

## Tintinnina (Ciliophora, Protista) of the North Sea during the spring of 1986

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**ABSTRACT:** This work is the first of a series in which the distribution patterns and the importance of the Tintinnina in the trophic chain of the North Sea are evaluated. In agreement with Foissner (1994), who stated "Most ecological papers on planktonic protozoans lack reliable identifications and modern nomenclature . . .", the series will start with the results of a taxonomic revision. Illustrations and brief descriptions of the 23 Tintinnina species found in this analysis are given, as well as comments about species identification. Differences between the present results and the previous work of Lindley (1975) can indicate some changes in the species structure. A higher number of species was found than that found by Lindley (1975) in seasonal samplings.

### INTRODUCTION

Despite many works on Tintinnina, including those on the North Sea species (e.g. Jørgensen, 1899; Brandt, 1907; Hofker, 1931), the taxonomy of the group is far from being accepted as definite (Laval-Peuto & Brownlee, 1986). The system proposed by Kofoid & Campbell (1929, 1939) is based solely on the morphology of the lorica. However, we know today that variations in the shape and size of the lorica occur with frequency due to changes in temperature, salinity, food concentration (Gold & Morales, 1975), cellular division rates (Gold, 1970; Verity, 1987; Pierce & Turner, 1992), polymorphism in biological cycles (Laval-Peuto, 1981), and the formation of resistance spores (Kamiyama & Aizawa, 1990).

Some pioneer works such as Daday (1887), Brandt (1907), Schulz & Wulff (1929) and Hofker (1931) called attention to the inter-specific variations in the shape of the lorica and followed the use of cell morphology to make safer descriptions and identifications. Usually, however, formaldehyde and lugol are used as preserving agents in marine biology, which retains only the lorica of the Tintinnina, giving a wide margin for the occurrence of synonyms, such as those included in the revisions of Kofoid & Campbell (1929, 1939) and which have been adopted by most of the authors who followed them. At present, the silver-protargol technique is being used more frequently, permitting comparisons of the tintinnids at the infraciliature level (Brownlee, 1977; Snyder & Brownlee, 1991; Choi et al., 1992); however, the number of works is still insufficient to attempt a new revision based on the morphology of the cell. Everything indicates that the lorica morphology shall remain, for the time being, the usual way to identify tintinnids.

In this context, it seems appropriate to present the results of a taxonomic revision of a collection from the whole North Sea, taken in spring of 1986, where only the lorica morphology was considered. This work should become, in agreement with Foissner (1994), a basis for the discussion about the ecology of the Tintinnina in the North Sea. This revision does not solve all the problems concerning the identification of Tintinnina from the North Sea, but, instead, stresses the necessity for more investigations in the future. The figures, descriptions and original references may prove to be helpful for future studies.

#### MATERIAL AND METHODS

The major objective of the German ZISCH program (acronym for "Zirkulation und Schadstoffumsatz in der Nordsee" – "Circulation and Pathways of Pollutants in the North Sea") was to actualize the existing data on the environmental conditions in the North Sea in relation to anthropic activity. Its fulfillment involved some research institutes of the Federal Republic of Germany and depended on the simultaneous mission of three oceanographic vessels: F. S. "Valdivia", F. S. "Gauss" and the F. S. "Planet". One of the participating institutes was the Biological Station of Helgoland (Biologische Anstalt Helgoland), where the microplankton samples of this work are deposited. The program was accomplished in two stages, one in spring (1986) and the other in winter (1987). The present study was made using as basis 129 oceanographic stations distributed in radials from the geographical center of the North Sea, during the late spring, between May 2nd and June 3rd, 1986. A total of 265 samples from 60 stations was selected for the analysis of the Tintinnina (Fig. 1).

Microplankton was collected with 5-liter Niskin bottles at 5 depths per station. The sampled depths varied according to the station and the thermocline depths. In shallow stations, in depths less than 30 m, only 3 or 4 depths were sampled. The samples were concentrated with a mesh of 20  $\mu\text{m}$  and kept in 2% formaldehyde neutralised with borax. Microscopic analysis was carried out with an inverted microscope according to the Utermöhl (1958) technique, using sedimentation chambers of 10, 25 and 50 ml. In order to permit the identification of the species level, it was necessary to photograph different specimens with a common reflex camera, adapted to the lens of the microscope. The identification of the Tintinnina was based principally on the works of Jørgensen (1899, 1924, 1940), Brandt (1906, 1907), Meunier (1919), Kofoid & Campbell (1929, 1939), Hofker (1931), Candeias (1932), Gaarder (1946), Marshall (1969) and Souto (1981), using only the lorica morphology as diagnostic criterion. The systematic position of the suborder Tintinnina adopted in this work was proposed by Montagnes & Lynn (1991):

PROTISTA kingdom  
 PROTOZOA subkingdom  
 CILIOPHORA phylum  
 SPIROTRICHEA class  
 CHOREOTRICHIDA order  
 TINTINNINA suborder

