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Planktonic choanoflagellates from Disko Bugt, West Greenland, with a survey of the marine nanoplankton of the area

Helge Abildhauge Thomsen

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Light and electron microscopy of whole mounts prepared from water samples collected in July and August 1977 at thirteen stations in the vicinity of Godhavn (Disko Bugt, West Greenland), has led to the enumeration of approximately 100 nanoplanktonic taxa. A full account is given of field and laboratory methods. The most conspicuous algal class was the Prymnesiophyceae with more than 38 species. Among the heterotrophic organisms listed the Choanoflagellida was the most important single group, comprising 28 species. Two new choanoflagellate taxa are described on the basis of West Greenland material: *Conion groenlandicum* gen. et sp.nov. and *Diaphanoeca undulata* sp.nov.

In order to facilitate immediate comparison of closely related taxa *Diaphanoeca sphaerica* sp.nov. is described on the basis of Danish material.

Thirteen of the loricate choanoflagellate species listed are new recordings for West Greenland. A summary of previous findings of the choanoflagellate species encountered in the Disko Bugt samples show that three species *(Conion groenlandicum, Pleurasiga caudata* and *Parvicorbicula serratula)* are so far known from arctic and subarctic localities only. A pronounced vertical distribution pattern of choanoflagellate species was observed at one station southeast of Godhavn. Three distinct species associations occurred in this particular water column (0–300 m).

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Introduction

The choanoflagellates (Choanoflagellida), and particularly the members of the Acanthoecidae, constitute a well defined group of marine and brackish water unicellular monads. The protoplast of these organisms is colourless and carries a single anteriorly directed flagellum surrounded by a ring of tentacles (the collar). In certain freshwater species of the family Codonosigidae a fibrillar flagellar vane has been demonstrated (Hibberd 1975). In marine and brackish water species there have, so far, been no reports on flagellar appendages. The most distinctive characteristic of the members of the Acanthoecidae is the range of cell loricas which are composed of silicified ribs (Thomsen 1973). In *Monocosta fennica* Thomsen, 1979 the lorica is simply a ring of four or five ribs (costal strips) surrounding the protoplast, whereas the lorica of e.g. *Stephanoeca norrisii* Thomsen, 1973 is composed of several hundred costal strips arranged in characteristic patterns. The taxonomy at both the species and genus levels is almost exclusively based on the shape and arrangement of the costal strips.

Members of the Acanthoecidae are particularly well suited to the whole mount technique for transmission electron microscopy. Such electron microscopical investigations on marine and brackish water nanoplankton, based on whole mounts prepared from freshly collected water samples, have resulted in the description of several new taxa (see e.g. Leadbeater 1972a, b, 1973, 1974; Manton et al. 1975; Thomsen 1973, 1976, 1979). The Acanthoecidae comprises for the moment approximately 55 species.

The taxonomic position of the choanoflagellates has been somewhat controversial. The description of a pigmented species *(Stylochromonas minuta* Lackey, 1940) and a superficial resemblance to some Chrysophyceae (goldenbrown flagellates) on one hand, and on the other hand the convincing similarity between the choanoflagellates and the choanocyte-like cells in

sponges and certain metazoan groups have given this group of organisms a position within botanical as well as zoological classification. Bourrelly (1957) treated the collared flagellates as an order (Craspedomonadales) within the Chrysophyceae and later (Bourrelly 1968) as a subclass within the same algal class. Chadefaud (1960) erected the class Craspedophyceae which was also adopted by Christensen (1962) and Parke & Dixon (1968). Recent ultrastructural evidence (Leadbeater 1972a; Leadbeater & Manton 1974; Hibberd 1975, 1976) showing e.g. a different mitochondrial substructure from that of other algal classes within the division Chromophyta *sensu* Christensen (1962), and a unique type of flagellar apparatus, suggest that these organisms should be deleted from the plant kingdom. Consequently the class Craspedophyceae was omitted in the third revision of the North Atlantic checklist (Parke & Dixon 1976) and listed separately (Parke & Leadbeater 1977). The classification adopted by Parke & Leadbeater (1977) was that of Honigberg et al. (1964) including the collared flagellates in the order Choanoflagellida referred to the Protozoan class Zoomastigophorea. This view is followed in the present paper, and consequently the rules of zoological nomenclature have been adopted.

Most papers on choanoflagellates refer to material from temperate regions, but choanoflagellates have been found numerously also in warm water samples (Leadbeater 1973; Thomsen 1978a) as well as in arctic samples (Throndsen 1970a; Manton et al. 1975, 1976, 1980). Although members of the Acanthoecidae are confined to saline environments, these flagellates are almost as frequent in oligohaline surroundings (Thomsen 1979) as they are in sea water of oceanic salinity. The choanoflagellates appear constantly to make up one of the three numerically most important taxonomical groups of nanoplankton organisms (see e.g. Manton & Leadbeater 1974 and Thomsen 1979). This statement, however, is primarily based on the inspection of whole mounts not specifically prepared for quantitative investigations. Very little information on the quantitative occurrence of choanoflagellates is available. Throndsen (1969), using the dilution culture technique on Norwegian coastal water samples, has given estimates of cell numbers per litre of naked flagellates in general. The highest estimate obtained for choanoflagellates was 50.000 cells per litre. In other investigations based on the Utermöhl technique much larger cell-numbers have been reported. Grøntved (1956) reported 43.000 *Calliacantha natans* cells per litre at Fyllas Banke (West Greenland). Rex (1976) working on plankton from the Swedish west coast calculated that the number of choanoflagellates in a surface sample from May 1972 was 1.788.000 cells per litre, and Bjørn-Rasmussen (1976) also counting Swedish west coast samples stated that *Bicosta spinifera* occurred with 107.000 cells per litre in a sample from May 1974. These figures clearly point to the importance of these bacteria and detritus feeding organisms in the pelagic foodweb.

The resolution of the transmission electron microscope is by no means an obligate prerequisite for work with choanoflagellates at the species level. Virtually all species can be identified from light microscopy using phase-, anoptral- or interference contrast equipment. In order to facilitate light microscopical recognition of choanoflagellate taxa and thus hopefully to make choanoflagellate counting and species determination a routine procedure in general plankton investigations, most of the West Greenland species collected in 1977 have been thorougly illustrated from light microscopy using interference contrast optics.

Previous investigations on choanoflagellates from West Greenland and adjacent areas are sparse. Grøntved (1956) included West Greenland material in the description of *Calliacantha natans*, and Bursa (1961) reported on the presence of two collared flagellates from the Canadian arctic (*Salpingoeca natans* and *Monosiga* sp.). Eleven species, four of which had not previously been described, were recorded from Arctic Canada and West Greenland localities by Manton et al. (1975, 1976).

The present paper reports on the finding of 25 choanoflagellates (Acanthoecidae) from Disko Bugt, West Greenland, collected in the summer 1977. A survey of the nanoplankton flora and fauna is included at the end of the paper.

In addition to the West Greenland material from 1977 it has been considered practical to include in the present paper material of *Diaphanoeca grandis* and *Diaphanoeca sphaerica* sp.nov. originating from the Isefjord (Denmark) and collected in January and February 1975 and in November 1979.

Material and methods

The material for this investigation was collected in July and August 1977 in the vicinity of Godhavn, Disko island, West Greenland (Fig. 1). All collecting sites and sampling depths are indicated in Fig. 1.

Surface samples were collected by lowering a bucket into the water, whereas samples down to c. 60 metres were collected by means of a hose connected to a hand-operated pump. Nansen water bottles were used for collecting deeper samples. The salinity of the samples ranged from 24.2 ‰ S in the surface to 33.7 ‰ S in the deeper samples. The temperature was from 0 to 13°C.

All water samples were brought with the least possible delay to the Danish Arctic Station for processing. Samples from st. 1 and st. 2 were processed at Nipisat. Prior to the concentration of the nanoplankton fraction

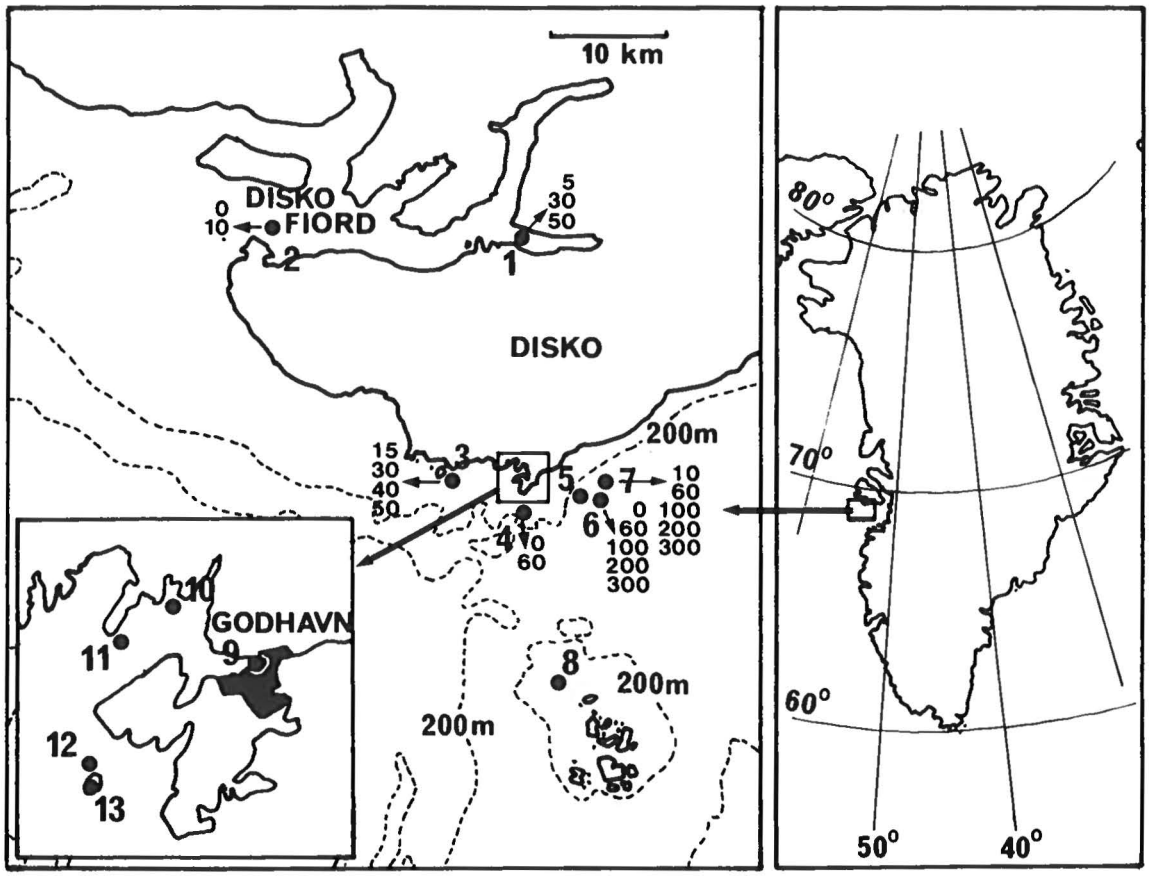


Fig. 1. Right: Greenland with sampling area. Left: Sampling area with collecting sites (1–13) and sampling depths. Dark circle alone indicating surface sample only.

all samples were prefiltered through 25 or 45 µm nets in order to remove the larger plankton organisms. A sufficient concentration of the nano-organisms for preparing electron microscopical whole mounts was achieved either by centrifugation alone or alternatively by Millipore filtration (3 µm) followed by centrifugation of the filtrate.

In every case small drops of the resuspended concentrate were pipetted on to formvar/carbon coated grids (200 mesh) using fine-pointed capillary pipettes. Fixation was in OsO_4 vapour (from a 2% aqueous solution) for approximately 30 seconds. After c. 60 seconds much of the water was removed from the grids by using absorbent dental points. When completely dry, the grids were washed in distilled water in order to remove salt crystals precipitated on the grid surfaces. The grids were stored individually in gelatine capsules.

At the Institut for Sporeplanter, University of Copenhagen the grids were later shadowcast with gold/palladium and viewed on a JEM-T8 electron microscope. The entire collection from 1977 comprises 177 grids.

The light microscopical preparations were all made from prefiltered samples (25 or 45 µm) which were subsequently Millipore filtered (3 µm) and further concentrated by centrifugation of the resuspended filtrate. The material was resuspended in c. 2 ml of filtered seawater and fixed in the centrifuge tube by adding 2–3 drops of a 2% aqueous OsO_4-solution. The fixation time was approximately five minutes. Finally, the material was washed three times in redistilled water by centrifugation. Small drops of the resuspended pellet of material were placed on rinsed coverslips and left dust-protected for airdrying. When dry the coverslips were mounted upside down on slides (by means of four feet of Depex), thus making possible the use of oil immersion objectives. These air-mounted preparations were later examined in a Leitz Dialux 20 light microscope equipped with interference contrast optics and a Wild MPS 55 photoautomat. The film used was a 24×36 mm Agfapan 25 which gave a 400 times initial magnification on the negative when using the high power oil immersion objective. A single anoptral contrast light micrograph of a living cell has also been in-

cluded (Fig. 50). The microscope used was a Reichert Zetopan.

The terminology used throughout the paper is that summarized by Leadbeater (1972a).

Taxonomy

Acanthoecidae

All data regarding local distribution of species are summarized in Table 1. The total distribution of each species is shown in Table 3 (p. 31). In the following text the main stress has been laid on taxa which are new to science, and furthermore on species which are morphologically divergent compared with earlier documented findings, very seldom recorded or previously not light microscopically illustrated. Three species appear in the tables only *(Acanthoeca spectabilis, Acanthoecopsis unguiculata, Bicosta antennigera).*

Acanthoecopsis Norris, 1965
Acanthoecopsis apoda Leadbeater, 1972a (Fig. 4)

Although commonly encountered in nanoplankton investigations (Table 3), no light micrographs of this species have been included in previous publications. *A. apoda* is easily distinguished in the light microscope. The most important diagnostic characteristics are the free anterior spines (c. 14) and the two closely appressed anterior transverse costae (Fig. 4, arrow). The costal strip pattern at the posterior lorica end appears rather complicated. A pedicel is, however, never present. The most closely related species is *A. asymmetrica* Thomsen, 1979.

Bicosta Leadbeater, 1978
Bicosta minor (Reynolds, 1976) (Figs. 3, 6, 7)

The lorica of this species is composed of only seven costal strips arranged as two longitudinal costae which join posteriorly (Fig. 7). The anterior and posterior spines are single costal strips; the lorica chamber is composed of four costal strips (Fig. 7).

The West Greenland specimens are generally somewhat smaller than those of the Norwegian type material (Reynolds 1976); overall lorica length: 17.3–33.6 µm (23.8 µm) as opposed to 30–45 µm; lorica chamber length: 6.9–14.1µm (9.4 µm) as opposed to 11.8 µm (mean lenght); posterior spine: 4.7–10.8 µm (7.1 µm) versus 9.75 µm (mean length). Numbers in brackets are mean values based upon measurements on electron micrographs of eleven specimens. Quite recently lorica and protoplast morphology and dimensions of this species have been thoroughly analysed on the basis of material from several localities including West Greenland (Manton et al. 1980).

B. minor is closely related to *B. spinifera* (Throndsen, 1970b). Lorica size and the presence or absence of a certain obliquity in the longitudinal costae are the most important specific characteristics (compare Fig. 7 and Fig. 2). A comparison between Fig. 6 *(B. minor)* and Fig. 10 *(B. spinifera)* shows that the two species are also easily distinguished in the light microscope.

