

WOOD 1954:279, f. 197; — 1963b:40, f. 45; YAMAJI 1966:92, t. 44, f. 12; SOURNIA 1968a:407, f. 30, 31; SUBRAHMANYAN 1968:28, f. 43–45; WOOD 1968:30, f. 60.

A distinctive small species, easily recognisable from other small *Amphiceratium*, such as *C. falcatifforme*, by means of the sigmoid flexure of the epitheca when seen in ventral view (usually less than in the specimen illustrated) and the three fin-like body folds also present on the epitheca. *C. pacificum* WOOD (non SCHRÖDER 1906) is almost identical, differing only in the distal inward bend of the left antapical horn. As indicated, his name is also invalid.

Stations: 36, 47, 56, 66, 91, 92, 103, 108, 302, 420.

The species was rare, occurring at scattered stations in the Andaman Sea, at one station in the eastern Arabian Sea, one station south of Réunion, and at one close to Mombassa. It is known from the tropical waters of the three major oceans. The Indian Ocean records comprise those of KARSTEN (1907), STEEMANN NIELSEN (1939a), WOOD (1962 — in 1963a), TAYLOR (1967), SOURNIA (1968 a, b, 1970), NEL (1968), and SUBRAHMANYAN (1968).

Ceratium inflatum (KOFROID) JÖRGENSEN Plate 13, Fig. 132

STEEMANN NIELSEN 1934:13, f. 20; SCHILLER 1936:376, f. 415; RAMPI 1939a:303, f. 15; GRAHAM et BRONIKOVSKY 1944:23, f. 11 O–S; WOOD 1954:281, f. 198; SILVA 1955:56, t. 7, f. 9; YAMAJI 1966:93, t. 45, f. 6; SOURNIA 1968a:412, f. 36; SUBRAHMANYAN 1968:29, f. 48, 49; STEIDINGER et WILLIAMS 1970:46, t. 10, f. 25.

Syn.: . . . *C. nipponicum* OKAMURA 1912:8, t. 3, f. 44 a–c.

C. pennatum KOFROID . . . NIE 1936:39, f. 10 A–E; KATO 1957:14, t. 3, f. 7.

This is one of the group of closely similar species discussed under *C. falcatum*. JÖRGENSEN (1920, p. 35) has drawn attention to two forms of this species: one in which the epitheca is somewhat bulbous in appearance immediately above the girdle and with a smoothly-curving left antapical horn (figs. 45, 46 in his 1911 monograph); and a second in which the expanded portion of the epitheca blends more gradually into the apical horn and the left antapical horn bends abruptly in the distal part (fig. 48a in JÖRGENSEN 1911, under the name of *C. pennatum* KOFROID, reproduced as *C. inflatum* in his 1920 paper, fig. 25, and also illustrated by KATO 1957). The latter form has not been formally recognised in the nomenclature. It contains individuals which closely approach the appearance of *C. falcatum* (see plate 13, fig. 132 here) but which can still be distinguished by the inequality of epi- and hypothecal lengths.

OKAMURA (1912) attempted to distinguish *C. nipponicum* from *C. inflatum* on the basis that the former was flattened in one plane, the original description by KOFROID making no mention of this feature. However, all later authors have observed this feature in specimens referable to *C. inflatum*. *C. nipponicum* OKAMURA was, incidentally, omitted by SCHILLER (1936) and from both the monographs on *Ceratium* by SOURNIA (1968a) and SUBRAHMANYAN (1968).

Station: 318.

Only one specimen (illustrated) is referred here to the species. It occurred at an equatorial station to the south of India. The species is described as “a rare, intolerant tropical species confined entirely to warm water” by GRAHAM & BRONIKOVSKY (1944).

Indian Ocean records: WOOD (1963a) plus SILVA (1960), SUKHANOVA (1962b), TSURUTA (1963), ANGOT (1965), ANGOT & GÉRARD (1967), TAYLOR (ms. 1964, 1967), SOURNIA (1968 a, b, 1970), NEL (1968), SUBRAHMANYAN (1968), THORRINGTON-SMITH (1969), and ANGOT (1970).

Ceratium longirostrum GOURRET Plate 13, Figs. 131 a, b

CANDEIAS 1930:31, t. 3, f. 62, 62 a, b; STEEMANN NIELSEN 1934:13, f. 21; SCHILLER 1936:376, f. 416; RAMPI 1939a:303, f. 9; GRAHAM et BRONIKOVSKY 1944:24, f. 11 T–V; MARGALEF 1948b:49, f. 2 g; MARGALEF et DURÁN 1953:40, f. 10 b–c; WOOD 1954:281, f. 199; SILVA 1955:57, t. 7, f. 10; HALIM 1960a, t. 4, f. 4; — 1963:496, f. 6; SOURNIA 1968a:413, f. 37; SUBRAHMANYAN 1968:30, f. 50–52; STEIDINGER et WILLIAMS 1970:46, t. 10, f. 27; RICARD 1970, t. 2, f. i.

Another member of the “*falcatum*-complex”, within the same size range, but quite readily recognisable by its distinctly longer epitheca (plus horn) than hypotheca (plus horn), the smooth, gradual curvature of the horns, and the gradual blending of the epitheca with its horn. It most closely resembles the “second form” of *C. inflatum* referred to under the latter species. *C. falcatum* also has a longer epitheca than hypotheca, but the hypothecal (left antapical) horn is sharply bent. Generally the latter species is smaller, but this was not noticeable in this material.

Stations: 32, 41, 42, 56, 67, 362, 367.

It was found in small numbers at clusters of stations in the Andaman Sea, Bay of Bengal, and the Mozambique Channel. The distribution of this species has been considered by previous authors as indistinguishable from *C. inflatum* (rare, high stenothermal). In the "Anton Bruun" material *C. longirostrum* was apparently less rare, although evidently also showing a preference for water of high temperature. Additional Indian Ocean records to those in WOOD (1963a) are SUKHANOVA (1962b), SOURNIA (1966b, 1968 a, b, 1970) TAYLOR (ms. 1964, 1967) NEL (1968), and SUBRAHMANYAN (1968).

Subgenus *Tripoceratium* KOFOID

Syn.: s.g. *Euceratium* (GRAN) OSTENFELD; s.g. *Orthoceratium* SOURNIA. [Includes *Macroceratium* KOFOID]

SOURNIA (1968a) proposed the name *Orthoceratium* to replace that originated by GRAN. Article 21 of the International Code of Botanical Nomenclature forbids the use of the prefix *Eu-*, combined with the name of the genus, for the creation of a subgenus or section. However, KOFOID's (1909b) name has priority within the same rank, even though it was used originally in a more restricted sense, excluding the section *Macroceras* which he raised to subgeneric status (*Macroceratium*).

This is a large subgenus, used here to encompass all members of *Ceratium* which exhibit the classical "anchor" shape in which both antapical horns usually proceed laterally after leaving the body. They are often recurved towards the anterior of the cell. Because of its size the use of sections in this subgenus is helpful. The following (fewer than are recognised by most recent authors) are used here, based primarily on antapical horn features:

Section *Densa* JÖRGENSEN — The left horn is much shorter than the right horn and is bluntly pointed.

Section *Macroceras* OSTENFELD — The posterior profile of the cell is moderately or strongly indented due to one or both antapical horns being directed posteriorly for a short distance before curving out laterally. The ends of the horns are usually narrow but truncated. The name of the section is commonly mis-spelled *Macroceros*.

Section *Palmata* (PAVILLARD) JÖRGENSEN — Similar to the section *Tripodos* but with the ends of the horns subdivided in a digitate manner.

Section *Platycornia* JÖRGENSEN — Horns as for section *Tripodos* but flattened strongly in their distal regions.

Section *Reflexa* JÖRGENSEN — The left horn is bent strongly towards the posterior and is short.

Section *Tripodos* — Horns arise laterally from the cell body with little indentation of the posterior profile. The tips of the horns are simple and acute.

Their arrangement is alphabetical for convenience although they are usually arranged "systematically", reflecting presumed relationships. Some, such as the sections *Platycornia*, *Palmata*, and *Densa*, are based on very superficial features.

Section *Densa* JÖRGENSEN

This section includes only one species at present.

Ceratium dens OSTENFELD et SCHMIDT Plate 17, Fig. 172

STEEMANN NIELSEN 1934:15, f. 27; SCHILLER 1936:381, f. 420 a, b; NIE 1936:44, f. 14 A, B; WOOD 1954:284, f. 204; YAMAJI 1966:105, t. 51, f. 3; SOURNIA 1968a:457, f. 80; SUBRAHMANYAN 1968:34, f. 58, t. 3, f. 16.

Vix STEIDINGER et WILLIAMS 1970: *Ceratium* sp., t. 15, f. 40.

This is a large distinctive species, readily recognisable due to the very short, bluntly acute left antapical horn. The body and right antapical horn are somewhat similar to *C. humile* in shape. The apical horn is straight and tilted to the left. The right antapical horn can exhibit autotomy in some specimens.

The species was thought to occur in two varieties, the var. *dens* in which the left horn projects laterally, and the var. *reflexa* J. SCHMIDT in which the horn projects more posteriorly. However, BÖHM (1931b) has observed heteromorphic chains in which both types occurred (his figure is repeated in SCHILLER 1936). In view of the structural resemblances to *C. humile* it is interesting that they are also similar in distribution. Because of the distributional features below, STEIDINGER & WILLIAMS' (1970) tentative attribution of their specimen to this taxon (which seems possible) is of great interest.

Stations: 14, 16, 20, 21, 28, 29, 34, 36, 38, 39, 42, 43, 47, 49, 50, 87, 283, 284, 287.

Although considered rare it occurred relatively frequently in the eastern Bay of Bengal — Andaman Sea area and at three stations in the Arabian Sea.

This appears to be an Indo-Pacific species, not having been recorded from the Atlantic Ocean or the Mediterranean Sea. If STEIDINGER & WILLIAMS' (1970) specimen is this taxon it would be a first record for the Atlantic Ocean. It has a high stenothermal, neritic distribution but the above distribution indicates more flexibility in its salinity response. SUKHANOVA's (1962b), SOURNIA's (1968a, 1970), SUBRAHMANYAN's (1968) and ANGOT's (1970) records need to be added to those listed by WOOD (1963a). Although not recorded in the literature from the eastern Pacific Ocean BALECH has found the species to be abundant on the coast of southern California (pers. comm. to A. SOURNIA).

Section *Macroceras* OSTENFELD

Ceratium carriense GOURRET

Plate 20, Fig. 200

CANDEIAS 1930:37, t. 3, f. 77; PETERS 1932:50, t. 2, f. 10h; STEEMANN NIELSEN 1934:26, f. 64; SCHILLER 1936:425, f. 464 a, b, 465, 466 b vix a; NIE 1936:65, f. 30 A-C; RAMPI 1939a:310, f. 35, 37; GRAHAM et BRONIKOVSKY 1944:39, f. 22 A; MARGALEF 1948a:21, f. 3, 7, 8, 9; MARGALEF et DURÁN 1953:42, f. 12 1; WOOD 1954:308, f. 236 a, b; SILVA 1955:172, t. 9, f. 5-8; TRÉGOUBOFF et ROSE 1957:116, t. 26, f. 16; HALIM 1960a, t. 5, f. 11; - 1963:499; TAYLOR 1967:102, t. 49, f. 12, 13, t. 50, f. 1; SOURNIA 1968a:469; SUBRAHMANYAN 1968:77, f. 143, 144, t. 7, f. 36; WOOD 1968:25, f. 46; STEIDINGER et WILLIAMS 1970:44, t. 5, f. 13 a, b, 14 a, b.

This species is very similar to *C. massiliense* and may, in fact, be conspecific although most previous authors have kept them separate. (REINECKE 1973b has reduced *C. carriense* to varietal status on the basis of polar co-ordinate data regarding the horns.) It has been separated by the widely spread antapical horns, greater than 60° from apical horn. In the var. *volans* (CLEVE) JÖRGENSEN the antapical horns are very slender, long, and the angle with the apical horn approaches 90°. Generally the posterior profile of the cell body appears more indented than in *C. massiliense* because of a short posterior deflection of the proximal region of the left antapical horn (in addition to the posteriorly-deflected base of the right antapical horn) but, as evident on plate 20, this character, although constant for *C. carriense*, is not always a reliable distinction. Similarly, distinctions based on cell body shape are not reliable.