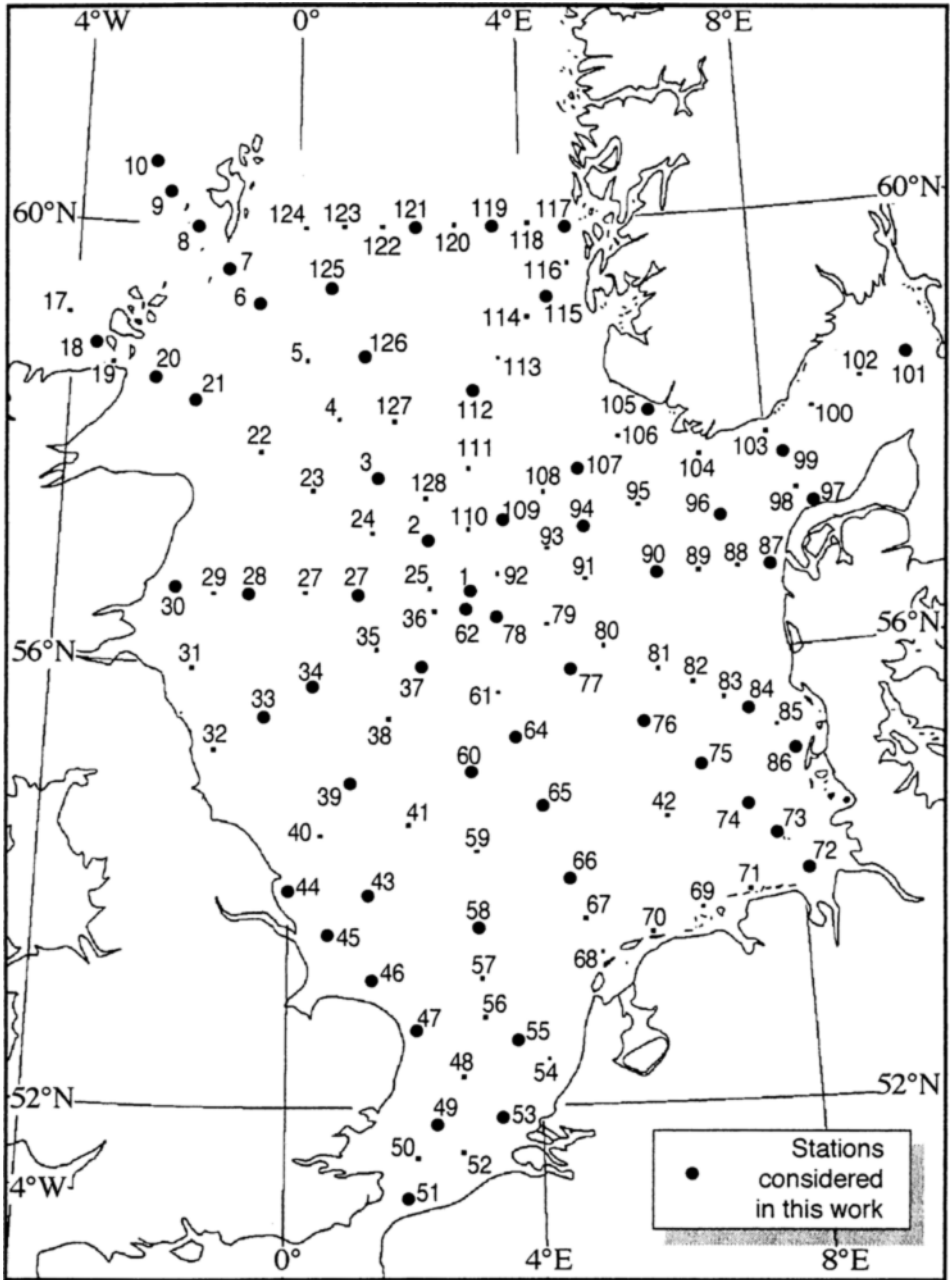


Fig. 1. Position of the oceanographic stations of the ZISCH program, from May 2nd to June 3rd, 1986

## RESULTS

Following the analysis of 265 samples of microplankton, 23 species were identified, distributed in 9 families and 12 genera, which are hereby listed as follows:

## Family Tintinnididae Kofoid &amp; Campbell, 1929

*Leprotintinnus pellucidus* (Cleve, 1899) (Fig. 2 a). Few loricae were found during the analysis of the samples of the ZISCH program; all occurrences were from the Baltic Sea and the coast of Norway. A notable characteristic of this species is the open lorica in the two extremities, the diameter diminishes from the oral to the aboral region, the upper part is hyaline and the presence of adhered particles increases gradually in the lower region, the aboral aperture is slightly enlarged and covered with particles. The mean ratio between length and breadth is 6.3.

## Family Codonellidae Kent, 1882

*Tintinnopsis beroidea* Stein, 1867 (Fig. 2 b). The lorica is cylindrical, widening slightly in direction of the oral aperture and ending in a cone whose profile resembles an isosceles triangle: being totally covered by particles such as grains of sand, which give the surface a granulated appearance. The length is quite variable during the development of the cell, which gives room for the creation of much synonymy. However, rarely does the length exceed 120  $\mu\text{m}$ .

*T. cf. cylindrica* Daday, 1887 (Fig. 2 c). Only one lorica of this species was found on the surface of station 97. The lorica has a granulated appearance as a result of the presence of adhered particles, is uniformly cylindrical up to the aboral cone, where a pronounced peduncle is located which corresponds to approximately 1/5 of total length and characterizes this species.

*T. nana* Lohmann, 1908 (Fig. 2 d) occurred only at station 45. The lorica is covered with material grasped by the cell and has small dimensions (Table 1), is the shape of a wedge with a slightly rounded profile. The oral region represents the widest part, from here on the diameter diminishes gradually until the lorica terminates in a slightly rounded aboral end.

*T. parvula* (Jørgensen, 1899) (Fig. 2 e). The lorica is covered by particles as are all other *Tintinnopsis* and is slightly bigger than *T. nana*. The widest part is located near the middle region, giving the lorica the appearance of a sectioned ellipse, and the aboral region is conical.

*T. cf. spiralis* (Meunier, 1910) (Fig. 2 f). Only one lorica of this species was found at a depth of 300 m at station 99, which prevents a reliable identification. The lorica is elongated; from the oral aperture until the superior third the diameter diminishes by around 1/5, increasing again until the inferior third and henceforth diminishing until terminating in a sharp angle. This specimen differs from that described by Marshall (1969), which has spiral striation in the wall of the lorica.

*T. tubulosa* Levander, 1900 (Fig. 2 g) was restricted to stations 45 and 47, however in densities which vary between 19 and 78  $\text{ind}\cdot\text{l}^{-1}$ . The lorica is approximately cylindrical, showing a slight narrowing beneath the oral aperture, with a small ratio between length