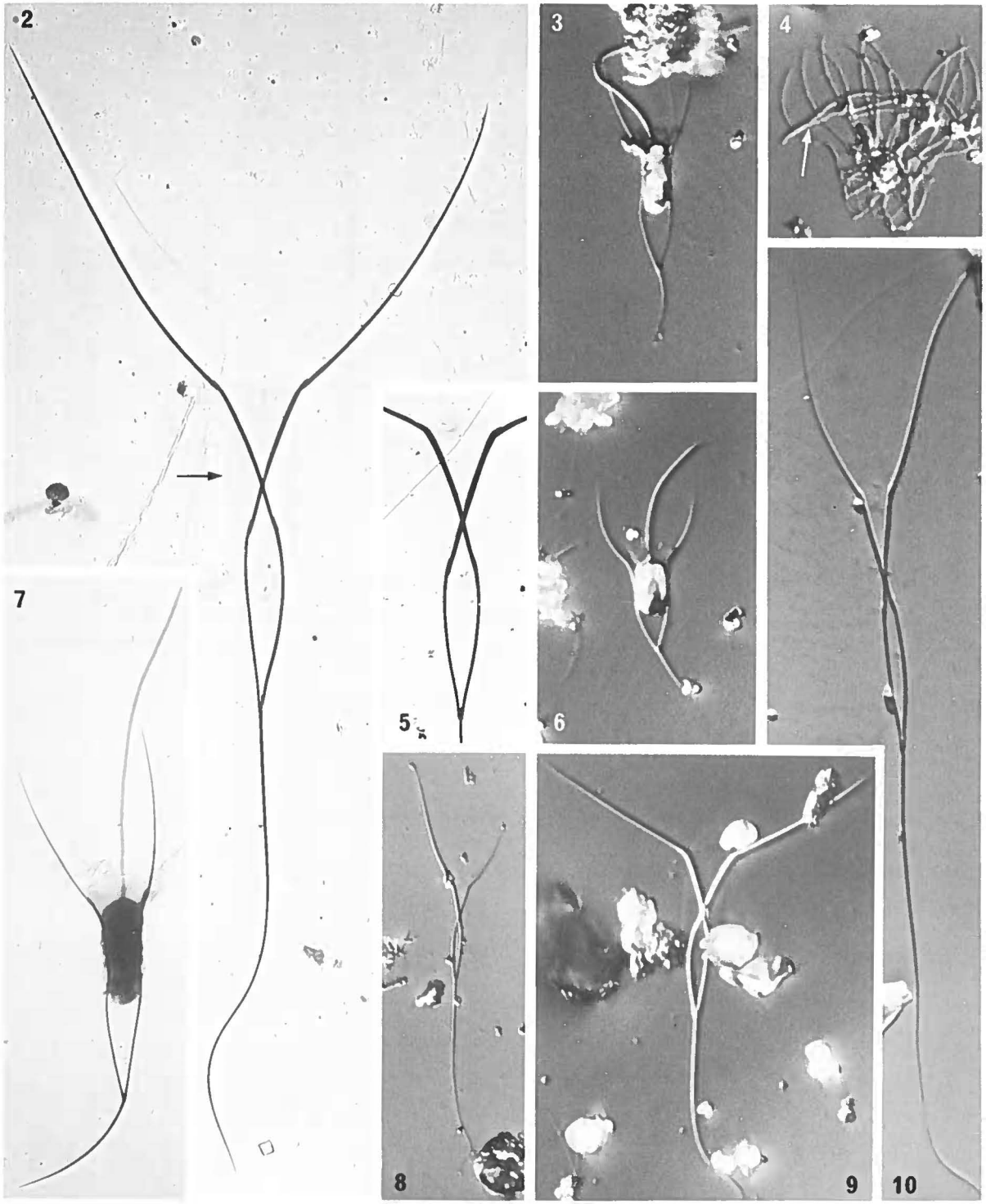
Bicosta spinifera (Throndsen, 1970b) (Figs 2, 5, 8–10)

Seven costal strips arranged as two elegantly arched longitudinal costae which converge posteriorly form the lorica of this species. The anterior and posterior spines are single strips. The remaining four strips make up the lorica chamber (Figs 2, 5). In most specimens examined the anterior spines are of slightly different length (15–20%) (Figs 2, 8, 10) and both differ from the longer and more slender posterior spine (Fig. 2). For a more comprehensive account of the morphology of this species, see Manton et al. (1980) comparing material from widely separated areas.

The overall lorica length of the West Greenland cells is 50–85 µm. The length of the lorica chamber (i.e. the distance between the bases of the anterior and posterior spines) is c. 20 µm; the posterior spine is 20–40 µm long. On a few occasions some much smaller specimens (Fig. 9) were observed in the light microscopical preparations (overall lorica length c. 35 µm; length of lorica chamber c. 12.5 µm; posterior spine c. 15 µm). These specimens occurred in samples (e.g. st. 6:60 m and st. 11:0 m) together with *B. spinifera* cells of normal cell size. Regarding lorica morphology these small specimens appear to be basically similar to the larger cells showing a distinct obliquity in the longitudinal costae. The anterior spines of the small specimens are of similar length. A few small cells have also been observed in all arctic and subarctic regions tested by Manton et al. (1980).

Calliacantha Leadbeater, 1978
Calliacantha longicaudata (Leadbeater, 1975) (Figs 11, 18)

The type locality of this species is Godhavn (Manton et al. 1975). The present material is in full agreement with the type material both regarding lorica construction and dimensions. The overall lorica length is 80–125 µm in the present material. A single light micrograph of *C. longicaudata* has been included here (Fig. 18) to show the amount of information obtainable from dried specimens observed in the light microscope (only electron micrographs were included by Manton et al. 1975). Due to the rather massive costal strips characteristic of this species all essential lorica details are clearly observable also in the light microscope. The lorica chamber is made of five longitudinal costae each composed of two costal strips. Two transverse costae attach to the anterior longitudinal costal strips leaving the ultimate tips of the latter as projecting spines (Figs 11, 18). The pedicel is composed of a variable number of costal strips (10 in Fig. 18) which become thinner distally.



Figs 2–10: **2.** *Bicosta spinifera,* empty lorica; notice pronounced dissimilarity in length of anterior spines; arrow: membrane securing protoplast to lorica (EM T2515, × 3000). **3.** *B.minor* (LM, × 2000). **4.** *Acanthoecopsis apoda;* arrow: double anterior transverse costa (LM, × 2000). **5.** *Bicosta spinifera,* detail of lorica with pronounced morphological difference between costal strips (EM T2564, × 3000). **6.** *B. minor,* whole cell (LM, × 2000). **7.** *B.minor,* lorica and complete protoplast (EM T2679, × 3000). **8–10.** *B.spinifera* (LM). **8.** Empty lorica with very dissimilar anterior spines (× 800). **9.** Empty lorica of small specimen, cf. Fig. 10, (× 2000). **10.** Empty lorica; all costal strip junctions are visible (× 2000).

Table 1. List of species (Acanthoecidae) and their occurrence in the Godhavn area, 1977. Station numbers refer to Fig. 1.

Station No.	1			2		3				4		5	6					7					8	9	10	11	12	Total
Date (20 July–6 August)	25			27		21				1		20	29					6					4	3	20	22	28	
Depth (in metres)	5	30	50	0	10	15	30	40	50	0	60	0	0	60	100	200	300	10	60	100	200	300	0	0	0	0	0	n=27
Acanthoeca spectabilis Ellis, 1930										○																		1
Acanthoecopsis apoda Leadbeater, 1972a	○			○									●														○	4
A. unguiculata Thomsen, 1973				○		○																			○	○	○	5
Bicosta antennigera Moestrup, 1979													○															1
B. minor (Reynolds, 1976)		○		○	○	●	○	○	○	○	○	●	○	○				○					○		○	○	○	17
B. spinifera (Throndsen, 1970b)	○	○	○	○	○	○	○	○	○		○	○	○	○						○			○		○	○		17
Calliacantha longicaudata (Leadbeater, 1975)						○	○	○	○		○	○		○						○						○		9
C. natans (Grøntved, 1956)		○		○	○	○	○	○	○	○	○	○	○	●	○	○	○	○		○			○		○	○	○	21
C. simplex Manton & Oates, 1979a		○	○		○	○	○				○			○		○	○			○								10
Conion groenlandicum gen. et sp. nov.											○						●					○						3
Crinolina isefiordensis Thomsen, 1976													○															1
Diaphanoeca grandis Ellis, 1930						○					○		○															3
D. pedicellata Leadbeater, 1972b								○		○	○			●		○	○											6
D. undulata sp. nov.											○			●														2
Parvicorbicula quadricostata Throndsen, 1970a					○	○		○	○		○	○		○														7
P. serratula Leadbeater, 1975							○				○		○	●		○	○			○								7
P. socialis (Meunier, 1910)						○	○	○			○	○		○			○					○						8
Pleurasiga caudata Leadbeater, 1975											○		○	○	○													4
P. minima Throndsen, 1970a			○	○	○	○	○	○	○	○		○	○	○				○							○	○	○	15
P. orculaeformis Schiller, 1925[1]											○			○		○	○			○		○						6
P. reynoldsii Throndsen, 1970a				○	○	○	○	○				○		○											○	○	○	10
Saroeca attenuata Thomsen, 1979														○														1
Stephanoeca diplocostata diplocostata Ellis, 1930																								○				1
S. diplocostata paucicostata Throndsen, 1969										○																		1
Choanoflagellate sp. "N"		○																		○								2
Species per sample	2	5	3	7	7	11	9	9	6	6	14	8	9	16	2	5	7	3	0	7	0	3	3	1	6	7	6	
Species per locality		7		9		13				17		8	20					11					3	1	6	7	6	

○ present; ● large cellnumbers; [1]sensu Leadbeater 1973.

Calliacantha natans (Grøntved, 1956) (Figs 12, 13, 15–17, 19, 20, 22–24, 27)

Qualitative details of the lorica construction of this species have been accounted for recently by Manton & Leadbeater (1978). Only a very distinct bimodal size distribution of the West Greenland specimens and possible problems in connection with the light microscopical identification of this taxon will be dealt with here.

Size ranges and mean values of the two size categories of *C. natans* are given in Table 2. The overall lorica length, which is best suited for immediate separation of the two forms is measured as the distance between the posterior end of the pedicel and a line connecting the two outermost anterior spines. The larger specimens are on the average twice as large as the smaller forms as regards overall lorica length and the length of the anterior spines. The difference in lorica chamber length is less pronounced; the mean values are 17.5 and 11 µm respectively but the size ranges are almost continuous. The two forms of *C. natans* cannot be distinguished on the basis of reliable morphological criteria (compare Fig. 13 and Fig. 17), nor is size alone useful for separation. Considering also *C. natans* specimens from other regions (e.g. from Danish coastal waters, Thomsen unpublished) size categories (different from those encountered along the West Greenland coast) appear to bridge the gap between the extremes represented in the present material.

The two forms of *C. natans* probably represent water masses of different origin mixing in the Disko Bugt, as the big form is abundant in water samples from larger depths (e.g. st.6: 60, 100m and st.4: 60m), whereas the small form is generally most frequent in surface samples. In Danish coastal waters the small form of *C. natans* dominates in summer and early autumn (Thomsen, unpublished) which points to the smaller form having a slightly higher temperature optimum than the large form of *C. natans*.

The essential characteristics for light- and electron microscopical identification of *C. natans* include (1) three anterior spines which are not continuous with the longitudinal costae (Fig. 22), (2) six longitudinal costae (Figs 22, 24) which become reduced in number to five (Fig. 16), four (Fig. 22) or three (Figs 12, 13, 24) at the posterior end of the lorica chamber, and (3) a triangular outline of the anterior transverse costa (Fig. 20).

Difficulties may arise in distinguishing *C. natans* from *C. simplex* Manton & Oates, 1979a and *C. multispina* Manton & Oates, 1979b. The most useful single characteristic for distinguishing *C. natans* from both species is the course of the anterior spines. In *C. natans* these are as mentioned above not continuous with the longitudinal costae (Fig. 22), whereas in *C. simplex* (Figs 21, 26) and *C. multispina* there is a regular continuity between spines and longitudinal costae.

Calliacantha simplex Manton & Oates, 1979a (Figs 14, 21, 25, 26)

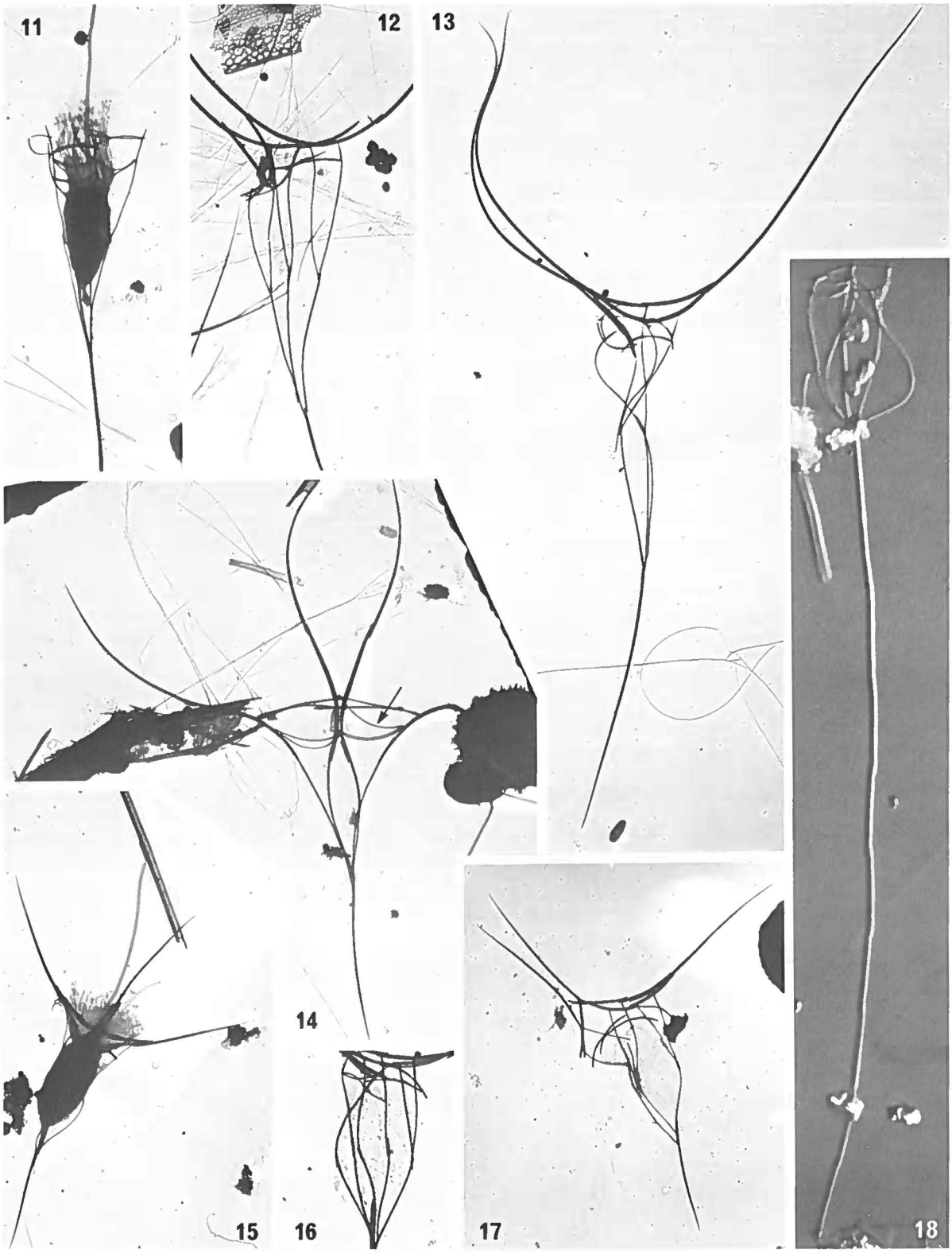
C. simplex is highly variable with regard to lorica dimensions, whereas the construction of the lorica appears to be fairly constant. The lorica size of this species is apparently inversely correlated with temperature (Manton & Oates 1979a). The West Greenland specimens (Figs 14, 21, 26) are in most details similar to the South Alaskan type material (Manton & Oates 1979a).

The two transverse costae of this species each consist of four costal strips (Manton & Oates 1979a). However, in some of the West Greenland cells examined extra costal strips are present, apparently interconnecting the two transverse costae (Fig. 14, arrow). It is also possible to observe extra costal strips in some of the light micrographs of *C. simplex*. In Fig. 25 there are nine transverse costal strips, and the strip pointed out in Fig. 26 (arrowhead) is probably also interconnecting the two transverse costae. The very precise location obviously rules out the possibility that the extra costal strip is either a dislocated duplicated strip or one of the extra costal strips produced prior to cell division.

