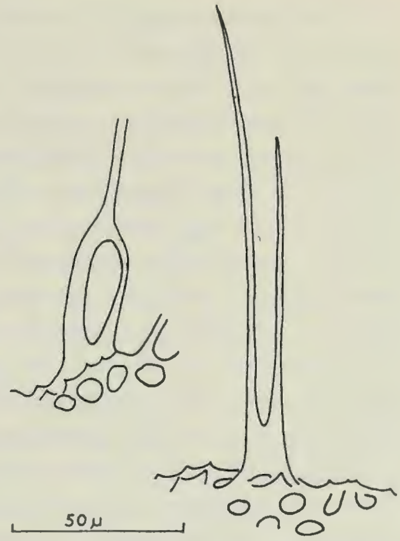
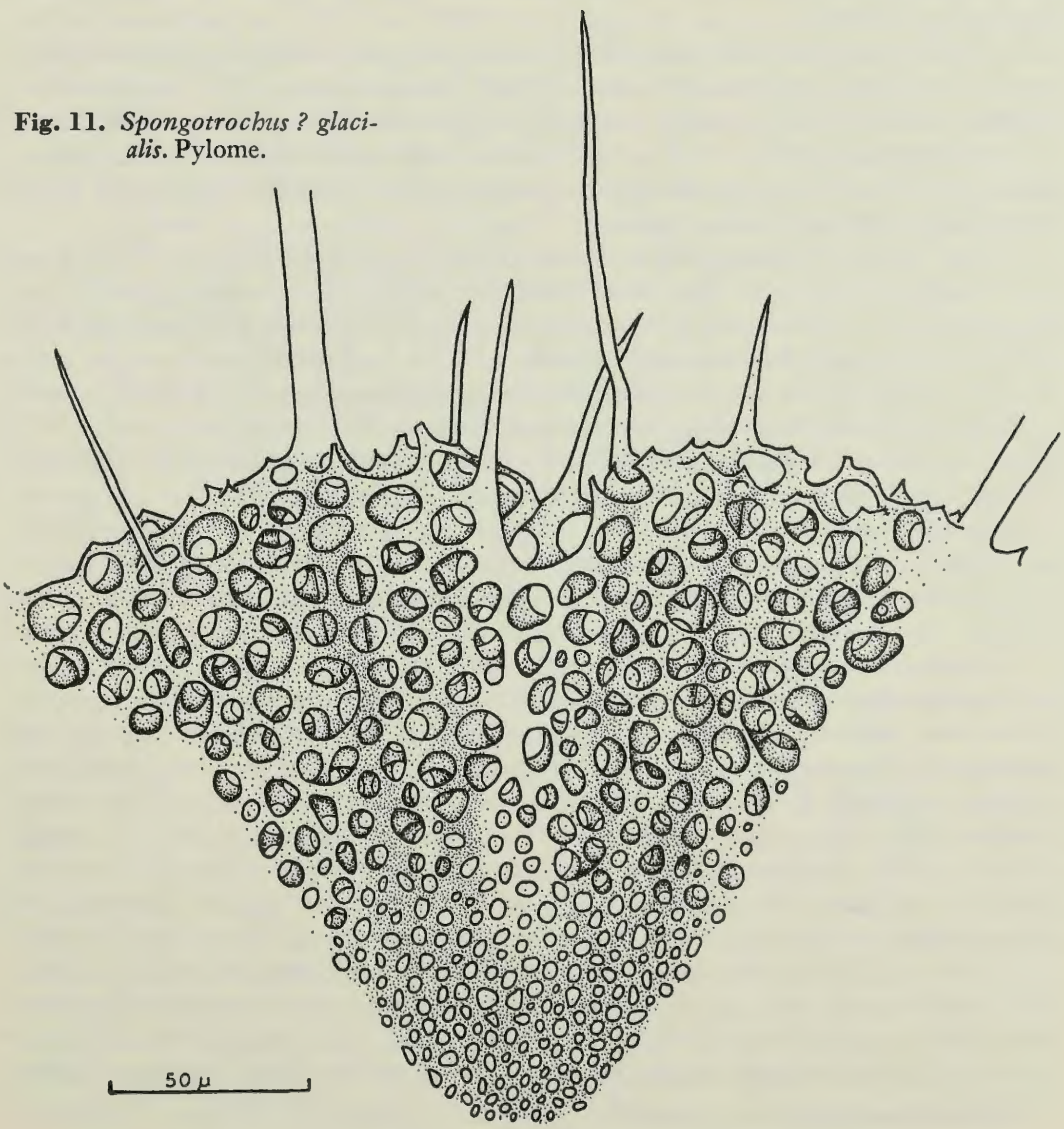


Fig. 11. *Spongotrochus ? glacialis*. Pylome.



It was not easy to identify these specimens with species already known to science. Apparently there is a wide variation in some of the species of the spongodiscids and without doubt there are transitional forms. All the specimens found have to be placed in the subfamily Spongotrochinae, defined as being equipped with solid spines. None lacked spines completely.

The most significant characteristics of *S. glacialis* as they appear in our samples are the number and length of the spines and their distribution on the disc. Twenty-five per cent of the specimens (of 90 measured) have spines only on the margin, the rest have them also on both sides of the disc. The former could be assigned to Popofsky's (1908) *Stylospongia arachnia* (= *Stylotrochus arachnius*) in spite of some basal teeth or wings on the spines in his figures. He mentions these only in the description of *Spongotrochus glacialis* as juvenile characteristics. However, apart from the distribution of spines on the disc, both forms are so much alike in other characters that it seems admissible to unite them in one species, *Spongotrochus glacialis*, as Riedel (1958) has suggested. Therefore the phrase, "On the margin and in most specimens on both sides of the disc there are . . . spines" has been embodied in the description.

The arctic specimens have from 5–16 larger spines, 9 being the commonest number with the odd numbers outweighing the even ones. The length of the larger spines does not usually exceed the diameter of the disc. Most of the spines continue within the disc, and some of the radial bars are recognizable through the meshes up to the darker central part. In about 15 per cent of the specimens there are no by-spines.

The arctic specimens are most similar to Popofsky's Figs. 1 (Pl. 27) and 2 (Pl. 28) (1908) from the Antarctic. He found more larger spines, 13–20 or more, and considers the occurrence of only a few small spines as a juvenile characteristic and a feature of *S. glacialis*. In his *S. glacialis*, however, he notes that the length of the spines, unlike the arctic specimens, was as great or greater than the diameter of the disc; his measurements of *Stylospongia arachnia* (1908, Table 5) are more similar to those of our specimens. By contrast Haeckel's (1862, 1887) measurements for warm-water forms give the disc as smaller, possessing spines 2–4 times as long as the diameter of the disc. The majority of Riedel's specimens from the South Atlantic (1958) had rather short spines.

Another significant characteristic of *Spongotrochus glacialis* is the so-called pylome, a kind of funnel-like opening in the disc, which is present in about two-thirds of the specimens from the Arctic. In half of these it is more or less inconspicuous and in half it is very distinct. The pylome is generally a narrow radial tube tapering into the dark central part of the disc and ending with an opening in the margin which is often surrounded by longer spines, sometimes slightly inclined to the pylome. The tube appears as a transparent radial channel (Fig. 11). The function of the pylome is unknown; so is its origin. Dreyer (1889) assumes that the protoplasm flowing in a radial direction produces the pylome and strengthens the radial bars preventing the development of a spongy texture and resulting in the transparency of this part of the disc.

Stöhr (1880) is the first author to mention a pylome in a spongodiscid. He found it only once, in *Stylospongia craticulata* (=*Spongotrochus craticulatus* Stöhr). Haeckel (1887) did not find it in other specimens which he identified with that species and considered it as an anomaly[1]. Dreyer (1889)

[1]Haeckel used the word osculum.

made an extensive study of the pylomatic radiolarians. In it he described several spongodiscids with pylomes for which he added the new subfamily Spongopylinae to the three existing ones. Its definition is simple: Spongodiscidae with pylomes. The only genus as yet is Spongopyle, with one pylome. In two subgenera Dreyer distinguished between animals with a circular and those with an elliptical or oval disc.

If Dreyer's separation of the pylomatic spongodiscids is ignored, which I feel it should be, the pylomatic species can easily be assigned to already known genera of two of the earlier three subfamilies, the Spongodiscinae (Spongophacida Haeckel) without spines and the Spongotrochinae (Spongotrochida Haeckel) with solid spines.

Riedel (1958) did not mention a pylome when describing *Spongotrochus ? glacialis*, neither did Popofsky (1908). However, if one tries to see a pylome in Popofsky's illustrations, one could be suspected in his *Stylospongia arachnia* in both Figs. 5 and 6 (Pl. 26), in the sector between 4 and 5 o'clock on a dial.

In our arctic material the two-thirds of *Spongotrochus glacialis* specimens with a pylome look just like the one-third without it. Both groups are found in the same samples. Dreyer (1889) also reports that he found every grade of transitional form between those with and without pylome, but he names the end-forms as new species in two different subfamilies (*Spongotrochus antarctica* and *Spongopyle setosa*). He admits that these forms would have to be understood not as juvenile stages but as variations of the very same adult form (p. 192), and on p. 195 confirms that some forms may at one time be developed with a pylome and at another without. He even writes that the development of a pylome is a phenomenon which can occur independently in the same way at different places in the system (p. 116). In spite of these facts he explains his establishing of several new species on the grounds that formation of species is going on at present and that when the intervening varieties die out the separation will have taken place (p. 193).

The writer cannot accept this thesis and considers the different forms with and without pylome as variations of the very same species. This belief might be extended to the genus *Schizodiscus*. Dogel' (in Dogel' and Reshetnyak, 1952) described three new species with pylome for which he established a new genus, *Schizodiscus*. Dogel' placed it in the family Porodiscidae Haeckel (now Euchitoniidae Haeckel emend. Campbell), the concentric-chambered rings of which are mentioned as visible only in the area of the pylome; in the figures, however, they are not recognizable. It would appear more reasonable that these species were simply pylomatic forms of non-pylomatic species, and that the genus *Schizodiscus* should be eliminated.

Spongotrochus glacialis is apparently a widely variable species. Riedel's specimens from the South Atlantic (1958) described as *Spongotrochus ? glacialis*, which occurred in great numbers in his bottom samples, differ in two marked respects from our arctic specimens. The central area of the disc is pronouncedly thickened in both Riedel's descriptions and figures, which is not the case in the arctic specimens or those from the Antarctic (Popofsky, 1909). The specimens from the North Pacific, mentioned by Riedel (p. 228), may come closer to those from the Arctic. Riedel also found a lenticular lattice-shell enclosing the spongy disc in a number of specimens. No such lattice-shell was observed in the Arctic, nor is there any known genus that has developed such a structure. The spongodiscids are expressly described as never being covered with porous plates (Haeckel, 1887, p. 573). Riedel has little doubt that those forms with lattice-shells are the completely developed individuals; the less developed, and at the same time more common ones, he treats as possible "juvenile" representatives of *S. glacialis.* He has avoided making nomenclatural changes, which he believes may be necessary with more thorough study, including a re-examination of earlier described forms. The spines in Riedel's animals are mostly short and stout, though some of his specimens have long spines. Riedel also includes some of the specimens which Popofsky (1908) identified as *Spongodiscus favus* Ehrenberg var. *maxima* in his *Spongotrochus ? glacialis,* considering them as incompletely developed forms. No spineless specimens were found in the Arctic so nothing can be added to this thesis. It is possible that none of the arctic specimens was fully developed as all their discs have notched margins, which Popofsky assumes points to possible continuing growth.

Suborder Nassellina Ehrenberg, 1875
Family Plectaniidae Haeckel, 1882
Genus Plectacantha Jörgensen, 1905
***Plectacantha oikiskos* Jörgensen**
? Peridium intricatum Cleve, 1899, p. 31, Pl. 2, Figs. 8 a, b; 1900c
? Peridium laxum Cleve, 1899, p. 31, Pl. 2, Figs. 9 a, b; 1900c
Periplecta intricata Jörgensen, 1900, p. 73
Plectacantha oikiskos Jörgensen, 1905, p. 131, Pl. 13, Figs. 50–7; Mielck, 1913; Bernstein, 1932; 1934

Description. The skeleton consists of a basal tripod. The dorsal and the two lateral spines are connected by three arches. Each spine has two paired forked branches. The branches of the radial spines unite to form an irregular meshwork which is only incompletely closed.

Collection. Arctic Ocean, stations 60 and 72; few specimens, 1500 and 1600 m. to the surface. First record for the Arctic Ocean.

Distribution. P. oikiskos was found in the northern Barents and Kara seas, off the Norwegian west coast, in the Greenland Sea, and as far south as the Skagerak.

Discussion. This species occurs only in the northern cool and cold-water region and usually in small numbers. It seems to live in fairly deep water.

Genus Phormacantha Jörgensen, 1905
***Phormacantha hystrix* (Jörgensen)**
Peridium hystrix Jörgensen, 1900, p. 76; Gran, 1902
Phormacantha hystrix Jörgensen, 1905, p. 132, Pl. 14, Figs. 59–63; ? Popofsky, 1908; Mielck, 1913; Bernstein, 1934

Description. This species closely resembles the preceding one. The skeleton also consists of a basal tripod with three arches, but it has a strong ventral sagittal spine. The united branches of the radial spines form a network of numerous meshes.