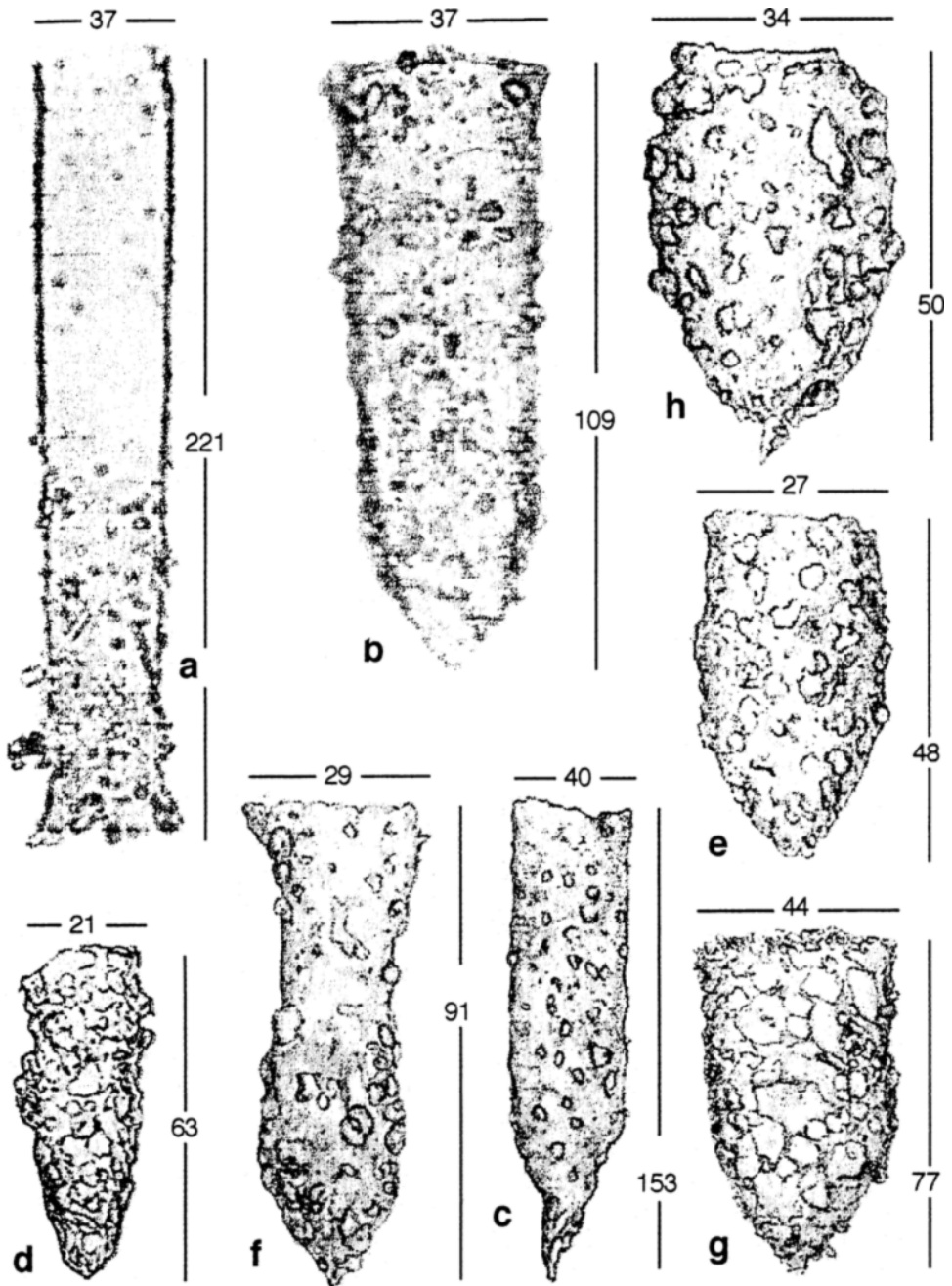


Fig. 2. Tintinnididae, *Leprotintinnus pellucidus* (a); Codonellidae, *Tintinnopsis beroidea* (b), *T. cf. cylindrica* (c), *T. nana* (d), *T. parvula* (e), *T. cf. spiralis* (f), *T. tubulosa* (g), *Tintinnopsis* sp. (h). Distances in  $\mu\text{m}$

and diameter in relation to all other species of Tintinnina described in this work (1.8); as such, length rarely attains double the diameter measured in the oral region.

*Tintinnopsis* sp. (Fig. 2 h) occurred in small quantities in the stations in the English Channel, in the German Bight, and along the coast of Norway. As in all the other *Tintinnopsis*, the lorica was completely covered with particles. The broadest part is in the middle region, tapering very little in direction of the oral aperture and strongly toward the base. The inferior part of the lorica resembles one half of an ellipse.

#### Family Codonellopsidae Kofoid & Campbell, 1929

*Stenosemella nivalis* (Meunier, 1910) (Fig. 3 a). This was the most abundant species in the samples, superseding all the others in the number of individuals sampled and frequency in the analysed stations, appearing in more than 52 % of the samples. The lorica is small and covered with foreign particles, the genus *Stenosemella* differing from *Tintinnopsis* in the presence of an oral collar, normally hyaline and free of encrustations. The ratio between length and breadth is small (1.3), the largest part being under the oral collar tapering until the base, forming an open angle.

*Stenosemella producta* (Meunier, 1919) (Fig. 3 b) occurred in only 5 samples. The morphological pattern of the lorica is similar to that of *S. nivalis*, however slightly longer and narrower, with an evident shoulder near the collar.

*Codonellopsis ovata* Jørgensen, 1924 (Fig. 3 c). Few individuals of this species were found, in depths of about 200 m at stations n° 115 and 117. Of small dimensions, the lorica is spheric and lightly covered by particles. The oral collar is quite fragile and often hard to observe.

#### Family Coxliellidae Kofoid & Campbell, 1929

*Coxliella pseudoannulata* (Jørgensen, 1901) (Fig. 3 d). This species occurred only at stations near the Norwegian coast. The lorica is banded in a spiral formation in which the number of rings is quite variable. The wall of the bands shows an alveolar structure, which is a distinctive characteristic of the genus *Coxliella*. The separation between the cylinder and aboral cone is well defined and located in a region between half and lower third of the length.

*Helicostomella subulata* (Ehrenberg, 1833) (Fig. 3 e) is a cosmopolitan species, well-known and very common in the Baltic Sea and the German Bight. Being a species of large dimensions, it contributed greatly to the total biomass of Tintinnina. The lorica is cylindrical, does not have encrustations, and the ratio between length and diameter is high, around 8. The peduncle is long and wide, surpassing by 1/5 the total length. The oral aperture is serrated or denticulate. Rings with the same serrated structure are observed for the whole upper third of the lorica, probably as a result of successive depositions during its growth cycle.