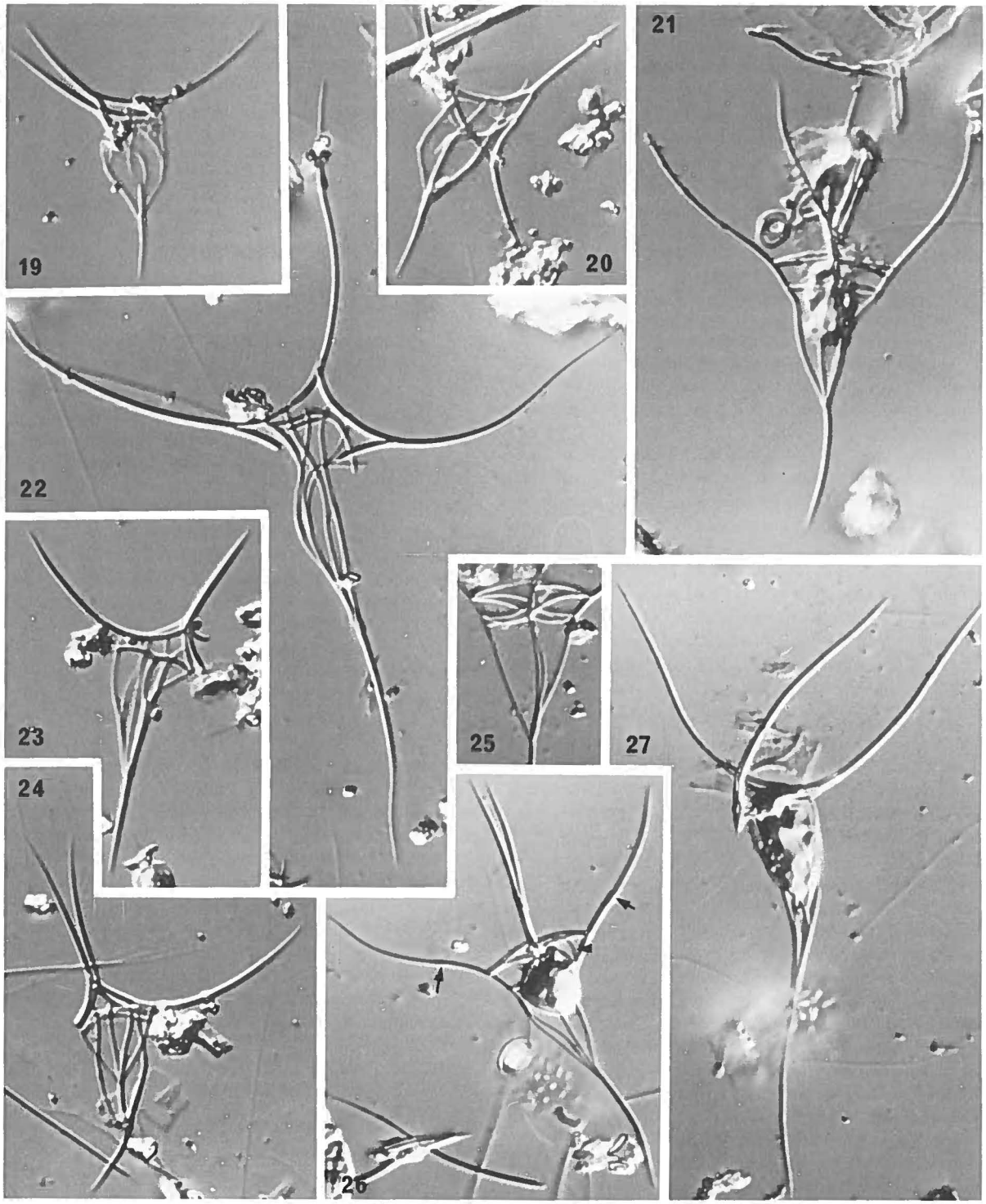
Light micrographs of *C. simplex* (Figs 21, 26) show all the essential characteristics for identification of this species; primarily four anterior spines approximately 1 1/2 costal strip long, each continuous with a longitudinal costa; and the longitudinal costae (each composed of three costal strips) which converge to a point posteriorly without amalgamating.

Table 2. Lorica dimensions (µm) of the two *C. natans* forms encountered in samples from Godhavn, 1977.

1: large form 2: small form		Overall lorica length	Anterior spine length	Lorica chamber length	Pedicel length	Costal strip length (ant. transv.) costa)	Number of cells measured
1	Size range	45–60	16–24	16–19	12–20	4.7–5.1	10
	Mean values	55	22	17.5	17	5	
2	Size range	20–32	8–12	9.5–14	3.5–9.5	4–5	17
	Mean values	27	10	11	6	4.5	



Figs 11–18: **11.** *Calliacantha longicaudata,* detail of anterior lorica end (EM T2868, × 2500). **12–13.** *C. natans,* large form. **12.** Detail of lorica showing amalgamation of longitudinal costae (EM T1904, × 2500). **13.** Empty lorica; notice conspicuous difference in costal strip thickness (EM T2214, × 2500). **14.** *C.simplex,* empty lorica; arrow: costal strip interconnecting the two transverse costae (EM T1907, × 2500). **15–17.** *C.natans,* small form. **15.** Complete cell with tentacles and flagellum (EM T1954, × 2500). **16.** Lorica chamber; the six longitudinal costae are reduced to five posteriorly (EM T1884, × 2500). **17.** Empty lorica (EM T1804, × 2500). **18.** *C.longicaudata,* empty lorica with pedicel composed of 10 costal strips (LM, × 2000).



Figs 19–27: *Calliacantha* species (LM, × 2000). **19.** *C.natans,* small specimen; notice the characteristic position of thick posterior spine. **20.** *C.natans,* small specimen; notice triangular shape of anterior transverse costa. **21.** *C.simplex,* whole cell; notice the continuity of longitudinal costae from the anterior spines to the posterior end of the lorica chamber. **22.** *C.natans,* empty lorica of large specimen. **23–24.** *C.natans,* empty loricas of small specimens. **25.** *C.simplex,* detail of lorica chamber. **26.** *C.simplex,* whole cell; arrows: costal strip joints in anterior spines; arrowhead: costal strip interconnecting the two transverse costae. **27.** *C.natans,* large cell with distinct collar.

Conion gen.nov. (from the Greek konos, cone, and ion, diminutive).

Diagnosis: Cell located in cone-shaped lorica composed of longitudinal and transverse costae. The anterior longitudinal costal strips, which project as short spines, join the following strips one third from their posterior end. The anterior transverse costa is positioned at the anterior end of the second longitudinal costal strip. At the posterior lorica end the longitudinal costae amalgamate before they converge and join with one or more costal strips forming a pedicel.

Type species: *Conion groenlandicum* sp.nov.

The erection of this new genus reflects the difficulties in allocating the present material to any of the previously described choanoflagellate genera rather than emhasizes distinctive lorica features within the new taxon.

Apart from basic lorica characteristics (i.e. number and position of transverse and longitudinal costae) the conical outer shape of the lorica and the anterior end costal strip connections are probably the most conspicuous features of the new genus. The mode of connection between transverse and longitudinal costal strips in *Conion* gen.nov. is basically similar to that observed in species of *Diaphanoeca*. The conical shape and the absence of distinct anterior spines, however, clearly distinguishes the present taxon from that genus.

Conion groenlandicum sp.nov. (Figs 28–34)

Diagnosis: Solitary, protoplast c. 5 µm long, located in a cone-shaped lorica composed of mostly 11 longitudinal costae and three transverse costae. The lorica is 13–14 µm long, and the diameter at the anterior transverse costa 9–12 µm; diameter at posterior transverse costa 6.0–8.5 µm. Most longitudinal costae are composed of five costal strips, others consist of only four costal strips due to amalgamation of longitudinal costae at the posterior lorica end. The anterior longitudinal costal strips join the next costal strip two thirds from the anterior end of this strip. The transverse costae are positioned at the anterior end of the second longitudinal costal strip, and at the middle of the third and fourth longitudinal costal strip counted from the anterior lorica end. The two anterior transverse costae consist of a number of costal strips which equals the number of longitudinal costae; the posterior transverse costa contains much fewer costal strips (c. 4).

At the posterior lorica end the longitudinal costae amalgamate and join with several costal strips forming a pedicel 7–10 µm long.

Holotype: Fig. 28 collected at Godhavn (West Greenland) from 300 metres depth, 29. August 1977.

Additional remarks: All costal strips of *C. groenlandicum* are of approximately the same length (c. 4 µm).

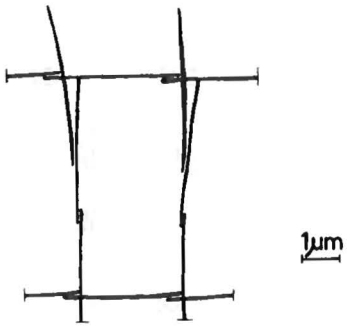


Fig. 34. *Conion groenlandicum* gen. et sp. nov. Schematic drawing of the costal strip connections at the anterior lorica end.

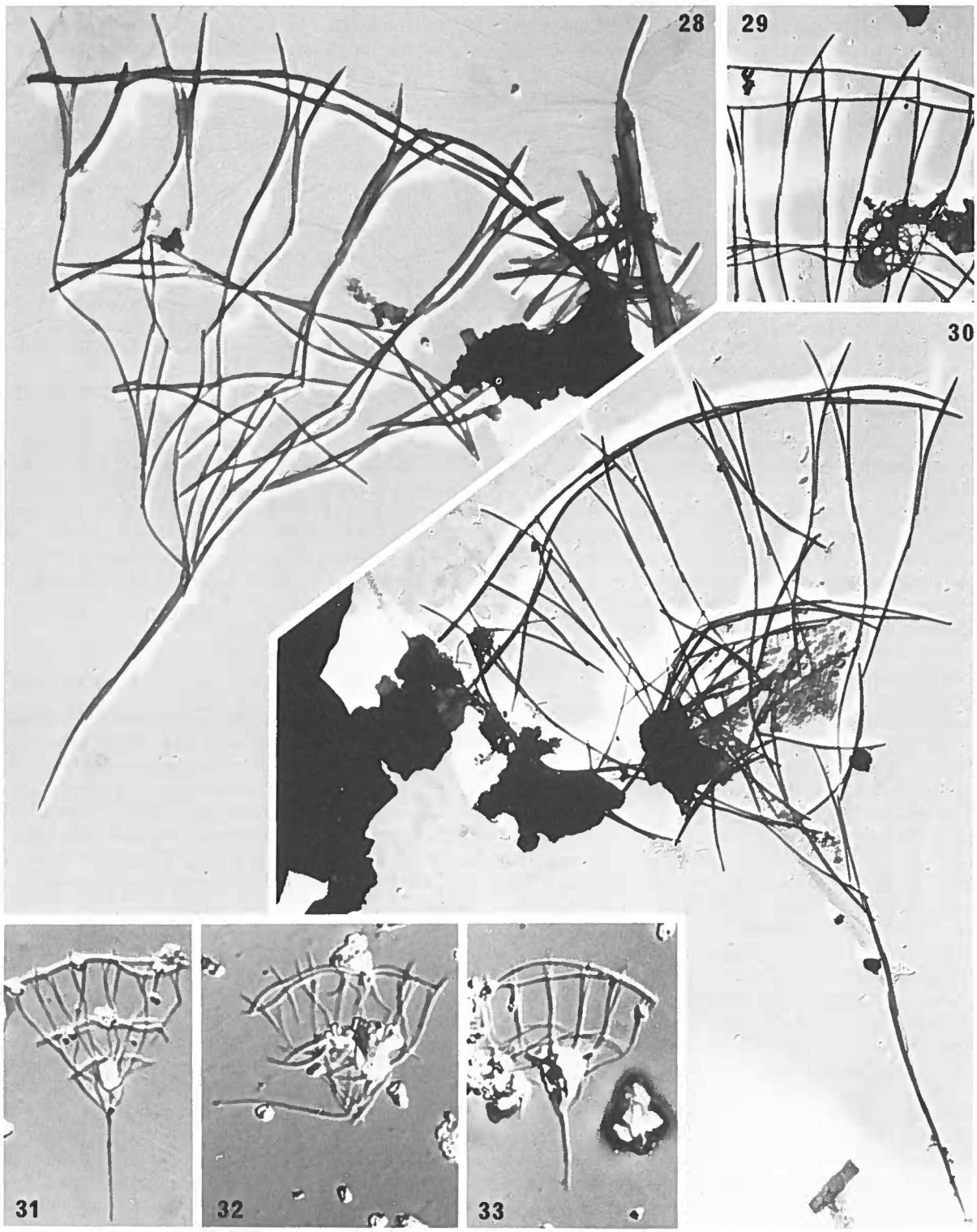
The costal strips of the anterior transverse costa and the pedicel commonly appear thicker than the remaining strips (Figs 28, 30). Also the anterior longitudinal costal strips occasionally appear somewhat different from the rest of the longitudinal costal strips (Fig. 29). Individual differences exist regarding the construction of the posterior part of the lorica chamber (Figs 28, 30). All loricas observed show different patterns of longitudinal costae convergence (one such example is particularly well illustrated in Fig. 28) resulting in a reduction in the number of longitudinal costae from c. 11 at the anterior lorica end to c. 4 at the transition to the pedicel. In the very few cells where a protoplast was actually observed it was located at the posterior end of the lorica chamber (Fig. 33).

C. groenlandicum is easily identified in the light microscope (Figs 31–33). The very characteristic mode of attachment between longitudinal and transverse costal strips at the anterior lorica end (Fig. 29) is also distinct in the light micrographs (Figs 31, 32), as are the general lorica characteristics (i.e. number of costae and their relative positions, Fig. 31).

C. groenlandicum was abundant in a sample from 300 metres depth collected at st. 6 (Fig. 1), and was furthermore observed in another deep water sample from st. 7 (300 m). A single specimen was observed in the 60 m sample from st. 4.

Crinolina Thomsen, 1976
Crinolina isefiordensis Thomsen, 1976 (Fig. 35)

The only cell observed (Fig. 35) was quite similar to the Danish type material (Thomsen 1976). *Crinolina aperta* (Leadbeater, 1975), described on the basis of material from Resolute Bay (Arctic Canada) (Manton et al. 1975), was somewhat surprisingly not observed in any of the West Greenland samples. Moestrup (personal communication) recently found in Antarctic samples specimens of *C. aperta* which appear similar to the type material from Arctic Canada. This fact in connection with the findings of *C. isefiordensis* in Danish coastal



Figs 28–33: *Conion groenlandicum* gen. et sp. nov. **28.** Type specimen (EM T2634, × 6000). **29.** Detail of anterior lorica end showing costal strip junctions (EM T2272, × 5000). **30.** Empty lorica; notice difference in costal strip thickness between transverse and longitudinal elements at anterior lorica end (EM T2270, × 6000). **31–33.** Light micrographs (× 2000). **31–32.** General lorica construction. **33.** Whole cell with protoplast located at posterior end of lorica chamber.

waters (Thomsen 1976), in New Zealand samples (Moestrup 1979) and along the West Greenland coast, (all cells examined appear almost identical), further emphasizes the interpretation of *C. isefiordensis* and *C. aperta* as two distinct taxa, rather than environmentally induced extremes of a variational continuum.

Diaphanoeca Ellis, 1930

Diaphanoeca pedicellata Leadbeater, 1972b (Figs 36–40, 57, 61)

D. pedicellata was described on the basis of material collected near Frederikshavn (Denmark). Later somewhat divergent specimens from the Adriatic Sea (Leadbeater 1973) and from Denmark (Thomsen 1976) have been referred to this taxon.

In the West Greenland samples from 1977 *D. pedicellata* sensu Leadbeater (1972b) was very common in certain samples, rendering possible a detailed reinvestigation of the species, most relevant in connection with the description of two new species of *Diaphanoeca* (p. 14, 20).

The overall length of the *D. pedicellata* lorica varies from c. 50 µm to c. 70 µm. The lorica chamber length is 25–30 µm and the diameter at the anterior transverse costa 8–9 µm. A variable number of longitudinal costae (12–14) form part of the lorica chamber. Each longitudinal costa is made of four or five costal strips. A certain reduction in number of longitudinal costae occurs below the posterior transverse costa. At the anterior lorica end the longitudinal costal strips project as spines beyond the anterior transverse costa (Fig. 36). Three transverse costae encircle the lorica chamber. The number of costal strips in the two anterior transverse costae equals the number of longitudinal costae (Figs 38, 40). The posterior transverse costa comprises much fewer costal strips (4 or 5). In Fig. 57A is shown schematically the mode of attachment between the costal strips of the anterior transverse costa and the longitudinal costal strips. This ring crosses at the junction between the first and the second longitudinal costal strip counted from the anterior end. Less than two longitudinal costal strips separate the two anterior transverse costae (Figs 36, 38). The middle transverse costa is located anterior to the junction of the third and the fourth longitudinal costal strip counted from the anterior end (Fig. 38). The mode of attachment between crossing strips is shown in Fig. 57A. It is difficult to describe in detail the costal strip arrangement at the posterior end of the lorica chamber. Costal strip amalgamation and the occasional duplication of single strips result in more or less individual patterns in this transition region between lorica chamber and pedicel. The pedicel varies in length between 25 and 40 µm.

At least three different types of costal strips form part of the *D. pedicellata* lorica. Those of the longitudinal costae are rather thin and approximately 6 µm long (Fig. 38). The transverse costal strips are somewhat thicker (at least in the middle) and characteristically c. 3.5 µm long (Fig. 38). The costal strips forming the pedicel are just as long as the longitudinal costal strips, but conspicuously thicker (Fig. 36). There seems to be a general reduction in costal strip diameter from one end of the pedicel to the other (Fig. 36).

The *D. pedicellata* protoplast is placed at the bottom of the lorica chamber (Figs 36, 39, 61), with the ring of tentacles just reaching the middle transverse costa (Fig. 38).