Collection. Arctic Ocean, stations 43.2 and 72; at least two specimens, 1500 and 1600 m. to the surface. First record for the Arctic Basin.

Distribution. P. hystrix is reported from the Norwegian and Greenland seas and the northern part of the Kara Sea.

Discussion. Bernstein (1934) found this species at one station in the Kara Sea in a depth of 200–100 m. As the water temperature at 150 m. was positive, she came to the conclusion that *P. hystrix* was carried in with Atlantic water which flows in between Franz Josef Land and Vize Island after mixing with water of the Arctic Basin. The presence of the species in our material supports Bernstein's supposition.

Family Triospyrididae Haeckel, 1882
Genus Aegospyris Haeckel, 1882
***Aegospyris* sp.** (Figs. 12, 13)

Description. The shell consists of a bilocular cephalis with unequal rounded pores and a slight sagittal constriction. There are four large basal pores. Five divergent basal feet extend downward being prolongations of the inner skeleton. The unpaired (dorsal) foot seems to be the strongest; it is connected proximally with the cephalis by a simple lattice-work. The dorsal part of the sagittal ring arises free to the apex penetrating the shell as an apical

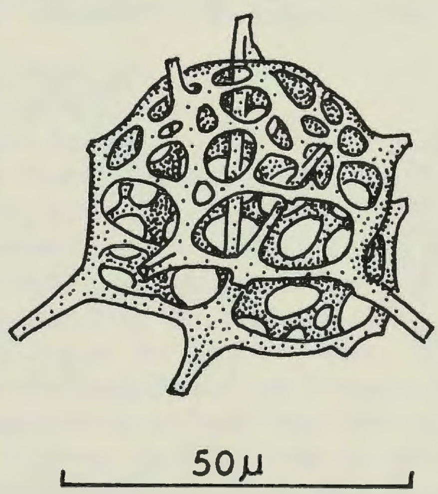


Fig. 12. *Aegospyris* sp. Basal-ventral view.

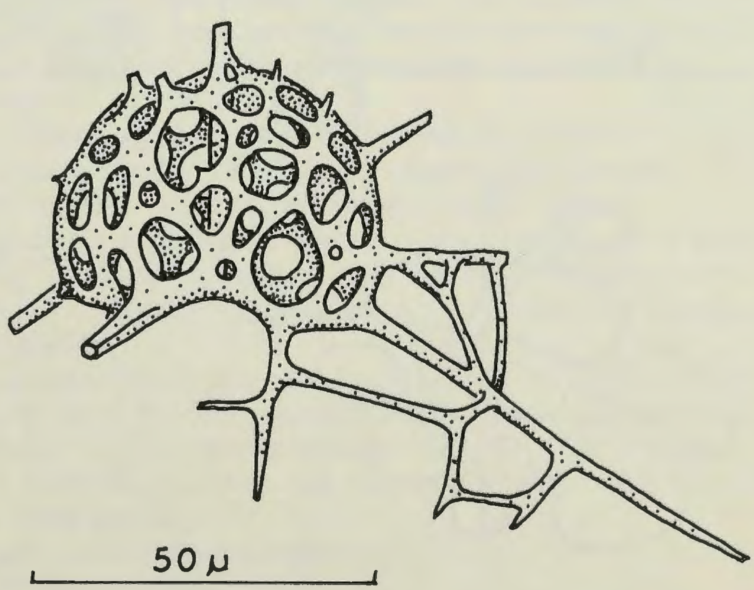


Fig. 13. *Aegospyris* sp. Lateral view (left side).

spine while the greater part of the ring lies enclosed in the shell wall. From this latter part of the ring a small vertical spine arises. Two additional spines are developed on the frontal apical portion of the cephalis; some less distinct spines are scattered over the cephalis.

Dimensions. Height of sagittal ring (3 specimens) 0.033–0.035 mm.; length of bilocular cephalis (1) 0.048 mm.

Collection. Arctic Ocean, stations 46, 60; three specimens, 200 and 1600 m. to the surface.

Discussion. The closest description for this species in Haeckel (1887) is that for *Aegospyris aequispina* Haeckel. However, the shell is described as tuberculate, and the dimensions are larger. In all our specimens the spines are broken short, so that it is impossible to say anything definite about their length, which characterizes the species.

Family Tholospyrididae Haeckel, 1887
Genus Tholospyris Haeckel, 1882
***Tholospyris gephyristes* sp. n.** (Figs. 14, 15 a, b)

Description. The shell consists of a bilocular cephalis with unequal,

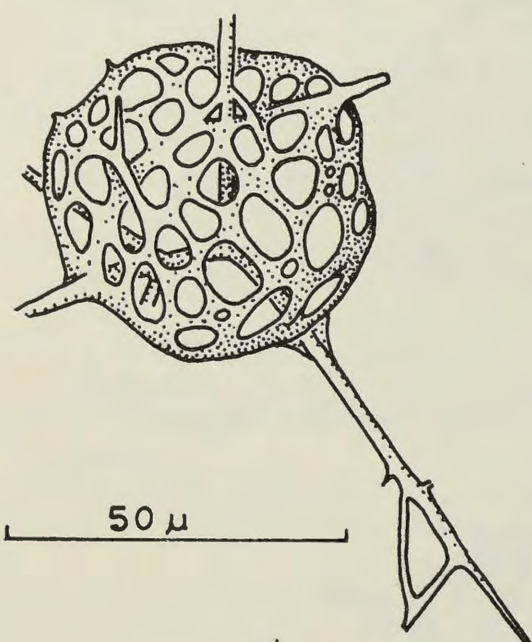


Fig. 14. *Tholospyris gephyristes* sp. n. View at upper (left) ventral side.

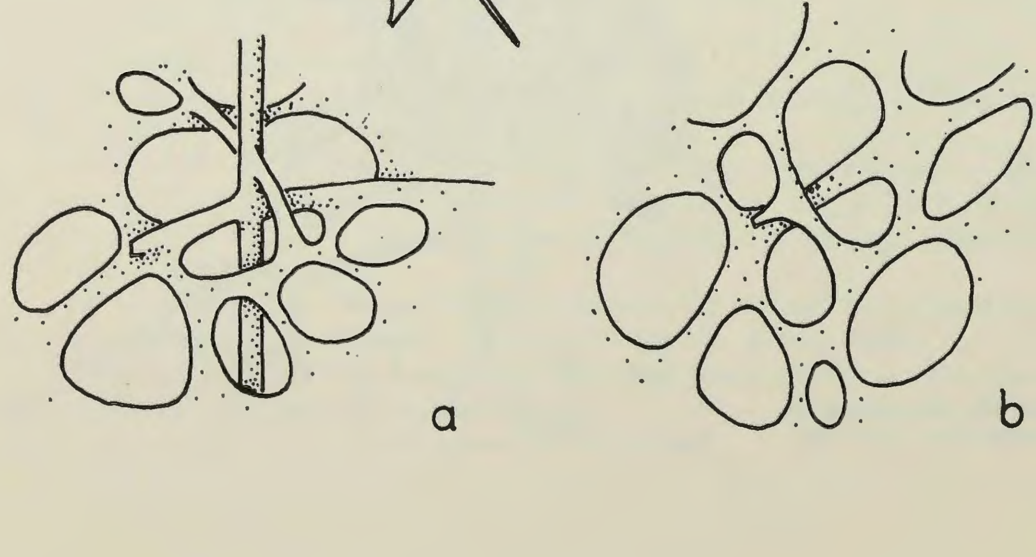


Fig. 15. *Tholospyris gephyristes* sp. n. a) Cupola, view at upper (right) dorsal side; b) Base of spine bridging the sagittal constriction of the shell. Higher magnification and different specimens from Fig. 14.

rounded pores and a small, fenestrated conical cupola which is prolonged into an apical spine. Three basal feet are prolongations of the dorsal and the paired lateral spines of the inner skeleton. Between their proximal portions a small amount of lattice-work connecting the spines may be present. From the lower part of the sagittal ring, where it is incorporated in the shell wall, arises a small vertical spine. There is a spine in the sagittal constriction on the dorsal side right below the cupola, like an elongation of the sagittal ring to the dorsal side. Another spine arises above the sagittal constriction on the ventral side; this spine does not originate in the constriction, but from a columella bridging the shallow groove. Haeckel (1887) shows a similar slender, bridge-like columella on the ventral side of *T. tripodiscus* (Pl. 89, Fig. 1), but no spine originates from there. Further, the insignificant cupola and small size of the new species, which is only about one-third of *T. tripodiscus*, distinguish the two species.

Dimensions. Two specimens: height of sagittal ring 0.032, 0.035 mm.; length of cephalis 0.044, 0.047 mm.

Collection. Arctic Ocean, stations 43.2, 60, 72; five specimens, one of them from 200 m., the others from 1500 and 1600 m. to the surface.

Family Sethopiliidae Haeckel, 1882

Genus Dictyophimus Ehrenberg, 1847

***Dictyophimus gracilipes* Bailey**

Dictyophimus gracilipes Bailey, 1856, p. 4, Pl. 1, Fig. 8; Haeckel, 1887; Cleve, 1900a; 1900c; Popofsky, 1908; Bernstein, 1932; 1934; Riedel, 1958.

Dictyophimus clevei Jörgensen, 1900, p. 80, Pl. 5, Fig. 26; 1907; Mielck, 1913

Description. The cephalis is hemispherical or caplike with numerous small pores, sometimes thorny, bearing an eccentric apical spine and an oblique vertical spine. The opening of the thorax is wide. The pores of the thorax are larger than those in the cephalis and are irregular. The three ribs in the thorax wall are prolonged into three long basal feet which are round in cross-section. The internal skeleton consists of one dorsal, two lateral, one apical, and one vertical spine, which corresponds to the formula of the *Plagiocarpa* type of Popofsky (1908, p. 264). Occasional accessory spines, mentioned by Bernstein (1932) and Riedel (1958), have not been found in the arctic material.

Dimensions. Twelve specimens: width of thorax 0.042–0.077 mm.; length of feet 0.032–0.103 mm.

Collection. Arctic Ocean, stations 43.2, 46, 53, 60, 72; frequent in the digested samples and entangled with spines of *Spongotrochus glacialis*, 200, 1500, and 1600 m. to the surface. First record for the Arctic Ocean.

Distribution. *D. gracilipes* had already been collected frequently in cold northern waters such as the Bering, Barents, and Kara seas (Bailey, 1856; Bernstein, 1934), but had not been reported from the Arctic Ocean. It had also been found in antarctic waters.

Discussion. Here *D. gracilipes* is understood as described by Riedel (1958) who allows the species a fairly wide variability. The present writer also suggests the possible identity of *D. platycephalus* Haeckel (1887) and *D. brandtii* Haeckel (1887) with *D. gracilipes*, but not, in contrast to Riedel, of *D. elegans* (see the following species).

This species apparently occurs at various depths.

***Dictyophimus histricosus* Jörgensen**
Dictyophimus histricosus Jörgensen, 1905, p. 138, Pl. 16, Fig. 89

Description. *D. histricosus* is similar to the preceding species, but is larger and bears on cephalis and thorax irregularly distributed, slender by-spines which are round in cross-section and more numerous on the cephalis.

Dimensions. Seven specimens: width of the thorax 0.080–0.100 mm.; length of feet 0.125–0.140 mm.

Collection. Arctic Ocean, stations 46, 60, 72; seven specimens, 1500 and 1600 m. to the surface. First report for the Arctic Ocean.

Distribution. West coast of Norway.

Discussion. Dogel' (in Dogel' and Reshetnyak, 1952) described a very similar species, *D. elegans* from the Northwestern Pacific Ocean. Although in *D. elegans* the separation of the cephalis from the thorax seems to be more complete, and the feet appear to be somewhat longer, it is considered as possibly identical with *D. histricosus.* One specimen was found on a spine of *Spongotrochus glacialis,* the others in digested samples.

Genus Eucecryphalus Haeckel, 1860
***Eucecryphalus histricosus* sp. n.** (Figs. 16, 17)

Description. The shell consists of cephalis and thorax. The cephalis bears an apical horn and numerous small bristles which also extend over the upper part of the thorax. The thorax has a straight end or is slightly constricted distally; the pores are hexagonally or unevenly rounded and stand in more or less regular vertical rows. In the cephalis the pores are smaller. The inner

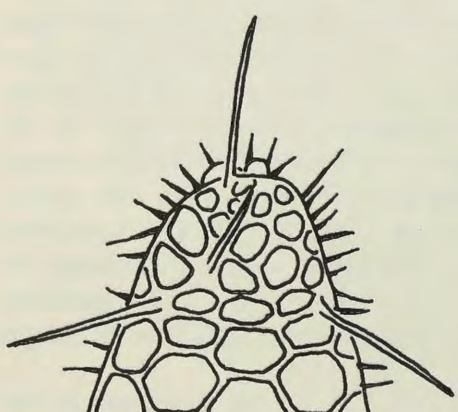


Fig. 16. *Eucecryphalus histricosus* sp. n.