#### Family Ptychocylidae Kofoid & Campbell, 1929

*Favella ehrenbergii* (Claparède & Lachmann, 1858) (Fig. 3 f). The description of *F. helgolandica* given by Hofker (1931) corresponds exactly to the specimens found in this

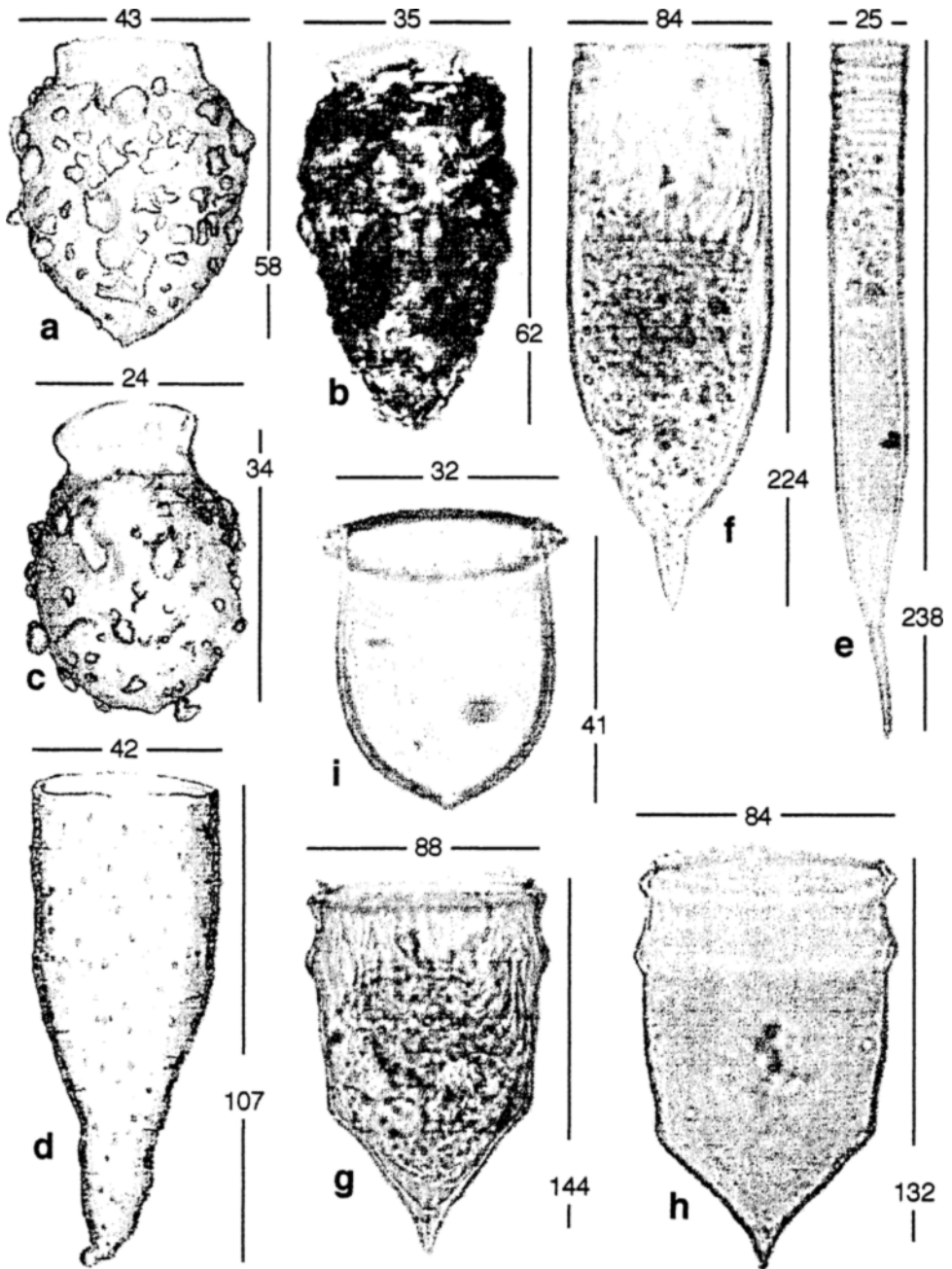


Fig. 3. Codonellopsidae, *Stenosemella nivalis* (a), *S. producta* (b), *Codonellopsis ovata* (c); Coxiellidae, *Coxiella pseudoannulata* (d), *Helicostomella subulata* (e); Ptychocyliidae, *Favella ehrenbergii* (f), *Ptychocyclus urnula* (g), *P. urnula (minor)* (h); Petalotrichidae, *Acanthostomella norvegica* (i). Distances in µm

investigation; but for reasons which will be explained hereafter, the name *F. ehrenbergii* was retained. The lorica is larger than that of the other species (Table 1), the shape is cylindrical with a ratio between length and diameter of 2.7. A slight constriction occurs in the oral aperture, together with a variable number of rings, which are superimposed during growth. The aboral cone is round, starting approximately from a third of the length and terminating in a peduncle which in general attains 1/7 of the total length. The walls of the lorica are thick but hyaline, without particle accumulation but of a coarse texture.

*Favella* sp. (not illustrated). Only one specimen found; the lorica was covered with an unknown material, possibly oil, which made the identification to species level impossible.

*Ptychocylis urnula* (Claparède & Lachmann, 1858) (Fig. 3 g-h). *P. urnula* was widely distributed throughout the North Sea, contributing largely to the total biomass of the Tintinnina. The lorica is identified by its cylindrical shape, with a small enlargement under the oral aperture and by the conical shape in the aboral region which terminates with a short peduncle. In vertical section, the cone ridge forms an angle of approximately 45° with the cylinder wall. The edge of the oral aperture is serrated and the sides of the whole lorica show a certain rugose texture. The proportion between the length and diameter is approximately 1.8.

#### Family Petalotrichidae Kofoid & Campbell, 1929

*Acanthostomella norvegica* (Daday, 1887) (Fig. 3 i). Species of small dimensions and very abundant along the Norwegian coast. The lorica is quite fragile and difficult to observe, the refraction of the lorica walls is very close to that of water. The inferior region is hemispheric with a small, aboral peduncle. The upper half forms a cylinder with a height approximately equivalent to half the total length. The oral aperture is denticulate on the margins and with a narrow flank underneath which encircles the oral opening.