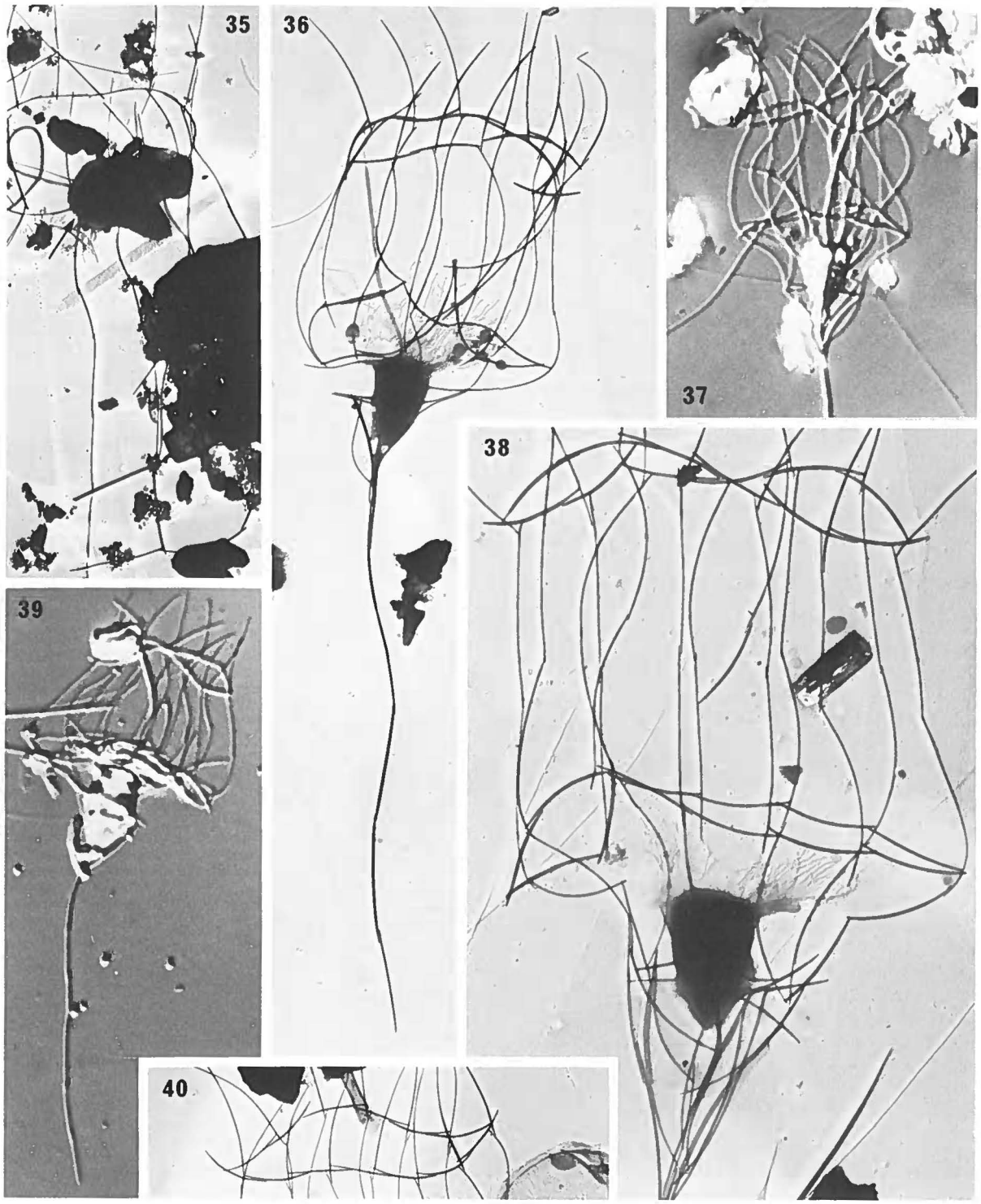
A comparison between light micrographs (Figs 37, 39, 61) and electron micrographs (Figs 36, 38) of *D. pedicellata* shows that all lorica details which are essential for species determination, i.e. particularly the location of the transverse costae (compare *D. undulata* sp. nov.) are clearly noticeable also in the light micrographs.

The Danish type material (Leadbeater 1972b, figs 20, 21) and the West Greenland specimens here accounted for are conspecific. The only noticeable difference, which can be observed, is a tendency towards a more prominent distinction between the different types of costal strips in the West Greenland material. The size difference between transverse and longitudinal costal strips in the Danish specimen (Leadbeater 1972b) is approximately 50% whereas in the West Greenland specimens almost 100%.

Diaphanoeca undulata sp. nov. (Figs 41–47, 57, 62, 64)

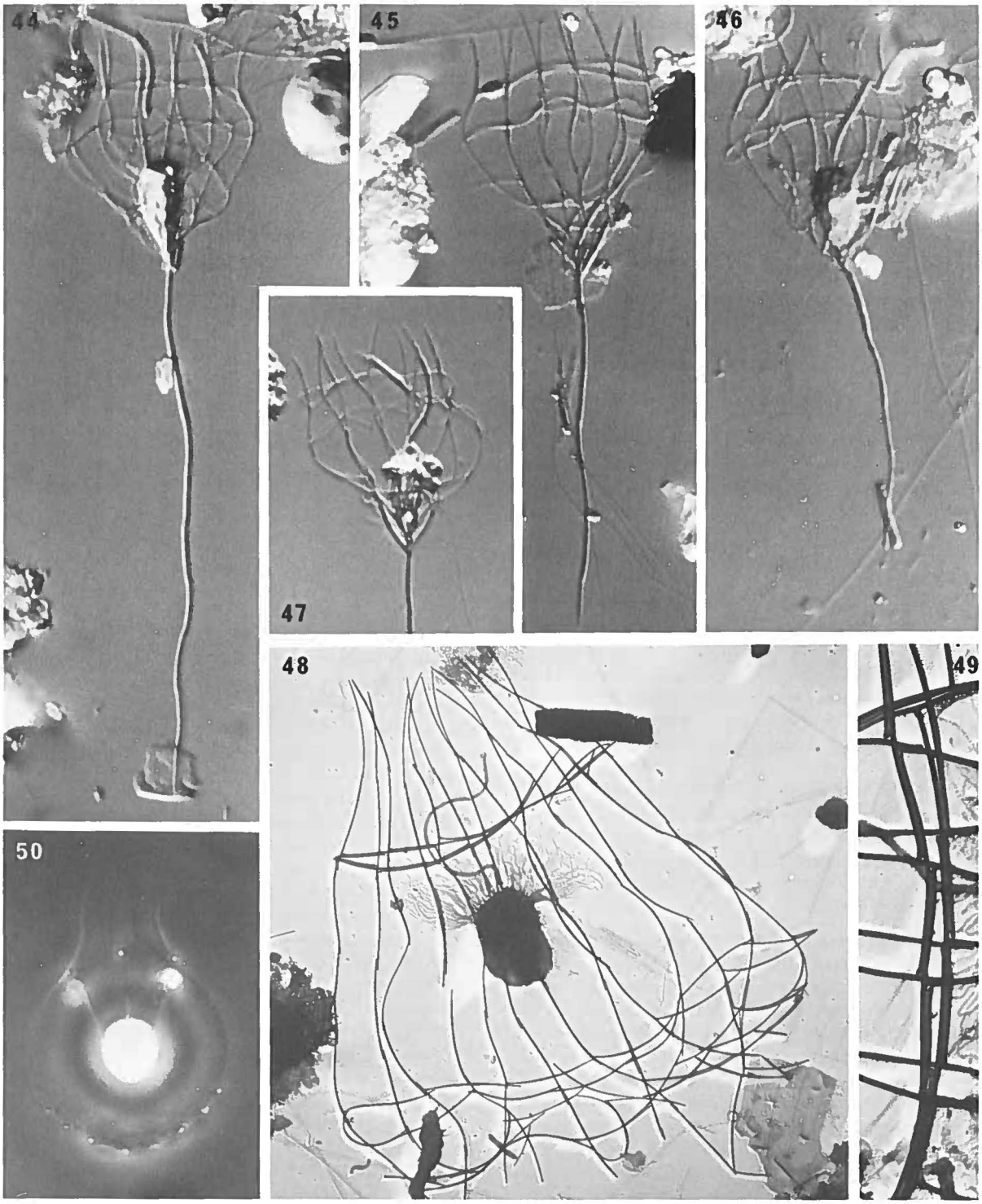
Diagnosis: Solitary; protoplast when measured in dried preparations 4.0–6.4 × 2.4–3.1 µm; single anteriorly inserted flagellum (8–15 µm long) surrounded by a collar of tentacles, c. 2µm long. Lorica (up to 65 µm long) consisting of one chamber (approximately 20 µm long) formed by 11 (12) longitudinal costae and three transverse costae. Each longitudinal costa consists of 5 costal strips. The two anterior transverse costae are made of a number of costal strips which equals the number of longitudinal costae. The mode of attachment between longitudinal and tranverse costal strips is basically end to end. The anterior transverse costa crosses the longitudinal costae at the junctions between the first and the second costal strip, leaving the anterior longitudinal costal strips as free projecting spines. The middle transverse costa crosses the longitudinal costae anterior to the junctions between the second and the third longitudinal costal strips. The distance between the two transverse costae (3 µm) is thus less than the length of one longitudinal costal strip. The posterior transverse costa is composed of much fewer costal strips (5–6) which cross the longitudinal costae at the junctions between the fourth and the fifth longitudinal costal strips counted from the anterior lorica end. Posteriorly the longitudinal costae converge and join with a pedicel (up to c. 50 µm long).

The protoplast is located at the posterior end of the



Figs 35–40: **35.** *Crinolina isefiordensis,* partly damaged lorica with protoplast (arrow); notice characteristic flagellar loop (EM T2237, × 2500). **36–40.** *Diaphanoeca pedicellata.* **36.** Lorica and complete protoplast (EM T2828, × 3000). **37.** Lorica chamber with protoplast (LM, × 2000). **38.** Detail of lorica chamber; notice conspicuous difference between transverse and longitudinal costal strips (EM T1890, × 5000). **39.** Complete cell in preparation for cell division: protoplast enlarged and extra costal strips deposited in collar region (LM, × 2000). **40.** Detail of anterior transverse costa showing costal strip junctions (EM T1900, × 3000).

Figs 41–43: *Diaphanoeca undulata* sp. nov. **41.** Detail of anterior lorica end showing costal strip junctions; arrow: thick costal strips of pedicel (EM T2040, × 10000). **42.** Complete cell, type specimen (EM T2812, × 4000). **43.** Detail of lorica chamber; notice the anterior edge of subtending membrane attached to middle transverse costa (EM T2811, × 7500).



Figs 44–50: **44–47.** *Diaphanoeca undulata* sp. nov. (LM, × 2000). **48–50.** *D.grandis,* the Isefjord, Denmark. **48.** Complete cell with well preserved suspended protoplast (EM T3016, × 3000). **49.** Detail of anterior transverse costa showing transverse costal strip overlap, and junctions between transverse and longitudinal elements (EM H328, × 7500). **50.** Living cell showing position of protoplast within lorica; tip of tentacles reaches anterior transverse costa, cf. Fig. 48 (LM, anoptral contrast, × 2000).

lorica chamber, and secured to the lorica by a delicate membrane which reaches the middle transverse costa.

Holotype: Fig. 42 collected outside Godhavn, West Greenland, st. 6, at 60 m depth on 29 August 1977; salinity c. 33 ‰ S, temperature c. 5°C.

Additional remarks: *D. undulata* was observed in two samples only (Table 1). It was particularly abundant in the 60 m sample from st. 6 (Fig. 1). A selection of light micrographs of dried specimens from this sample are shown in Figs 44–47, 62, 64.

The general mode of lorica assemblage has been accounted for in the species diagnosis. A few additional morphological characteristics not necessary for species identification will be dealt with in the following paragraphs.

All costal strips of the *D. undulata* lorica are practically of the same length (4–5 μm), yet different types exist. The costal strips forming the stalk are thus considerably thicker than the others (Figs 41, 42). Also the projecting spines seem to be morphologically distinct. At the point of connection with the second longitudinal costal strip the anterior spines are generally somewhat thicker than this strip (Fig. 41) and they are furthermore characteristically tapering towards the anterior end (Fig. 43). The costal strips of the middle transverse costa appear to be thinner and more flexible than the rest (Figs 41, 43). The specific epithet reflects the wavy appearance of the middle tranverse costa (Figs 41, 44, 47). Concerning the mode of attachment between longitudinal and transverse costal strips this species is similar to *D. pedicellata* (see schematic drawings Fig. 57A, B).

The anterior end of the *D. undulata* lorica chamber appears to be identical in all specimens observed whereas the posterior part of the lorica chamber (including the posterior transverse costa) is much more variable in construction (in that respect also similar to *D. pedicellata).*

D. undulata is obviously closely related to *D. pedicellata* (cf. Figs 36–39 of the present paper). The distinguishing characteristics between the two species are: the size of the lorica chamber (*D. pedicellata:* c. 25 μm; *D. undulata:* c. 20 μm); the lorica shape (compare Fig. 61 and Fig. 62); this difference in outer shape of the lorica chamber is occasioned by the pushing forward of the middle transverse costa in *D. undulata;* the number of longitudinal costae (*D. pedicellata:* c. 13; *D. undulata:* c. 11). The most generally applicable characteristic for immediate specific recognition is the close-set transverse costae in *D. undulata,* a characteristic which is easily observable also in the light microscope (Figs 44–47).

Leadbeater (1973) reported the finding of two forms of *D. pedicellata* from the coast of Jugoslavia. One of these (Leadbeater 1973, pl. 20 a–d) was later described as a separate species: *D. cylindrica* Leadbeater, 1974. The other form (Leadbeater 1973, pl. 20 e, f) differed from the Danish type material (Leadbeater 1972b) by having 11 or 12 longitudinal costae (as opposed to 14) and a somewhat smaller lorica chamber. It is evident from the published micrographs that this form of *D. pedicellata* is furthermore characterized by having closely spaced anterior transverse costae. These specimens from the Adriatic Sea are most likely identical to *D. undulata.*

Diaphanoeca grandis Ellis, 1930 (Figs 48–50, 57, 59)

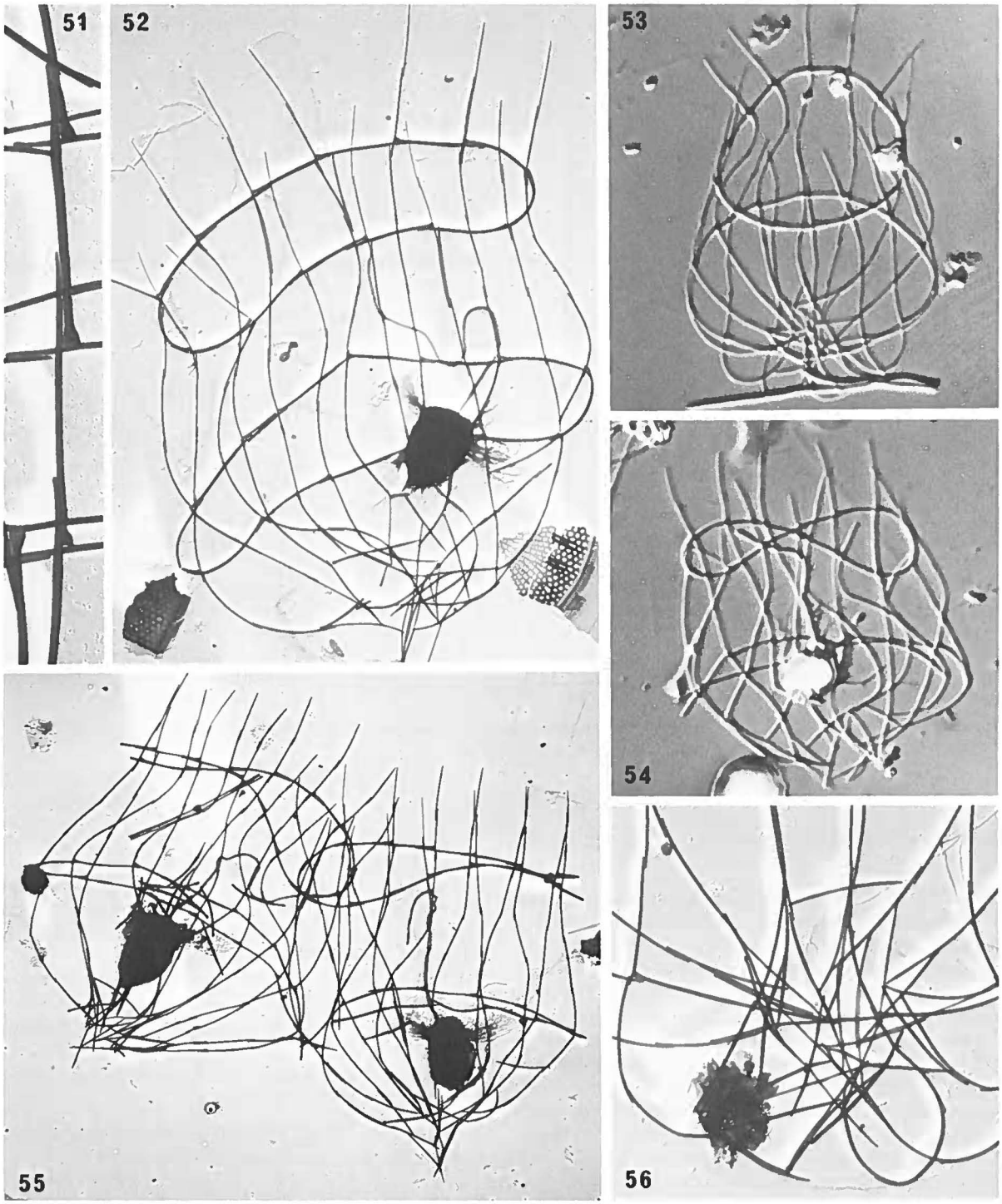
D. grandis was observed in three of the West Greenland samples (Table 1). Only a few rather damaged specimens were, however, encountered and the species has consequently been illustrated on the basis of Danish material (Figs 48–50, and Fig. 59) originating from the Isefjord. *D. grandis* is the generic type (Bourrelly 1957), for which reason it is relevant to examine thoroughly the lorica details of this species in order to facilitate a comparison with other species allocated to the genus.