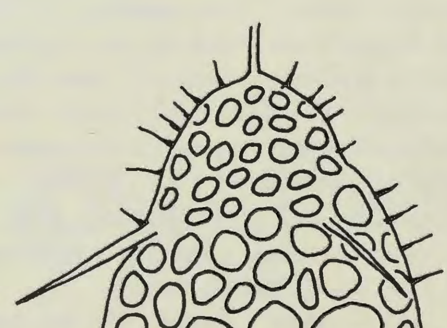


Fig. 17. *Eucecryphalus histricosus* sp. n.

skeleton is of the *Plagiocarpa* type of Popofsky (1908), i.e. there are the dorsal, two lateral, one apical, and one vertical spines which all project beyond the shell wall, being only little longer than the bristles.

Dimensions. Two specimens: length of cephalis 0.013, 0.016 mm., of thorax 0.058, 0.060 mm.; width of thorax 0.045, 0.050 mm.

Collection. Arctic Ocean, station 72; three specimens, 1500 m. to the surface.

Discussion. This species, as it is described here, should be placed within the genus *Eucecryphalus,* the characteristics of which are, according to Campbell (1954): three free wings or solid spines outside the thorax; without apical hole; with apical spine. The shell mouth which is devoid of spines classifies it in the subgenus *Eucyrtomphalus.*

There is a similarity to *Sethoconus tabulatus* of Cleve (1899) in the form and dimensions of the shell and the bristles. However, Cleve mentions the apical spine as the only one, and his illustration shows also the part within the cephalis. When tracing *S. tabulatus* back to the previous collector, Haeckel (1887), it turns out that he had added "a distinct small horn" to the original description of Ehrenberg (1873a, p. 306; 1873b, Pl. 4, Fig. 18; as *Cycladophora tabulata*) and it was Cleve who had added the bristles to the characteristics of the species. Ehrenberg specified only the part of the apical spine within the cephalis (costa media). The writer considers with reservation the identity of *Eucecryphalus tabulatus* with Cleve's *Sethoconus tabulatus* from the Greenland Sea, but is very hesitant about extending this identification to the specimens found by Haeckel and Ehrenberg.

Genus Lithomelissa Ehrenberg, 1847

***Lithomelissa ? laticeps* Jörgensen** (Fig. 18)

Lithomelissa laticeps Jörgensen, 1905, p. 136, Pl. 16, Fig. 84

Description. The cephalis of this delicate form is longer than wide, of slightly oval form. It bears numerous small, fine thorns. Cephalis and thorax are distinctly separated. The thorax widens distally. Its roundish pores vary in size and stand in subregular vertical rows; the pores of the cephalis are more uniform in size and arrangement. The inner skeleton consists of one apical and one vertical spine which are incorporated in the shell wall as cephalic ribs and prolonged as slender apophyses, and by the dorsal and two lateral spines only the minor part of which continues into the shell wall as thoracic ribs. They are prolonged as free solid spines outside the thorax.

Dimensions. Length of cephalis 0.038 mm., width 0.033 mm.; length of thorax 0.024 mm., width 0.050 mm.; length of apical spine 0.064 mm., of thoracic spines 0.105, 0.109 mm.

Collection. Arctic Ocean, station 72; two specimens, 1500 m. to the surface.

Distribution. L. laticeps was found between Shetland and Faeroe islands, and west of Norway.

Discussion. The very thin thorax wall and the large pores in its basal end indicate that the specimen illustrated is not fully grown. Jörgensen (1905) found this species in a sample taken from 900 m. to the surface. Since he expressly mentioned the lack of by-spines on the skeleton, and since the spines are considerably longer in the arctic specimens, the writer placed her two specimens here with reservation.

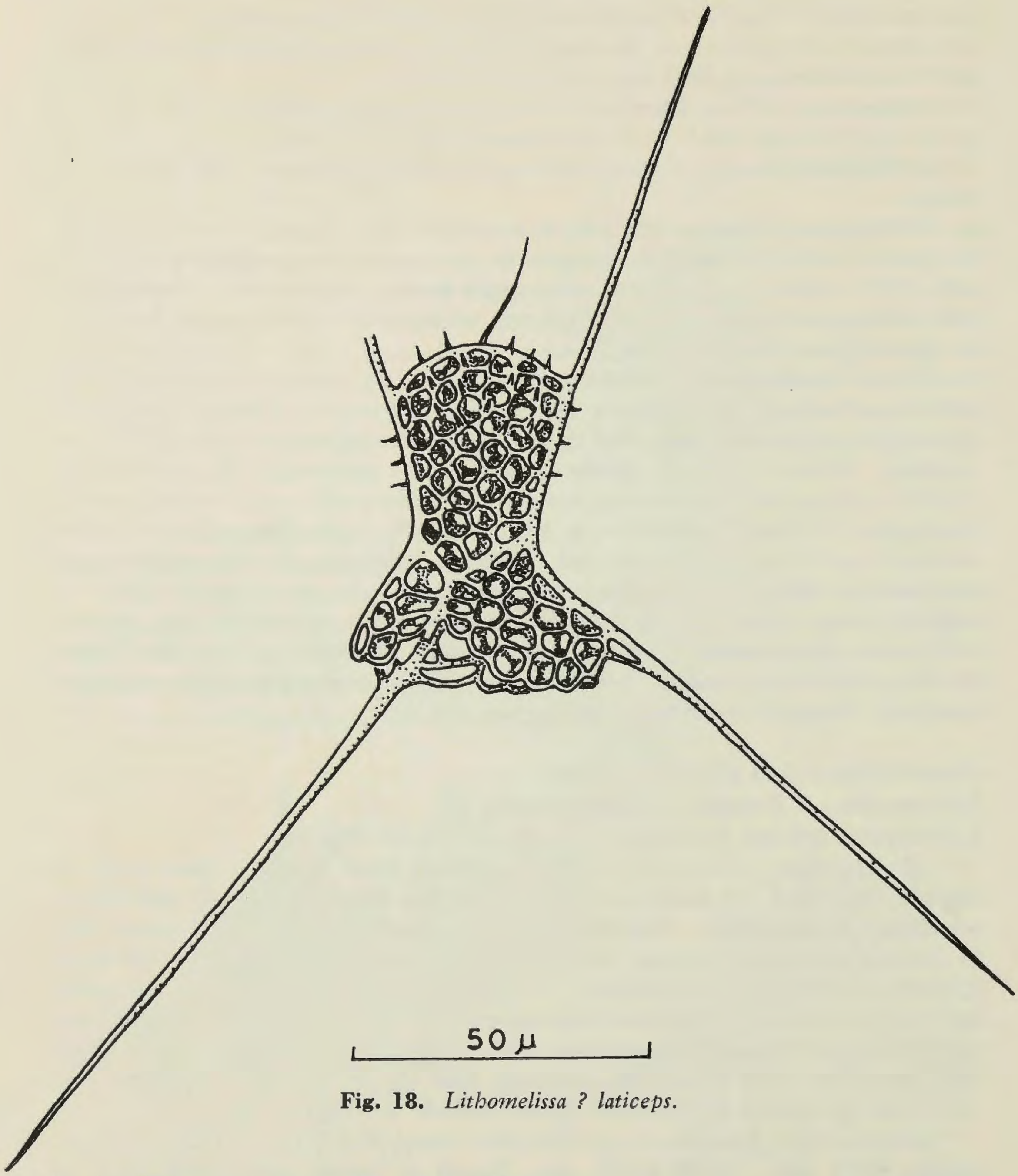


Fig. 18. *Lithomelissa ? laticeps.*

Family Sethophormididae Haeckel, 1882
Genus Tetraphormis Haeckel, 1882
***Tetraphormis rotula* (Haeckel)**
Enneaphormis rotula Haeckel, 1882
Sethophormis rotula Haeckel, 1887, p. 1,246, Pl. 57, Fig. 9; Popofsky, 1908, *partim*; Dogel' and Reshetnyak, 1952

Description. The large cephalis is cap-shaped, flat, and tri-lobed. Three rods diverge from the centre of its top and unite with the three radial ribs shortly before these meet the collar ring. A fine, irregular network fills in the sectors between the radial rods. Cephalis and thorax are separated by a hexagonal collar ring which has three larger sides and three alternating shorter ones. The three ribs from the centre of the collar septum continue radially through the middle of the larger sides of the collar ring (primary ribs); from each of the six corners of the ring one radial rib originates (secondary ribs), making nine ribs in all. These thicken towards their distal ends and bear at equal distances five pairs of opposite branches, the outermost being the biggest. The opposite branches of neighbouring ribs unite in five concentric nine-angled rings lying nearly in one plane.

Dimensions. Two specimens (sta. 72): diameter of cephalis 0.100–0.112 mm., of thorax 0.260–0.275 mm.

Collection. Arctic Ocean, stations 43.2, 60, 72; six adult and several juv. animals, 1500 and 1600 m. to the surface. First record for the Arctic Ocean.

Distribution. Central and North Pacific, antarctic waters, perhaps Greenland Sea (Cleve, 1899).

Discussion. Popofsky (1908) unites under the name *Sethophormis rotula* three species of Haeckel (1887) which he considers as only different stages of development in the following order: *Tetraphormis triloba, T. rotula, T. enneastrum.* This would mean, that *rotula* develops from *triloba,* and *enneastrum* again from *rotula;* in other words, the radial ribs and the concentric nine-angled rings of the thorax should develop first and then produce additional interpolated radial beams subdividing the meshes in smaller ones. However, the findings in our collection do not support Popofsky's opinion. On pp. 29–31, discussing *T. triloba* and *T. enneastrum,* I have explained why I have split this species and have followed the original classification of Haeckel. However, there is no doubt about the very close relationship between the three species.

The adult specimens collected correspond to the description and figure Haeckel gives for *T. rotula,* although their dimensions are somewhat smaller.

The specimens of Popofsky (1908) from cold antarctic waters were found in hauls from 385 m. and less to the surface. Haeckel's Pacific stations are all deeper than 2300 fathoms; this does not necessarily mean that the animals were caught in these great depths. However, if one assumes with Popofsky (p. 199) that the specimens did occur in considerable depth — especially since they were lacking in surface hauls from the same place — then *T. rotula* would be a cold-water form which in the lower latitudes submerges under the warm-water surface layers. Popofsky suspected that this species reappears again in northern polar waters, as our findings have shown.

***Tetraphormis triloba* Haeckel** (Fig. 19)

Sethophormis triloba Haeckel, 1887, p. 1,246

? Sethophormis rotula Popofsky, 1908, p. 285, *partim*

Description. The cephalis is similar to the preceding species, but the three rods are much stronger (according to Haeckel, 1887). The collar ring and the thorax are also very similar to the preceding species, except that *T. triloba* has four instead of five concentric nine-angled rings in the thorax.

Dimensions. Two specimens (sta. 72): diameter of cephalis 0.125 mm., of thorax 0.295 mm. A reconstruction from a broken part (sta. 43.2) gives: diameter of cephalis 0.100 mm., of thorax 0.290 mm.

Collection. Arctic Ocean, stations 43.2, 72; five specimens, 1500 and 1600 m. to the surface. First record for the Arctic Ocean.

Distribution. Northern Central Pacific.

Discussion. In Fig. 19 the thickened ends of the two secondary ribs of *T. triloba* are obvious. I do not believe that an animal with such a skeleton could grow an additional fifth ring to become the form described as *T. rotula.* Popofsky (1908) evidently found exclusively young stages since he expressly mentions that his specimens were young and that none of the radial ribs was thickened at its distal end. If he had had an adult representative of this species in his material from the Antarctic, he would not have considered it as a juvenile form of *T. rotula.*

The dimensions of the arctic specimens are greater than those of the Pacific ones given by Haeckel.

***Tetraphormis enneastrum* (Haeckel)** (Fig. 20)
Sethophormis enneastrum Haeckel, 1887, p. 1,246
Sethophormis rotula Popofsky, 1908, p. 285, *partim,* Pl. 34, Fig. 5 only

Description. Shell as in *Tetraphormis rotula,* only additional, shorter interpolated radial beams subdivide the meshes of the thorax into smaller, irregular ones.

Dimensions. Diameter of cephalis 0.110 mm.

Collection. Arctic Ocean, stations 60, 72; three juvenile specimens, 1500 and 600 m. to the surface. First record for the Arctic Ocean.

Distribution. Northern Central Pacific, antarctic waters.

Discussion. The specimens found in the collection have developed only parts of their second or third nine-angled ring (Fig. 20), but have already

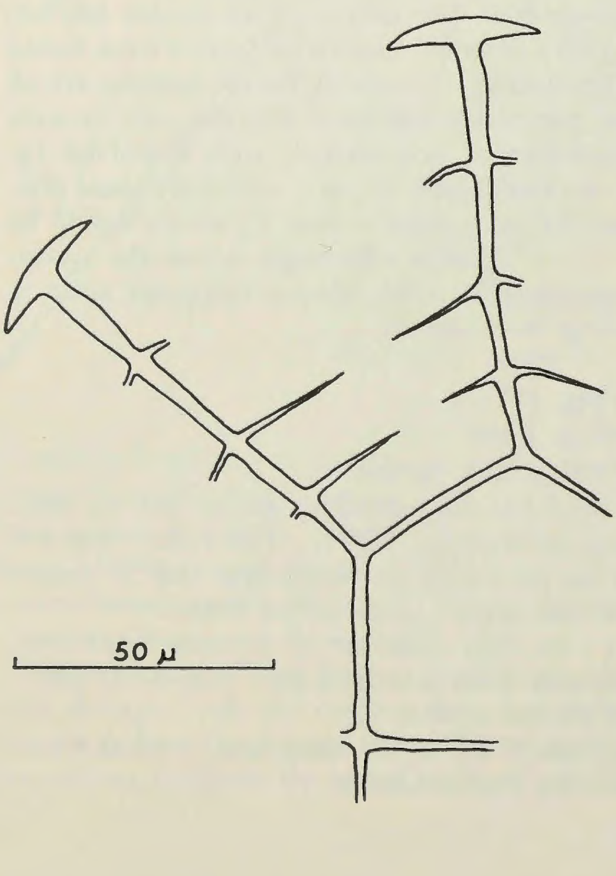


Fig. 19. *Tetraphormis triloba.* Two ribs.