#### Family Xystonellidae Kofoid & Campbell, 1929

*Parafavella denticulata* (Ehrenberg, 1840) (Fig. 4 a) is the second largest species found in the ZISCH program. Small quantities occurred at 15 stations, the species was absent in the English Channel and the German Bight. The lorica is cylindrical and the walls show a typical pattern for this genus, similar to the honeycombs of a beehive. The oral aperture is denticulated and the base of the lorica terminates in a peduncle which attains approximately 1/7 of total length. The length of the lorica is quite variable, despite the fact that the diameter of the oral region could be considered constant (Table 1), the length-diameter ratio varied from 2.4 to 4.8.

*P. elegans* (Ostenfeld, 1899) (Fig. 4 b-f) showed the largest biomass on the west coast of Norway, becoming the dominant species in the region. The shape of the lorica is slightly variable but always keeps cylindrical-conical. The wall of the lorica shows hexagonal alveoli, and the oral aperture presents, in the most cases, denticles curving outwards. The peduncle is generally long and fine, attaining up to 1/3 of the total length. The mean ratio between total length and diameter is around 3.4.

*P. parumdentata* (Brandt, 1906) (Fig. 4 g-h). Identification was based on the descriptions by Marshall (1969). The lorica is conical as in *P. elegans*, but of smaller proportions;



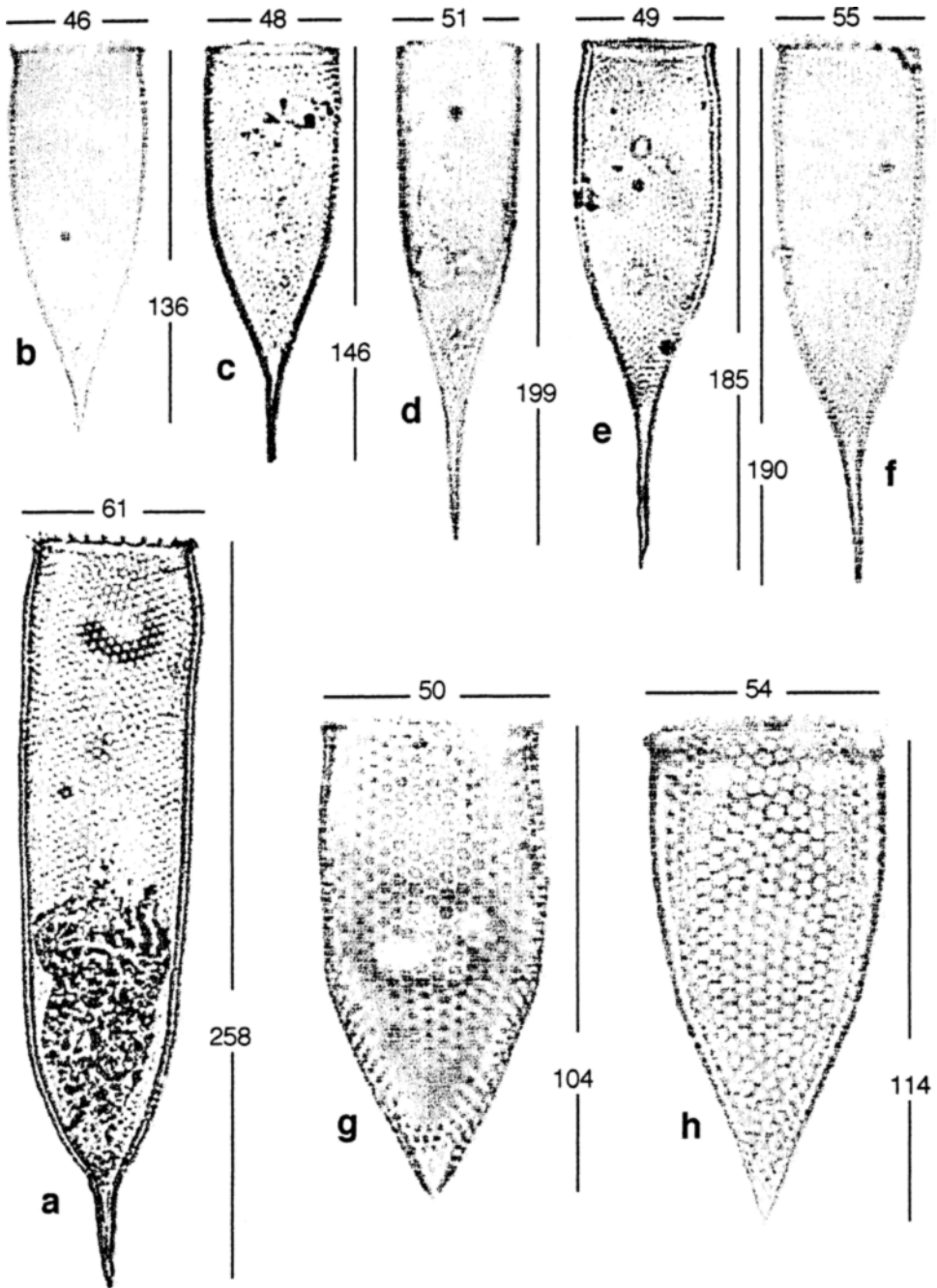


Fig. 4. Xystonellidae, *Parafavella denticulata* (a), *P. elegans* (b-f), *P. parumdentata* (g-h). Distances in µm

the walls show a honeycomb-like texture, as in all the other *Parafavella*. The peduncle is very short or absent and the margin of the oral aperture is serrated.

*Parundella caudata* (Ostenfeld, 1899) (Fig. 5 a). Few loricae of this species have been found, which up to the present time does not pose difficulties as to its taxonomy. *P. caudata* was found only in the Baltic Sea and on the coast of Norway, at stations 99, 101, 105 and 115. The lorica is totally hyaline, with thick walls, without the presence of foreign material or striae, alveolus, etc. The shape of the lorica is that of an elongated cone, slightly curved, with a slight narrowing where the aboral peduncle starts, which attains approximately 1/5 of the total length.

#### Family Tintinnidae (Claparède & Lachmann, 1858)

*Salpingella acuminata* (Claparède & Lachmann, 1858) (Fig. 5 b–d) was present in neritic and oceanic areas in the northern half of the studied area, though not occurring in the Baltic Sea. The lorica is fine and hyaline, the oral aperture is dilated like that of a trumpet, being able to attain double the breadth of the lorica. The aboral cone is coiled as in *Salpingacantha undata* and the ratio between the length and diameter is 15.5.