Electron micrographs of *D. grandis* have been published by Gold et al. (1970), Throndsen (1970a), Leadbeater (1972a) and Thomsen (1973). Light micrographs are included in Throndsen (1974) and Valkanov (1970).

The anterior spines of *D. grandis* are composed of two costal strips (Fig. 48), and the distance between the anterior transverse costa and the next transverse costa is always equal to the length of three longitudinal costal strips (Figs 48, 59). The number of costal strips in the anterior transverse costa equals the number of longitudinal costae (12–14), each costal strip covering two intervals between longitudinal costae thereby giving this transverse costa the appearance of a double transverse costa (Figs 48, 49; see also the schematic drawing, Fig. 57C). Lorica details are on the whole less well-defined at the posterior lorica end. The number of transverse costae thus varies between two and four. The mode of connection between the transverse costae and the longitudinal costae is shown in Fig. 57C. Longitudinal costal strips are about 10% longer than the transverse costal strips.

The protoplast is suspended in the middle of the bulbous part of the lorica (Figs 50, 59). The collar reaches the anterior transverse costa (Figs 48, 50).

As *D. grandis* is a rather large species and moreover very distinct in lorica construction it is non-mistakable in the light microscope even in water preparations of living cells (Fig. 50). Light micrographs (interference contrast) of dried specimens (Fig. 59) are almost as informative as electron micrographs of whole mounts of *D. grandis* (Fig. 48).



Figs 51–56: *Diaphanoeca sphaerica* sp. nov., the Isefjord, Denmark. **51.** Detail of anterior transverse costa showing morphology of individual costal strips and mode of connection with longitudinal costal strips (EM T3055, × 10000). **52.** Complete cell, type specimen (EM T3042, × 3000). **53.** Empty lorica (LM, × 2000). **54.** Complete cell (LM, × 2000). **55.** Two cells attached to each other between the two anterior transverse costae, cf. Fig. 58 (EM T3053, × 2000). **56.** Detail of posterior lorica end (EM T3041, × 5000).

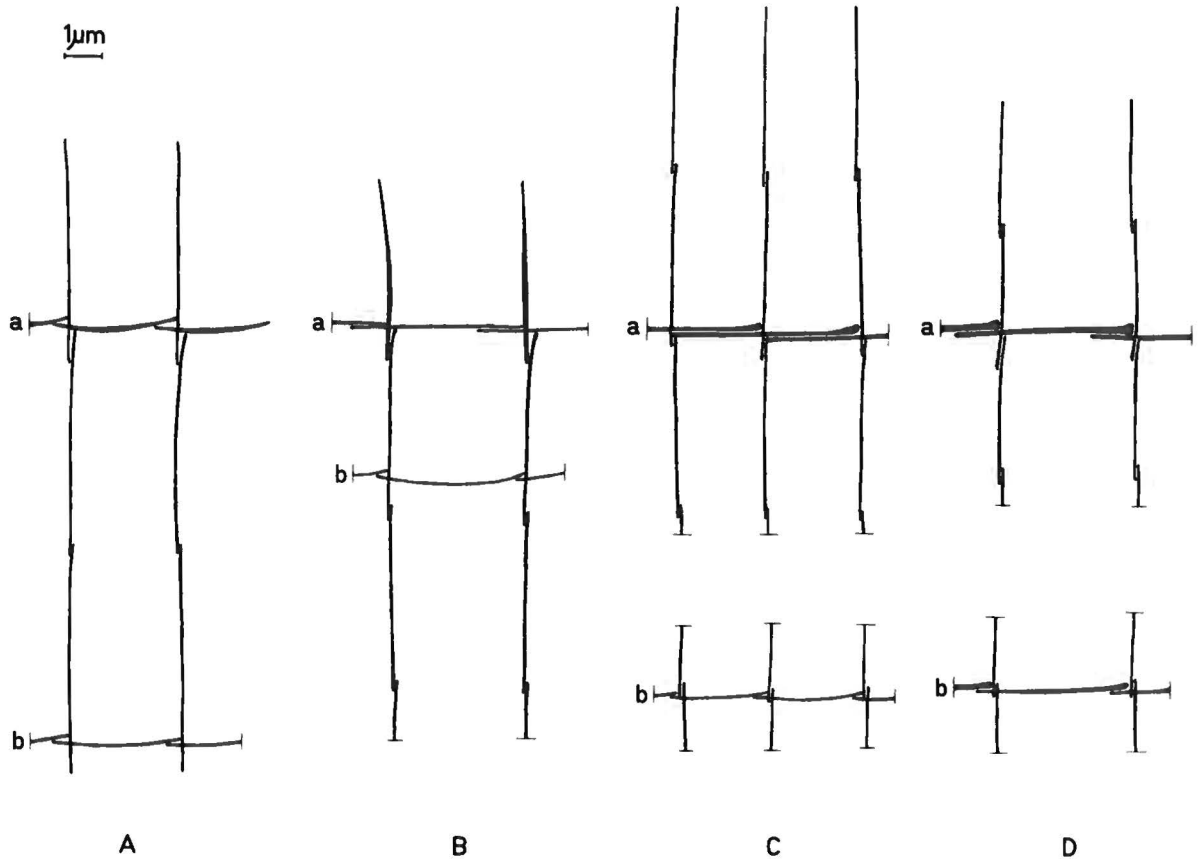


Fig. 57. Schematic drawings of the costal strip connections in A: *Diaphanoeca pedicellata*, B: *D.undulata*, C: *D.grandis*, D: *D.sphaerica*. (a: anterior transverse costa; b: middle transverse costa).

Diaphanoeca sphaerica sp. nov. (Figs 51–56, 57, 58, 60, 63)

Diagnosis: Protoplast c. 7 × 4 µm, with a single anterior flagellum (10–12 µm) surrounded by a ring of tentacles. The protoplast is located in a bell-shaped lorica 22.5–30 µm long, with a maximum diameter of 16.0–17.5 µm; diameter at the anterior end 10.0–15.0 µm. The lorica is formed by 14 (13–15) longitudinal costae and three transverse costae. Each longitudinal costa consists of 9 (10) costal strips. The number of costal strips in the two anterior transverse costae equals the number of longitudinal costae. The posterior transverse costa contains much fewer costal strips. All connections between transverse and longitudinal elements are basically end to end. The anterior transverse costa crosses the longitudinal costae at the junction between the second and the third costal strip counted from the anterior end. The middle transverse costa attaches to the junctions of the fifth and sixth longitudinal costal strips (counted from the anterior end).

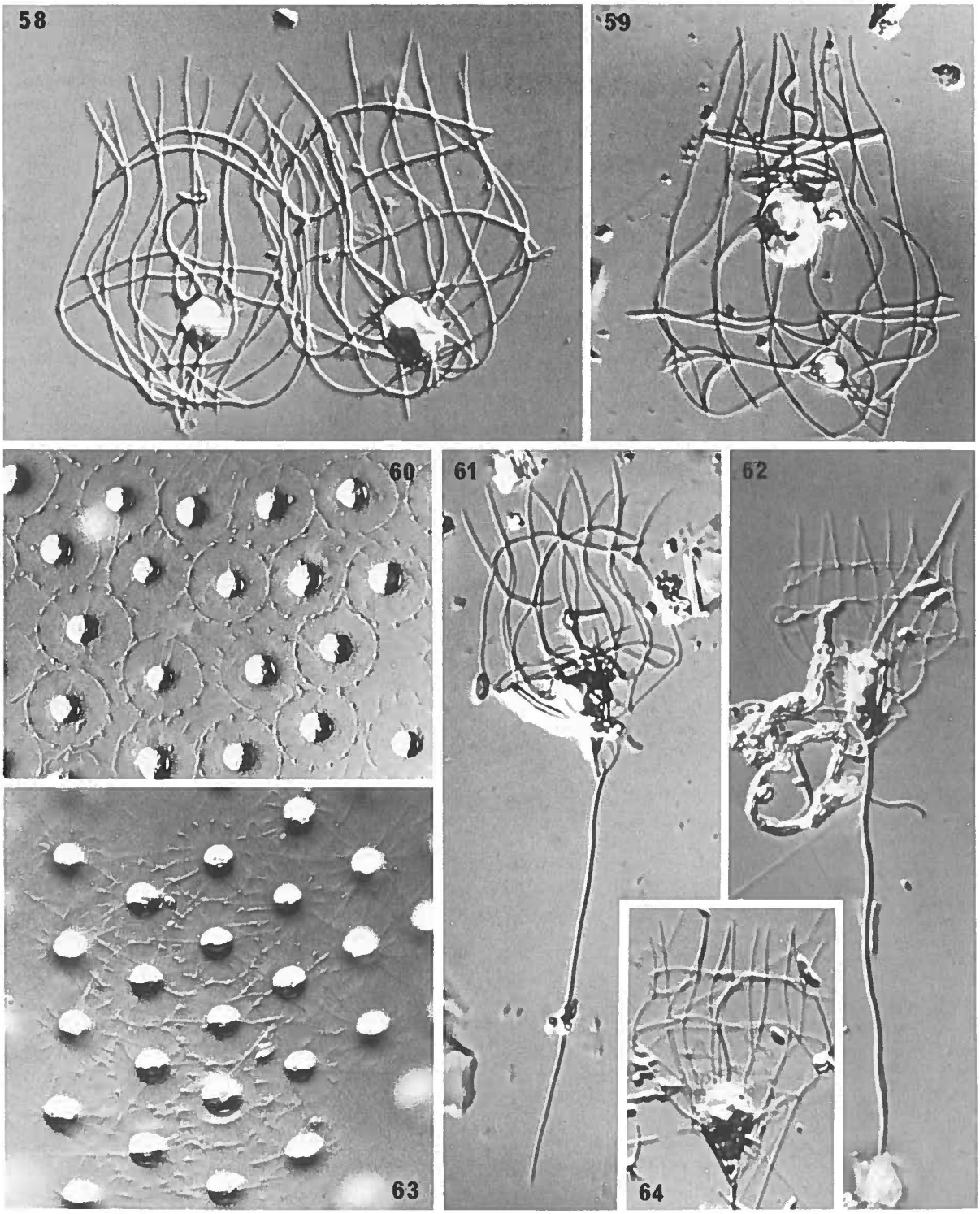
The costal strips of the anterior transverse costa (and to some extent those of the middle transverse costa) are asymmetrical, tapering at one end and possessing triangular, slightly bifurcate enlargements at the other end.

The posterior lorica end is characterized by rather irregular interconnections between the longitudinal costae and costal strip duplication, producing a short triangular spine at the lorica end.

Cells commonly united into sphaerical colonies (hence the specific epithet) with the lorica apertures pointing towards a common cavity. Cells in the colonies are arranged in clusters of six, and neighbouring cells are united along adjoining longitudinal costae between the two anterior transverse costae.

Holotype: Fig. 52 collected in a surface water sample from the Isefjord (Denmark), November 1979.

Additional remarks: Although not encountered in the West Greenland samples from 1977, it has been considered convenient to include in the present paper (alongside with the reinvestigations of *D. pedicellata* and *D. grandis* and the description of *D. undulata* sp. nov.) the formal description of *D. sphaerica* sp. nov., previously referred to *D. pedicellata* (Thomsen 1976).



Figs 58–64: Light micrographs of four *Diaphanoeca* species (× 2000 except Figs 60, 63). **58.** Twin pair of *D.sphaerica,* the Isefjord, Denmark, cf. Fig. 55. **59.** *D.grandis,* the Isefjord, Denmark; notice suspended position of protoplast. **60, 63.** *D.sphaerica* colonies, the Isefjord, Denmark; cells arranged in hexagonal pattern (× 800). **61.** *D.pedicellata.* **62, 64.** *D.undulata.*

Apart from the diagnostic features presented for *D. sphaerica*, some further details of lorica morphology should be briefly commented on.

All longitudinal costal strips of *D. sphaerica* are rather thin and approximately 4 μm long (Figs 52, 55). Those of the two anterior transverse costae are c. 4.7 μm long. In Fig. 51 (and schematically in Fig. 57D) is shown the mode of connection between transverse and longitudinal costal strips. A comparison between Fig. 57A *(D. pedicellata)* and Fig. 57D *(D. sphaerica)* shows basically similar modes of attachment. The costal strips of the anterior transverse costa are morphologically highly characteristic. They are generally rather thick (tapering towards one end) and spatulate at the end which makes contact to the longitudinal system (Fig. 51). Less pronounced end-enlargements are present on the costal strips of the middle transverse costa (Fig. 52).

As emphasized by Thomsen (1976) it is difficult to describe in detail the costal strip pattern of the posterior end of the lorica chamber due to individual patterns of interconnections between longitudinal costal strips and the frequent duplication of longitudinal costal strips (Figs 52, 55, 56). The basic principle, however, appears to be convergence and amalgamation of longitudinal costae to a point a little bit above the posterior tip of the lorica. From the outside of the posterior longitudinal costal strips several costal strips descend and converge to a point thus forming the characteristic triangular lorica termination.

The protoplast is located at the posterior lorica end below the middle transverse costa (Fig. 55).

It is evident from Figs 53, 54, 58 that *D. sphaerica* due to its large size and simple lorica construction is easily identified from light microscopical preparations. Electron microscopy is only slightly more informative than interference contrast light microscopy (compare Fig. 55 and Fig. 58).

The change in opinion as regards *D. sphaerica* sp. nov. (previously referred to *D. pedicellata)* is basically a result of the reinvestigation of *D. pedicellata* (p. 14).

D. sphaerica actually deviates from *D. pedicellata* concerning a number of important lorica characteristics. The anterior spines of *D. sphaerica* consist of two costal strips (Fig. 52) whereas those of *D. pedicellata* (Fig. 36) consist of only one strip. Each longitudinal costa in *D. sphaerica* is made of 9 or 10 costal strips as opposed to only 5 in *D. pedicellata.* Finally the absence of a pedicel in *D. sphaerica* should also be added to the list of differences.

D. sphaerica is also known from Finland (Thomsen 1979) and Sweden (Wallström, personal communication).

Apart from the four species of *Diaphanoeca* dealt with here *(D. pedicellata, D. undulata* sp. nov., *D. grandis* and *D. sphaerica* sp. nov.) one further species is allocated to this genus, *D. fiordensis* (Scagel & Stein, 1961), so far known from the type locality only (British Columbia) and only light microscopically examined.

Light micrographs (Figs 58, 59, 61, 62) of the four *Diaphanoeca* species accounted for in this paper are assembled on a single plate to facilitate immediate comparisons. The four species fall within two distinct subgroups, one comprising *D. sphaerica* (Fig. 58) and *D. grandis* (Fig. 59), the other *D. pedicellata* (Fig. 61) and *D.undulata* (Fig. 62). The following characteristics distinguish the two groups (with the characteristics of *D. grandis* and *D. sphaerica* mentioned first): anterior spines composed of two longitudinal costal strips (one strip only); each longitudinal costa composed of c. 9 costal strips (c. 4); lorica without pedicel (lorica with pedicel); lorica chamber large and bulbous (lorica chamber much smaller); protoplast more or less anteriorly positioned (protoplast placed at the posterior lorica end).

All four species have in common a general transverse/longitudinal costal strip arrangement, a basically similar mode of attachment between crossing costal strips (Fig. 57), and the presence of anterior spines.

From the above it is evident that the genus *Diaphanoeca* as presently circumscribed is not particularly well defined. Actually it appears that two genera each based on one of the subgroups compared above would make up somewhat more comprehensible and well defined groupings. Notice that *D. sphaerica* (previously referred to *D. pedicellata)* and *D. pedicellata* sensu stricto would be placed in different genera following this procedure. Prior to such possible splitting up of the genus *Diaphanoeca* it would, however, be relevant to reexamine (electron microscopically) *D. fiordensis* and the type species of *Campanoeca* Throndsen *(C. dilatata* Throndsen, 1974) to which genus *D. pedicellata* was also allocated by Throndsen (1974).