Only the var. *carriense* was recognised in the "Anton Bruun" material although many tended towards the var. *volans*.

Stations: 42, 64, 87, 95, 96, 99, 114, 115, 117, 125, 129, 134, 150, 153, 154, 294, 313, 315, 325, 326, 335, 341, 347, 358, 370, 399, 415, 417.

This distribution is intriguing in that, with the exception of a few stations in the Bay of Bengal, the species occurred predominantly in two latitudinal belts, one between 5° S to 5° N and the other between 20° and 30° S. This pattern suggests that it was largely absent from the westward-flowing South Equatorial Current but was present in its eastward-flowing returns. The southern limit of approximately 30° S in the central area accords with other authors' observations that the species is less thermotolerant than *C. massiliense*. However, like it, *C. carriense* appears to be an inter-oceanic, surface species (STEEMANN NIELSEN 1934, GRAHAM et BRONIKOVSKY 1944). It has been recorded from the Indian Ocean quite frequently (cf. WOOD 1963a plus the references of SILVA 1956a, SUKHANOVA 1962 a, b, TSURUTA 1963, DURAIRATNAM 1964, SOURNIA 1966a, 1968 a, b, 1970, TAYLOR 1967, NEL 1968, SUBRAHMANYAN 1968, THORRINGTON-SMITH 1969, and REINECKE 1973b).

Ceratium contrarium (GOURRET) PAVILLARD

Plate 21, Fig. 213

CANDEIAS 1930:37, t. 4, f. 78; PETERS 1932:50, t. 2, f. 10c; STEEMANN NIELSEN 1934:77, f. 67; GRAHAM et BRONIKOVSKY 1944:40, f. 22 E, 24 A, B; MARGALEF 1948b:49, f. 2h; SILVA 1949:361, t. 9, f. 12; MARGALEF 1957a:47, f. 3f; TRÉGOUBOFF et ROSE 1957:116, t. 26, f. 18; HALIM 1960a, t. 5, f. 14; HALIM 1963:499, f. 30; SOURNIA 1968a:473, f. 90; WOOD 1968:26, f. 49; HERMOSILLA 1973a:26, t. 2, f. 17.

Syn.: *C. trichoceros* var. *contrarium* (GOURRET) SCHILLER 1936:431, f. 471, (et f. 470 sub *C. trichoceros*); WOOD 1954:311, f. 239c (non b); SUBRAHMANYAN 1968:82, f. 148 (et f. 147 sub *C. trichoceros*); REINECKE 1973b:365, f. 22 G-K, f. 24 A-E.

Several authors have followed SCHILLER's (1936) proposal that this taxon should be united with *C. trichoceros* (EHRENBERG) KOFOID. However, others (most recently SOURNIA 1968a), have kept them distinct. The distinction is based primarily on the antapical horn arrangement. In *C. contrarium* the proximal parts of the antapical horns and particularly the left horn, are directed more posteriorly than in *C. trichoceros* and the distal regions proceed in a constantly divergent manner after they bend anteriorly. In *C. trichoceros* the distal horn regions run subparallel to each other. REINECKE (1973b) indicated that the girdle transdiameter of the latter is less than 45 μm. In both taxa the antapical horns commonly exhibit undulations. In addition, SOURNIA has drawn attention to the larger cell body and the continuation of the proximal part of the left horn in the same plane as the posterior profile of the cell body. He found that the flexure of the right horn occurred nearer the cell body than the left horn. Unfortunately the specimens illustrated here (pl. 21, fig. 210, 213) do not support SOURNIA's observations other than the presence of a larger cell body in *C. contrarium*, demonstrating that intermediates between the two species may exist in cell body features and REINECKE's data also suggests the varietal separation is probably more appropriate.

Stations: 39, 41, 42, 46, 65, 72, 87, 287, 288, 293, 311.

It occurred at scattered stations in both the northern and southern regions. Although it was moderately abundant at st. 41 near the Irrawaddy delta it also occurred at 35°S (cruise V, April 1963) on one occasion. This occurrence at a cool southerly station agrees with GRAHAM et BRONIKOVSKY's (1944) observations in the Pacific Ocean where the species, although thermophilic, tolerated lower temperatures than in the Atlantic Ocean. It is considered to be a surface species (above 50 m).

Records are probably confused due to the resemblance of the species to *C. trichoceros* but as indicated above, this may not matter. Indian Ocean records other than those listed by WOOD (1963a) are: SILVA (1956a, 1960), SUKHANOVA (1962 a, b – var. *contrarium*), TSURUTA (1963 as the synonymous *C. inflexum*), DURAIRATNAM (1964 – var. *contrarium*), SOURNIA (1966a – var. *contrarium*, 1968a, b, 1970), SUBRAHMANYAN (1968), and REINECKE (1973b).

Ceratum deflexum (KOFOID) JÖRGENSEN Plate 20, Fig. 197

STEEMANN NIELSEN 1934:25, f. 63; SCHILLER 1936:428, f. 467 a non b; NIE 1936:63, f. 29 A, B; GRAHAM et BRONIKOVSKY 1944:39, f. 22 C, D; WOOD 1954:310, f. 237; KATO 1957:19, t. 7, f. 25; TORIUMI 1964:25, t. 3, f. 14; YAMAJI 1966:101, t. 49, f. 3; SOURNIA 1968a:464, f. 86; SUBRAHMANYAN 1968:78, f. 145 non 146; WOOD 1968:27, f. 51; RICARD 1970, t. 2, f. a; REINECKE 1973b:303, f. 7 A–L, f. 8 A, B, f. 12 I, L, f. 14 C.

This is usually distinctive, with antapical horns which are directed first posteriorly and then both curving ventrally. KOFOID (1907a) and PETERS (1932) have included the species with *C. macroceros* and *C. massiliense* respectively, because of resemblance of the proximal portions of the horns and body shape, but the strong ventral bend of the horns is usually sufficient to separate the species, REINECKE (1973b) considers that some specimens formerly assigned to *C. macroceros* may be members of this species with weak ventral deflection of the antapical horns (e.g. that of OSTENFELD & SCHMIDT 1901). In ventral view the antapical horns may appear to diverge or to run parallel. BÖHM (1931a) has figured a continuous variability between these two conditions, REINECKE (1973b) recognising forms on this basis, the divergent condition being termed the f. *deflectomassum* REINECKE.

Stations: 14, 28, 29, 39, 47, 53, 65, 69, 71, 88, 90, 92, 93, 99, 100, 102, 112, 113, 116, 147, 290, 293, 313, 314, 317, 320, 406, 411, 412, 416.

The species was present at a few stations, all north of 30°S. It was only fairly widespread during cruise V. It is a rare, warm, inter-oceanic species and appears to be relatively stenothermal. It has been found to be a surface species (GRAHAM & BRONIKOVSKY 1944). There are relatively few Indian Ocean records. In addition to those listed by WOOD (1963a) there are those of SUKHANOVA (1962 a, b), TSURUTA (1963), DURAIRATNAM (1964), SOURNIA (1968a, 1970), SUBRAHMANYAN (1968), and REINECKE (1973b).

Ceratum hexacanthum GOURRET Plate 22, Figs. 214, 215, 219

CANDEIAS 1930:39, t. 4, f. 82; PETERS 1932:54, t. 2, f. 10a, 11b; STEEMANN NIELSEN 1934:29, f. 73; SCHILLER 1936:421, f. 462 a–c; RAMPI 1939a:308, f. 44; – 1939c:111, f. 13; – 1942:227, f. 7, 10, 11, 12; GRAHAM et BRONIKOVSKY 1944:44, f. 27 F, G; MARGALEF 1946:94, f. III 3–6; SILVA 1949:362, t. 7, f. 9, 10, t. 9, f. 14; KISSELEV 1950:254, f. 438; MARGALEF et DURÁN 1953:42, f. 10u; WOOD 1954:306, f. 234 a, b; TRÉGOUBOFF et ROSE 1957:116, t. 26, f. 13, 14; HALIM 1960a, t. 4, f. 17; – 1963:499, f. 35; KLEMENT 1964:357, t. 3, f. 6; MARGALEF et HERRERA 1964:62; DAVIS 1965:1, f. I–IV; SOURNIA 1968a:484, f. 98; SUBRAHMANYAN 1968:72, f. 140–142; WOOD 1968:31, f. 63; STEIDINGER et WILLIAMS 1970:45, t. 9, f. 23 a–c.

This species is striking in appearance. It is most similar to *C. obesum* PAVILLARD but it has different horn dispositions (see notes under the latter species) and the cell body is usually strongly reticulated.

The var. *hexacanthum* forma *hexacanthum* is characterised by a left antapical horn which is directed anteriorly, not curled proximally into a spiral, not directed ventrally for any great distance, and therefore not appearing to cross in front of the apical horn when seen from the ventral side. Here the variety is illustrated by an autotomised form (fig. 214; similar to that figured by PETERS 1932, f. 11b).

The forma *spirale* (KOFOID) SCHILLER is a modification of the preceding taxon in which the distal region of the left antapical horn is coiled spirally (fig. 215). GRAHAM & BRONIKOVSKY (1944) saw no value in recognising such forms but their recurrent characteristic development suggests that this phenomenon may have value as an indicator of some as yet unknown internal or external factor.

Another variant which can be recognised is the var. *contortum* LEMMERMANN, in which the antapical horns are long but not coiled, the right horn passing to the left side, well to the dorsal side of the cell, and the left horn directed strongly towards the ventral side and to the right (f. 219). GRAHAM & BRONIKOVSKY (1944) have illustrated a chain of such individuals. JÖRGENSEN (1920) has excluded KARSTEN's (1906) specimens from this variety. The forma *biemale* (PAVILLARD)

JÖRGENSEN is a winter form of the var. *contortum*, the horns being much shorter and set closer to the body. It was not found in the "Anton Bruun" material.

The var. *aestuarium* (SCHRÖDER) JÖRGENSEN has subparallel, apically-directed antapical horns, with reduced reticulation on the body.

Other infraspecific taxa recognised are the var. *karstenii* PAVILLARD and the forma *pavillardii* (RAMPI) SOURNIA (= *C. aestuarium* var. *pavillardii* RAMPI 1939a).

REINECKE (1973a) believes that this taxon is sufficiently distinct from others of the section *Macroceras* to warrant recognition within the separate section *Reticulata* (JÖRG.) BÖHM.

Stations: var. *hexacanthum* forma *hexacanthum*: 17, 52, 56, 57, 99, 361, 375.
var. *hexacanthum* forma *spirale*: 43.
var. *contortum*: 59, 71, 97, 130, 135, 144, 287, 294.

The species was very widely scattered but not common, ranging from lower salinity Andaman Sea waters to high salinity Gulf of Aden waters. The occurrence was too sporadic to draw conclusions other than its apparent preference for higher temperatures. It occurred furthest south at st. 130 (34°S) during cruise II.

It has usually been considered an inter-oceanic thermophilic species found in water above 20 °C but it is sometimes tolerant of colder conditions in the North Atlantic Ocean (GRAHAM & BRONIKOVSKY 1944). STEEMANN NIELSEN (1934) found that it occurred closer to the surface in samples rich in plankton (upwelling?) but was deeper, below 100 m, at stations poorer in plankton. GRAHAM & BRONIKOVSKY (1944) could not confirm this observation with the "Carnegie" material.

Many references require being added to those listed by WOOD (1963a): SILVA (1956a, 1960); SUKHANOVA (1962b), TSURUTA (1963, as *C. reticulatum*), DURAIRATNAM (1964, both as the species and its synonym *C. reticulatum*), SOURNIA (1966a, 1968a, b, 1970) TAYLOR (1967), NEL (1968), and SUBRAHMANYAN (1968).

Ceratium horridum (CLEVE) GRAN Plate 20, Fig. 202, Plate 21, Figs. 203–208, 211, 212

CANDEIAS 1930:38, t. 4, f. 79–81 a; SCHILLER 1936:413, f. 455 a–c; GRAHAM et BRONIKOVSKY 1944:42, f. 23 I–L, 24 C–I, 25 A–G; MARGALEF 1948b:49, f. 2 i; SILVA 1949:362, t. 7, f. 5, 6, 7, 8, t. 9, f. 19; KISSELEV 1950:253, f. 50, 430; MARGALEF et DURÁN 1953:42, f. 12 g–k; WOOD 1954:300, f. 230 a, b; HERRERA, MUÑOZ et MARGALEF 1955:18, f. 1 K; KATO 1957:17, t. 5, f. 14; HALIM 1960a, t. 5, f. 10; – 1963:499, f. 32; TAYLOR 1967, t. 93, f. 54; SOURNIA 1968a:474, f. 91–95; SUBRAHMANYAN 1968:63, f. 113, 115–122, vix 114 (SCHILLER emend.); WOOD 1968:32, f. 65; MARGALEF 1969a, f. 5 D.