*Salpingacantha undata* (Jørgensen, 1899) (Fig. 5 e–f). Few loricae of this species were found, and were identified on the basis of the descriptions by Jørgensen (1899) and Marshall (1969). This species was also present only in the northern part of the studied area, mainly near the coasts of Scotland and Norway. The lorica is long and hyaline, with the aboral region generally being coiled to the right forming grooves in a spiral pattern. The oral margin is widened and denticulated in varying shapes and quantities. The length of the lorica attains on average 14 times its breadth.

The mean values of length, diameter and volume of the lorica of each identified species, as well as the number of measured individuals, are shown in Table 1.

## DISCUSSION

The greatest difficulty in the identification of the material from the ZISCH program was due to the genus *Tintinnopsis*. Baker & Phaff (1976) considered *T. beroidea*, *T. minuta*, *T. nana*, *T. parvula* and *T. rapa* variations of the same species. In the present work, *T. parvula*, *T. nana* and *T. beroidea* showed different shapes and sizes, and for this reason were considered separately in the evaluation of the biomass. Nevertheless, this does not invalidate the suppositions of Baker and Phaff, if we consider the degree of polymorphism already seen in the other genera, such as *Favella* (Laval-Peuto, 1981), *Ptychocylis* (Schulz & Wulff, 1929; Davis, 1981) and *Cymatocylis* (Wasik & Mikolajczyk, 1994).

Some loricae found resembled those of *T. rapa*, which were attributed to *T. parvula*, since the volume of the lorica and the geographic distribution were similar. Our *T. beroidea* was similar to *T. karajacensis* Brandt (1906), which could be another synonym of this very polymorphic species. *T. beroidea* is one of the cosmopolitan species widely distributed both in tropical and temperate neritic waters of the world. *T. tubulosa* from ZISCH Program resembles also some specimens of *T. lata* Meunier, which were illustrated by Balech (1945).

Table 1. Mean lorica dimensions and volume of the Tintinnina of ZISCH program

Species	Dimension	Mean ( $\mu\text{m}$ )	Standard deviation	n (ind.)	Lorica volume ( $\mu\text{m}^3$ )
<i>Leprotintinnus pellucidus</i>	diameter	38	2	11	276.271
	length	244	62	10	
<i>Tintinnopsis beroidea</i>	diameter	35	4	64	71.611
	length	86	17	64	
<i>T. cf. cylindrica</i>	diameter	40		1	154.818
	length	154		1	
<i>T. nana</i>	diameter	25	5	2	24.554
	length	63	1	2	
<i>T. parvula</i>	diameter	27	2	64	15.293
	length	50	6	65	
<i>T. cf. spiralis</i>	diameter	29		1	53.661
	length	91		1	
	oral diam.	36		1	
<i>T. tubulosa</i>	diameter	43	2	7	99.216
	length	78	6	7	
<i>Tintinnopsis</i> sp.	diameter	31	9	10	26.841
	length	53	13	10	
<i>Stenosemella nivalis</i>	diameter	40	3	107	43.256
	length	54	4	106	
	oral diam.	25	2	66	
<i>S. producta</i>	diameter	39	5	6	50.964
	length	66	5	6	
	oral diam.	23	6	5	
<i>Codonellopsis ovata</i>	diameter	30	3	2	18.850
	length	40	8	2	
	oral diam.	19	4	2	
<i>Coxiella pseudoannulata</i>	diameter	48	5	7	110.050
	length	106	10	7	
<i>Helicostomella subulata</i>	diameter	24	1	73	59.931
	length	185	40	73	
<i>Favella ehrenbergii</i>	diameter	86	4	8	904.227
	length	234	17	8	
<i>Favella</i> sp.	diameter	91		1	740.230
	length	194		1	
<i>Ptychocylis urnula</i>	diameter	85	6	58	641.826
	length	151	9	57	
<i>Acanthostomella norvegica</i>	diameter	29	2	36	23.291
	length	42	5	37	
<i>Parafavella denticulata</i>	diameter	57	6	12	783.007
	length	197	73	12	
<i>P. elegans</i>	diameter	50	4	26	634.512
	length	168	26	26	
<i>P. parumdentata</i>	diameter	49	2	15	157.585
	length	115	15	15	
<i>Parundella caudata</i>	diameter	42	1	6	65.469
	length	121	5	6	
<i>Salpingella acuminata</i>	diameter	18	2	26	59.879
	length	279	27	26	
<i>Salpingacantha undata</i>	diameter	18	1	11	55.483
	length	256	22	11	

The aboral region of our *T. cf. cylindrica* is more regularly conical than the typical *T. cylindrica*, resembling also *T. kofoidi* Hada, 1938 and *T. aperta* Brandt, 1906, two very close species which seem to be highly polymorphic. Some loricae of *T. aperta* were pictured with a more prominent projection near the middle region, resembling some *T. tocantinensis* specimens. We have maintained our specimens as *T. cf. cylindrica* but we believe it is very urgent to make a revision of the *cylindrica-kofoidi-aperta-tocantinensis* complex, which may be different morphotypes of the same species.

The species *Codonellopsis ovata*, first described by Jørgensen (1899) as a variety of *Codonella lagenula* (*Codonella lagenula* var *ovata* Jørgensen, 1899), was raised to the status of species by Kofoid & Campbell (1929) who accepted as the type locality the Bergen Coast, Norway. It seems to be a rare species in the marine plankton. Other registers include some temperate and cold waters from the Gulf of California (Osório-Tafall, 1941; López-Ochoterena & Roure-Cane, 1970), Angola (Silva, 1954) and South Shetland and Orkney Islands (Wasik & Mikolajczyk, 1990). The characters which distinguish this species from *C. contracta* Kofoid & Campbell, 1929, seem to be too subjective to support the division between these two taxa.

The specimens of *H. subulata* were found with a very constant oral diameter but with highly variable total lengths (Table 1). Cospers (1972) suggests that the extremely variable size of *H. subulata* is related to temperature.