Parvicorbicula Deflandre, 1960

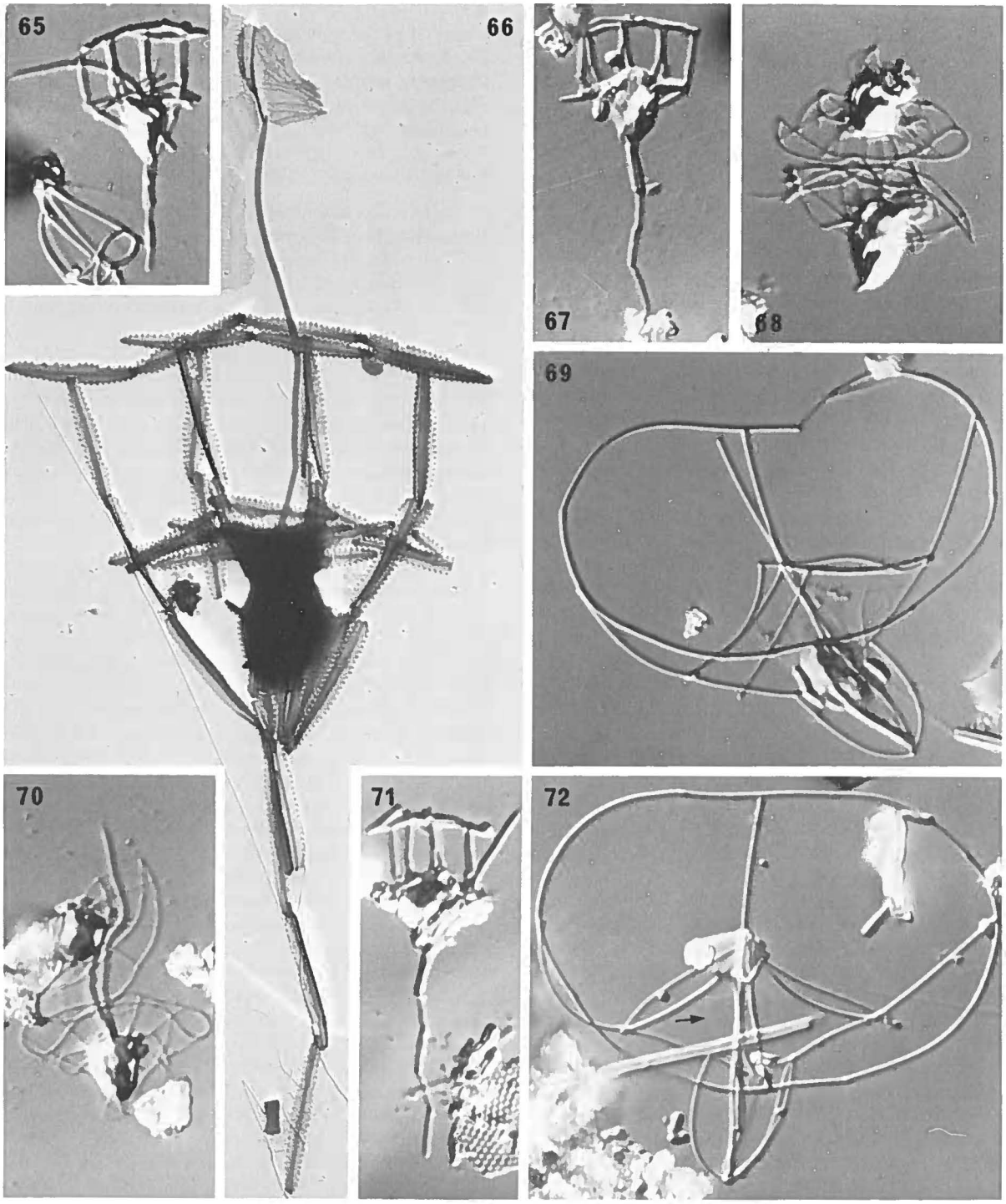
Parvicorbicula serratula Leadbeater, 1975 (Figs 65–67, 71)

In most details the West Greenland specimens are similar to the type material from Arctic Canada (Manton et al. 1975). The lorica chamber of the Greenland cells is slightly smaller 10–12 × 6–7.5 μm as opposed to 12–16 × 10–14 μm in the type material. The number of longitudinal costae is invariably 7 in the West Greenland material, whereas 7 or 8 in the Canadian material (Manton et al. 1975).

The very regular and simple lorica construction and the broad costal strips (Fig. 66) make this species recognizable also as dried specimens observed in the light microscope (Figs 65, 67, 71).

Parvicorbicula socialis (Meunier, 1910) (Figs 68, 70)

In samples from Arctic Canada two distinct size categories of this taxon were observed (Manton et al. 1976). The West Greenland specimens are similar to



Figs 65–72: **65–67.** *Parvicorbicula serratula.* **65.** Lorica and complete protoplast; with lorica chamber of *Calliacantha longicaudata* in lower corner (LM, × 2000). **66.** Complete cell; notice dentate, broad costal strips (EM T1788, × 6000). **67.** Specimen with long pedicel (LM, × 2000). **68, 70.** *P.socialis* cell pairs (LM, × 2000). **71.** *P.serratula* with pedicel composed of five costal strips (LM, × 2000). **69, 72.** *P.quadricostata;* arrow: delicate membrane securing protoplast to lorica (LM, × 2000).

the smaller specimens from Arctic Canada (i.e. lorica length c. 10 µm, diameter at the anterior lorica end 11–12 µm, 10 longitudinal costae). Cells united in pairs were occasionally observed (Figs 68, 70).

Parvicorbicula quadricostata Throndsen, 1970a (Figs 69, 72)

The West Greenland specimens are identical with the cells from Arctic Canada (Manton et al. 1976) both regarding lorica details and dimensions. Due to its large size and characteristic lorica construction this species is normally distinguishable also in light microscopical preparations. It can, however, be confused with *Parvicorbicula circularis* Thomsen, 1976. The distinguishing characteristic between *P. quadricostata* and *P. circularis* is the shape of the posterior transverse costa which is square and composed of four costal strips in the former (Fig. 72), while circular and composed of six costal strips in *P. circularis*.

Choanoflagellate species »N« (Norway, Fig. 73)

Observed in two samples (Table 1). The specimen shown in Fig. 73 is identical with the New Zealand material of this yet undescribed taxon (Moestrup 1979) and also in general agreement with material from Norway (Leadbeater 1972a, pl. IV A; erroneously recorded as *Parvicorbicula socialis)* and Denmark (Thomsen, unpublished). A detailed account of the taxonomical complications as regards this taxon is found in Moestrup (1979).

Pleurasiga Schiller, 1925
Pleurasiga reynoldsii Throndsen, 1970a (Figs 74, 75)

Characteristic dimensions of West Greenland specimens from 1977 are: lorica length 25–27 µm and lorica diameter c. 23 µm. These figures are in agreement with those of the type material (Throndsen 1970a) and specimens from Denmark (Thomsen 1976). Cells from Arctic Canada and West Greenland (Manton et al. 1976) were approximately 50% larger, but otherwise (regarding lorica construction and costal strip morphology) in agreement with cells from the other localities.

Two light micrographs of *P. reynoldsii* are shown in Figs 74, 75. This species is easily recognizable in the light microscope due to its large size and simple and precise construction. Important diagnostic characteristics are the anterior »T«-junctions (Fig. 74), and the union of the seven longitudinal costae at the posterior lorica end in three pairs and one single strip (Fig. 75, arrows).

Pleurasiga minima Throndsen, 1970a (Figs 76, 77)

Regarding lorica morphology and dimensions the present material is in agreement with both the type material (Throndsen 1970a) and material from West Greenland (Manton et al. 1976), i.e., lorica length 10–12 µm, lorica diameter 9.5–11 µm, 7 longitudinal costae.

Useful characteristics of the present species when observed in the light microscope (Figs 76, 77) include lorica size, the anterior »T«-junctions, the iso-diametric transverse costae, the number of longitudinal costae (7), the posteriorly located protoplast, and the very prominent flagellum.

Pleurasiga caudata Leadbeater, 1975 (Figs 78, 79, 80)

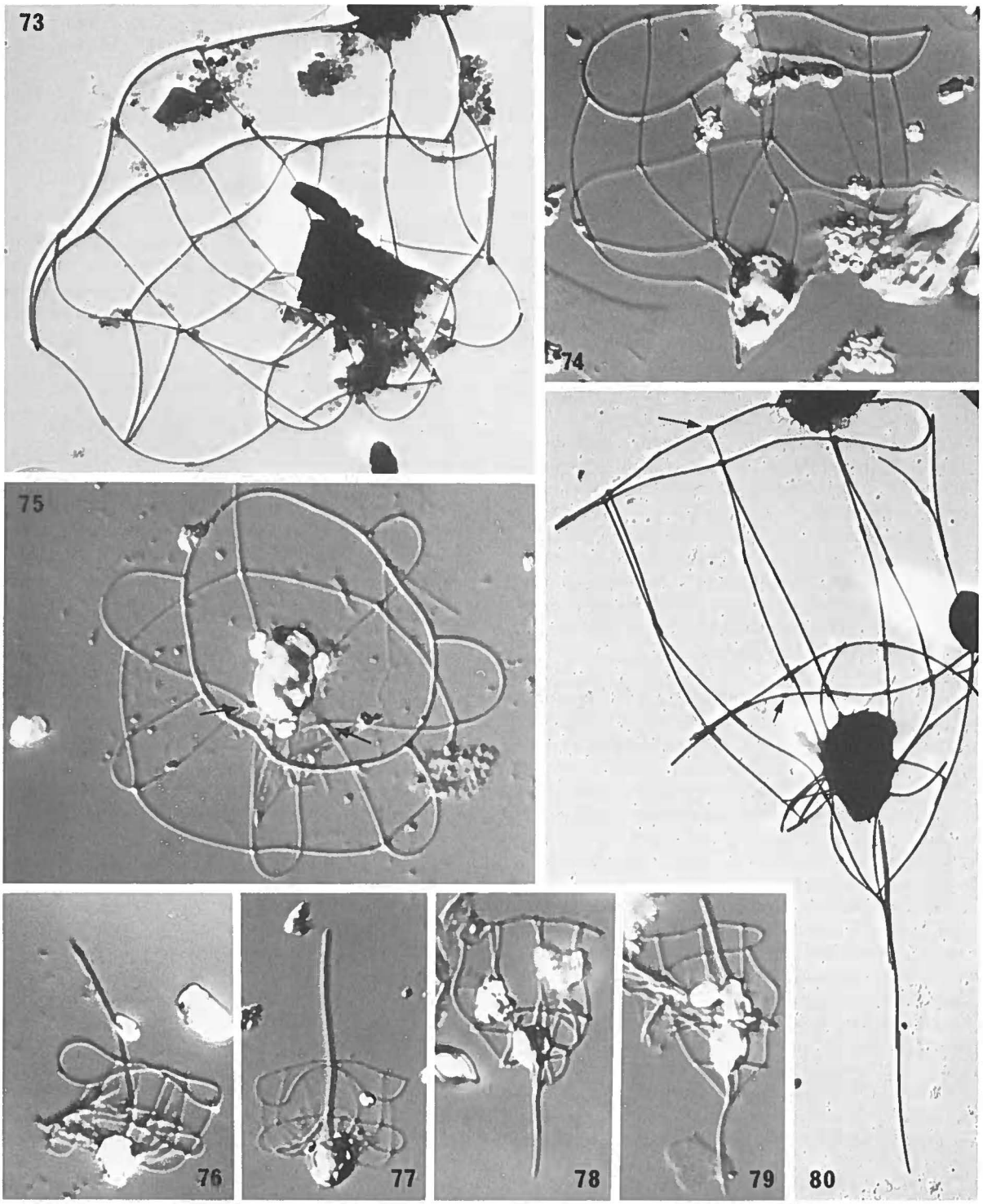
P. caudata was described on the basis of material from Button Bay near Churchill, Hudson Bay (Manton et al. 1975). The West Greenland specimens deviate from the type material in being slightly smaller (lorica dimensions of West Greenland cells: lorica chamber length 14–16 µm, diameter at orifice c. 8 µm, pedicel c. 8 µm), and furthermore by having seven rather than six longitudinal costae. As regards lorica construction (i.e. »T«-junctions anteriorly, three transverse costae located at the anterior end of the first, third and fourth longitudinal costal strip) and costal strip morphology (all components of the two anterior transverse costae have central, flattened dilatations, Fig. 80) there appear to be no differences between Hudson Bay and West Greenland specimens.

A species complex exists characterized above all by the facets on the transverse costal strips (*P. sphyrelata sphyrelata* Thomsen, 1973, *P. spyrelata elatensis* Thomsen, 1978a and *P. caudata)*. These taxa are distinguished by differences in number of longitudinal costae, presence or absence of a pedicel, and projecting or non-projecting longitudinal costal strips anteriorly. For the moment, however, it is not at all obvious how to subdivide this complex most logically. The new observation that *P. caudata* may have seven rather than six longitudinal costae, further contributes to the present uncertainty as regards species delimitation. Much more material from different parts of the world (and from different seasons at fixed localities) must be examined to provide more definite knowledge of the variability of the different forms so far described.

Light micrographs of *P. caudata* have not previously been published. Two interference contrast light micrographs (Figs 78, 79) are included here together with a single electron micrograph for comparison (Fig. 80). The basic lorica construction, including the anterior »T«-joints is clearly visible in the light microscope (Figs 78, 79) making possible a positive identification of this taxon also from light microscopy alone. The dilatations on the transverse costal strips are not directly observable. The conspicuous and bulbous appearance of the joints between the costal strips of the anterior transverse costa and the longitudinal costal strips (Fig. 79), however, indirectly point to the presence of such dilatations (compare Fig. 80).

Pleurasiga orculaeformis Schiller, 1925 (Figs 81–87)

Cells of *P. orculaeformis* sensu Leadbeater (1973) were frequent in several samples (Table 1). The cells ob-



Figs 73–80: **73.** Choanoflagellate sp. »N« (EM T2702, × 5000). **74–75.** *Pleurasiga reynoldsii;* arrows (75) pointing to junctions of longitudinal costae (LM, × 2000). **76–77.** *P.minima,* two complete cells (LM, × 2000). **78–79.** *P.caudata* (LM, × 2000). **80.** *P.caudata,* whole cell with detached flagella; arrows pointing out facets on transverse costal strips (EM T2699, × 5000).

served fall in two distinct size categories. All specimens from the 60 m samples (Table 1) were rather large (Figs 86, 87) (lorica length c. 30 µm; the distance between the two anterior transverse costae c. 18 µm; lorica diameter c. 25 µm) thus corresponding to specimens from Danish coastal waters (Thomsen 1976). The cells encountered in the 300 m samples (Table 1) were considerably smaller (Figs 81–85) (lorica length 15–17 µm; the distance between the two anterior transverse costae c. 8 µm; lorica diameter approximately 10 µm). These lorica dimensions almost exactly equals those of the Adriatic Sea specimens examined by Leadbeater (1973). With regard to lorica morphology the two West Greenland forms are basically similar and in general agreement with previously investigated material (Leadbeater 1973; Thomsen 1976). It should be mentioned, however, that the costal strips of the small specimens are relatively somewhat thicker than those of the large specimens (compare e.g. Fig. 83 and Fig. 87).

All West Greenland cells have nine longitudinal costae and three transverse costae. Those from Denmark (Thomsen 1976) showed invariably ten longitudinal costae, whereas cells from the Adriatic Sea (Leadbeater 1973) had from nine to eleven longitudinal costae.

The occurrence, within the same area, of two distinct size categories of cells belonging to the same species is known from several other taxa, viz., *Calliacantha natans* (Figs 13, 17), *Bicosta spinifera* (Figs 9, 10) and *Parvicorbicula socialis* (Manton et al. 1976).

Due to the find of some empty loricas it has been possible to examine in detail the costal strip arrangement at the posterior lorica end, the only part of the lorica which has not previously been fully analyzed. The posterior transverse costa is composed of three costal strips (Fig. 86) which are readily distinguished due to their thickness (transverse costal strips generally appear more prominent than longitudinal strips). The penultimate longitudinal costal strips touch the triangular posterior transverse costa at the corners and at equidistant points along each transverse costal strip (Fig. 86, arrows). The ultimate longitudinal costal strips join the penultimate longitudinal strips subapically (Fig. 86, arrowheads) and converge to a single point. The number of longitudinal costal strips may be slightly reduced at the hind end of the lorica. The delicate membranous investment which covers the protoplast and part of the tentacles too (Thomsen 1976) and which secures the protoplast to the lorica is attached to the lorica where the penultimate longitudinal costal strips join the posterior transverse costa.

As shown in Figs 81–84 and Fig. 87 *P. orculaeformis* sensu Leadbeater is easily identified in the light microscope also. All basic lorica details (including the end to end junctions at the anterior lorica end and the presence of two costal strips between the isodiametric transverse costae) are clearly shown in all light micrographs.