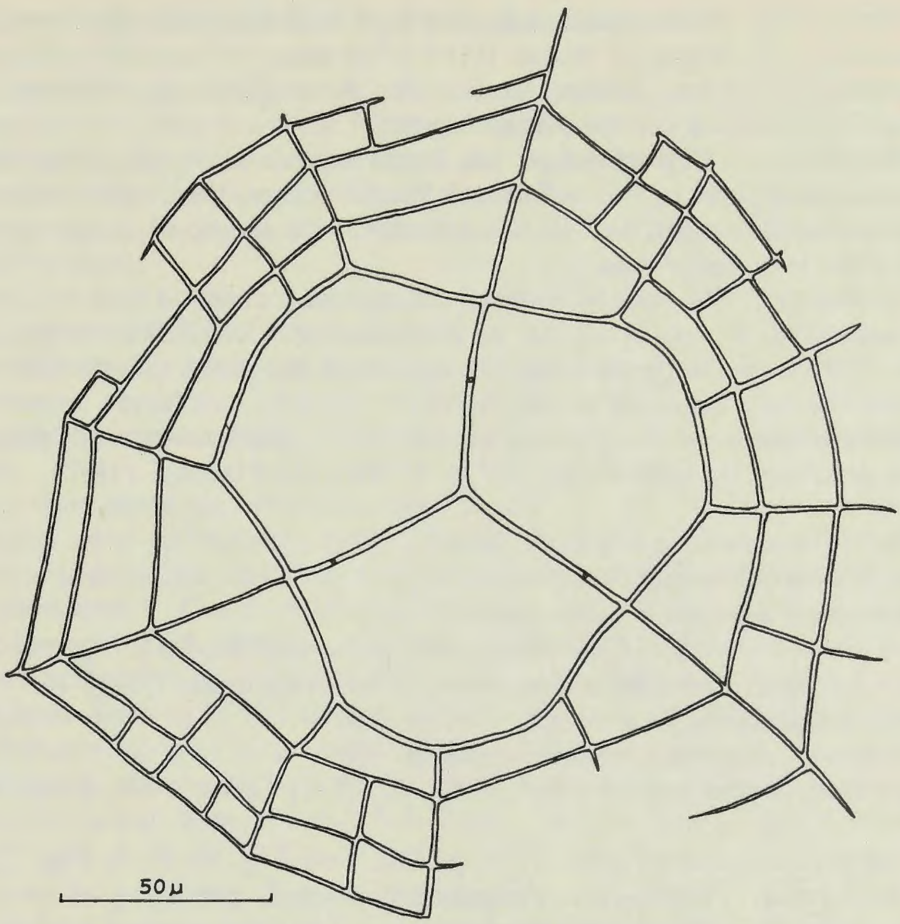


Fig. 20. *Tetraphormis enneastrum.* Juvenile specimen. The cephalis is not shown.

started to build additional radial beams into the skeleton. They are considered to be juvenile stages. On the basis of their morphology the writer concludes that the additional radial beams develop first rather than after completion of the nine radial ribs and their five connecting rings — as is to be gathered from Popofsky's study. For this reason *T. enneastrum* is treated here as a distinct species as was done by Haeckel. A still younger stage would be Popofsky's (1908) Fig. 5 on Pl. 34.

Family Lophophaenidae Haeckel, 1882
Genus Conarachnium Haeckel, 1882
***Conarachnium profundum* (Ehrenberg)**
Cornutella clathrata β *profunda* Ehrenberg, 1854, Pl. 35B, Fig. 21; Bailey, 1856
Cornutella profunda Ehrenberg, 1858, p. 31; 1873b; Haeckel, 1862; Riedel, 1958
Sethoconus profundus Haeckel, 1887, p. 1,294
Cornutella hexagona Haeckel, 1887, p. 1,180, Pl. 54, Fig. 9

Description. The cephalis is small, spherical, and poreless; it bears a short, single, apical horn. The thorax is slender, conical, smooth. Its subcircular pores stand in vertical rows gradually increasing in size towards the open basal shell mouth.

Dimensions. Three specimens: length of cephalis 0.008–0.012 mm., width 0.010–0.012 mm.; length of thorax 0.125–0.160 mm., width 0.045–0.052 mm.

Collection. Arctic Ocean, station 72; three specimens, 1500 m. to the surface. First record for the Arctic Ocean.

Distribution. *C. profundum* was found at various depths in the Mediterranean, tropical parts of the Indian and Pacific oceans, the North Atlantic and northern Pacific oceans, and in the Indian Ocean sector of antarctic waters. The species is cosmopolitan.

Discussion. The generic name of this species is changed here to *Conarachnium* according to the definition of the genus in Campbell's (1954) system. Riedel (1958), too, suggested that the species of the genus (there: *Cornutella*) are probably best regarded as dicyrtid.

Riedel considered the possible identity of *C. profundum* with ten similar species described by Ehrenberg (1873a, 1873b) and Haeckel (1887).

Family Theocorythidae Haeckel, 1882

Genus Theocalyptra Haeckel, 1882

***Theocalyptra davisiana* (Ehrenberg)**

Cycladophora ? davisiana Ehrenberg, 1862, p. 297; 1873b, Pl. 2, Fig. 11

Pterocodon davisianus Ehrenberg, 1862, p. 300; 1873b, Pl. 2, Fig. 10

Eucyrtidium davisianum Haeckel, 1862, p. 328

Pterocanium davisianum Haeckel, 1862, p. 332

Stichopilium davisianum Haeckel, 1887, p. 1,437; Cleve, 1899; 1901; Mielck, 1913

Theocalyptra davisiana Riedel, 1958, p. 239, Text-Fig. 10, Pl. 4, Figs. 2, 3

Description. The shell is campanulate, conical, consisting of two, three, or four segments, with an open basal mouth. The hemispherical cephalis bears two spines one of which is nearly apical, the other one is oblique; its pores are small, irregular. The collar stricture is indistinct, but always recognizable. The thorax, as it is termed by Riedel (1958), namely the entire subsequent portion of the shell, is conical or bell-shaped, and in some specimens, very indistinctly divided into two parts. The thoracic pores, rounded proximally and larger, rectangular distally, form transverse rings or endless rows. In many specimens a further, short segment follows that is flared at a wider angle than the thorax. More delicate bars than those of the thorax separate its large, polygonal pores. Three divergent spines penetrate the thorax wall in its upper portion as free prolongations of the dorsal and the two lateral spines of the inner skeleton which corresponds to the *Plagiocarpa* type of Popofsky (1908). The two cephalic spines are prolongations of the apical and the vertical spines of the inner skeleton.

Dimensions. Three specimens: length of cephalis 0.016–0.021 mm., of postcephalic portion 0.040–0.051 mm.; width of postcephalic portion 0.062–0.071 mm.

Collection. Arctic Ocean, stations 43.2, 60, 72; eight specimens, 1500 and 1600 mm. to the surface. First record for the Arctic Ocean.

Distribution. *T. davisiana* is apparently cosmopolitan. It was reported from the northern and tropical Pacific Ocean, tropical Indian Ocean, the Greenland and Norwegian seas, and from antarctic waters south of the Indian Ocean and the American continent. Riedel suggests that this species occurs more frequently in middle and high latitudes than in the tropical parts of the oceans.

Discussion. It is difficult to classify this species correctly. For reasons of simplicity the present author follows Riedel (1958) in placing it in the genus *Theocalyptra.* In the arctic specimens, the cephalis is set off. A segmentation in the subsequent portion is indistinct and inconstant. The specimens in this collection are distinctly smaller than those measured by Riedel; some of them may be juvenile.

Family Stichocorythidae Haeckel, 1882
Genus Artostrobus Haeckel, 1887
***Artostrobus annulatus* (Bailey)** (Fig. 21)
Cornutella ? annulata Bailey, 1856, p. 3, Pl. 1, Figs. 5 a, b; Ehrenberg, 1862; 1873b
Eucyrtidium annulatum Haeckel, 1862, p. 327
Cornutella annulata Haeckel, 1887, p. 1,182
Artostrobus annulatus Haeckel, 1887, p. 1,481; Cleve, 1899; Riedel, 1958

Description. The shell is slender and subcylindrical; its diameter is the widest close to the distal end. The cephalis is subglobular, without pores, and bears an eccentric apical spine. The collar stricture is indistinct. The entire postcephalic portion of the shell – the thorax, as regarded by Riedel (1958)– bears numerous rings of rounded or rectangular pores increasing in size towards the distal end. In the cephalic region there is an inner skeleton which consists, besides the apical spine, of the dorsal and the two lateral spines which are

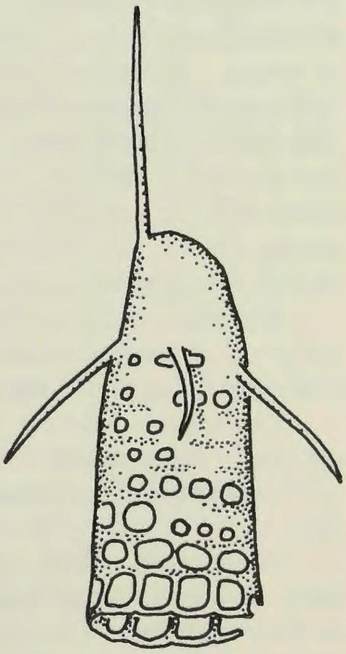


Fig. 21. *Artostrobus annulatus.* 50 μ

prolonged downward beyond the thoracic wall. A prolongation of the median bar can be looked at as a vertical spine which, however, does not penetrate the shell.

Dimensions. Length of shell 0.045 mm.; width of thorax (2 specimens) 0.025 and 0.029 mm.; length of apical spine 0.035 mm.

Collection. Arctic Ocean, stations 60 and 72; three specimens, 1500 and 1600 m. to the surface. First record for the Arctic Ocean.

Distribution. A. annulatus is a cosmopolitan species. It was found in the Bering and Greenland seas, in Davis Strait, tropical Pacific and Indian oceans, and in the Indian Ocean sector of antarctic waters.

Discussion. There is much uncertainty about the classification of the species (see above). Riedel (1958) regards the entire post-cephalic part of the shell as thorax with numerous horizontal rings of pores rather than as segments following one another each with one ring of pores. The writer is inclined to look at *A. annulatus* as a species with rudimentary segmentation, indications of which are present in the specimens at hand. If this view is adopted, there would be no need for a new revision of the position of this species. The specimens in this collection are relatively short. Probably they are not fully grown.

Genus Lithamphora Popofsky, 1908

***Lithamphora furcaspiculata* Popofsky**

Lithamphora furcaspiculata Popofsky, 1908, p. 295, Pl. 36, Figs. 6–8; 1913
? no name Cleve, 1899, p. 30, Pl. 2, Fig. 6

Description. The shell is formed by several portions of various length. The cephalis is irregular, subglobular with irregular, round pores. Thorax, abdomen, and postabdomen have five to eight or more regular transversal rings of pores. Above or below the strictures between thorax and abdomen and between abdomen and postabdomen there may be a narrow zone without pores. The shell mouth is open. There is a complicated inner skeleton in the cephalis and the upper part of the thorax, from which spines proceed into the cephalic lobes and the neck stricture, but are not prolonged as apophyses. From the centre of this skeleton three or four spines descend downwards through the thorax, the abdomen, and the upper portion of the postabdomen.

Dimensions. Length of cephalis 0.013, 0.016 mm., of thorax 0.019, 0.022 mm.; of abdomen 0.018, 0.042 mm.; width of thorax 0.038, 0.039 mm., of abdomen 0.043, 0.046 mm.

Collection. Arctic Ocean, station 72; two specimens, 1500 m. to the surface. First record for the Arctic Ocean.

Distribution. Antarctic waters, South Atlantic Ocean, possibly Greenland Sea.

Discussion. Both specimens of *L. furcaspiculata* apparently were not fully developed; they had only one section of the postabdomen instead of two to four sections. One specimen is closer to Fig. 6, Pl. 36 of Popofsky (1908), the other is very similar to Text-Fig. 136 of Popofsky (1913, p. 410). The specimen in Cleve's (1899) Fig. 6 (Pl. 2) mentioned without description on p. 30 as "a nearly related form" to *Lithomitra australis* (Ehrenberg) ?, may be identical with *Lithamphora furcaspiculata;* two descending spines within the shell are recognizable in the drawing.