The species *Codonella nucula* was described first by Fol (1884) and then transferred to the genus *Tintinnopsis* by Laackmann (1908). Jørgensen (1924) created the genus *Stenosemella* in order to separate those *Tintinnopsis* which had a firmer lorica and a small oral collar; as such, the species that Fol (1884) had described began to be known as *Stenosemella nucula*. In the revision made by Kofoid & Campbell (1929), *S. nucula* was rightly placed with the synonym *S. nivalis* described by Meunier (1910). However, Kofoid & Campbell (1929) adopted the more recent name *nivalis*, which can be found in most publications that followed. Hofker (1931) redescribed this species and adopted the name *S. nucula*, but it remains dubious whether the original *C. nucula* of Fol is a *Stenosemella*, since the oral collar is absent in his picture. Thus, *C. nucula* could be in fact a still valid *Tintinnopsis* species, and for this reason we use the name *S. nivalis* as adopted by Kofoid & Campbell (1929). Loricae with the characteristics of *S. oliva* Meunier (1910) were included in *S. nucula*.

Loricae of the genus *Acanthostomella* were found corresponding to those of *A. norvegica* and *A. gracilis*, but also intermediary forms were found. All the phenotypes of *Acanthostomella* were included in the taxon *A. norvegica*, in agreement with Balech (1971), who described the variations in the lorica of this species. This species is widely distributed in the cold waters of the Atlantic and Pacific Oceans (Hada, 1938) and is considered by Davis (1985) as a holarctic species.

Some loricae of the genus *Parafavella* were found which had the same shape as the loricae of *P. edentata*, which were included in *P. elegans*. The shape and the size of the lorica of both phenotypes are very similar and the diagnostic characteristic which would differentiate them would be the absence of a serrated crown circumferencing the oral aperture of the lorica in *P. edentata*. In the reference material, some loricae of *P. elegans* were found with part of the serrated crown loose. Lindley (1975) also mentioned the phenotype *P. edentata*, but included it in *P. denticulata*. Perhaps the absence of the serrated

crown in *P. elegans* is part of the process of cellular division or lorica augmentation, where the cell withdraws the crown in order to include another piece, before secreting a new crown.

If *Parafavella elegans* shows a complex biological cycle, alternating the shape and size of the lorica, as observed in the closely related genus *Favella* (Laval-Peuto, 1981), could leave to supposition the taxon *P. parumdentata*, which also occurred at the stations with *P. elegans*, which is a morphotype of the latter. A few minutes after the cellular division the proter (or the trophont) starts the construction of a new lorica which resembles the shape of an adult, but it is smaller. While the variation in the lorica of *P. elegans* was observed (Fig. 4 b–f), it was also noted that the smaller specimens had a shape resembling *P. parumdentata* (Fig. 4 g–h), with a short peduncle in comparison with the larger specimens.

*F. serrata* (Möbius, 1887) and *F. helgolandica* (Brandt, 1906) are accepted here as synonyms of *F. ehrenbergii*. This decision was taken in agreement with Sassi & Melo (1989), who included different phenotypes in *F. ehrenbergii*. The specimens found during the samplings of the ZISCH program showed a phenotype closer to *F. serrata* as illustrated by Marshall (1969) and *F. helgolandica* mentioned by Hofker (1931), without the presence of lamellas between the base of the lorica and the peduncle as in *F. ehrenbergii* of Brandt (1906). The name was defined according to priority: *Tintinnus ehrenbergii* Claparède & Lachmann, 1858, *Cyttarocyclus serrata* Möbius, 1887 and *C. helgolandica* Brandt, 1906. The genus *Favella* is due to Jørgensen (1924).

Laval-Peuto (1981) recognized *Coxiella annulata* and *C. decipiens* as polymorphic phases of *F. ehrenbergii*. This put in doubt the validity of the whole genus *Coxiella* and, consequently, all the family *Coxiellidae*. Inasmuch as *C. pseudoannulata* could also be a polymorphic phase of another species, in the present work this nomenclature was maintained, since the found loricae did not correspond to the size and shape of the descriptions of *C. annulata* or of *C. decipiens*.

The lorica with a denticulate oral aperture differentiates the genus *Salpingacantha* from *Salpingella*. However, if we imagine that *Salpingacantha undata* could retract the margins of the lorica and in so doing close the oral aperture, the result would be an oral aperture with thorn-like undulations as in *Salpingella acuminata*. Speculations aside, the fact remains that, excepting the thorn-like undulations, the loricae are extremely similar (Figs 5 b–d, 5 e–f), and besides this, the salinity, temperature, depth and sigma-T where the two species occurred are practically equal (Cordeiro et al., 1997). *Salpingacantha undata* and *Salpingella acuminata* may be different names of the same species.

The identification of *Tintinnopsis cf. spiralis* was made with one unique specimen whose size and shape corresponded to the shape described by Marshall (1969), except for the absence of spiral striae. The presence or absence of striae is a taxonomical characteristic of dubious validity, since it is sometimes conditional to the availability of food (Capriulo et al., 1986). According to Marshall (1969), *T. spiralis* is restricted to the Arctic. However, the specimen was found at a depth of 300 m, at the entrance of the Baltic Sea at temperatures below 4 °C. The shape shown in Figure 2 f could again be a specimen of *T. parvula* in cellular division, especially if we observe the illustrations of other species in division made by Hofker (1931): *Tintinnopsis beroidea* (p. 336, Fig. 17), *Stenosemella ventricosa* (p. 360, Fig. 36), *Codonellopsis morchella* (p. 366, Fig. 45). Given the impossibility to clarify this doubt and, for motives of biomass calculations, we preferred to accept the taxon *T. cf. spiralis*.