Vix WAILES: 1928, t. 1, f. 1; – 1939:45, f. 136.

Syn.: . . . *C. buceros* ZACHARIAS . . . SCHILLER 1936:415, f. 456 a–c, 457 a–c; MARGALEF, HERRERA, RODRIGUEZ-RODA et LARRAÑETA 1954:92, f. 3 b; HERRERA, MUÑOZ et MARGALEF 1955:18, f. 1 H, I, J; WOOD 1968:24, f. 43; MARGALEF 1969a, f. 5 C; STEIDINGER et WILLIAMS 1970:44, t. 4, f. 12.

C. claviger KOFOID . . . STEEMANN NIELSEN 1934:28, f. 70; YAMAJI 1966:104, t. 50, f. 9.

C. intermedium (JÖRGENSEN) JÖRGENSEN . . . WANG et NIE 1932:300, f. 13; WANG 1936:163, f. 31; SILVA et PINTO 1948:172, t. 2, f. 14; YAMAJI 1966:104, t. 50, f. 8.

C. mollis KOFOID . . . STEEMANN NIELSEN 1934:28, f. 71, WANG 1936:162, f. 30 (sub *C. molle*); YAMAJI 1966:104, t. 50, f. 10.

C. tenue OSTENFELD et SCHMIDT . . . STEEMANN NIELSEN 1934:28, f. 69; NIE 1936:71, f. 34; GRAHAM et BRONIKOVSKY 1944:43, f. 26 C–D; YAMAJI 1966:103, t. 50, f. 4, 5, 6; REINECKE 1973b:342, f. 18 A–H, 19 A–K, 20 A–F.

This small species encompasses a great deal of variability. It was first fully assembled and sorted out by JÖRGENSEN (1920) and its taxonomic history is summarised by SOURNIA (1968a). VON STOSCH (1964) has observed an instance of sexual conjugation involving anisogametes in this species, the male conjugant resembling a small member of the subgenus *Ceratium*. The following are the main infraspecific taxa, treated as varieties in a similar manner to GRAHAM & BRONIKOVSKY (1944, who, however, recognised *C. tenue* as a separate species):

The var. *horridum*, so-named because it includes the type specimen, is relatively robust with antapical horns only moderately divergent or subparallel. The horns are shorter than in the other varieties.

The var. *claviger* (KOFOID) GRAHAM et BRONIKOVSKY is distinctive because of the small terminal inflated regions present on elongate, subparallel antapical horns (SOURNIA has termed this a *forma*, implying a solely phenotypic modification). Very small terminal inflations have also been seen in the var. *tenue* and var. *denticulatum*.

The var. *molle* (KOFOID) GRAHAM et BRONIKOVSKY is very similar to the preceding variety and perhaps should not be distinguished from it except at the level of a *forma*. It lacks the terminal inflations, possibly due to autotomy.

The var. *inclinatum* (KOFOID) stat. et comb. n. [= *C. inclinatum* KOFOID, *C. tenue* f. *inclinatum*] is a long-horned, delicate variety with a distinctive antapical horn configuration. They bend outwards at first and then bend somewhat abruptly to become subparallel in the apical plane, this change of direction occurring well above the cell body.

The var. *tenuis* (OSTENFELD et SCHMIDT) stat. nov. is a slender, long-horned variety, similar to the preceding but lacking the angular mid-bends of the antapical horns. Perhaps the taxon *inclinatum* could be considered a form of this variety but the necessary information for this decision is lacking. BÖHM (1931b) interpreted the var. *inclinatum* quite differently, basing it on body features, his specimens having short horns. If the taxon *tenuis* is regarded as a separate species (e.g. REINECKE 1973b) it has priority over *C. buceros* although most earlier authors have not recognised this fact.

The var. *patentissimum* (OSTENFELD et SCHMIDT) stat. et comb. nov. [basonym *C. patentissimum* OSTENFELD et SCHMIDT 1901:168, f. 22; also = *C. tenuissimum* KOFOID] has the antapical horn very widespread, almost at 90° to the apical horn, and thus resembles *C. carriense* from which it is distinguished by being smaller, lacking a proximal ventrally-directed region on the right antapical horn, and having a small spine arising at the base of the left horn (as do other members of *C. horridum*).

Finally, the var. *denticulatum* JÖRGENSEN can be recognised by its moderately widespread antapical horns with moderately extensive denticulations on the under sides of the flexure of the horns (fig. 202). In many respects it resembles a small *C. carriense*, emphasised by its position on plate 20.

Stations: var. *horridum*: 16, 19, 20, 27, 30, 32, 35, 36, 38, 42, 44, 53, 54, 56, 60, 63, 64, 67, 70, 71, 91, 92, 97, 99, 100–103, 109, 112–114, 147, 150, 286, 297, 308, 324, 327.
 var. *claviger*: 63, 282, 298, 370, 417.
 var. *molle*: 60, 67, 70–72, 93, 99, 100, 103, 104, 142, 324.
 var. *inclinatum*: 327.
 var. *tenuis*: 16, 50, 63, 72, 89, 93, 96, 98, 101, 108, 129, 131, 132, 134, 153, 160, 291, 294, 296, 310, 312, 323, 325–327.
 var. *patentissimum*: 113, 147, 150, 298, 301, 302, 305, 318, 328, 342.
 var. *denticulatum*: 91, 101, 113, 294, 312–314, 319, 320, 324–326, 334, 341, 360, 374, 396, 410, 411, 412, 414.

The var. *horridum* had a predominantly northern distribution, only one occurrence being south of 12°S and that at an extreme southern station (308). It was abundant at st. 99 in the southern Bay of Bengal.

The second most abundant variety, the var. *tenuis*, was more widespread, six stations being south of 30°S in the central area. The var. *molle* and the var. *claviger* occurred at scattered stations. The var. *claviger* was the only representative of the species to occur west of Madagascar. The latter pair of varieties did not co-occur at any stations.

The var. *denticulatum* was also fairly common, mostly in the central Indian Ocean on cruise V and at near-shore localities off the east coast of Africa and the west coast of Madagascar.

The var. *patentissimum* occurred at scattered stations in the central Indian Ocean from 20°N to 30°S. It did not co-occur with the var. *tenuis*.

The var. *inclinatum* was found at only one station to the south of India.

Both the var. *horridum* and the var. *tenuis* have been reported as relatively oligophotic, preferentially occurring at deeper levels to 100 m or more (GRAHAM & BRONIKOVSKY 1944). The species is considered to be inter-oceanic and tropical to subtropical although the var. *horridum* is considered to be more thermotolerant (SOURNIA 1968a).

The following Indian Ocean records (including synonymous records) should be added to those listed by WOOD (1963a): SILVA (1956a, 1960), SUKANOVA (1962b), TSURUTA (1963), DURAIRATNAM (1964), SOURNIA (1966a, 1968a, b, 1970), TAYLOR (1967), NEL (1968), SUBRAHMANYAN (1968), THORRINGTON-SMITH (1969), and REINECKE (1973b).

Ceratium macroceros (EHRENBERG) VANHÖFFEN Plate 20, Figs. 198, 199; Plate 22, Fig. 218

CANDEIAS 1930:35, t. 4, f. 75; WANG 1932, f. 29; PETERS 1932:47, t. 4, f. 17b; STEEMANN NIELSEN 1934:25, f. 59; SCHILLER 1936:428, f. 468 a–d; NIE 1936:62, f. 28 A, B; WAILES 1939:45, f. 137; WANG 1936:160, f. 29; RAMPI 1939a:310, f. 42; GRAHAM et BRONIKOVSKY 1944:37, f. 21 B–F; SILVA 1949:360, t. 7, f. 2, t. 9, f. 11; – 1952b, t. 6, f. 11; KISSELEV 1950:254, f. 63 e-p. 422; MARGALEF 1951:57, f. 2 e, f; MARGALEF et DURÁN 1953:42, f. 12 a–f; WOOD 1954:310, f. 238 a, b; TRÉGOUBOFF et ROSE 1957, t. 26, f. 17; KATO 1957:18, t. 7, f. 23; HALIM 1960, t. 4, f. 6, t. 5, f. 7; – 1963:498, f. 27; BALLANTINE 1961:225, f. 56; KLEMENT 1964:357, t. 3, f. 1; YAMAJI 1966:100, t. 48, f. 12, 13; SOURNIA 1968a:460, f. 83–85; SUBRAHMANYAN 1968:79, f. 149–151; WOOD 1968:36, f. 77; STEIDINGER et WILLIAMS 1970:46, t. 11, f. 29 a, b; RICARD 1970, t. 2, f. c; REINECKE 1973b:281, f. 1 A–F, f. 2 A–E, f. 3 A–F, f. 12 M.

[CUESTA 1919, t. 52 (f. 1), A–C, SCHILLER 1936 praetermissavit.]

Non CURL 1959:306, f. 118 (= *C. horridum*).

Syn.: *C. gallicum* KOFOID . . . WOOD 1968:59, f. 59.

Although several of the species in the section *Macroceras* have a right antapical horn which is strongly directed towards the posterior for a distance of nearly a body length before curving anteriorly, only *D. deflexum* also has the left antapical horn similarly directed and in the latter case it is easily distinguished by both antapical horns also being strongly ventral in their deflection. REINECKE (1973b) has provided a more detailed account of the distinction of the species.

The species is recognised in two main varieties which also tend to have geographic distinction (see distribution below): the var. *macroceros* is a robust variety with a heavily developed theca of large size (girdle diameter exceeding 60 μm and occasionally 100 μm) and less abrupt antapical horn flexure (f. 218); and the var. *gallicum* (KOFOD) SOURNIA [= subsp. *gallicum* (KOFOD) JÖRGENSEN] which is much more delicate with a smaller body size, slender horns abruptly curved, and often a somewhat angular left body profile (f. 199). A posterior accessory list is often well developed in association with the base of the left antapical horn. The designation of variety was used before SOURNIA by both PETERS (1932) and SCHILLER (1936). However, both of the latter attributed the variety incorrectly to others.

Autonomy is common in this species. PETERS (in SCHILLER 1936, and KISSELEV 1950) has found heteromorphic chains, some anterior members of which have very short antapical horns with no reflexed portions (thus resembling the section *Biceratium*). Incomplete girdle development has also been seen (f. 199).

Stations: var. *macroceros*: 302, 306, 311, 323.

var. *gallicum*: 15, 17, 21, 34, 50, 51, 58–60, 62, 63, 65, 66, 69, 70, 88, 89, 91–95, 98–100, 102, 104, 108, 109, 114, 125, 129, 130, 132, 134, 135, 141, 142, 150, 154, 157, 161, 162, 285, 287, 293–295, 298, 299, 301, 302, 312–315, 317–319, 322, 325, 327, 342, 347, 348, 355, 358, 360, 362, 370, 371, 416, 419.

In accord with authors such as PETERS (1932), STEEMANN NIELSEN (1934, 1939a), and GRAHAM & BRONIKOVSKY (1944) who have studied large areas of the major oceans it was found that the var. *gallicum* not only predominated over the var. *macroceros* but was also one of the commonest taxa in the material from tropical and subtropical areas. Together with *C. euarcuratum*, *C. contortum*, *C. paradoxides*, and others it could be used as a general indication of the southern limit of moderately eurythermal species in the Indian Ocean. Also in common with many it was notably absent from most of the Mozambique Channel stations, occurring only to the north and south of the Channel.

The var. *macroceros* had a much more limited distribution. Two of the four stations were below the warm temperature boundary indicated by the var. *gallicum*, but two other records (including the specimen illustrated) were from stations further north. In fact, station 323 is not far from the equator. This distribution partially confirms views that the variety is a cooler water representative but it may also co-occur with the var. *gallicum* (as at st. 302). The species has been found by other authors (STEEMANN NIELSEN 1934, GRAHAM & BRONIKOVSKY 1944) to occur predominantly above 100 m depth. REINECKE (1973b) has discussed the correlation of phenotypes with environmental conditions.