Family Glycobotrydidae Campbell, 1954

Genus Botryopyle Haeckel, 1882

***Botryopyle setosa* Cleve**

Botryopyle setosa Cleve, 1899, p. 27, Pl. 1, Fig. 10 a, b; 1900; 1901; Linko, 1907; Meunier, 1910; Bernstein, 1932

Amphimelissa setosa Jörgensen, 1905, p. 137, Pl. 18, Fig. 109; Ostenfeld, 1910; Mielck, 1911; 1913; Bernstein, 1934; Bogorov, 1946

Description. The skeleton is divided by a horizontal stricture into cephalis and thorax. The cephalis is trilobate. In the skeleton wall are irregular, rounded pores and on the outside some long, slender spikes being elongations of bars of the inner skeleton. This corresponds to the *Campylacantha* type of Jörgensen (1905) and Popofsky (1908) which has in addition to the four basic (dorsal, apical, and two lateral) spines a ventral and two lateral dorsal spines. To these come a few strong arches, also situated inside the cephalis. The proximal part of the apical spine forms a free columella within the cephalis. In cross-section the shell is oval, the dorsoventral axis being the longer one. The thorax mouth is wide open.

Dimensions. Twelve specimens: total length of shell 0.048–0.062 mm.; maximum width (long diameter) of thorax 0.047–0.066 mm.

Collection. Arctic Ocean, stations 43.2, 46, 60, 72, 87, 104; sixty specimens, 200, 1500, and 1600 m. to the surface.

Distribution. The numerous findings of *B. setosa* were all located in the cold-water region to the north of the Atlantic Ocean and in the Arctic Basin (Bogorov, 1946).

Discussion. Cleve (1901) lists *B. setosa* in an account of plankton from the Malay Archipelago. One may, however, assume with confidence, that he had specimens of *Lithomelissa setosa* in his collection, since he has elsewhere (Cleve, 1900b) identified *B. setosa* with *L. setosa* Jörgensen, 1900.

B. setosa is apparently a typical representative of arctic-boreal and polar plankton of mainly deeper water, although it was also found in hauls from less than 200 m. (Cleve, 1899; Bogorov, 1946).

Suborder Phaeodarina Haeckel, 1879

Family Aulacanthidae Haeckel, 1862

Genus Aulacantha Haeckel, 1860

***Aulacantha scolymantha* Haeckel forma *typica* Haecker**

Aulocantha scolymantha Haeckel, 1860, p. 799; 1862, p. 263, Pl. 2, Figs. 1, 2, Pl. 4, Figs. 1–5; Hertwig, 1879

Aulacantha scolymantha Haeckel, 1887; Hensen, 1887; Möbius, 1887; Vanhöffen, 1897; Jörgensen, 1900; Cleve, 1900c; Borgert, 1901; Wolfenden, 1902; Lo Bianco, 1903; Immermann, 1904; Jörgensen, 1907; Schröder, 1913; Dogel' and Reshetnyak, 1952

Aulacantha scolymantha forma *typica* Haecker, 1908, p. 93; Meyer, 1933

Aulacantha laevissima Fowler, 1898

Description. The skeleton consists of a veil of fine tangential needles forming a ball and 30–50 (and more) cylindrical radial spines which have numerous small thorns on their distal third. All specimens found belong to the small and delicate form *typica* Haecker.

Collection. Arctic Ocean, 11 stations: 25, 31, 38, 53, 60, 72, 73, 74, 76, 92, 96; sixty-eight specimens. They were present only in the longer vertical tows; in the closing net tows just two specimens were found above 400 m. (400–200 m.). It appears that this form inhabits the deeper layers in this part of the Arctic Ocean.

Distribution. A. scolymantha is a cosmopolitan and eurythermal species. Including the findings in the Arctic it is reported from all oceans. Haecker (1908) gives the vertical distribution of *A. s. typica* as 50–1700 m. Meyer (1933) lists its occurrence in all depths but it was most frequent in the layers from 0–400 m.

Genus Aulographis Haeckel, 1879

***Aulographis taumorpha* Haeckel** (Fig. 22)

Aulographis taumorpha Haeckel, 1887, p. 1,577, Pl. 103, Fig. 16

Description. The skeleton consists of a veil of tangential needles forming a sphere, with 18–24 radial tubes meeting in the centre. The tubes are cylindrical, slender, straight, and taper gradually toward the distal end, their diameter being widest after the first proximal third of the entire length. The terminal branches are two, opposite each other, smooth, straight or slightly concave in the proximal part, recurved in the distal part (Fig. 22).

In one specimen there was one radial tube with three instead of the usual two terminal branches. These were equidistantly spaced from each other. They were shaped normally, not like the distal crown of recurved branches of *A. triglochin* Haeckel.

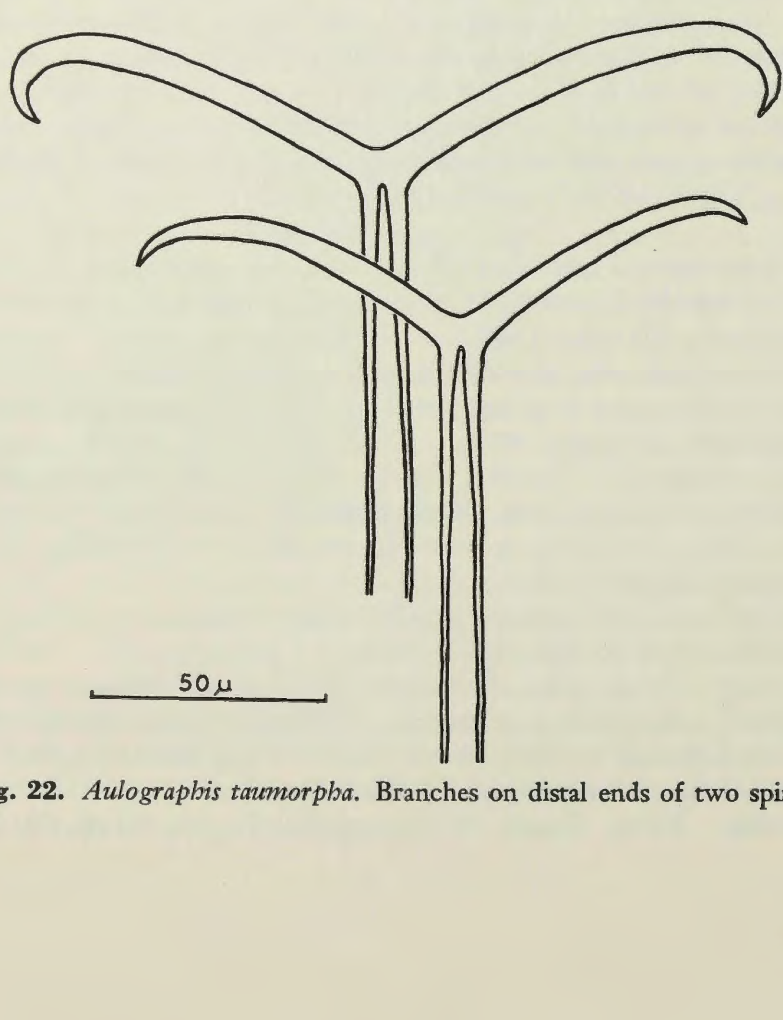


Fig. 22. *Aulographis taumorpha.* Branches on distal ends of two spines.

Dimensions. The dimensions of the tubes are as follows:

	tubes (25)		*branches* (45)
	length (*mm.*)	*width* (*mm.*)	*length* (*mm.*)
Haeckel	0.7 –0.8	0.01 –0.015	0.1 –0.15
Arctic	0.33–0.61	0.008–0.013	0.045–0.110

Collection. Arctic Ocean, 8 stations: 5, 11, 25, 38, 53, 73, 74; eleven specimens; at station 72 eighteen single tubes from a digested sample indicate the presence of a twelfth specimen. The specimens come from closing net tows from depths of 1400–1200, 1600–1400, and 1600–400 m., and from open net tows from depths of 2000, 1600, 1500, and 1400 m. to the surface. First record for the Arctic Ocean.

Distribution. A. taumorpha was reported from the North Pacific Ocean at lat. 31°8N., long. 137°8E. Haeckel almost uniformly lists only one station when describing a species. Therefore we do not have further information on *A. taumorpha* from other stations nor on the frequency of its occurrence. A depth of 2250 fathoms is given for the station he cites.

Discussion. Since Haeckel (1887) described *A. taumorpha*, it has not been reported again. The arctic specimens correspond very well with the description Haeckel has given, except for the slightly different shape of the radial tubes, which he describes as gradually tapering towards the proximal end, and their smaller dimensions.

Family Aulosphaeridae Haeckel, 1862
Subfamily Aulosphaerinae Haeckel, 1862

Parts of one broken specimen of the subfamily Aulosphaerinae were found (sta. 5). The regular network of the shell is diagnostic.

Subfamily Auloniinae Haeckel, 1887
Genus Aulastrum Haeckel, 1887
***Aulastrum spinosum* Borgert**

Aulastrum spinosum Borgert, 1901, p. 24, Fig. 23; Haecker, 1904; 1908; Schröder, 1913; Peters, 1929; Dogel' and Reshetnyak, 1952

Description. The skeleton is a lattice-sphere with subregular, mostly pentagonal or hexagonal meshes. On the tangential bars of the lattice-shell there are fine, single thorns. Radial spines with thorns originate at nodal points. In the proximal end of the radial spines the thorns are irregularly distributed and in the distal end they are arranged in one or two whorls.

One specimen found in sta. 46 lacked the thorns on the tangential bars of the lattice-shell.

Collection. Arctic Ocean, 4 stations: 31, 46, 92, 104; in each haul one specimen was present. They came from open net tows from depths of 1600, 1400, 730, and 480 m. to the surface. Two of the specimens were damaged. This is the first report of the species from the Arctic Ocean.

Distribution. This bipolar species has been reported from Antarctica (Haecker, 1904; 1908; Schröder, 1913; Peters, 1929), the Labrador Current (Borgert, 1901), and the Northwest Pacific (Dogel' and Reshetnyak, 1952). It occurred sometimes in numbers (Borgert, 1901) in hauls from various depths to the surface, including hauls less than 100 m. (Borgert, 1901; Haecker, 1904; Peters, 1929).

Discussion. The thorns on the tangential bars are fine and single as described by Borgert (1901); however, both Haecker (1908) and Schröder (1913) describe them as button-ended small threads. The thorns on the radial spines end bluntly or with an insignificant button, forms which are mentioned by Borgert only as thorns. Their distribution in the arctic specimens is closer to that in Borgert's original description and figure than to the one given by Haecker. In other words, the button-ended thorns on the radial spines are irregularly distributed on the proximal end of the radial spines rather than "mit . . . häufig paarweise angeordneten Seitenästen" (frequently arranged in pairs) (Haecker, 1908, p. 124); and arranged only occasionally in one or two whorls in the distal end of the radial spine rather than in 2–3 (Haecker, 1908) or even 2–6 whorls (Schröder, 1913). Both Haecker and Schröder worked on plankton from Antarctica, on the other hand, Borgert's material came from the Labrador Current. Hence it is supposed that *A. spinosum* from the northern cold-water region is not identical with that from Antarctica. Other authors, Peters (1929) and Dogel' and Reshetnyak (1952), do not mention such details. However, Peters lists Haecker (1908) as his source for identifying the species.

Family Cannosphaeridae Haeckel, 1879

Genus Cannosphaera Haeckel, 1879

***Cannosphaera antarctica* Haeckel** (Figs. 23, 24)

Cannosphaera antarctica Haeckel, 1887, p. 1,640, Pl. 112, Figs. 1–3; Vanhöffen, 1897; ? Jörgensen, 1900; Borgert, 1901; Jörgensen, 1907; Haecker, 1904; 1908; Borgert, 1909; Schröder, 1913; Peters, 1929; Dogel' and Reshetnyak, 1952

Description. The outer shell consists of irregular, mostly pentagonal meshes the bars of which bear on the outside tridentate anchor threads in groups of two or three and contain a fine thread inside. The inner shell has a wide opening on one side and is therefore not truly spherical. It is connected with the outer lattice-shell through numerous fine radial rods equipped with verticils of four very delicate anchor-threads. At each nodal point of the outer lattice-shell arises a simple radial spine bearing at its distal end a verticil of 3 to 5 small, curved terminal branches. In the arctic specimens the radial spines contain a fine thread and are thorny (Fig. 23). The thorns are usually distributed in whorls.

Two animals were found which had four central capsules (stations 96, 99).

Dimensions. Diameter of inner shell 0.195–0.225 mm.; width of tangential bars (33) 0.008–0.012 mm. (Jörgensen, 1900: 0.017 mm.); length of radial spines (13) 0.280–0.480 mm.

Collection. Arctic Ocean, 21 stations: 5, 11, 22, 25, 31, 38, 39, 43.2, 46, 53, 60, 72, 73, 74, 76, 80, 81, 92, 96, 99, 104; more than 110 intact specimens. In the closing net tows specimens were taken at depths of 200 m. to the surface and 400–200 m. Broken parts of this very brittle species, mainly inner shells, can be ascribed to at least 390 more specimens. This is the first report of its occurrence in the Arctic Ocean.

Distribution. C. antarctica has been reported repeatedly from the Antarctic Ocean and from northern cool-water regions. It was present in most cases in fairly large numbers, up to the 50 m. level.