Most probably some of the specimens from Igloolik in the Canadian arctic referred to as *Monosiga* sp. (Bursa 1961, fig. 18 B, C, D) are identical to *P. orculaeformis* sensu Leadbeater. The remaining two *Monosiga* sp. cells illustrated (Bursa 1961, fig. 18 A, E) appear somewhat different from those referred to above. They may be identical with *Conion groenlandicum* (Fig. 28).

Saroeca Thomsen, 1979
Saroeca attenuata Thomsen, 1979 (Fig. 95)

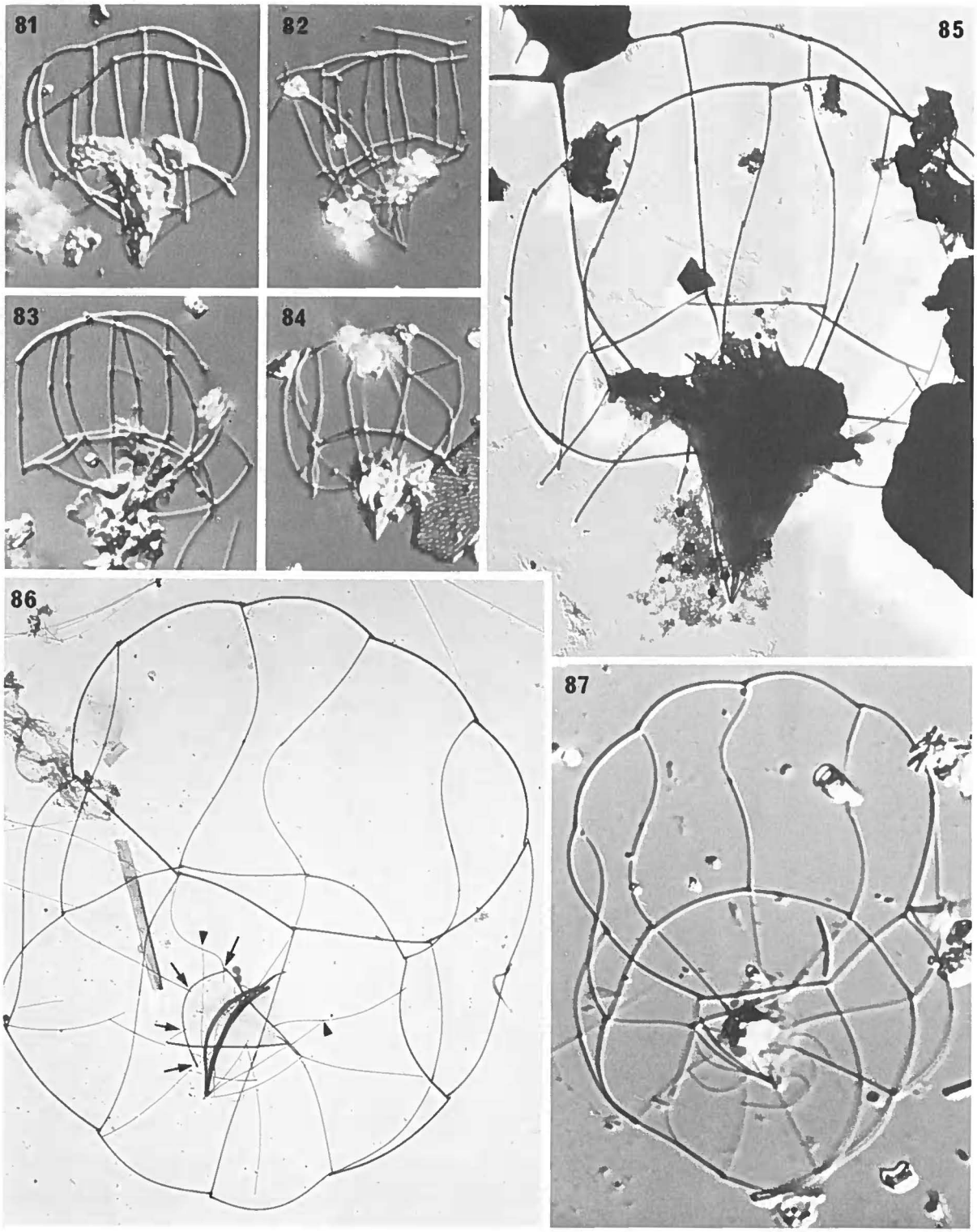
Only a single empty lorica was observed in the West Greenland samples (Table 1). The most characteristic features of this species hitherto only recorded from the Baltic (Thomsen 1979), are the long tapering anterior longitudinal costal strips, and the short curved anterior transverse costal strips (Fig. 95).

Stephanoeca Ellis, 1930
Stephanoeca diplocostata Ellis, 1930 (Figs 88–93)
syn. *S. pedicellata* Leadbeater, 1972a

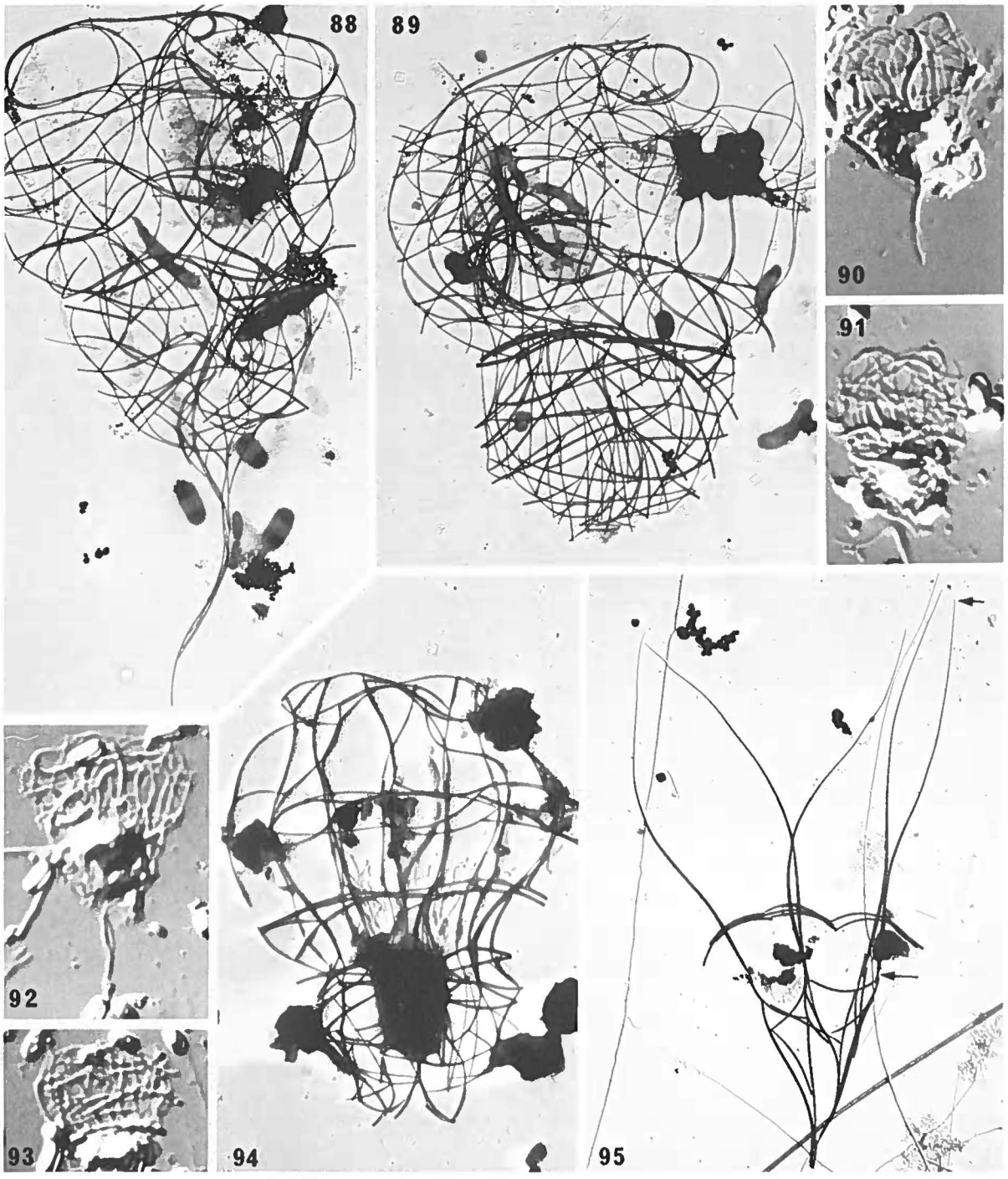
Culture experiments on *S. diplocostata* (Leadbeater 1979b) have shown that clonal material contained cells with pedicels (= *S. pedicellata*) and others without (= *S. diplocostata*). Free floating cells developed distinctive pedicels whereas specimens that attached posteriorly to a surface prior to lorica assembly usually lacked a pedicel (Leadbeater 1979c).

The West Greenland specimens (Figs 88–93) all fall within the range of variation tabulated by Leadbeater (1979b) (lorica length c. 15 µm, maximum diameter c. 8 µm, diameter at the waist c. 5 µm, approximately 20 longitudinal costae). All specimens observed appeared in a crude culture based on a water sample from the Godhavn harbour area (st. 9; Fig. 1). In the surface film of the culture very dense populations of bacteria, *S. diplocostata* and various members of the Salpingoecidae and the Codonosigidae developed. The majority of the *S. diplocostata* cells observed carried a pedicel (Figs 88, 90, 92). Apart from the pedicel the two forms (Figs 88, 89) were otherwise almost identical with regard to lorica dimensions and costal strip morphology and arrangement.

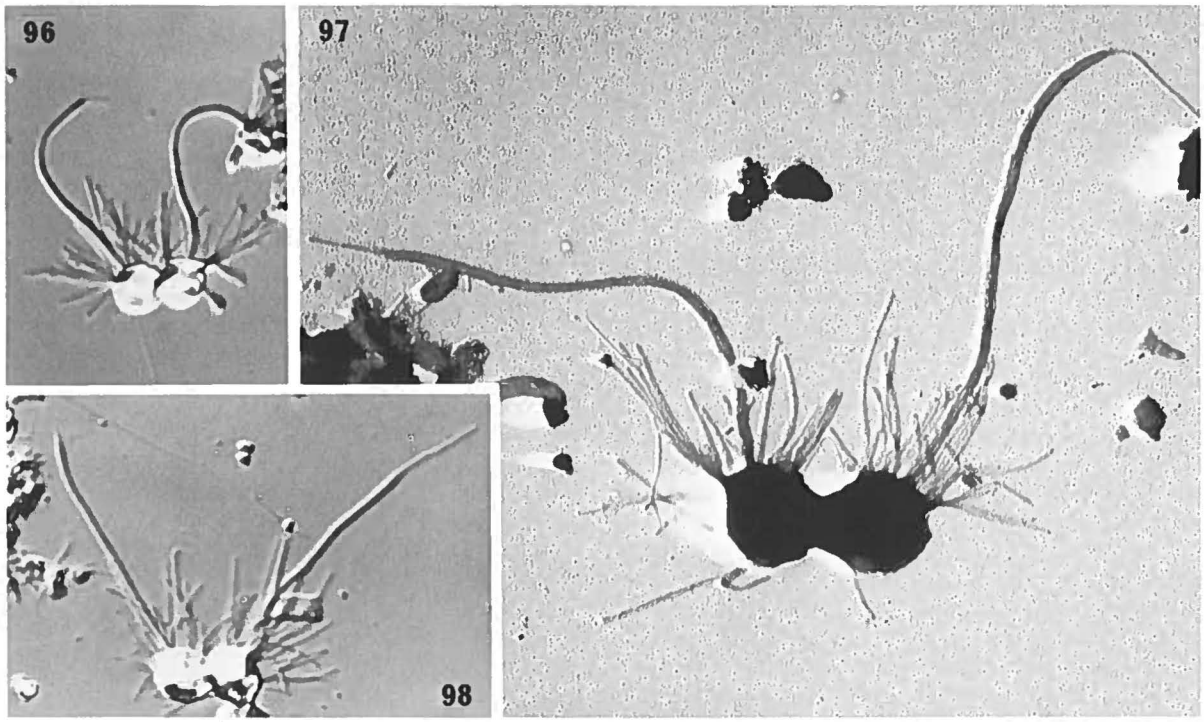
A comparison between light micrographs (Figs 90–93) and electron micrographs shows, that irrespective of the technique involved, this species, which has a lorica containing more than 150 costal strips (Leadbeater 1979b), always makes a rather disorganized impression. Yet, *S. diplocostata* can be identified also in the light microscope, and certain characteristics such as the general longitudinal/transverse arrangement of costal strips are actually more distinct in some of the light micrographs (e.g. Figs 90, 92). It is necessary, however, to draw attention to the general confusion which exists within this genus regarding species delimitation. Several species described from light microscopy have not been reinvestigated in the electron microscope (e.g., *S. ampulla* (Kent, 1880–82), *S. campanula* (Kent,



Figs 81–87: *Pleurasiga orculaeformis*. **81–84.** Small form, cf. Fig. 87 at same magnification, (LM, × 2000). **85.** Small form (EM T2267, × 5000). **86.** Empty lorica of large form showing costal strip connections at posterior lorica end; arrows and further discussion: see text p. 26 (EM T1903, × 2500). **87.** Large cell (LM, × 2000).



Figs 88–95: *Stephanoeca diplocostata.* **88.** Empty lorica of pedicellate form (EM T1798, × 5000). **89.** Empty lorica of apedicellate form (EM T1795, × 5000). **90–93.** Complete cells for comparison with electron micrographs (LM, × 2000). **94.** *S.d.paucicostata,* notice very regular arrangement of anterior costal strips (EM T2561, × 5000). **95.** *Saroeca attenuata,* empty lorica showing the very long anterior longitudinal costal strips (between arrows) (EM T2804, × 4500).



Figs 96–98: *Desmarella moniliformis*. **96, 98.** Light micrographs (× 2000). **97.** Shadowcast preparation of twin pair (EM T2718, × 5000).

1880–82), *S. complexa* (Norris, 1965), *S. constricta* Ellis, 1930 and *S. kenti* Ellis, 1930).

Stephanoeca diplocostata paucicostata Throndsen, 1969 (Fig. 94)

This form is characterized by a much less complicated costal strip arrangement in the anterior chamber involving a double transverse costa where the lorica has its maximum diameter, and a single transverse costa at the posterior end of the anterior lorica chamber (Fig. 94). The specimen shown in Fig. 94 was the only cell observed in the West Greenland material.

Codonosigidae

Desmarella Kent, 1878
Desmarella moniliformis Kent, 1878 (Figs 96–98)

A few choanoflagellates without silicified lorica were also encountered in the West Greenland samples (included in Table 4). Most of these were observed in the surface film of the crude culture set up from the water sample from the Godhavn harbour area (st. 9). In a rock-pool sample dominated by the dinoflagellate *Oxyrrhis marina* Dujardin several specimens of *D. moniliformis* were also observed, always occurring in highly characteristic two-cell colonies (Figs 96–98).

Discussion

Altogether 25 taxa of Acanthoecidae are listed from the area (Table 1). In addition the material comprised a few undescribed loricate choanoflagellates, all of which, however, occurred with too few cells to allow for a proper species description. Four species *(Calliacantha natans, Bicosta minor, Bicosta spinifera* and *Pleurasiga minima)* were present in more than half of the samples examined (Table 1, right column), *C. natans* occurring in 21 out of 27 samples. Six species *(Calliacantha longicaudata, Calliacantha simplex, Parvicorbicula quadricostata, Parvicorbicula serratula, Parvicorbicula socialis* and *Pleurasiga reynoldsii)* were observed in 25–50% of all samples. The remaining 15 taxa listed in Table 1 were all found in less than 25% of the samples, six of them occurring in single samples only.

Considerable differences in species number exist among the stations sampled (Table 1). Stations 6 and 4 are thus particularly rich in species (80% and 68% of all species listed), whereas e.g. st. 8 (Brændevinsskær) and st. 9 (Godhavn harbour) exemplify localities which are very poor in loricate choanoflagellates.

Some of the species listed in Table 1 appear to be rather uniformly distributed both horizontally and vertically within the area investigated (e.g. *Calliacantha natans, Bicosta minor, Bicosta spinifera* and *Pleurasiga minima).* However, it is evident from the data presented in Table 1 and the general knowledge of species occurrence and frequency acquired through the examination of the preparations, that other species show fairly distinct vertical distributional patterns. *Acanthoecopsis apoda* is thus almost exclusively observed in surface water samples, whereas *Conion groenlandicum* and the small form of *Pleurasiga orculaeformis* are frequent in the deep-water samples only (st. 6,7: 300 m).*Parvicorbicula socialis,* though present also in surface samples, was also relatively more abundant in these deep-water samples. A rather large group of species *(Calliacantha longicaudata, Calliacantha simplex, Diaphanoeca pedicellata, Diaphanoeca undulata, Parvicorbicula quadricostata, Parvicorbicula serratula, Pleurasiga caudata* and the large form of *Pleurasiga orculaeformis)* were most frequent in the subsurface samples, in particular the 60 m samples from st. 4 and st. 6.