Indian Ocean records: Many listed by WOOD (1963a) plus those of SILVA (1956a, 1960), TSURUTA (1963), DURAIRATNAM (1964), ANGOT (1965), SOURNIA (1966a, 1968 a, b, 1970), TAYLOR (1967), NEL (1968), SUBRAHMANYAN (1968), THORRINGTON-SMITH (1969), and REINECKE (1973b).

Ceratium massiliense (GOURRET) KARSTEN Plate 20, Figs. 193–196.

CANDEIAS 1930:36, t. 3, f. 76; PETERS 1932:50, t. 1, f. 2 a, b, t. 2, f. 10 f, t. 3, f. 16 a; WANG et NIE 1932:301, f. 14; STEEMANN NIELSEN 1934:25, f. 60–62; SCHILLER 1936:422, f. 463 a–d; RAMPI 1939a:308, f. 32, 33, 40; GRAHAM et BRONIKOVSKY 1944:38, f. 22 F, I–L (vix G, non H); MARGALEF 1946, f. III 2; SILVA 1949:361, t. 7, f. 3; MARGALEF et DURÁN 1953:42, f. 12 m–r; WOOD 1954:306, f. 235 a–c; MARGALEF 1957a:48, f. 3 g; TRÉGOUBOFF et ROSE 1957:116, t. 26, f. 15; KATO 1957:18, t. 6, f. 18, 20; CURL 1959:306, f. 117; HALIM 1960a, t. 5, f. 15; – 1963:498, f. 28, 29; MARGALEF 1961a:81, f. 26 h; KLEMENT 1964:357, t. 3, f. 2; YAMAJI 1966:104, t. 50, f. 11, 12, 13; TAYLOR 1967, t. 91, f. 39; SOURNIA 1968a:465, f. 87, 88; SUBRAHMANYAN 1968:74, t. 4, f. 23, t. 7, f. 34, 35; TORIUMI 1968:3, f. 5, 8, 9; WOOD 1968:36, f. 78; STEIDINGER et WILLIAMS 1970:46, t. 11, f. 30 a, b, t. 12, f. 30 c–e; AVARIA 1970, t. 3, f. 6; HERMOSILLA 1973b:64, t. 33, f. 3, 4; TAYLOR 1973b, f. 4 b; REINECKE 1973a, f. 6 E; – 1973b:315, f. 12 A–H, J, K, f. 13 D, E, f. 14 A, B, f. 15 A–E, vix f. 13 F–H, non fig. 16 A–G.

The confusion concerning the correct name for this common warm-water taxon has been outlined by JÖRGENSEN (1920) and REINECKE (1973b). SOURNIA (1968a) considered JÖRGENSEN's (1911) combination as the first legal establishment of *C. massiliense* but REINECKE has convincingly argued in favour of attributing it to KARSTEN (1906), this also avoiding some difficulties of priority which would otherwise go to SCHRÖDER's (1906) species names.

The species shows resemblances to *C. horridum* (which is much smaller), *C. deflexum* (in which the left antapical horn is strongly posteriorly directed in its proximal region like *C. macroceros*), and *C. carriense* (see comments under that taxon), the latter having been combined with it by REINECKE (1973b, as a variety).

Three main infraspecific taxa were recognised by SOURNIA but only two are used here:

The var. *massiliense* [= var. *α macroceroides* (KARSTEN) JÖRGENSEN] has relatively slender horns and, apart from the occasional presence of small fins near the base of the apical horn and small spines on the posterior proximal regions of the antapical horns, it is not strongly ornamented. The proximal region of the left antapical horn usually curves slightly to the posterior before bending anteriorly (f. 196), but not always (f. 194).

The var. *armatum* (KARSTEN) JÖRGENSEN, including the var. *protuberans* (KARSTEN) JÖRGENSEN, has more robust horns and cell body. Fins are usually (f. 193), but not invariably (f. 195) developed on the proximal contours of the apical horn and can also be present on the upper curves of the antapical horns. The antapical spinulae on the horns are somewhat stronger. The proximal region of the left antapical horn is only slightly bent to the posterior after leaving the cell body before curving anteriorly. The cell body is usually more convex than in the var. *massiliense*.

The var. *protuberans* has been recognised in the past as being smaller and lacking fins on the apical horn and upper antapical horn profiles. These horn features agree with the specimen illustrated here as fig. 195. However, this specimen was not notably smaller than the other varieties. Furthermore, the var. *protuberans* is presumed to have longer horns than the var. *armatum*, whereas this specimen did not (compare to f. 193). Because of the contradictions posed by this and other specimens, the taxon is not recognised here.

SOURNIA (1968a) relegated the var. *armatum* to a forma, using JÖRGENSEN's (1920) combination. This may be a reasonable action in view of the apparent cooler temperature preference of the taxon.

Stations: var. *massiliense*: 18, 20, 21, 23, 28, 30, 37–39, 41, 42, 47, 48, 50, 51, 53, 59, 60, 62, 63, 68, 69, 85, 91, 95, 98–101, 103, 106, 112, 116, 125, 140, 144, 150, 153, 161, 284, 287, 291, 293, 294, 298, 301, 302, 305, 306, 312–315, 318, 320, 325, 327, 362, 371, 406, 413, 415, 418, 419.

var. *armatum*: 87, 131, 134, 147, 310.

The var. *massiliense* was one of the most widely spread taxa in the material. The limits of its southern distribution closely resembled those of *C. trichoceros*, exhibiting large north-south fluctuations.

The var. *armatum* was less common and, from the above stations, appeared to occur in both warm and colder waters. However, if a distinction is made between specimens with the outward deflected antapical horn with fins (f. 193) versus those with an incurving antapical horn (f. 195) an interesting distribution emerges. The former, which could be designated a warm-water form, occurred at a few scattered stations (87, 134, 147) not south of 28°S. The latter was confined to two extreme southern stations (131, 310) near the Subtropical Convergence Region.

Both varieties are considered inter-oceanic and the var. *massiliense* is one of the commonest taxa in tropical and subtropical waters. TAYLOR (ms. 1964, 1967) found it to be the commonest representative of *Ceratium* in the southwest Indian Ocean. The var. *armatum* has been found in cold temperate waters by several authors (JÖRGENSEN 1911, PETERS 1932, etc.). The species is considered to have a surface distribution (GRAHAM & BRONIKOVSKY 1944).

The species has been recorded from the Indian Ocean by many authors, usually as the var. *massiliense* (var. *macroceroides*). The following should be added to those listed by WOOD (1963a): SILVA (1956a, 1960), SUKHANOVA (1962 a, b), ZERNOVA (1962), TSURUTA (1963), DURAIRATNAM (1963, 1964), ZERNOVA & IVANOV (1964), ANGOT (1965), SOURNIA (1966a, 1968 a, b, 1970), TAYLOR (1967), SUBRAHMANYAN (1968), NEL (1968), ANGOT (1970), and REINECKE (1973b).

Ceratium obesum PAVILLARD Plate 22, Figs. 216, 217
– 1930:10, f. 11; – 1931:95, t. 3, f. 11 A, B.

This rare species has apparently not been seen previously other than by its discoverer, and it was omitted from the works of SCHILLER, and SUBRAHMANYAN (1968). It resembles *C. hexacanthum* (to which it was appended by SOURNIA 1968a) but it has a robust body lacking any surface reticulation and the apical horn is strongly deflected towards the ventral side. PAVILLARD's figures show a slender body shape which results partly from distortion arising from the angle at which the species usually rests on the slide, the ventral flexure of the apical horn making that structure look shorter than it is. These spatial relationships, including the ventrally-curved left horn, are illustrated by the multiple views given here.

Station: 294.

Several specimens were found at only one station immediately to the north of the Seychelles Bank.

The only previous records of the species are from the vicinity of the Azores in the North Atlantic and Monaco in the Mediterranean.

Ceratium recurvatum SCHRÖDER Plate 21, Fig. 209
– 1906:367, f. 40.

Syn.: *C. deflexum* var. *recurvatum* (SCHRÖDER) JÖRGENSEN 1911:65, f. 139; SCHILLER 1936:428, f. 467b; SUBRAHMANYAN 1968, f. 146.

The "Anton Bruun" specimens of this very rare species did not resemble *C. deflexum* at all, although JÖRGENSEN (1911) assigned this species to *C. deflexum* at the varietal level (after a re-examination of SCHRÖDER's samples). In fact, as can be seen from fig. 209, there was a marked resemblance in the body shape and the formation of the right antapical horn to *C. trichoceros* and *C. contrarium*. Perhaps this taxon is a conglomerate of several species exhibiting a particular type of horn aberration. All the "Anton Bruun" specimens resembled fig. 209. It is distinctive in being the only taxon in the section *Macroceros* in which the left antapical horn proceeds posteriorly (and ventrally), and then turns to the right distally.

All the figures by other authors are reproductions of SCHRÖDER's original figure.

Stations: 338, 342, 413, 414, 417.

Single specimens were found at two equatorial stations on cruise VI and at three stations near northern Madagascar. This clustered distribution tends to negate the view that these are aberrant forms of one or more species.

The species was first described from the Arabian Sea (one cell) and does not appear to have been seen again, other than perhaps mistakenly by JÖRGENSEN (1911) from the same sample. KARSTEN (1907) referred to it but had not apparently seen it. This applies also to SUBRAHMANYAN (1968).

Ceratium trichoceros (EHRENBERG) KOFOD Plate 12, Fig. 117; Plate 21, Fig. 210

WANG et NIE 1932:303, f. 15; PETERS 1932:51, t. 1, f. 3 a-c, t. 2, f. 17a; STEEMANN NIELSEN 1934:27, f. 68; SCHILLER 1936:430 non f. 470 nec 471; NIE 1936:70, f. 33 A-C; RAMPI 1939a:310, f. 38, 39; GRAHAM et BRONIKOVSKY 1944:40, f. 22B; SILVA 1949:361, t. 7, f. 4 (sub *trichoceros*); WOOD 1954:311, f. 239 a, b, c (sub *C. macroceros* var. *contrarium*); KATO 1957:19, t. 6, f. a, b; CURL 1959:306, f. 122; HALIM 1960a, t. 5, f. 18; - 1963:499, f. 31; BALLANTINE 1961:225, f. 57; MARGALEF 1961a:81, f. 26i; KLEMENT 1964:358, t. 3, f. 8; TORIUMI 1964a:43, t. 2, f. 8; DAVIS et STEIDINGER 1966:1, f. 1-4; YAMAJI 1966:103, t. 50, f. 2; STEIDINGER, DAVIS et WILLIAMS 1967, t. 6, f. c; SOURNIA 1968a:472, vix f. 89 (= *C. ramakrishnii* SUBRAHMANYAN?); SUBRAHMANYAN 1968:81, t. 7, f. 37, non f. 147 nec 148; WOOD 1968:40, f. 91; MARGALEF 1969a, f. 5E; STEIDINGER et WILLIAMS 1970:47, t. 14, f. 36 a-d; REINECKE 1973b:353, f. 13 A-C, f. 22 A-F, f. 24 F-L (non 22 G-K, 24 A-E); TAYLOR 1973b, f. 4 a.

Vix MARGALEF et DURÁN 1953, f. 12f (sub *C. macroceros*); RICARD 1970, t. 2, f. b (*C. contrarium?*).

This large species resembles *C. contrarium* and the two may be conspecific variants as suggested by SCHILLER (1936) and REINECKE (1973b). The distinctions have been discussed here under *C. contrarium*. As indicated, SOURNIA's figure resembles the recently described *C. ramakrishnii* SUBRAHMANYAN (1968) with its domed, convex body shape contracted towards the base of the hypotheca. The type specimens had more inwardly curved horns but SUBRAHMANYAN's species is otherwise very similar to *C. trichoceros*.

STEIDINGER & WILLIAMS (1970) have observed a strong dimorphism in living cells, an anterior daughter cell resembling a member of the section *Ceratium* in having its slender, short antapical horns projecting directly backwards (their fig. 36c; here fig. 117). This form is very similar to *C. ehrenbergii* (pl. 12, f. 116) but the angle of the posterior cell body profile to the girdle plane is not as great. MARGALEF & DURÁN's (1953, f. 12f) specimen may also correspond to this form.

The formal recognition of the short-horned variant with both antapical horns directed posteriorly accords with the principles by which formae are here recognised (see Introductory section) and consequently it is named the forma *crypticum* f. nov.

In view of VON STOSCH's (1964) observations on sexuality in *C. horridum* it seems possible that this form may also be a "male" gamete prior to sexual conjugation, resembling the heteromorphism in *C. tripos* (which may also be associated with sexuality, VON STOSCH 1964).