Discussion. Haeckel describes this species as having 60–90 radial rods; in the arctic specimens I counted 40 (3 specimens) or even less, a number Jörgensen (1900) gives as probable for his broken specimens from the Norwegian west coast. He suspected he had a new species, with a larger inner shell (0.346–0.400 mm.). However, the diameter of the inner shell of the arctic specimens is smaller, which more nearly corresponds to the original description (0.2–0.3 mm.). The radial rods are widened at their proximal end and funnel-shaped in the arctic specimens (Fig. 24) as in Haecker's Fig. 18 (1904, p. 621) rather than mammillate expanded as in Haeckel's 1887 figure.

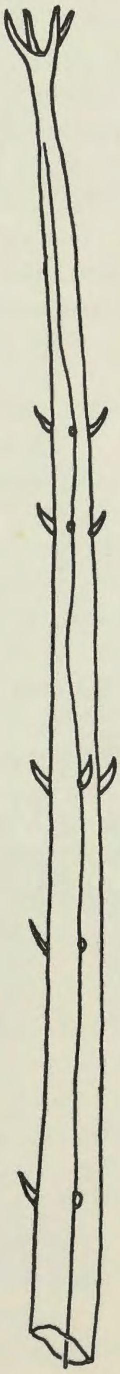


Fig. 23. *Cannosphaera antarctica.* Radial spine, upper part.

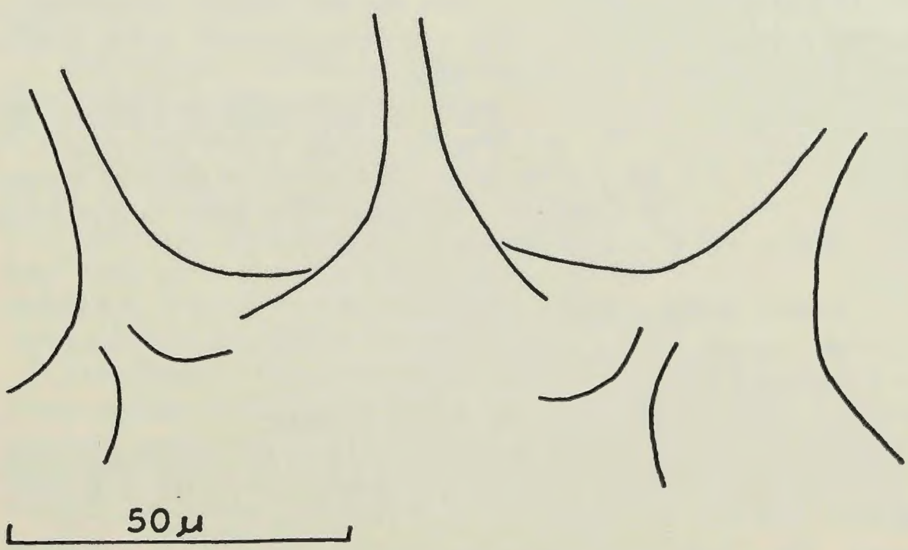


Fig. 24. *Cannosphaera antarctica.* Funnel-shaped proximal ends of radial rods on inner shell.

The radial spines on the outer shell bear thorns. Other authors (Haeckel, 1887; Borgert, 1901; Haecker, 1908) described and illustrated the spines as being smooth.

In summary, the differences of the arctic specimens from the original description are: about 40 radial rods rather than 60–90, their funnel-shaped proximal widening rather than a mamillate expansion, and finally, thorny radial spines rather than smooth ones.

Because of these evident differences in the shell structure and because of their occurrences in great numbers (see above) the writer considers it justified to separate the specimens from the Arctic Ocean as a new form, *oligobactria.*

Family Cadiidae Borgert, 1901

Genus Cadium Bailey, 1856

***Cadium melo* (Cleve)**

Cadium Wallich, 1862

Cadium marinum var. β Wallich, 1869, p. 109, Pl. 3, Figs. 6, 11, 13, 14; var. c Certes, 1889; Borgert, 1892; Jörgensen, 1900

Beroetta melo Cleve, 1899, p. 27, Pl. 1, Fig. 8; 1900c

Cadium melo Borgert, 1901, p. 50, Fig. 58; 1903; Jörgensen, 1905; Haecker, 1906; Jörgensen, 1907; Haecker, 1908; Borgert, 1910; Schröder, 1913; Meyer, 1933

? Cadium schlumbergeri Certes, 1889, p. L31, Pl. 4, Fig. 4

Description. The shell is elliptical. Its opening is on the end of a short collar-like peristome cut off at right angles to the main axis. The surface of the shell bears longitudinal striae. Although lacking in three out of the ten specimens, there is generally an apical spine (or a button).

Dimensions. Six specimens (stas. 60 and 72): length of shell 0.071–0.083 mm.; width 0.048–0.061 mm.

Collection. Arctic Ocean, stations 60, 72, 92, 96; ten specimens, 1600, 1500, 730, and 200 m. to the surface.

Distribution. C. melo has been found in the North and South Atlantic and Indian oceans, and in arctic waters (Greenland Sea and west of Spitsbergen). The species occurred in various depths, but was more frequent in the deeper zones. Usually it was present in small numbers.

Discussion. The dimensions of the measured specimens are smaller than the ones given by Haecker (1908) and Borgert (1910) which are: length of shell 0.085–0.138 mm., width 0.053–0.096 mm. The length of the shell agrees, however, with the data given by Certes (1889): 0.060–0.080 mm. It is possible that this species is identical with *C. schlumbergeri* Certes.

Family Porospathididae Borgert, 1901

Genus Porospathis Haeckel, 1879

***Porospathis holostoma* (Cleve)**

Polypetta holostoma Cleve, 1899, p. 32, Pl. 3, Fig. 4; 1900c

Porospathis holostoma Borgert, 1901, p. 48, Figs. 56, 56a; 1903; Jörgensen, 1907; Haecker, 1908; Borgert, 1910; Schröder, 1913; Dogel' and Reshetnyak, 1952; Somov, 1955

Description. The shell is spherical with a regular surface pattern of triangular ridges; the opening is located on the end of a cylindrical tube with a trumpet-like end. On the shell there are radial spines the lengths of which are about 3–4 times the diameter of the shell. In the half of the shell on the side of the tube (adtubal) the spines are more numerous than on the abtubal side.

One of the specimens could be identified as belonging to the egg-shaped variety *oligostyla* Haecker (1908). It was in a tow from a depth of 1600 m. to the surface (sta. 76).

Dimensions. Diameter of shell ranges from 0.070–0.150 mm. (Haecker, 1908), eight specimens: 0.120–0.160 mm.

Collection. Arctic Ocean, 16 stations: 3, 5, 9, 11, 31, 39, 43.2, 46, 53, 60, 72, 73, 74, 76, 81, 92; more than 420 specimens. Only eleven out of these were found in depths above 400 m.

Distribution. Since its description *P. holostoma* has been reported from all oceans. The depth of occurrence is specified as being exclusively greater than 400 m. (Haecker, 1908).

Discussion. The findings of *P. holostoma* in the collection give further proof that its main distribution is below 400 m.

Family Coelographididae Haeckel, 1887
Genus Coelodecas Haeckel, 1887
***Coelodecas pygmaea* Haecker**
Coelodecas pygmaea Haecker, 1907, p. 167, Fig. 19; 1908; Schröder, 1913; Popofsky, 1926

Description. The outline of the lattice mantle is a broad egg-shape. The styles project only a little beyond the lattice. The terminal coronets of the styles are produced by branches which taper dichotomously three times or, rarely, four times on the distal end, therefore having 8 or 16 fingers. These fingers are long and slender, mostly more or less undulating, and armed along their entire length with recurved hooks which decrease in size distally. At the end each finger bears 3–5 stout teeth bent outward.

One animal was found having one terminal coronet made of two singly bifurcated branches; the other coronets of this animal had the usual eight fingers (sta. 76).

Dimensions. Length of terminal coronet, from first fork to distal ends of fingers 0.250–0.385 mm. (45), extreme values 0.200 and 0.420 mm.; length of recurved hooks 0.009–0.028 mm. (88), extreme values 0.006 and 0.034 mm.

Collection. Arctic Ocean, 18 stations: 5, 9, 22, 31, 38, 43.2, 46, 53, 60, 72, 73, 74, 76, 87, 92, 96, 99, 104; sixty specimens. In sta. 72 parts only were found. The specimens were found in the hauls from depths greater than 200 m., but four hauls on different stations from only 200 m. to the surface yielded six specimens, five of which were fairly intact. This is the first coelodendrid reported from the Arctic Ocean.

Distribution. C. pygmaea has been reported from the warm- and cold-water regions of the Indian Ocean (Haecker, 1907; 1908), from the warm and northern cool-water regions of the Atlantic (Popofsky, 1926) and possibly from Antarctica (Schröder, 1913). In the Plankton-Expedition (Popofsky, 1926) *C. pygmaea* was present only in hauls from 500 m. and deeper to the surface.

Discussion. Popofsky (1926) interprets these results as indicating that

C. pygmaea occurs mainly in the upper layers of the so-called skotoplankton (a depth of 350–400 m. to 1000–1500 m.).[1] He ascribes the absence of this species from the closing net tows of the Plankton-Expedition to its sparsity.

The localities for *C. pygmaea* in the North Atlantic were in the Irminger Sea and the Labrador Current. The species has been found neither in the East nor in the West Greenland currents. Borgert (1911) mentioned these currents as poor in tripylean radiolarians. Popofsky (1926, p. 75) held that coelodendrids should not be expected to occur in the currents from the Arctic Ocean, since he considers warm-water regions as their main habitat. He believes that the coelodendrids living in the North Atlantic areas were carried alive into regions of cool water.

On the basis of the results of the Plankton-Expedition, Popofsky lists *C. pygmaea* as rare both in number of catches and of individuals. But in the part of the Arctic Basin where our material originates this species does not seem to be rare. Among the seven species of tripylean radiolarians found here it holds second place in frequency of occurrence (in 18 stations) although it ranks fourth in number of individuals taken.

These results encourage the writer to assume that *C. pygmaea* has its centre of distribution in the Arctic Ocean. With our records, this species can be called eurythermal, and the writer suspects that upon further investigation it will also be shown to be cosmopolitan even though it has not been reported from the Pacific.

Summary

In plankton collected in the Arctic Ocean in the area between the north pole and Ellesmere Island thirty-two species of Radiolaria were found. Their taxonomy is studied and the ecology discussed. Three new species and one new form are described.

Zusammenfassung

In Plankton, das vom Polarmeer aus der Gegend zwischen Nordpol und Ellesmere Island stammt, wurden zweiunddreissig Radiolarien-Arten gefunden. Ihre taxonomische Stellung wird erörtert und ihre Ökologie diskutiert. Drei neue Arten und eine neue Form werden beschrieben.

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[1]According to a scale introduced by Lo Bianco (1903).

TABLES AND REFERENCES

Table 1. Biological stations at which plankton was collected.

Station No.	*Date*	*Lat.*	*Long.*	*Depth of water (m.)*	*Depth of tow* (m.)*	*No. of tows*
3	6 12 52	86° 53 N.	82° 00 W.	2800	200 + 2500 + 2500	3
5	29 12 52	86 06	95 20	2386	200 + 200 2000 + 2000	4
9	5 1 53	86 00	93 40	2205	200 + 200 + 2000 + 2000	4
11	16 1 53	85 58	91 10	2000	? ? ? ?	4
21	14 4 54	84 41	81 31	—	200	1
22	15 4 54	84 41	81 31	—	200	1
25	19 4 54	84 39	81 20	1600	200 1400	2
31	25 4 54	84 40	81 30	1537	200 1400	2
38	3 5 54	84 36	81 10	—	surface + 200 400– 200 + 600– 400 + 800– 600 1000– 800 1200–1000 + 1400–1200	8 closing net
39	4 5 54	84 35	81 10	1531	200 1400 1400	3
43.2	18 5 54	83 27	89 50	1600	200 200 1600 1600	4
46	21 5 55	83 15	90 30	1772	200 200 1600 1600	4
53	28 5 55	83 15	90 15	1683	200 200 1600 1600	4
60	5 6 55	83 11	89 20	1654	200 200 1600 1600	4
72	20 6 55	83 07	90 20	1670	200 200 1500	3
73	23 6 55	83 12	90 15	1700	200 200 400– 200 400– 200 1600– 400 1600– 400	6 closing net

* = depth in metres to the surface, unless otherwise indicated.
? = incomplete, or doubtful, information, omitted in Table 2.
+ = no Radiolaria present, omitted in Table 2.
† = figure given in record.

Table 1.—Continued

Station No.	*Date*	*Lat.*	*Long.*	*Depth of water (m.)*	*Depth of tow* (m.)*	*No. of tows*
74	25 6 55	83° 07 N.	91° 35 W.	—	200 200 400– 200 400– 200 600– 400 600– 400 800– 600 800– 600 1000– 800 + 1000– 800 1200–1000 + 1200–1000 1400–1200 1400–1200 1600–1400 1600–1400	16 closing net
76	3 7 55	83 00	92 35	1514	400 ft. (133) 200 200 1600 1600	5
80	9 7 55	82 47	93 10	490	200 200 480 480	4
81	16 7 55	82 49	93 20	515	200 200 500 500	4
87	23 7 55	82 54	92 45	823	200 200 934† 800 ?	5
92	30 7 55	82 48	93 00	739	200 200 730 730	4
96	6 8 55	82 38	94 15	441	200 200 420 420	4
99	13 8 55	82 32	95 40	436	200 200 432 432	4
104	20 8 55	82 45	94 10	492	200 200 486 486	4
107	25 8 55	82 40	95 00	—	?100 ?100 ? ? ? + ? ? ? ?	9 closing net

* = depth in metres to the surface, unless otherwise indicated.
? = incomplete, or doubtful, information, omitted in Table 2.
+ = no Radiolaria present, omitted in Table 2.
† = figure given in record.