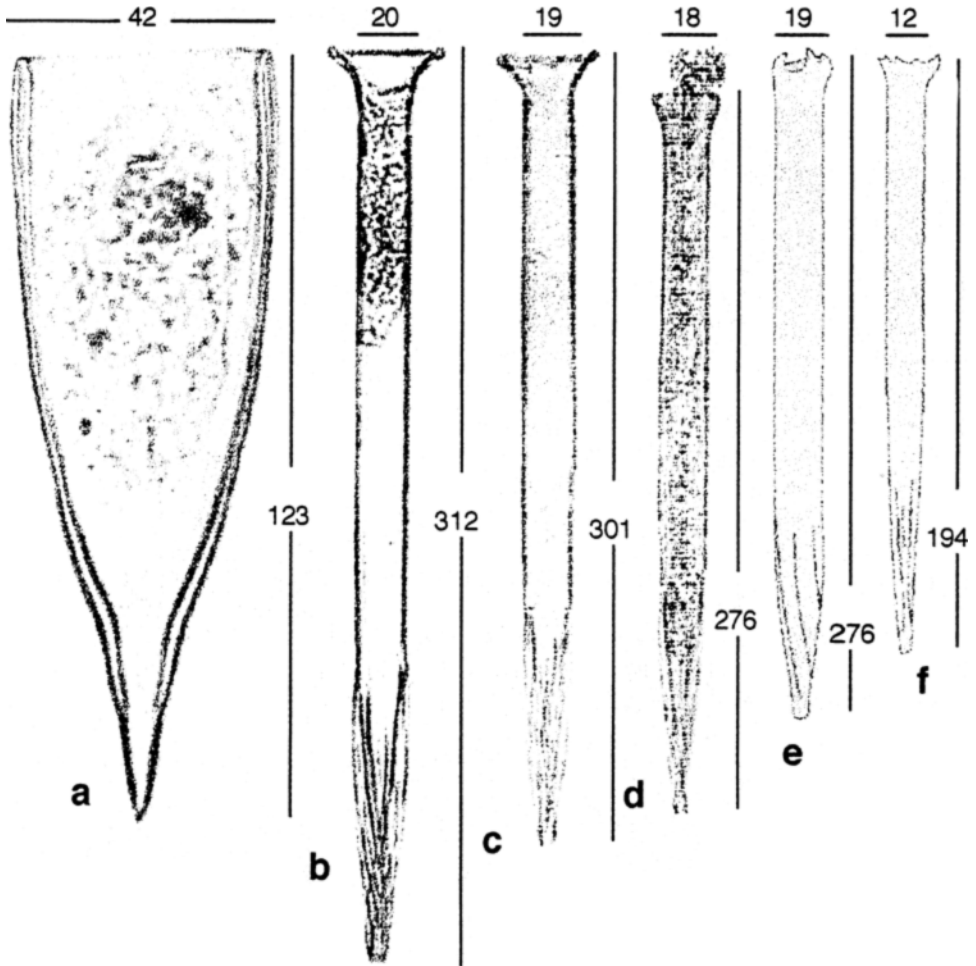


Fig. 5. Xystonellidae, *Parundella caudata* (a); Tintinnidae, *Salpingella acuminata* (b–d), *Salpingantha undata* (e–f). Distances in  $\mu\text{m}$

The above-listed species, excepting *T. cf. spiralis*, have already been registered in the North and Baltic seas and adjacent regions.

Lindley (1975) showed more recent data on seasonal and spatial distribution of Tintinnina in the North Sea, using material available from continuous plankton recorders (Hardy, 1941) towed by commercial ships during the year 1965. A comparison between the species found by Lindley and those of the present study was rendered difficult due to identification problems. But if we consider *Favella serrata* as synonym of *F. ehrenbergii*, *Stenosemella* spp. as being various names of *S. nucula*, and *Tintinnopsis* spp. as being species of *Tintinnopsis* identified in the ZISCH program, we would have at least 6 of the species found by Lindley (op. cit.) in the North Sea that were not identified during the

Table 2. Species of Tintinnina found by Lindley (1975) in the North Sea, and a possible synonymy with the species found during the ZISCH program

Species found by Lindley (1975)	Species from ZISCH program
<i>Acanthostomella norvegica</i>	=
<i>Dictyocysta elegans</i>	not found
<i>Codonellopsis lagenula</i>	not found
<i>Eutintinnus lususundae</i>	not found
<i>Parundella caudata</i>	=
<i>Parafavella denticulata</i>	=
<i>Ptychocyclus obtusa</i>	<i>P. urnula</i>
<i>P. urnula</i>	=
<i>Favella serrata</i>	<i>F. ehrenbergii</i>
<i>Helicostomella subulata</i>	=
<i>Parafavella gigantea</i> group	<i>P. denticulata</i>
<i>Stenosemella</i> spp.	=
<i>Tintinnidium mucicola</i>	not found
<i>Tintinnopsis</i> spp.	=
<i>Coxiella pseudoannulata</i>	=
<i>Cymatocyclus</i> spp.	not found
<i>Epiplocyclus acuminata</i>	not found
<i>Salpingella acuminata</i>	=

ZISCH program. The 18 taxa found by Lindley are shown in Table 2, where possible synonymy with the species of the ZISCH program is also shown.

The difference in the number of species found by Lindley and in the ZISCH program is due, in part, to the methods employed: a) Lindley carried out seasonal sampling; b) the Tintinnina are partially retained by the continuous sampler, which according to Zeitzschel (1966), retains only 3 % of the large species such as *P. gigantea* and besides this, c) the continuous sampler collects at a relatively constant depth of 10 m and at a speed superior to 10 knots. On the other hand, the disagreeing results could be indicating an alteration in the local population, similar to that observed by Hagmeier (1978), Hagmeier & Bauerfeind (1990) and Rick (1990) in the case of phytoplankton populations. These authors pointed out the growth of non-indigenous species, eutrophication processes and the increase in heavy-metal concentrations, respectively, as factors affecting the phytoplankton population structure.

#### CONCLUSIONS

A total of 23 species of Tintinnina was identified in the North Sea during the spring of 1986. However, future investigations on the taxonomy of the group could alter this number. Some doubts remain as to the validity of the taxa *Tintinnopsis beroidea*, *T. parvula*, *T. nana*, *Parafavella parudentata*, *Coxiella pseudoannulata* and as to the correct taxonomic position of *Tintinnopsis* sp.

*Salpingacantha undata* and *Salpingella acuminata* seem to be different names for one and the same species. This is also the case of *P. urnula* and *P. parudentata*.

*T. beroidea* and *T. parvula* were relatively common in coastal regions and could be important in the trophic chain, which increases the necessity for new taxonomic research.

There were differences between the results obtained previously by Lindley (1975) and those of the ZISCH program, which should be investigated further to determine whether these differences are due to methodological differences or to an alteration in the species composition of the Tintinnina in the North Sea, like that observed in the phytoplankton.

There exists a consensus between the present specialists that the taxonomy of the Tintinnina, considered the best known amongst the ciliates, is in urgent need of revision. The variability of shapes within a single species is very large and could lead to erroneous identifications. This revision should be performed with more comprehensive methods, including ecology, cellular morphology, laboratory cultivations versus field samples and comparisons at the molecular level.

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