Stations: forma *trichoceros*: 28, 31, 37-39, 41, 46, 48, 49, 56, 59, 62-64, 67-69, 71, 88, 90, 98-103, 115-117, 140, 284, 287, 294, 299, 301, 305, 306, 314, 315, 317-319, 324-326, 328, 331, 332, 342, 361, 362, 396, 405, 412, 413, 420.

forma *crypticum*: 47.

The distribution of this species is interesting not only in that it is one of more widely spread tropical species in the material but also because it achieved maximum numbers at the southern edge of the south equatorial current region (st. 318). A preference for equatorial waters has been commented on by GRAHAM & BRONIKOVSKY (1944) and SUKHANOVA (1962 a, b; see also TAYLOR 1973b). Its depth distribution is not clear. The species was strikingly absent from the central regions in the material from cruise III (August-September, 1963). On the other hand it was one of the few species of *Ceratium* present within the Mozambique Channel on cruise VIII (September-October, 1964), most species only occurring at stations at either end of the Channel. It also occurred at two southern stations (305, 306) below 30°S.

Due to probable confusion with *C. contrarium*, records of this species are of doubtful value. The following authors have recorded it from the Indian Ocean (excluding those referring to *C. trichoceros* var. *contrarium*, although both are often listed together) other than those listed by WOOD (1963a): SILVA (1956a, 1960), ZERNOVA (1962), SUKHANOVA (1962 a, b) TSURUTA (1963), DURAIRATNAM

(1963, 1964), ZERNOVA & IVANOV (1964), ANGOT (1965), ANGOT & GÉRARD (1967), SOURNIA (1966a, 1968 a, b, 1970) TAYLOR (1967), SUBRAHMANYAN (1968), NEL (1968), THORRINGTON-SMITH (1969), ANGOT (1970), and REINECKE (1973b).

Ceratum vultur CLEVE Plate 20, Fig. 201? ; Plate 22, Figs. 220–224; Plate 40, Fig. 483, Plate 43, Fig. 511
 PETERS 1932:54, t. 1, f. 7 a, b; STEEMANN NIELSEN 1934:27, f. 65, 66; SCHILLER 1936:418, f. 459, a, b, 460 a–c; GRAHAM et BRONIKOVSKY 1944:41, f. 23 A–H (vix C, G); WOOD 1954:304, f. 233 a; BALLANTINE 1961:225, f. 55; WOOD 1963c:16, f. 53; KLEMENT 1964:356, t. 2, f. 4; YAMAJI 1966:101, t. 49, f. 4–7; SOURNIA 1968a:480, f. 96, 97; SUBRAHMANYAN 1968:68, f. 131–133, t. 5, f. 27, 28, t. 6, f. 31 non f. 134; WOOD 1968:41, f. 94; STEIDINGER et WILLIAMS 1970:47, t. 15, f. 39, t. 41, f. 155; RICARD 1970, t. 2, f. d; REINECKE 1973a:58, f. 5 A–N, f. 6 A–D, F–H, L–R, f. 7 A–F, f. 8 A–E, f. 14 D.
 Non WOOD 1963c:16, f. 53 (= *C. reflexum* CLEVE?).

Syn.:... *C. sumatranum* (KARSTEN) JÖRGENSEN . . . NIE 1936:68, f. 31, 32; YAMAJI 1966:102, t. 49, f. 8, 9.
C. recurvum (JÖRGENSEN) REINECKE 1973a:75, f. 6, J, f. 7 G.

Ceratum vultur is highly variable in form but is nevertheless recognisable in most of its variations. The apical horn of subapical members of chains is usually very short. SOURNIA (1968a) recognised four principal variations as formae. REINECKE (1973a) has provided a detailed description of the species, including many earlier figures. She has recognised two varieties and five forms. She has raised the f. *recurvum* to specific status, a practice not followed here, and considered *C. pavillardii* JÖRGENSEN to be a variety, following GRAHAM & BRONIKOVSKY (1944). The treatment here is based on simpler criteria than hers, the polar co-ordinate technique not being used at the time the analyses were made.

The var. *vultur* has a very short, antapically-directed basal portion of the left antapical horn before it is sharply bent towards the anterior. Forms within this variety are the forma *vultur*, with robust, long horns (not found in this material); the forma *sumatranum* (KARSTEN) SOURNIA in which the right antapical horn is directed almost laterally from the body (fig. 224, 201?) and which seems to intergrade with the f. *valdiviae* REINECKE; the forma *angulatum* (JÖRGENSEN) comb. nov. [basonym *C. sumatranum* forma *angulatum* JÖRGENSEN 1911, p. 74, f. 155] in which both the left and right horns turn abruptly towards the anterior shortly after leaving the body and the girdle ends are inclined at an angle to each other because of a dorsal flexure (fig. 222); and the forma *recurvum* (JÖRGENSEN) SCHILLER in which regrowth after autotomy is out of line with the original curve of the horns, bending sharply laterally (fig. 220).

The var. *japonicum* (SCHRÖDER) JÖRGENSEN has a left antapical horn which extends posteriorly for more than 0.5 of the girdle width before being bent sharply towards the anterior. It occurs in both robust (fig. 223, 483) and delicate (fig. 221) forms, not previously recognised at an infraspecific level. The robust form corresponds to that described as *C. robustum* by OSTENFELD et SCHMIDT (1901, p. 166, fig. 17) and so is here termed *C. vultur* var. *japonicum* forma *robustum* stat. nov. (basonym given above), the delicate form being the forma *japonicum*. REINECKE (1973a) has distinguished a f. *neglectum* from the latter on the basis of a differing curvature of the left antapical horn.

Stations: var. *vultur* – f. *sumatranum*: 15, 16, 19, 21, 29, 35, 41, 43, 50, 57, 59, 61, 92, 97, 100, 102, 103, 106, 112, 113, 294, 325, 327.
 – f. *angulatum*: 52–54, 57, 59, 62, 64–66, 70, 87–91, 95, 98, 99.
 – f. *recurvum*: 24, 47, 91, 101, 103, 116, 418.
 var. *japonicum* – f. *robustum*: 13, 14, 23, 39, 41, 50, 109, 125, 134, 135, 147, 285, 288, 301, 334, 413.
 – f. *japonicum*: 56, 91.

The species as a whole was widespread, but it was notably absent from the open ocean in the equatorial current regions (5°S to almost 20°S). The f. *angulatum* was entirely restricted to the Bay of Bengal, the f. *sumatranum* having a similar but wider distribution including a few open northern Indian Ocean stations.

It was the robust form of var. *japonicum* (and to a much lesser extent var. *vultur*) which represented the species in the wider oceanic areas, being absent from the equatorial current. No representative was found south of 30°S although it has been found in the southwestern Indian Ocean by TAYLOR (1967) and NEL (1968).

This pattern corresponds with the view that the species is an intolerant thermophile (PETERS 1932; GRAHAM et BRONIKOVSKY 1944). It has been found to prefer deeper levels although it also occurs in surface water. There are many Indian Ocean records (WOOD 1963a) to which those of SUKHANOVA (1962b), TSURUTA (1963), DURAIRATNAM (1964), ANGOT (1965), SOURNIA (1966a, 1968a, b, 1970), TAYLOR (1967), NEL (1968), SUBRAHMANYAN (1968), and REINECKE (1973a) can be added.

Section Palmata (PAVILLARD) JÖRGENSEN

Ceratium ranipes CLEVE Plate 19, Figs. 189–192

CANDEIAS 1930:35, t. 4, f. 74; PETERS 1932:47, t. 2, f. 12 d, e; STEEMANN NIELSEN 1934:24, f. 58; SCHILLER 1936:409, f. 451 a, b; RAMPI 1939a:307, f. 2; GRAHAM et BRONIKOVSKY 1944:37, f. 19 I–K, 20, 21 A; WOOD 1954:299, f. 227; SILVA 1955:168, t. 9, f. 1; TRÉGOUBOFF et ROSE 1957:115, t. 26, f. 10; HALIM 1960a, t. 4, f. 16; — 1963:498, f. 26; KLEMENT 1964:356, t. 3, f. 3; LOPEZ 1966, f. 19, 20; SOURNIA 1968a:459, f. 81, 82; SUBRAHMANYAN 1968:60, f. 110; WOOD 1968:38, f. 84; STEIDINGER et WILLIAMS 1970:47, t. 13, f. 33.

Syn.: . . . *C. palmatum* var. *ranipes* [sic]. . . NIE 1936:61, f. 27.

This species is highly distinctive, having unusual finger-like extensions which radiate from the ends of the antapical horns. GRAHAM & BRONIKOVSKY indicated that the number of fingers, when present, may range from three to twenty-one and can be unequal on the left versus right horn. The length of the fingers and the antapical horns is also variable. The presence of numerous chloroplasts within these extensions supports the view expressed by STEEMANN NIELSEN (1934) that these structures represent adaptations to shade conditions (see Discussion section).

Autotomy, by which the distal portions of the horns are cut off, was observed frequently in the "Anton Bruun" material (figs. 190–192), as were signs of regrowth (fig. 191). At such times there is a superficial resemblance to *C. platycorne* (see comments under the latter). Autotomised specimens have been recognised as the var. *furcellatum* (LEMMERMANN) BÖHM although, if recognised, the designation of forma would be more appropriate [*C. ranipes* var. *palmatum* (SCHRÖDER) CLEVE forma *furcellatum* (LEMMERMANN) stat. nov.; basionym *C. tripos* var. *furcellata* LEMMERMANN 1900:363].

Although variability is consequently considerable there still appear to be two distinguishable varieties which are, in a sense, analogous of the variants observed in members of the section *Tripos* such as *C. gibberum*. In the var. *ranipes* the horns are strongly incurved towards the body, the right horn in particular being also directed dorsally (e.g. fig. 192, BÖHM 1931b, f. 30 f, g; GRAHAM & BRONIKOVSKY 1944, figs. 19 I–K). In the var. *palmatum* (SCHRÖDER) CLEVE the horns are open and subparallel, both sloping towards the cell's left in contrast to the apical horn which slopes strongly to the right in both varieties. Distinctions based on the number of fingers have not been found to be useful and consequently the distinction of the var. *palmatum* here is on an emended feature, having been formerly based on the small number of fingers. There is a general tendency for the longer-horned specimens to have fewer fingers but short-horned individuals with only a few fingers have also been seen.

Stations: var. *ranipes*: 32, 65, 103.

var. *palmatum*: 13, 17, 22, 31, 32, 58, 62, 69, 117, 129, 140, 144, 155, 282, 319, 370, 416, 419.

The species was occasional, being widespread throughout most of the area sampled. It did not occur further south than 31° S in the central region but other studies (see below) have recorded it from the southwestern Indian Ocean.

It is usually considered an inter-oceanic tropical species. It appears to be a consistent shade species, usually occurring below 50 m in earlier studies (STEEMANN NIELSEN 1934; GRAHAM & BRONIKOVSKY 1944). In addition to the records listed by WOOD (1963a) the species has been found in the Indian Ocean by SILVA (1960), SUKHANOVA (1962b), TSURUTA (1963), TAYLOR (1967), SOURNIA (1968 a, b, 1970), NEL (1968), SUBRAHMANYAN (1968), and THORRINGTON-SMITH (1969).

Section *Platycornia* JÖRGENSEN*Ceratium platycorne* VON DADAY Plate 19, Figs. 185, 188

PETERS 1932:47, t. 2, f. 12b; STEEMANN NIELSEN 1934:24, f. 56, 57; SCHILLER 1936:408, f. 450 a, b; CANDEIAS 1938:249, f. 10; RAMPI 1942:223, f. 3, 4; GRAHAM et BRONIKOVSKY 1944:36, f. 19 C–H; SILVA et PINTO 1948:173, t. 2, f. 15; KISSELEV 1950:252, f. 426; MARGALEF et DURÁN 1953:42, f. 11 a–d; WOOD 1954:297, f. 226; TRÉGOUBOFF et ROSE 1957:115, t. 26, f. 8, 9; KATO 1957:17, t. 5, f. 16 a, b; HALIM 1960a, t. 4, f. 12; LOPEZ 1966, f. 17, 18; YAMAJI 1966:99, t. 48, f. 6, 7; SOURNIA 1968a:453, f. 78, 79; SUBRAHMANYAN 1968:58, f. 108, 109; LÉGER 1971b:27, f. 11.