Table 2. Depth of plankton tows and numbers of specimens of the larger species collected.

Species	Depth of tows (m.)	2500	2000	1600	1500	1400	930	800	730	500	480	430	420	200	133	1600 –400	1600 –1400	1400 –1200	1200 –1000	1000 –800	800 –600	600 –400	400 –200	Total no. spec- imens
	No. of tows	1	2	10	1	4	1	1	2	2	4	2	2	37	1	2	2	3	1	2	3	2	4	
Spongotrochus glacialis	No. taken		9	504	40	34	35	24	45	26	146	34	84	1196	26	6			1		2	3	35	*2250*
	% at depth		30	61.6	65.6	31.5	97	100	65.2	96	73	72.3	92.3	77.2	87	5.5			20		74	25	72.9	
	Av. no. per tow		4.5	50.4	40	8.5	35	24	22.5	13	36.5	17	42	32.3	26	3			1		0.7	1.5	9	
Aulacantha scolymantha	No. taken			12	†	3			2			2				21	1	2			17	5	2	*68*
	% at depth			1.5		2.8			2.9			4.3				19	5	16.3			62.9	41.6	4.2	
	Av. no. per tow			1.2		0.8			1			1				10.5	0.5	0.7			6	2.5	0.5	
Aulographis taumorpha	No. taken		1	3	†	2											3	2						*12*
	% at depth		3.3	0.4		1.9											16	16.3						
	Av. no. per tow		0.5	0.3		0.5											1.5	0.7						
Aulastrum spinosum	No. taken			1		1			1		1													*4*
	% at depth			0.1		0.9			1.5		0.5													
	Av. no. per tow			0.1		0.25			0.5		0.25													
Cannosphaera antarctica	No. taken			62	†	22			10		49	11	5	337				2					4	*502*
	% at depth			7.6		20.4			14.5		24.5	23.4	5.5	21.8				16.4					8.3	
	Av. no. per tow			6.2		5.5			5		12.25	5.5	2.5	9.1				0.7					1	
Cadium melo	No. taken			1	5				3					1										*10*
	% at depth			0.1	8.2				4.3					0.06										
	Av. no. per tow			0.1	5				1.5					0.03										
Porospathis holostoma	No. taken	1	18	215	16	45			4	1				5	4	75	15	6	4		7	2	2	*420*
	% at depth	100	60	26.3	26.2	41.6			5.8	4				0.3	13	70	79	50	80		26	16.7	4.2	
	Av. no. per tow	1	9	21.5	16	11			2	0.5				0.13	4	37.5	7.5	2	4		2.3	1	0.5	
Coelodecas pygmaea	No. taken		2	19	†	1	1		4		4		2	10		6				2	1	2	5	*60*
	% at depth		6.7	2.4		0.9	3		5.8		2		2.2	0.64		5.5				100	3.7	16.7	10.4	
	Av. no. per tow		1	1.9		0.25	1		2		1		1	0.27		3				1	0.3	1	1.25	
Total no. Radiolaria		*1*	*30*	*817*	*61*	*108*	*36*	*24*	*69*	*27*	*200*	*47*	*91*	*1549*	*30*	*108*	*19*	*12*	*5*	*2*	*27*	*12*	*48*	
No. of species		*1*	*4*	*8*	*7*	*7*	*2*	*1*	*7*	*2*	*4*	*3*	*3*	*5*	*2*	*4*	*3*	*4*	*2*	*1*	*4*	*4*	*5*	
Animals per tow		*1*	*15*	*82*	*61*	*27*	*36*	*24*	*35*	*14*	*50*	*24*	*46*	*42*	*30*	*54*	*10*	*4*	*5*	*1*	*9*	*6*	*12*	

† = Parts of animal present.

Table 3. Species and their geographical range.

Species	Arctic Basin	Labrador Curr.	Greenland Sea	Irminger Sea	West of Norway	Kara Sea	Barents Sea	North Sea	Faeroe and Shetland Ids.	N. Atlantic	Central Atlantic	S. Atlantic	Mediterranean	Indian Ocean	Bering Sea	N. Pacific	NW. Pacific	Central Pacific	S. Pacific	Antarctic Ocean	arctic-boreal	bipolar	cosmopolitan
Haliomma sp.	x																				x		
Cladococcus leptus sp.n.	x																				x		
Echinomma leptodermum	x		x		x	x		x	x	x											x		
Cromyechinus borealis	x		x		x					x											x		
Sphaeropyle langii	x				x											x		x					
Spongotrochus ? glacialis	x											x								x		x	
Plectacantha oikiskos	x		x		x	x	x	x	x												x		
Phormacantha hystrix	x		x		x	x			x												x		
Aegospyris sp.	x																				x		
Tholospyris gephyristes sp.n.	x																				x		
Dictyophimus gracilipes	x		x			x	x			x					x	x				x		x	
Dictyophimus histricosus	x				x												?				x		
Eucecryphalus histricosus sp.n.	x		?																		x		
Lithomelissa ? laticeps	x				x				x	x											x		
Tetraphormis rotula	x		?														x	x		x			?
Tetraphormis triloba	x																	x					
Tetraphormis enneastrum	x																	x		x			
Conarachnium profundum	x									x			x	x		x		—x—		x			x
Theocalyptra davisiana	x		x		x									x		x		x		x			x
Artostrobus annulatus	x		x								—x—			x	x			—x—		x			x
Lithamphora furcaspiculata	x		?								—x—			x						x			?
Botryopyle setosa	x		x		x	x	x	x													x		
Aulacantha scolymantha	x			x	x				x	x		x	x	x			x—	—x—		x			x
Aulographis taumorpha	x															x							
Aulastrum spinosum	x	x															x			x		x	
Cannosphaera antarctica	x	x	x	x	x					x							x			x		x	
Cadium melo	x		x		x					x	x	x		x									?
Porospathis holostoma	x		x							x	x	x		x			x			x			x
Coelodecas pygmaea	x	x		x						x	x			x						?			?

x = present
? = uncertain
—x— = no exact position given

Table 4. Dimensions of the shells of *Echinomma leptodermum*, *Cromyechinus borealis*, and *Sphaeropyle langii*.

	first shell (mm.)	*second shell (mm.)*	*third shell (mm.)*	*fourth shell (mm.)*
Echinomma leptodermum (Jörgensen, 1900)	0.015–0.017	0.035–0.040	0.085–0.088	
Echinomma leptodermum (Jörgensen, 1905)	0.015 or more	0.040		
Actinomma boreale (Cleve, 1899)				0.100–0.120
Cromyomma boreale (Jörgensen, 1900)	0.015–0.017	0.034–0.037	0.077–0.085	0.096–0.115
Cromyechinus borealis (Jörgensen, 1905)	0.016	0.034–0.040	0.077–0.089	0.096–0.121
Sphaeropyle langii (Dreyer, 1889)	0.012	0.043	0.112	0.169
Arctic specimens				
Echinomma leptodermum juv.	0.020	0.043	(0.072)	
Echinomma leptodermum ad.	0.019	0.042	0.082	
Cromyechinus borealis juv.	0.012–0.015	0.040	0.078–0.085	(0.115)
Cromyechinus borealis ad. (2 specimens)	0.015, 0.016	0.040, 0.042	0.078, 0.085	0.108, 0.127
Sphaeropyle langii	0.015	0.040	0.075	0.104–0.108

Table 5. Dimensions of *Spongotrochus glacialis*.

	Diameter of disc. (mm.)	*Length of larger spines (mm.)*
Spongotrochus glacialis		
Popofsky (1908) Antarctic	0.2 –0.24	up to 0.22
Popofsky (1912) South Atlantic	0.13 –0.14	
Riedel (1958) Antarctic	0.195–0.465	0.005–0.170 (often about 0.070)*
Arctic specimens (90)	0.100–0.485	0.070–0.310
Stylospongia arachnia		
Popofsky (1908)	up to 0.37	up to 0.2
Haeckel (1862, 1887)	0.12 –0.15	0.2 –0.6

*Larger and smaller spines are not distinguished.

References

Bailey, J. W. 1856. "Notice of microscopic forms found in the soundings of the Sea of Kamtschatka". *Amer. J. Sci. Arts,* Second Ser. Vol. 22, pp. 1–6.

Bernstein, T. 1932. "Uber einige arktische Radiolarien". *Arch. Protistenk.* Vol. 76, pp. 217–27.

1934. "Zooplankton Karskogo morya po materialyam ekspeditsiy Arkticheskogo instituta na *Sedove* 1930 goda i *Lomosove* 1931 goda". (Zooplankton of the Kara Sea from the Arctic Institute's expeditions in the *Sedov* (1930) and *Lomonosov* (1931)). *Leningrad, Trudy Arktichesk. Inst.* Vol. 9, pp. 3–58 (Russian with German summary).

Bogorov, V. G. 1946a. "Zooplankton po sboram expeditsii na L/P 'G. Sedov' 1937–1939 gg" (Zooplankton collected by the *Sedov* Expedition 1937–1939) in Buynitskiy V. Kh., ed. 'Trudy Dreyfuyushchey expeditsii Glavsevmorputi na ledokol'nom parokhode "G. Sedov" 1937–1940 gg'. *Moskva, Izd. Glavsevmorputi,* 1946–. Vol. 3, pp. 336–70 (Russian with English summary).

1946b. "Materialy po zooplankton Polyarnogo basseyna" (Some notes about plankton in the Polar Basin) in 'Ekspeditsiya na samolete "SSSRN-169" v raion "Polyusa Nedostupnosti".' *Nauch. rezul'taty,* pp. 180–96 (Russian with English summary).

Borgert, A. 1892. "Vorbericht über einige Phäodarien- (Tripyleen-) Familien der Plankton-Expedition". *Plankton-Exped. Humboldt-Stiftung, Ergeb.* Vol. 1, A, pp. 126–84.

1901. "Die nordischen Tripyleen-Arten". *Nord. Plankton,* Vol. 7, No. 15, pp. 1–52.

1903. "Mitteilungen über die Tripyleen-Ausbeute der Plankton-Expedition. II. Die Tripyleenarten aus den Schliessnetzfängen". *Zool. Jahrb. Abt. Syst.* Vol. 19, pp. 733–60.

1910. "Die tripyleen Radiolarien der Plankton-Expedition: Porospathidae und Cadiidae". *Plankton-Exped. Humboldt-Stiftung, Ergeb.* Vol. 3, Pt. Lh 10, pp. 383–415.

1911. "Die tripyleen Radiolarien der Plankton-Expedition: Challengeridae". *Plankton-Exped. Humboldt-Stiftung, Ergeb.* Vol. 3, Pt. Lh 11, pp. 419–536.

Brady, H. B. 1878. "On the Reticularien and Radiolarien Rhizopoda (Foraminifera and Polycystina) of the North-Polar Expedition of 1875–76". *Ann. Nat. Hist.* 5th Ser., Vol. 1, pp. 425–40.

Brodskiy, K. A. 1956. "Zhizn' v tolshche vody Polyarnogo basseyna". (Life in the deep waters of the Polar Basin). *Priroda,* Vol. 5, pp. 41–8 (Transl. by R. Flagg).

Campbell, A. S. 1954. "Radiolaria" in Moore, R. C. ed. 'Treatise on invertebrate paleontology'. Pt. D, Protista, Vol. 3, pp. 11–163.

Certes, A. 1889. "Protozoaires". *Mission scientif. Cap Horn 1882–1883.* Vol. 6, Zoologie Vol. 3, pp. L1–43.

Cleve, P. T. 1899. "Plankton collected by the Swedish expedition to Spitzbergen in 1898". *Sv. Vetensk.-Akad. Handl.* Vol. 32, N.S., No. 3, pp. 1–51.

1900a. "Report on the plankton collected by the Swedish expedition to Greenland in 1899". *Sv. Vetensk.-Akad. Handl.* Vol. 34, N.S., No. 3, pp. 1–21.

1900b. "Plankton from the southern Atlantic and the southern Indian Ocean". *Sv. Vetensk.-Akad. Ofversigt Förhandl.* Vol. 57, No. 8, pp. 919–38.

1900c. "The seasonal distribution of Atlantic plankton organisms". *Göteborgs Kungl. Vetensk. och Vitterhets. Handl.* Ser. 4, Vol. 3, pp. 1–368. (Radiolaria pp. 127–99).

1901. "Plankton from the Indian Ocean and the Malay Archipelago". *Sv. Vetensk.-Akad. Handl.* Vol. 35, N.S., No. 5, pp. 1–58.

Coachman, L. K. and C. A. Barnes. 1961. "The contribution of Bering Sea water to the Arctic Ocean". *Arctic,* Vol. 14, pp. 147–61.

Crary, A. P. and N. Goldstein. 1957. "Geophysical studies in the Arctic Ocean". *Deep-Sea Research,* Vol. 4, pp. 185–201.