A distinct vertical distribution of choanoflagellate species was particularly evident at st. 6 (Table 1). In the surface sample from this station the number of species was generally low and only *Acanthoecopsis apoda* occurred in large numbers. At 60 m the number of choanoflagellate taxa observed was 16, several of which were very abundant. The samples from larger depths (100, 200 m) showed a pronounced reduction in species number. The water sample examined from 300 m depth was again dominated by choanoflagellates (*Conion groenlandicum, Pleurasiga orculaeformis* small form, and *Parvicorbicula socialis).*

Stephanoeca diplocostata and *Acanthoecopsis unguiculata* have most frequently been reported from inshore localities. Their occurrence in West Greenland is quite in agreement with this general picture. *S. diplocostata* was observed only in a crude culture set up from a water sample from the Godhavn harbour area, and *A. unguiculata* was mostly observed in surface samples from stations close to the shore (e.g., sts 10, 11, 12).

It is for the moment not possible to interpret in any detail either the differences between the localities as regards species diversity or the characteristic vertical distribution observed at certain stations, in either case phenomena which are dependent on, e.g., hydrographical conditions, quantitative variations in bacterioplankton (food) and zooplankton (predators) and different levels of nutrients in general. Too little is known about the Disko Bugt environmental conditions in general to allow for any explanations. Choanoflagellate requirements for optimum growth is furthermore insufficiently studied. It is obvious, however, from the results presented here that Disko Bugt would be a most relevant study area for e.g. the interaction between choanoflagellates and abiotic factors. A large species potential is present and a sufficient vertical range is found within a short distance from the Danish Arctic Station.

In Table 3 is summarized our present knowledge concerning the global distribution of the species encountered in the West Greenland samples. Thirteen taxa have not been recorded from West Greenland previously.

Some of the choanoflagellate species are by now known from so many parts of the world that they can be expected to have a worldwide distribution. Examples of such apparently cosmopolitan species are: *Acanthoeca spectabilis, Acanthoecopsis apoda, Bicosta minor, Calliacantha natans, Calliacantha simplex, Crinolina isefiordensis, Diaphanoeca grandis, Parvicorbicula socialis, Pleurasiga orculaeformis* and *Stephanoeca diplocostata.* Other species although widely distributed appear to favour cold water, e.g. *Bicosta antennigera, Bicosta spinifera, Calliacantha longicaudata, Pleurasiga reynoldsii* and *Parvicorbicula quadricostata.* Similarly a number of species not encountered in the West Greenland samples

Table 3. Distribution of choanoflagellates (Acanthoecidae) encountered in samples from Godhavn 1977.

	1+	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	Arctic Canada/ Greenland W	Greenland E	Kara Sea	Norway	England	Denmark	Finland	France	Jugoslavia	Algiers	Israel	Black Sea	Alaska	USA W	Galapagos	S. Africa	New Zealand	Antarctica
Acanthoeca spectabilis	●			●	●	●	●	●						●		●		
**Acanthoecopsis apoda*				●		●	●		●	●							●	
– *unguiculata*	●			●		●	●											
Bicosta antennigera	●												●				●	
– *minor*	●			●	●	●							●		●	●	●	
– *spinifera*	●			●		●							●			●		
Calliacantha longicaudata	●					●												
– *natans*	●			●	●	●	●				●		●				●	
* – *simplex*	●				●	●	●		●	●			●		●	●		
**Conion groenlandicum*																		
**Crinolina isefiordensis*						●											●	
Diaphanoeca grandis	●			●	●	●	●	●	●	●		●		●				
– *pedicellata*	●					●												
* – *undulata*									●									
**Parvicorbicula quadricostata*	●			●		●												
* – *serratula*	●																	
– *socialis*	●	●	●	●		●		●			●							●
**Pleurasiga caudata*	●																	
– *minima*	●			●		●			●	●	●							
* – *orculaeformis*						●	●		●	●								
– *reynoldsii*	●			●		●											●	
**Saroeca attenuata*						●	●											
**Stephanoeca d. diplocostata*				●	●	●		●	●	●								
* – *diplocostata paucicostata*				●		●	●											
*Choanoflagellate sp. "N"				●		●											●	

*: New recording for West Greenland.
+References: 1: Grøntved (1956), Leadbeater (1979), Manton & Oates (1979a), Manton et al. (1975, 1976, 1980). 2: Braarud (1935). 3: Meunier (1910). 4: Leadbeater (1972a), Reynolds (1976), Throndsen (1969, 1970a, b, 1974). 5: Ellis (1930), Manton & Leadbeater (1978), Manton & Oates (1979a), Manton et al. (1980). 6: Grøntved (1956), Leadbeater (1972b), Manton & Leadbeater (1974), Thomsen (1973, 1976, 1979, unpublished results). 7: Thomsen (1979). 8: Boucaud-Camou (1967), Pavillard (1917). 9: Leadbeater (1973). 10: Leadbeater (1974). 11: Thomsen (1978a). 12: Valkanov (1970). 13: Manton & Leadbeater (1978), Manton & Oates (1979a), Manton et al. (1980). 14: Norris (1965). 15: Manton & Oates (1979a), Manton et al. (1980). 16: Leadbeater (1979), Manton & Oates (1979a), Manton et al. (1980). 17: Moestrup (1979). 18: Deflandre (1960).

nor in any of the nanoplankton investigations from cold water areas appear to be distributionally limited to warmer waters. This seems to be the case for *Parvicorbicula pulchella* Leadbeater, *Parvicorbicula infundibuliformis* Leadbeater and *Parvicorbicula campaniformis* Leadbeater) (Leadbeater 1973, 1974; Thomsen 1978a; Moestrup 1979). Three of the species listed in Table 3 (*Conion groenlandicum, Pleurasiga caudata* and *Parvicorbicula serratula)* are so far known from arctic and subarctic surroundings only.

Survey of marine nanoplankton from the Godhavn area

In Table 4 are included all species observed in the nanoplankton samples from 1977. Most of the identifications originate from electron microscopical inspection of the whole mounts, although some species have also been added to the list during light microscopical inspection of (1) the living cells (in connection with the preparational work) and (2) the special light microscopical preparations comprising airmounted dried cells on inverted coverslips.

It is evident that two taxonomic groups, the algal class Prymnesiophyceae with more than 38 species, and the zooflagellate family Acanthoecidae (Choanoflagellida) with more than 25 species, are particularly well represented within the area investigated. It should be emphasized that eleven undescribed *Chrysochromulina* species are included in the number of Prymnesiophytes. The absence of suitable whole cells with flagella and haptonema has, however, prevented the formal de-

Table 4. List of species encountered in nanoplankton preparations from the Godhavn area, 1977.

Dinophyceae (Dinoflagellates)
Oxyrrhis marina Dujardin

Chrysophyceae (Golden algae)
Actinomonas mirabilis Kent
Bicosoeca maris Picken
B. gracilipes James-Clark
Chrysosphaerella salina Birch-Andersen
Dinobryon balticum (Schütt) Lemmermann
D. petiolatum Willén
Paraphysomonas aff. *foraminifera* Lucas

Bacillariophyceae (Diatoms)
Twelve taxa recorded including:
Attheya decora West
Minidiscus trioculatus (F. J. R. Taylor) Hasle
Thalassiosira antarctica Comber
T. gravida Cleve
T. proschkinae Makarova

Prymnesiophyceae
Prymnesiaceae
Chrysochromulina acantha Leadbeater & Manton
C. cyathophora Thomsen
C. cymbium Leadbeater & Manton
C. ephippium Parke & Manton
C. ericina Parke & Manton
C. herdlensis Leadbeater
C. hirta Manton
C. mantoniae Leadbeater
C. spinifera (Fournier) Pienaar & Norris
C. spp. (at least 11 undescribed species)
Phaeocystis pouchetii (Hariot) Lagerheim
P. sp.

Coccolithophoraceae
Balaniger balticus Thomsen & Oates
Calciarcus alaskensis Manton, Sutherland & Oates
Hymenomonas carterae (Braarud & Fagerland) Braarud
Pappomonas flabellifera Manton & Oates var. *flabellifera* Manton & Oates
P. flabellifera var. *borealis* Manton, Sutherland & McCully
P. virgulosa Manton & Sutherland
Papposphaera sagittifera Manton, Sutherland & McCully
P. sarion Thomsen
Quaternariella obscura Thomsen
Trigonaspis diskoensis Thomsen
T. minutissima Thomsen
Turrisphaera arctica Manton, Sutherland & Oates
T. borealis Manton, Sutherland & Oates
T. polybotrys Thomsen
Wigwamma annulifera Manton, Sutherland & Oates
W. arctica Manton, Sutherland & Oates
W. scenozonion Thomsen

Prasinophyceae/Loxophyceae
Dolicomastix nummulifera Manton
Mantoniella squamata (Manton & Parke) Desikachary
Micromonas pusilla (Butcher) Manton & Parke
Nephroselmis longifilis (Butcher) Norris
Pyramimonas obovata N. Carter
P. orientalis Butcher
P. virginica Pennick
P. spp. (at least two taxa)

Incertae Sedis
Gyromitus disomatus Skuja
Luffisphaera spp. (at least two taxa)
Meringosphaera mediterranea Lohmann

Zoomastigophorea
Choanoflagellida
Acanthoeca spectabilis Ellis, 1930
Acanthoecopsis apoda Leadbeater, 1972a
A. unguiculata Thomsen, 1973
Bicosta antennigera Moestrup, 1979
B. minor (Reynolds, 1976)
B. spinifera (Throndsen, 1970b)
Calliacantha longicaudata (Leadbeater, 1975)
C. natans (Grøntved, 1956)
C. simplex Manton & Oates, 1979a
Choanoeca perplexa Ellis, 1930
Conion groenlandicum gen. et sp. nov.
Crinolina isefiordensis Thomsen, 1976
Desmarella moniliformis Kent, 1878
Diaphanoeca grandis Ellis, 1930
D. pedicellata Leadbeater, 1972b
D. undulata sp. nov.
Parvicorbicula quadricostata Throndsen, 1970a

P. serratula Leadbeater, 1975
P. socialis (Meunier, 1910)
Pleurasiga caudata Leadbeater, 1975
P. minima Throndsen, 1970a
P. orculaeformis Schiller, 1925[1]
P. reynoldsii Throndsen, 1970a
Salpingoeca infusionum Kent, 1880–82
S. inquillata Kent, 1880–82
Saroeca attenuata Thomsen, 1979
Stephanoeca diplocostata Ellis, 1930
S. diplocostata paucicostata Throndsen, 1969

Kinetoplastida
Rhyncomonas nasuta Klebs, 1892

Heliozoea
Centrohelida
Pinaciophora aff. *candelabrum* Thomsen, 1978b[2]
P. aff. *denticulata* Thomsen, 1978b[2]
P. fluviatilis Greeff, 1873
P. aff. *tridentata* Thomsen, 1978b[2]

1. *sensu* Leadbeater 1973.
2. only plate-scales observed.

scription of these well defined taxa. Other taxonomic groups (Bacillariophyceae, Chrysophyceae, Prasinophyceae/Loxophyceae) were all represented with much fewer species in the nanoplankton preparations.

A comparison between these results and similar data from other geographical regions is shown in Table 5. All data come from short-time investigations carried out at different seasons and with slightly diverging sampling strategies and preparational procedures. Notwithstanding these differences it is of interest to notice that all investigations (apart from the collections from the oligohaline Finnish coastal waters, Thomsen 1979) show similar trends as to species distribution within major taxonomic groups. No doubt the Prymnesiophyceae is generally the most important nanoplanktonic group regarding number of species in euhaline and mixopolyhaline areas. The Choanoflagellida in most cases constitute the second largest taxonomic group. When evaluating the results presented in Table 5 it must be remembered that nanoplankton investigations primarily based on electron microscopical inspection of whole mounts obviously favours the scaly or loricated groups of organisms. Members of e.g. the Cryptophyceae and the Chlorophyceae (previously shown to be of quantitative importance from experiments involving the serial dilution culture technique, Throndsen 1976, 1978) are thus easily overlooked in the electron microscopical preparations due to their lack of characteristic surface ornamentation.

Table 5. Number of taxa recorded in nanoplankton investigations.

	Chrysophyceae	Prymnesiophyceae (total)	Chrysochromulina spp.	Loxoph./Prasinoph.	Choanoflagellida (Acanthoecidae)	All groups – total	Approx. ‰ S	
Norway	7	27	21	5	8	48	35	Leadbeater (1972c)
Jugosl./Algiers	11	23	18	6	16	59	35–37	Leadbeater (1974)
Denmark	10	24	19	14	13	63	25–30	Manton & Leadbeater (1974)
New Zealand	6	>20	>15	>11	11	c.50	35	Moestrup (1979)
Finland*	3	5	1	4	16	32	3–7	Thomsen (1979)
Greenland	7	>38	>20	> 9	25	c.100	24–33	Present paper

*only marine forms included.

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1981

6. Ole G. Norden Andersen:
»The annual cycle of phytoplankton primary production and hydrography in the Disko Bugt area, West Greenland«, 65 pp.

The distribution and size of phytoplankton production and biomass in relation to physical and chemical parameters in the upper 50 m at Godhavn and in Kangikerdlak in the inner part of Disko Fjord was investigated through 2½ years (1973–75). Some data from other parts of Disko Bugt are presented.

In both locations the hydrography alternates between an unstable winter situation with isothermal (÷1.75°C) and isohaline (33.5–34.0‰) conditions throughout, and a highly stable summer situation when dilution and heating, especially of the upper 20–30 m, raise the temperature at the surface to 9.9°C and at 50 m to 3.8°C at Godhavn, and to 12°C and 3.5°C respectively in Kangikerdlak. Salinities drop correspondingly to 30.6‰ in Kangikerdlak.

The 1% depth for green light is greatly reduced beneath ice and snow. During the ice free period at Godhavn it varies from 12 m during the spring phytoplankton bloom to more than 60 m from Oct. through the winter. In Kangikerdlak the 1% depth reaches only 40 m in winter, and outflowing turbid fresh water creates 1% depths of as little as 4–5 m in June–Aug.

At Godhavn NO_3-N reaches highs of 10.05 µgat/liter and 10.15 µgat/liter at 0 and 50 m respectively in winter, whereas during the summer, depletion to less than 0.01 µgat/liter occurs in the upper 40 m and to 1.0 µgat/liter at 50 m. PO_4-P is similarly reduced from 0.8 µgat/liter and 1.1 µgat/liter to less than 0.01 µgat/liter in the upper 20 m and to 0.21 µgat/liter at 50 m. The N:P ratio drops from 13 to less than 0.01 in the upper 30 m and to 1.0 at 50 m. In Kangikerdlak depletion of NO_3-N is similar to conditions at Godhavn, whereas PO_4-P reaches a low of 0.1 µgat/liter only, while in mid summer it reaches 1.88 µgat/liter at the surface, giving an N:P ratio which is below 0.1 in the upper 5 m only.

At Godhavn primary production is about 90 $gC \cdot m^{-2} \cdot yr^{-1}$ (75–104 g) with a maximum of about 5.5 $gC \cdot m^{-3} \cdot yr^{-1}$ at 5–10 m, whereas in Kangikerdlak production was concentrated near the surface with about 6.0 $gC \cdot m^{-3} \cdot yr^{-1}$ and a total of 35 $gC \cdot m^{-2} \cdot yr^{-1}$ at most. Production at Jacobshavn off the glacier fjord is probably greater than at Godhavn, whereas at Christianshåb and Egedesminde it is definitely lower.

Phytoplankters larger than 56 µ contribute about 50% of annual and up to 90% of daily production.

Due to the great stability, production usually extends no deeper than compensation depth, and most of the chlorophyll is usually in the nutrient rich water below this depth, where it sinks, is consumed, or degrades into phaeopigment. P/B is highest where there is least chlorophyll. Light reduces production in the upper 5–10 m, and inhibition may extend to 30 m. Correlations between production, P/B, or P/B/light and nutrients reveal possible saturation values of 0.08–0.78 µgat NO_3-N/liter and 0.17–0.22 µgat PO_4-P/liter. PO_4-P seems to be the limiting nutrient in some cases, although NO_3-N is most quickly and thoroughly depleted.

Dark fixation at Godhavn is about 24 $gC \cdot m^{-2} \cdot yr^{-1}$, and at Kangikerdlak about 15 $gC \cdot m^{-2} \cdot yr^{-1}$. 55–60% of dark fixation is presumed to be biotic and 16–64% is associated with particulate matter larger than 56 µ.

Although oxygen is never at a minimum in Disko Bugt, saturation as well as absolute O_2 values and pH show profiles in the bay that clearly reflect the high degree of stratification compared to waters south of the bay.

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