Syn.: . . . *C. compressum* GRAN . . . SCHILLER 1936:390, f. 427b; KISSELEV 1950:248, f. 424; WOOD 1954:312, f. 240; YAMAJI 1966:99, t. 48, f. 3.

? *Ceratium* sp. SILVA 1949:357, t. 6, f. 23, t. 9, f. 3.

The body of this species, allowing for size variation, is fairly regular, but the antapical horns exhibit strong, characteristic variability. At one extreme the horns are tapering, like other members of the section, this occurring in the cold-water variety *compressum* (GRAN) JÖRGENSEN. The apical horn tapers gradually into the epitheca. In the var. *dilatatum*

(KARSTEN) JÖRGENSEN (= *C. lamellicorne* KOFROID) the antapical horns are tubular for most of their length, extending beyond the base of the apical horn before becoming irregularly flattened distally (fig. 188). The apical horn arises more abruptly than in the preceding or following varieties. The var. *platycorne* has a body similar to the var. *compressum* but the horns are laterally compressed into flattened "paddles" shortly after leaving the body, being obviously flattened at the girdle plane. The ends of the "paddles" may be truncated or more or less irregularly cleft. Specimens exhibiting the greatest lateral extension of the paddles used to be referred to the var. *cuneatum* (JÖRGENSEN) GRAHAM et BRONIKOVSKY (e.g. fig. 185) in which the width of the "paddle" approximates the girdle width and the ends are usually fairly flat. However, GRAHAM & BRONIKOVSKY (1944) stated that it blended fully into the central variety. The forma *incisum* JÖRGENSEN refers to deeply cleft ends to the antapical horns of the var. *platycorne*. In the var. *platycorne* the paddle walls are greatly thinned except for the outer margin. Chloroplasts are densely packed into the paddle regions.

The differences between the above varieties are so great as to suggest to many earlier authors that they should be kept separate at the species level. In the "Anton Bruun" material specimens of the var. *compressum* did not occur. Also intergrades between the other varieties were not seen. However, they have been reported by other authors such as JÖRGENSEN (1920) and GRAHAM & BRONIKOVSKY (1944) and consequently they have been retained here at the varietal level.

The body of this species resembles *C. ranipes* CLEVE, particularly in the row of finned spines along the post-margin. After autotomy of the distal portions of the antapical horns (which are extremely distinctive) the species can still be readily distinguished by the strongly sloping apical horn, the widely set antapical horns, and less rounded cell body (in ventral view) than *C. ranipes*.

Stations: var. *platycorne*: 32, 103, 133, 302, 418.
var. *dilatatum*: 320.

The species was rare, occurring only at scattered warm-water stations throughout the area. The single station at which the var. *dilatatum* occurred was near 11°S in the central region. It can be considered as an inter-oceanic, high stenothermal species.

Both STEEMANN NIELSEN (1934) and GRAHAM & BRONIKOVSKY (1944) found a marked preference for deeper levels, below 50 m and often below 100 m.

The list of Indian Ocean records given by WOOD (1963a) requires augmentation by those of TAYLOR (1967), SOURNIA (1968a, b, 1970), SUBRAHMANYAN (1968) and THORRINGTON-SMITH (1969). NEL (1968) has recorded *C. compressum* from the southwestern Indian Ocean.

Section Reflexa JÖRGENSEN

Ceratium reflexum CLEVE Plate 17, Fig. 173

STEEMANN NIELSEN 1934:29, f. 74; SCHILLER 1936:420, f. 461; GRAHAM et BRONIKOVSKY 1944:45, f. 27H; WOOD 1963b:40, f. 149; YAMAJI 1966:106, t. 51, f. 5; SOURNIA 1968a:485, f. 99, t. 3, f. 13; SUBRAHMANYAN 1968:70, f. 135-139; WOOD 1968:38, f. 85; REINECKE 1973a:77, f. 6 S, f. 7 H.
Non SILVA 1955:172, t. 9, f. 9.

Although often poorly illustrated the species is readily recognisable by the posteriorly-directed left antapical horn. Proximally it diverges very slightly from the cell body and then bends abruptly towards the posterior in a plane approximately parallel with the apical horn. However, in some instances the distal portion has been bent at right angles to the apical axis. The posterior cell body margin is strongly sloped in relation to the girdle plane. Autotomy has been observed (fig. 173).

Stations: 63, 100, 116, 129, 144.

The species was rare in the material, occurring only at a few Bay of Bengal and central Indian Ocean stations. It was found furthest south at station 129.

It has been observed infrequently in the Indian, Pacific, and tropical North Atlantic Oceans. It is apparently a high stenothermal, oceanic species (e.g. DESROSIÈRES 1969 in the Pacific Ocean) and was considered probably shade-loving by GRAHAM & BRONIKOVSKY (1944) although the records are too few to be conclusive as yet. The records of SOURNIA (1966a, 1968a, 1970), SUBRAHMANYAN (1968), and REINECKE (1973a) should be added to those listed by WOOD (1963a).

Section Tripes

Ceratium arietinum CLEVE Plate 16, Figs. 162, 165

PETERS 1932:41, t. 4, f. 22 a-c; STEEMANN NIELSEN 1934:21, f. 45; SCHILLER 1936:403, f. 414 a-c; RAMPI 1939a:307, f. 28; GRAHAM et BRONIKOVSKY 1944:31, f. 16 A-K (vix G); SILVA 1949:359, t. 9, f. 7; KISSELEV 1950:252, f. 420 a, b; MARGALEF et DURAN 1953:42,

f. 11 h, i, j, k; WOOD 1954:294, f. 221 a-c; GAARDER 1954:9, f. 10; KATO 1957:16, t. 6, f. 21; TRÉGOUBOFF et ROSE 1957:115, t. 26, f. 4; HALIM 1960a, t. 4, f. 4; - 1963:497, f. 10; TORIUMI 1964a:43, t. 1, f. 3; SOURNIA 1968a:429, f. 51-54; LOPEZ 1966, f. 27; YAMAJI 1966:97, t. 47, f. 7 (sub *C. arietinum*); SUBRAHMANYAN 1968:54, f. 95-97; WOOD 1968:23, f. 37; HERMOSILLA 1973a:22, t. 1, f. 15, t. 3, f. 20. Syn.: . . . *C. bucephalum* (CLEVE) CLEVE . . . MARTIN 1928:29, t. 6, f. 6, t. 8, f. 8; CANDEIAS 1930:33, t. 3, f. 69; SCHILLER 1936:392, f. 430; SILVA 1949:358, t. 9, f. 6; KISSELEV 1950:248, f. 421 a, b, 423, 429; WOOD 1954:288, vix f. 210 a-c; KATO 1957:16, t. 6, f. 22; TORIUMI 1964a:43, t. 1, f. 2; YAMAJI 1966:97, t. 47, f. 8, 9; TORIUMI 1968:3, f. 4.

C. arietinum is a distinctive, medium-sized species. It is distinguished from *C. declinatum* (KARSTEN) JÖRGENSEN, perhaps the most similar species to it, in the shape of the body, the latter being more elongate and having a less convex left profile to the body combined with an apical horn arising further to the left. The latter is also generally smaller but there is an overlap between the smallest variants of *C. arietinum* and the largest of *C. declinatum*. The right side parts of the girdle are reduced in *C. arietinum* but much more so in *C. declinatum*.

As early as 1911 JÖRGENSEN indicated the great similarity of *C. bucephalum* to this species. GRAHAM & BRONIKOVSKY (1944) were the first to "sink" *C. bucephalum* into *C. arietinum* although they made it a subspecies of the latter. SOURNIA's (1966b, 1968) designation of the taxon as a variety is more compatible with the treatment of infraspecific taxa here. The var. *bucephalum* represents the most widely separated antapical horn state.

Other varieties have been named, the value of which is not clear. They are: the var. *arietinum* (= f. *detortum* and f. *valens*) in which the cells are relatively large with a short to medium-length apical horn and a strongly incurved right antapical horn; and the var. *gracilentum* (JÖRGENSEN) SOURNIA which is more slender with a long apical horn.

Stations: var. *arietinum*: 294, 325, 362, 366, 371, 416.
var. *gracilentum*: 135, 153, 313.

The former occurred at two open Indian Ocean stations and several in the Mozambique Channel region. The latter was found only at several southern Indian Ocean stations. This species was one of the very few which were not found in either the Bay of Bengal or the Arabian Sea. STEEMANN NIELSEN (1934) considered it a deep species as it often occurred below 50 m. Both varieties are warm water taxa but the latter seems to be a more strictly tropical oceanic variety. WOOD's (1963a) Indian Ocean records require augmentation by those of SILVA (1956a), DURAIRATNAM (1964), TAYLOR (1967), SOURNIA (1966b; 1968 a, b, 1970), and NEL (1968).

Ceratium axiale KOFROID Plate 15, Fig. 158

PETERS 1932:41, t. 2, f. 12h; STEEMANN NIELSEN 1934:20, vix f. 42; SCHILLER 1936:402, f. 442; GRAHAM et BRONIKOVSKY 1944:30, f. 15 D, E; WOOD 1954:293, vix f. 219; - 1968:23, f. 39 (errata f. 38); SUBRAHMANYAN 1968:52, f. 93.

This is a distinctive species similar in body form and left antapical horn to *C. euarcuratum* but with a closely-set right horn with a sharp flexure approximately half way along its length. The apical horn curves to the right. *C. symmetricum* var. *coarctatum* sometimes mimics *C. axiale* in right antapical horn features but can be recognised easily by the cell body size and shape.

Stations: 32, 92, 98, 129.

Rare, at three stations within the Bay of Bengal/Andaman Sea and one southern central station (30°S). It is a rare warm-water, inter-oceanic species. It has been recorded previously from the Indian Ocean by STEEMANN NIELSEN (1939), WOOD (1954), TRAVERS & TRAVERS (1965), SOURNIA (1968b), NEL (1968), and SUBRAHMANYAN (1968).

Ceratium azoricum CLEVE Plate 15, Fig. 160

WAILES 1928, t. 1, f. 3; CANDEIAS 1930:34, t. 3, f. 70; PETERS 1932:43, t. 3, f. 14h; STEEMANN NIELSEN 1934:20, f. 43; SCHILLER 1936:406, f. 447; RAMPI 1939a:307, f. 25; WAILES 1939:44, f. 132; GRAHAM et BRONIKOVSKY 1944:30, f. 16 M-P; KISSELEV 1950:252, f. 413 a, b; MARGALEF et DURÁN 1953:11, f. e-g; TRÉGOUBOFF et ROSE 1957:115, t. 26, f. 6; HALIM 1960a, t. 4, f. 13; BALECH 1962b, f. 398, 399; TORIUMI 1964b:24, t. 3, f. 11; LOPEZ 1966, f. 26; YAMAJI 1966:98, t. 48, f. 1; SOURNIA 1968a:435, f. 58, 62, 63; SUBRAHMANYAN 1968:56, f. 102; HERMOSILLA 1973a:23, t. 2, f. 10; - 1973b:67, t. 36, f. 1-4. Vix SILVA 1949:358, t. 6, f. 24; WOOD 1954:295, f. 222 a, b; - 1968:23, f. 38 non f. 39 (errata); HALIM 1960a, t. 4, f. 13.

This is a small species (diameter of body 38-51 µm) very similar to, if not conspecific with *C. petersii* STEEMANN NIELSEN. It is here kept separate, recognition being based on the features indicated by STEEMANN NIELSEN. These are a wider body diameter (50-57 µm), more widely spread horns and the occurrence of lists on the base of the apical horn of *C. petersii*. Here, in addition, the body of *C. azoricum* seemed narrower at the top than *C. petersii* but the figures of BALECH (1962b) from the Pacific Ocean indicate that this is not reliable. The difference in antapical horn spread is chiefly due to the degree of divergence of the right antapical horn, being least in *C. azoricum*.

In the specimens seen here the girdle was almost totally undeveloped. WOOD's records are cited as doubtful above because the drawings do not permit a clear distinction between *C. azoricum* and *C. petersii*. Also, the presence of lists on the Atlantic Ocean specimens (1968) strongly suggests that they were, in fact, *C. petersii*.

Stations: 17, 103.