Dogel', V. A. and V. V. Reshetnyak. 1952. "Materialy po radioliariyam severo-zapadnoy chasti Tikhogo okeana". (Some notes on Radiolaria of the northwestern section of the Pacific Ocean) in 'Glubokovodnaya fauna severo-zapadnoy chasti Tikhogo okeana'. *Akad. Nauk SSSR. Zool. Inst. Issled. dal'nevostochnykh morey SSSR.* No. 3, Moskva-Leningrad: pp. 5–36. (Investigations of Far Eastern Seas of the USSR. No. 3. Deep-sea fauna of the northwestern section of the Pacific Ocean).

Dreyer, F. 1889. "Die Pylombildungen in vergleichend-anatomischer und entwicklungsgeschichtlicher Beziehung bei Radiolarien und bei Protisten überhaupt". *Jena: Ztschr. Naturw.* Vol. 23, N.F., Vol. 16, pp. 77–214.

Ehrenberg, C. G. 1839. "Ueber die Bildung der Kreidefelsen und des Kreidemergels durch unsichtbare Organismen". *Akad. Wissensch. Berlin, Abh.* 1838, pp. 59–147.

———— 1854. 'Mikrogeologie. Das Erden und Felsen schaffende Wirken des unsichtbaren kleinen selbständigen Lebens auf der Erde'. Leipzig: 2 vols. 374 + 88 pp.

———— 1859. "Kurze Characteristik der 9 neuen Genera und der 105 neuen Species des ägäischen Meeres und des Tiefgrundes des Mittel-Meeres". *Akad. Wissensch. Berlin, Monatsb.* 1858, pp. 10–41.

———— 1862. "Die Tiefgrund-Verhältnisse des Oceans am Eingange der Davisstrasse und bei Island". *Akad. Wissensch. Berlin, Monatsb.* 1861, pp. 275–315.

———— 1873a. "Mikrogeologische Studien als Zusammenfassung seiner Beobachtungen des kleinsten Lebens der Meeres-Tiefgründe aller Zonen und dessen geologischen Einfluss". *Akad. Wissensch. Berlin, Monatsb.* 1872, pp. 265–322.

———— 1873b. "Mikrogeologische Studien über das kleinste Leben der Meeres-Tiefgründe aller Zonen und dessen geologischen Einfluss". *Akad. Wissensch. Berlin, Abh.* 1872, pp. 131–399.

———— 1876. "Fortsetzung der mikrogeologischen Studien als Gesammt-Uebersicht der mikroskopischen Paläontologie gleichartig analysierter Gebirgsarten der Erde, mit specieller Rücksicht auf den Poycystinen-Mergel von Barbados". *Akad. Wissensch. Berlin, Abh.* 1875, pp. 1–169.

Fowler, G. H. 1898. "Contributions to our knowledge of the plankton of the Faeroe Channel. No. VII. B. The Protozoa". *Proc. Zool. Soc. Lond.* pp. 1,020–30.

Gordienko, P. A. 1961. "The Arctic Ocean". *Sci. Amer.* Vol. 204, No. 5, pp. 88–102.

Gran, H. H. 1902. "Das Plankton des norwegischen Nordmeeres". *Norwegian Fishery and Marine Investig. Rept.* Vol. 2, No. 5, pp. 1–222 (Radiolaria pp. 150–4).

Green, K. E. 1959. "Ecology of some arctic foraminifera" in 'Scientific studies at Fletcher's Ice Island, T-3 (1952–1955)'. Vol. 1, pp. 59–81. *Geophys. Res. Papers* No. 63, AFCRC-TR-59-232 (1). ASTIA Document No. AD-216813.

Grice, G. D. 1962. "Copepods collected by the nuclear submarine *Seadragon* on a cruise to and from the north pole, with remarks on their geographical distribution". *Sears Foundation: J. Marine Res.* Vol. 20, pp. 97–109.

Haeckel, E. 1861a. "Ueber neue, lebende Radiolarien des Mittelmeeres". *Akad. Wissensch. Berlin, Monatsb.* 1860, pp. 794–817.

———— 1861b. "Neue Gattungen und Arten von Radiolarien des Mittelmeeres". *Akad. Wissensch. Berlin, Monatsb.* 1860, pp. 835–45.

———— 1862. 'Die Radiolarien (Rhizopoda radiaria). Eine Monographie'. Berlin: 572 pp. with atlas.

———— 1882. "Entwurf eines Radiolarien-Systems auf Grund von Studien der Challenger-Radiolarien". *Jena: Ztschr. Naturw.* Vol. 15, N.F. 8, pp. 418–72.

———— 1887. "Report on the Radiolaria collected by H.M.S. *Challenger* during the years 1873–1876". *Challenger Exped. Rept.*, Zoology Vol. 18, 1,803 pp. with atlas.

Haecker, V. 1904. "Ueber die biologische Bedeutung der feineren Strukturen des Radiolarienskelettes. Anhang, die Phäosphärien der 'Valdivia'- und 'Gauss'-Ausbeute". *Jena: Ztschr. Naturw.* Vol. 39, pp. 581-648 (Anhang, p. 632).

———— 1907. "Zur Statik und Entwicklung des Coelographiden-skelettes". *Arch. Protistenk.* Vol. 9, pp. 139–69.

———— 1908. "Tiefsee-Radiolarien". *Deutsche Tiefsee-Exped. Wissensch. Ergeb.* Vol. 14, Pt. 1, pp. 1–476; Pt. 2, pp. 477–706.

Hensen, V. 1887. "Uber die Bestimmung des Planktons oder des im Meere treibenden Materials an Pflanzen und Tieren". *Fünfter Ber. der Komm. zur wissensch. Untersuchung der deutschen Meere Kiel,* 1882–86. Berlin.

Hertwig, R. 1879. "Der Organismus der Radiolarien". *Jena: Denkschr.* Vol. 2, pp. 129–277.

Hollande, A. and M. Enjumet. 1960. "Cytologie, évolution et systématique des Sphaeroidés (Radiolaires)". *Paris, Mus. Nat. Hist. Nat. Archives,* Sér. 7, Vol. 7, pp. 1–134.

Immermann, F. 1904. "Die Tripyleen-Familie der Aulacanthiden der Plankton-Expedition". *Plankton-Exped. Humboldt-Stiftung, Ergeb.* Vol. 3, Pt. Lh 1, pp. 1–92.

Jörgensen, E. H. 1900. "Protophyten und Protozoën im Plankton aus der norwegischen Westküste". *Bergens Mus. Aarb.* 1899. No. 6, pp. 1–112.

——— 1905. "Protistplankton" in 'Hydrographical and biological investigations in Norwegian fiords'. *Bergens Mus. Skr.* Vol. 7, pp. 49–151.

——— 1907. "Note sur les Radiolaires". *Orléans, Duc d'. Croisière océanographique accomplié à bord de la Belgica dans la mer du Grönland en 1905.* Brussels: pp. 455–9.

Linko, A. K. 1907. "Issledovaniya nad sostavom i zhizn'yu planktona Barentsogo morya". (Research on the plankton of the Barents Sea). *Ekspeditsiya dlya nauchno-promyslovyk issledovaniy u beregov Murmana.* St. Petersburg: 245 pp.

Lo Bianco, S. 1903. "Le pesche abissali eseguite da F. A. Krupp col Yacht *Puritan* nelle adiacenze di Capri ed in altre località del Mediterraneo". *Zool. Sta. Neapel, Mitt.* Vol. 16, pp. 109–280.

Mast, A. 1910. "Die Astrosphaeriden". *Deutsche Tiefsee-Exped. Wissensch. Ergeb.* Vol. 19, pp. 123–90.

Meunier, A. 1910. "Microplankton des Mers de Barents et de Kara". *Orléans, Duc d'. Campagne Arctique de 1907.* Pt. 5, pp. 1–255 (Radiolaria pp. 196–203).

Meyer, K. 1933. "Die geographische Verbreitung der tripyleen Radiolarien des Südatlantischen Ozeans". *Deutsche Atlant. Exped. "Meteor" 1925-27, Wissensch. Ergeb.* Vol. 12, Pt. 1, pp. 122–98.

Mielck, W. 1911. "Quantitative Untersuchungen an dem Plankton der deutschen Nordsee-Terminfahrten im Februar und Mai 1906". *Wissensch. Meeresunters.* N.F., Vol. 13. Kiel: pp. 313–57.

——— 1913. "Résumé des observations sur le plankton des mers explorées par le conseil pendant les années 1902–1908; Radiolaria". *Conseil Permanent Internat. pour l'Exploration de la Mer, Bull. Trimestr.* Pt. 3, pp. 303–402.

Möbius, K. 1887. "Systematische Darstellung der Thiere des Plankton gewonnen in der westlichen Ostsee und auf einer Fahrt von Kiel in den Atlantischen Ocean bis jenseits der Hebriden". *Fünfter Ber. der Komm. zur wissensch. Untersuchung der deutschen Meere Kiel,* 1882–86. Berlin.

Mohr, J. L. 1959. "Marine biological work" in 'Scientific studies at Fletcher's Ice Island, T-3 (1952–1955)'. Vol. 1, pp. 82–103. *Geophys. Res. Papers* No. 63. AFCRC-TR-59-232 (1). ASTIA Document No. AD-216813.

Müller, J. 1857. "Uber die Thalassicollen, Polycystinen und Acanthometren des Mittelmeeres". *Akad. Wissensch. Berlin, Monatsber.* 1856, pp. 474–503.

Ostenfeld, C. H. 1910. 'Marine plankton from the East Greenland Sea. II. Protozoa'. *Medd. om Grønland,* Vol. 43, pp. 287–99.

Peters, N. 1929. "Beiträge zur Planktonbevölkerung der Weddell-See. 4) Die tripyleen Radiolarien der Weddell-See". *Internat. Rev. ges. Hydrobiol. Hydrogr.* Vol. 21, pp. 383–401.

Popofsky, A. 1905, 1907. "Die nordischen Acantharien. 1) Acanthometriden. 2) Acanthophracten". *Nord. Plankton,* No. 16, pp. 43–69, 71–90.

——— 1908. "Die Radiolarien der Antarktis (Mit Ausnahme der Tripyleen)". *Deutsche Südpolar-Exped.* Vol. 10, Zoologie Vol. 2, pp. 183–306.

——— 1912. "Die Sphaerellarien des Warmwassergebietes". *Deutsche Südpolar-Exped.* Vol. 13, Zoologie Vol. 5, pp. 73–159.

——— 1913. "Die Nassellarien des Warmwassergebietes". *Deutsche Südpolar-Exped.* Vol. 14, Zoologie Vol. 6, pp. 217–416.

——— 1917. "Die Collosphaeriden der Deutschen Südpolar-Expedition 1901–1903. Mit Nachtrag zu den Spumellarien und Nassellarien". *Deutsche Südpolar-Exped.* Vol. 16, Zoologie Vol. 8, pp. 235–78.

——— 1926. "Die tripyleen Radiolarien der Plankton-Expedition. Coelodendridae (einschliesslich Coelographidae Haeckel)". *Plankton-Exped. Humboldt-Stiftung, Ergeb.* Vol. 3, Pt. Lh 13, pp. 1–101.

Riedel, W. R. 1958. "Radiolaria in antarctic sediments". *B.A.N.Z.A.R.E. 1929–31. Rept.* Ser. B, Vol. 6, Pt. 10, pp. 217–55.

Schröder, O. 1909. "Die nordischen Spumellarien. II. Unterlegion Sphaerellaria". *Nord. Plankton,* Vol. 7, No. 17, pp. 1–63.

——— 1911. "Nassellarien". *Nord. Plankton,* Vol. 7, No. 17, pp. 67–140.

——— 1913. "Die tripyleen Radiolarien (Phaeodarien)". *Deutsche Südpolar-Exped.* Vol. 14, Zoologie Vol. 6, pp. 113–215.

——— 1929. "Die nordischen Spumellarien. I. Unterlegion Sphaerocollida". *Nord. Plankton,* Vol. 7, No. 16, pp. 91–120.

Shirshov, P. P. 1944. "Nauchnye resul'taty dreyfa stantsii 'Severnyy Polyus' ". (Scientific results of the drift station North Pole). *Akad. Nauk SSSR. Obshch. sobraniye.* Feb. 1944, pp. 110–40.

Somov, M. M., ed. 1955. "Observational data of the scientific-research drifting station of 1950–51". Vol. 1, Sect. 4. *Leningrad, Izd. Morskoy Transport.* (Transl. by Amer. Met. Soc. under Contract AF 19 (604)-1936) ASTIA Document No. AD 117135.

Stöhr, E. 1880. "Die Radiolarien-Fauna der Tripoli von Grotte". *Palaeontogr.* Vol. 26, pp. 69–124.

Wallich, G. C. 1869. "On some undescribed testaceous rhizopods from the North Atlantic deposits". *Monthly Micr. J.* Vol. 1, pp. 104–10.

Wolfenden, N. R. 1902. "The plankton of the Faroe Channel and Shetlands. Preliminary notes on some Radiolaria and Copepoda". *J. Marine Biol. Ass. Plymouth,* Vol. 6, pp. 344–72.

Worthington, L. V. 1959. "Oceanographic observations" in 'Scientific studies at Fletcher's Ice Island, T-3 (1952–1955)'. Vol. 1, pp. 31–5. *Geophys. Res. Papers* No. 63, AFCRC-TR-59-232 (1). ASTIA Document No. AD-216813.

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