The species was observed at only two stations, one in the southern Andaman Sea and the other off Madras in the Bay of Bengal. This conforms to the view that it is essentially a tropical to subtropical species. It appears to prefer relatively eutrophic waters, occurring in the tropical Pacific Ocean most abundantly in the vicinity of the Galapagos Islands (DESROSIÈRES 1969). There are several records from colder temperate waters (e.g. WAILES 1928, British Columbia) but some of these may refer to *C. petersii*.

The references of TSURUTA (1963), ANGOT (1965), SOURNIA (1968 a, b, 1970), NEL (1968), SUBRAHMANYAN (1968) and ANGOT (1970) should be added to the Indian Ocean records listed by WOOD (1963a).

Ceratum breve (OSTENFELD et. J. SCHMIDT) B. SCHRÖDER Plate 14, Figs. 141–146

WANG et NIE 1932:306, f. 19; PETERS 1932:39, t. 3, f. 13d; STEEMANN NIELSEN 1934:18, f. 36 non f. 35; SCHILLER 1936:391, f. 429 a, b; NIE 1936:50, f. 18 A–C, 19 A, B (sub *C. brave*); GRAHAM et BRONIKOVSKY 1944:27, f. 14 G–J, L, O, P (vix K, M, n); SILVA 1949:357, t. 9, f. 4; WOOD 1954:288, non f. 209 a, b; SILVA 1958, f. 5; BALLANTINE 1961:225, f. 53; KLEMENT 1964:355, t. 3, f. 4; BARTH et OSORIO 1965, f. 1d (sub *C. tripos*); YAMAJI 1966:95, t. 46, f. 1, 2, 3; SOURNIA 1968a:426, f. 47–50, t. 2, f. 7; SUBRAHMANYAN 1968:40, f. 62, 63, t. 3, f. 13–15; MARGALEF 1969a, f. 5 F.

Syn.: . . . *C. schmidtii* JÖRGENSEN . . . WANG et NIE 1932:308, f. 20; STEEMANN NIELSEN 1934:18, f. 37; NIE 1936:54, f. 22 A–D; SCHILLER 1936:400, f. 440; WOOD 1954:291, f. 216 a (non b); HALIM 1963:498, f. 20, 21; LOPEZ 1966:419, f. 22; YAMAJI 1966:95, t. 46, f. 6; SUBRAHMANYAN 1968:49, f. 88 [sic 38, errat.].

A large-bodied distinctive species in which variability (other than the usual length of the apical horn) involves the curvature of posterior horns and the degrees of ventral concavity of the body. Four varieties are recognised: the var. *breve* in which the right posterior horn curves moderately inward towards the body (figs. 141, 142); the var. *parallelum* (J. SCHMIDT) JÖRGENSEN in which the right posterior horn opens away from the body and the left posterior horn also opens wider from the body (f. 146); the var. *curvulum* JÖRGENSEN in which the right posterior horn is tightly curved in towards the body (f. 143) and which can probably be included in the var. *schmidtii*; and the var. *schmidtii* (JÖRGENSEN) SOURNIA in which the body is distinctly concave ventrally, the posterior horns also thus directed ventrally (f. 144, 145).

The species is closest to *C. humile* JÖRGENSEN, from which it is readily separated by its body shape, the latter having a straighter posterior margin and much less convex right upper profile. The horns of the latter are larger and relatively more slender in appearance with the left antapical horn unusually long.

Stations: var. *breve*: 15–17, 19, 20, 23, 49, 110, 144, 148–150, 153, 288, 294, 297, 325, 420.

var. *parallelum*: 13, 14, 19, 21, 28, 34, 36–39, 41, 44, 47, 50, 62, 64, 65, 71, 87, 91, 99, 100, 102–106, 108–110, 113, 115, 116, 142, 147, 288, 295, 296, 299, 314, 327, 331, 334, 341, 374, 414, 418.

var. *schmidtii*: 23, 30, 42, 67, 88, 89, 91, 96, 99–101, 103, 104, 106, 109, 110, 113, 115, 140, 142, 294.

The most widespread and abundant variety was the var. *parallelum* which was common throughout the northern Indian Ocean and the neritic waters of the Bay of Bengal and Andaman Sea. It was most abundant at station 105 near Madras. The var. *breve* occurred at scattered stations in the Andaman Sea and over the northwestern Indian Ocean. The var. *schmidtii* was found at a few northern stations, particularly in the eastern Arabian Sea on cruise II. These stations were all not far from islands.

SOURNIA (1968a) examined Mozambique Channel material from this expedition. He commented (p. 428) that it was not possible to discern latitudinal or other ecological distinctions between the varieties (he did not recognise var. *breve*) with regard to their distribution.

However, the distribution of the var. *schmidtii* in the present material conformed to STEEMANN NIELSEN's (1939a) observation of a neritically-biased distribution in the Indian Ocean.

The Indian Ocean references of WOOD (1963a) require augmentation by those of MENON (1931, 1945), HORNELL & NAYUDU (1923), SUKHANOVA (1962b, *breve* and *schmidtii*), TSURUTA (1963), DURAIRATNAM (1964, *breve* and *schmidtii*), TAYLOR (1967, *breve* and *schmidtii*), SOURNIA (1968 a, b, 1970, *breve* and *schmidtii*), NEL (1968), SUBRAHMANYAN (1968), and THORRINGTON-SMITH (1969).

The species is characterised as an inter-oceanic warm-water form of sporadic occurrence.

Ceratum carnegiei GRAHAM et BRONIKOVSKY Plate 17, Fig. 174

— 1944:34, f. 18 A–C; GAARDER 1954:10, f. 11; SOURNIA 1968a:452, f. 77, t. 3, f. 11; SUBRAHMANYAN 1968:91, f. 162–164.

This is a distinctive, rare species. It is large and robust, being somewhat similar to *C. lunula* and *C. longipes* f. *ventricosum* (SOURNIA 1968a, has indicated that fig. 18 A of GRAHAM & BRONIKOVSKY may be the latter). Its most

distinctive feature is the relatively large volume of the epitheca. It is markedly higher than its nearest relatives and is sometimes wider near the apical horn than near the girdle.

Station: 420.

Several individuals were observed at this station close to the east African coast. SOURNIA (1968a, 1970) the only other author to encounter the species in the Indian Ocean, found his specimen near the Comoro Islands (Comores) also in the west central Indian Ocean. It was originally described from the Pacific Ocean and has also been found in the North Atlantic Ocean.

Ceratium concilians JÖRGENSEN Plate 19, Fig. 186

PETERS 1932:44, t. 2, f. 8; STEEMANN NIELSEN 1934:22, f. 49; SCHILLER 1936:396, f. 435; RAMPI 1939a:306, f. 36; GRAHAM et BRONIKOVSKY 1944:33, f. 17 H, I; MARGALEF 1948a:20, f. 3, 4; WOOD 1954:290, f. 213; TRÉGOUBOFF et ROSE 1957:115, t. 26, f. 2; HALIM 1960a, t. 4, f. 20; — 1963:497, f. 11; LOPEZ 1966, f. 28; SUBRAHMANYAN 1968:45, f. 74, 75; WOOD 1968:26, vix f. 47; STEIDINGER et WILLIAMS 1970:44, t. 6, f. 15.

This species resembles the distorted right horn form of *C. gibberum* GOURRET and some authors have suggested that they may be linked by transitional forms (BÖHM 1931b; WOOD 1954; SOURNIA 1968a — no figures given) although this has not been established. In the present material *C. concilians* could always be recognised by its smaller body, being rounder in profile (especially the epitheca which is much more convex). The apical horn bends strongly to the right and there is a lack of ridge ornamentation on the theca. The figures on plate 19 illustrate these distinctions well. In both taxa the girdle plane is strongly bent in the centre.

WOOD's (1968) figure is curious in that it shows the right antapical horn passing ventrally in front of the cell instead of dorsally. This is presumably an error as he makes no comment on what would otherwise be considered a major variation and he refers to dorsal flexure in the description.

Stations: 37, 63, 65, 91, 101, 118, 140, 142, 153–155, 294, 341.

Found at scattered northern Indian Ocean stations, often close to land. This confirms STEEMANN NIELSEN's (1934) contention that this is a neritic species which extends into the oceanic region fairly frequently. It is an inter-oceanic warm-water species. In addition to the records listed by WOOD (1963a) it has been found in the Indian Ocean by TRAVERS & TRAVERS (1965), SOURNIA (1966a, 1968 a, b), TAYLOR (1967), NEL (1968), SUBRAHMANYAN (1968), and ANGOT (1970).

Ceratium contortum (GOURRET) CLEVE Plate 18, Figs. 179–181, 184

PETERS 1932:46, t. 2, f. 10g, 12a; STEEMANN NIELSEN 1934:23, f. 52, 53; SCHILLER 1936:395, f. 433, 434; NIE 1936:58, f. 25 A, B, 26; GRAHAM et BRONIKOVSKY 1944:34, f. 18 D–H, J, M, N, vix I, J non L, K; SILVA 1952b:604, t. 6, f. 10; WOOD 1954:289, f. 212 a–c; SILVA 1955:167, t. 8, f. 2; TRÉGOUBOFF et ROSE 1957:115, t. 26, f. 1; BARTH et OSORIO 1965, f. 1 b, c, h (sub *C. tripos*); YAMAJI 1966:96, t. 46, f. 10, 11; WOOD 1968:26, f. 48; SOURNIA 1968a:441, f. 67–70, 72 vix 71 t. 2, f. 9; SUBRAHMANYAN 1968:44, f. 69–71; STEIDINGER et WILLIAMS 1970:44, t. 6, f. 16 a, b, 17 a, b; RICARD 1970, t. 2, f. e.

Syn.: *C. arcuatum* CLEVE . . . PETERS 1932:44, t. 2, f. 9 (*C. arcuatum longinum*), 10c, non 11c; SILVA 1949:357, t. 9, f. 5; YAMAJI 1966:98, t. 47, f. 10.

Non *C. arcuatum* VANHÖFFEN nec *C. tripos* var. *arcuatum* GOURRET.

C. karstenii PAVILLARD . . . STEEMANN NIELSEN 1934:23, f. 51; SCHILLER 1936:393, f. 431b vix a, non f. 432a vix b; RAMPI 1939a:306, f. 18; KISSELEV 1950:249, f. 463, 512; MARGALEF et DURÁN 1953:40, f. 10 r; WOOD 1954:289, f. 211a non b; SILVA 1955:162, t. 8, f. 1; TRÉGOUBOFF et ROSE 1957:116, t. 25, f. 16; HALIM 1960a, t. 5, f. 5; — 1963:498, f. 19; BALLANTINE 1961:225, f. 54; MARGALEF 1961b:142, f. 3/8; KLEMENT 1964:355, t. 2, f. 8; LOPEZ 1966, f. 37; YAMAJI 1966:96, t. 46, f. 12, 13; SUBRAHMANYAN 1968:42, f. 67, 68.

Vix WOOD 1968:33, f. 68.

C. longinum KARSTEN . . . SCHILLER 1936:398, f. 438; NIE 1936:57, f. 24 A, B; KISSELEV 1950:250, f. 439; WOOD 1954:297 vix f. 225 (f. 211b sub *C. karstenii*); — 1968:34, f. 73; YAMAJI 1966:98, t. 46, f. 14; SUBRAHMANYAN 1968:48, f. 79–81.

There is a strong similarity between *C. contortum* and *C. longinum* KARSTEN, *C. karstenii* PAVILLARD and, in the case of the largest specimens of both species, *C. lunula* (SCHIMPER ex KARSTEN) JÖRGENSEN. SOURNIA (1968a) has "lumped" the first three as *C. contortum*, whereas SUBRAHMANYAN (1968) has kept them distinct. SOURNIA's action conformed with observations of GRAHAM & BRONIKOVSKY (1944, p. 35: "In the Carnegie collections every possible intergrade was found between *C. contortum*; *C. longinum*, and *C. karstenii* . . ."). In the "Anton Bruun" material there were indeed many variants exhibiting intergrades, four of which are shown on plate 18. However, specimens corresponding to SCHILLER's interpretation of *C. karstenii* could always be distinguished quite readily from the others (see comments

under that taxon). Among the others it was found that nearly all of the specimens could be assigned to one of four varieties, suggesting that their recognition as morphological "clusters" seem realistic. The four varieties used here were:

C. contortum var. *contortum*, recognised by its slender form with a compound bend of the right horn, the sharpest flexure occurring distally;

C. contortum var. *saltans* (SCHRÖDER) JÖRGENSEN, in which the right horn is strongly bent in the proximal portion;

C. contortum var. *karstenii* (PAVILLARD) SOURNIA emend.; large-bodied (transdiameter 90 to 100 μm) with the ant-apical horns forming a smooth arc, the right horn sometimes bent in the distal region if the horn is long;

C. contortum var. *subcontortum* (SCHRÖDER) stat. nov. [basonym: *C. subcontortum* SCHRÖDER 1906 = *C. contortum* f. *subcontortum* (SCHRÖDER) STEEMANN NIELSEN 1934, p. 23], in which the right horn is bent only moderately and lacks an additional proximal or distal bend.

To these might be added the var. *longinum* (KARSTEN) SOURNIA, resembling the latter but with the left horn bent abruptly towards the interior close to the body. The latter variety was not found in this material.

SOURNIA (1968a) considered that the var. *saltans* could not be satisfactorily distinguished from the var. *contortum*, although here it has been used to see if there are biogeographic differences.

SOURNIA's derivations of his var. *karstenii* and var. *robustum* are confusing for he seems to interpret them oppositely to their designation by JÖRGENSEN (cf. 1920, p. 76, 77 under *C. arcuatum* CLEVE). However, the difficulty lies in the recognition of the var. *robustum* for JÖRGENSEN's original figure (1911, f. 118) shows only the dorsal side. SCHILLER's (1936, f. 432a) specimen, shown in ventral view, may be a separate taxon (see here under *C. schrankii* KOFOID). For present purposes the var. *karstenii* is emended to include individuals SOURNIA would consider being in the var. *robustum* and to exclude those conforming with *C. schrankii* KOFOID.

The var. *karstenii* recognised here is best exemplified by the figures of JÖRGENSEN (1911, pl. 6, f. 117; 1920, f. 71). The taxon was considered by PAVILLARD (1907) to be best illustrated by KARSTEN's (1907) plate 20, figure 13 b.

Stations: var. *contortum*: 13, 35, 71, 100, 102, 104, 106, 108, 112, 118, 134, 135, 147, 318, 347, 375, 399, 413, 414.

var. *saltans*: 85, 89, 94, 97, 282, 283, 290, 294, 299, 322, 323, 325.

var. *subcontortum*: 13, 62, 65, 91, 99, 100, 102, 318, 320.

var. *karstenii*: 13, 17, 21, 26, 31, 33, 38, 59, 61–63, 65, 70, 71, 98, 101, 103, 104, 106, 109, 110, 112, 129–131, 135, 142, 150, 155, 161, 162, 287, 288, 300, 311, 313, 325, 329, 337, 340, 360, 371, 374.

The species as a whole was widespread throughout the warmer waters of the Indian Ocean. The most widespread variety, the var. *robustum*, was absent between 5° and 15° S and below 36° S. The var. *contortum* had a similar but more sparse distribution and did not occur as far south. The var. *saltans* occurred only north of 16° S. The var. *subcontortum* was limited to a few stations in the western Bay of Bengal and a few south of India.

The species is an inter-oceanic warm-water species. JÖRGENSEN (1911) reported the var. *saltans* as being abundant in the Red Sea and near Zanzibar. STEEMANN NIELSEN (1934) has suggested that the var. *subcontortum* is a shade form, the other varieties being surface forms.

In addition to the Indian Ocean records listed by WOOD (1963a) there are those of SILVA (1956a), SUKHANOVA (1962b), TSURUTA (1963), DURAIRATNAM (1964), SOURNIA (1966a, 1968 a, b, 1970), SUBRAHMANYAN (1968), THORRINGTON-SMITH (1969), and ANGOT (1970). Unlike other tropical species it does not seem to extend far southwards in the Agulhas Current.

Ceratum declinatum (KARSTEN) JÖRGENSEN Plate 16, Figs. 163, 164, 166, 167

PETERS 1932:43, t. 4, f. 23 a–c; STEEMANN NIELSEN 1934:22, f. 46, 47; SCHILLER 1936:404, f. 445 a–d; NIE 1936:52, f. 20 A, B; RAMPI 1939a:307, f. 26, 29; GRAHAM et BRONIKOVSKY 1944:32, f. 16 Q–T, 17 A–C; KISSELEV 1950:249, f. 425; RAMPI 1952b:121, f. 8; MARGALEF et DURÁN 1953:42, f. 10 o, p; WOOD 1954:293, f. 218 a–c; TRÉGOUBOFF et ROSE 1957:115, t. 26, f. 5; HALIM 1960a:185, t. 4, f. 22–26; – 1963:497, f. 12; BARTH et OSORIO 1965, f. 1c (sub *C. tripos*); LOPEZ 1966, f. 32; YAMAJI 1966:98, t. 47, f. 11; STEIDINGER, DAVIS et WILLIAMS 1967, t. 6, f. b; SOURNIA 1968a:438, f. 66, t. 2, f. 8; SUBRAHMANYAN 1968:54, f. 98–101, t. 4, f. 20; WOOD 1968:27, f. 50; STEIDINGER et WILLIAMS 1970:45, t. 7, f. 18; HERMOSILLA 1973a:25, t. 2, f. 11–16; – 1973b:66, t. 34, f. 1–3.

This is a small, distinctive species (body length 40–60 μm) more closely resembling *C. arietinum*. The cell body is narrow, the apical horn arising close to the left side of the body and the left side of the body is less convex than *C. arietinum*. The girdle is not fully developed around the body. As with the latter species there is a range of variation

which has been recognised, various infraspecific epithets being used (JÖRGENSEN's formae and varieties, and the subspecies of PETERS and STEEMANN NIELSEN). The var. *declinatum* (=f. *debile* JÖRGENSEN) is represented by individuals in which the right horn curves outwards distally (PETERS 1932, f. 23a; STEEMANN NIELSEN 1934, f. 46; GRAHAM & BRONIKOVSKY 1944, f. 16 R; and f. 166 here). In the var. *normale* (JÖRGENSEN) stat. nov. the right horn is straight in its distal part. The var. *angusticornum* (PETERS) stat. nov. is one of the smallest variants, being distinguished rather dubiously from the var. *laticornum* (PETERS) GRAHAM et BRONIKOVSKY by a more incurved right antapical horn than the latter. It projects up almost straight as in the var. *normale*. The var. *majus* JÖRGENSEN is the most robust variant, the antapical horns not curving inward and being relatively short.

GRAHAM & BRONIKOVSKY (1944) and SUBRAHMANYAN (1968) considered that there was little value in the recognition of these infraspecific taxa. SOURNIA (1968a) recognised three formae: f. *normale* JÖRGENSEN, f. *declinatum*, and f. *brachiatum* JÖRGENSEN (with which he considered the subspecies *angusticornum* and *laticornum* might be included) and the var. *majus* JÖRGENSEN. His use of formae here was based on the observations of HALIM (1960a) in the Mediterranean where it appeared that at least some variation may be attributable to seasonal environmental changes. This phenotypic plasticity would accord with the concept of formae used here also. However, as the factors regulating these phenotypes are still not established the use of varieties for all variants is preferred here.

Stations: var. *declinatum*: 16, 17, 19, 20, 28, 34, 55, 56, 59, 65, 68, 71, 72, 85, 91, 94, 98, 100, 102–105, 108, 112, 113, 314, 323, 325, 326.

var. *angusticornum*: 62, 64, 68, 69, 71, 72, 93, 95, 99, 158, 294.

var. *majus*: 14, 150, 159.

The var. *declinatum* was by far the most common variant found. It was widespread throughout the Andaman Sea and Bay of Bengal and was also present at several stations to the west and south of India. It occurred furthest south at station 314 (24°S). The smallest variety (*angusticornum*) was found in the central and western Bay of Bengal, at one station north of the Seychelle Islands, and at one far southern station (158, 35°S). The var. *majus* was rare at three stations, one of which (159, 38°S) was the most southerly record for the species in the Indian Ocean.

The species is inter-oceanic, ranging from tropical to temperate waters. GRAHAM & BRONIKOVSKY (1944) considered that cold water records of the species (they found it at one cold station in the Atlantic in addition to many warm water records), were the result of displacement from its normal tropical distribution. The following records are additional to those listed by WOOD (1963a): ANGOT (1965), SOURNIA (1966a, 1968 a, b, 1970), TAYLOR (1967), NEL (1968), SUBRAHMANYAN (1968), and ANGOT (1970).

Ceratium euarquatum JÖRGENSEN Plate 15, Figs. 155, 157, 159

PETERS 1932:40, t. 1, f. 4 a–c; STEEMANN NIELSEN 1934:18, f. 38; SCHILLER 1936:402, f. 443; RAMPI 1939a:306, f. 30; GRAHAM et BRONIKOVSKY 1944:28, f. 15 N, M; WOOD 1954:294, f. 220; HALIM 1960a:185, t. 5, f. 2, 3; MARGALEF 1961b:140, f. 3/7; HALIM 1963:497, f. 13 (sub *euarquatum*); SOURNIA 1968a:436, f. 64, 65; SUBRAHMANYAN 1968:53, f. 94; WOOD 1968:28, f. 53; MARGALEF 1969a, f. 5 A, B.

A distinctive species, somewhat similar to *C. symmetricum*, from which it can be readily recognised by its much more steeply angled posterior profile (in relation to the plane of the girdle). Slender horned specimens tend to have a larger apical horn than the more robustly horned specimens (see JÖRGENSEN 1920; SOURNIA 1968a). *C. axiale* KOFOID is also very similar to this species when the cell body characteristics are examined (see comments under that species), and the three species may eventually be united.

Fig. 159 illustrates an unusual specimen interpreted here to be a malformation of the left antapical horn in *C. euarquatum* rather than a new taxon, this being based on the observations on aberrant specimens of other species of *Ceratium* by NIELSEN (1956) and HASLE & NORDLI (1951, cf. their fig. 8a).

SUBRAHMANYAN (1968) has relegated *C. filicorne* STEEMANN NIELSEN to synonymy with this species. The former has very widespread posterior horns. The original figure (1934, f. 39) resembled a variant of *C. euarquatum* but the figures of GRAHAM & BRONIKOVSKY (1944, f. 15 B, C) resemble *C. symmetricum* more closely.

Stations: 15, 16, 37, 60, 63–66, 89, 99, 101, 103, 108–110, 125, 129, 130, 134, 135, 153–155, 159, 161, 162, 282, 292, 294, 298, 300–302, 306, 312–315, 317–322, 331, 341, 342, 347, 359, 361, 371, 374, 412, 417–420.

GRAHAM & BRONIKOVSKY (1944) considered this species to be "one of the best indicators of warm tropical water". They did, however, find it occasionally in tropical upwelling regions. In the Indian Ocean material here it had a most interesting distribution, being widely distributed in the southern Indian Ocean and strikingly absent (or in very low numbers) from stations near the equator other than 292 and 294. Also it showed a curious anomaly with regard to the Mozambique Channel, being found at both northern and southern ends but not

within it. These features seem to suggest a factor other than temperature as governing the distribution of this species over much of the Indian Ocean. It is clearly oceanic.

The records of DURAIRATNAM (1964), SOURNIA (1966a, 1968 a, b, 1970), NEL (1968), and SUBRAHMANYAN (1968) need to be added to the Indian Ocean records listed by WOOD (1963a).

Ceratium gibberum GOURRET Plate 19, Fig. 187

CANDEIAS 1930:34, t. 3, f. 71-73; PETERS 1932:44, t. 3, f. 13c; STEEMANN NIELSEN 1934:22, f. 48; SCHILLER 1936:397, f. 436 a, b, 437; NIE 1936:54, f. 21; WANG 1936:158, f. 28; RAMPI 1939a:306, f. 24; GRAHAM et BRONIKOVSKY 1944:33, f. 17 D-G; SILVA 1949:359, t. 9, f. 8, 9; KISSELEV 1950:250, f. 437; MARGALEF et DURÁN 1953:42, f. 10 s-t; WOOD 1954:290, f. 214 a-c; KATO 1957:16, t. 5, f. 17; CURL 1959:306, f. 117; HALIM 1960a, t. 4, f. 19; - 1963:498, f. 14; KLEMENT 1964:356, t. 2, f. 7; TORIUMI 1964a:43, t. 1, f. 1; LOPEZ 1966, f. 23, 24; YAMAJI 1966:95, t. 46, f. 4, 5; HADA 1967:20, f. 32; SOURNIA 1968a:446, f. 73, 74; SUBRAHMANYAN 1968:46, f. 76-78; TORIUMI 1968:3, f. 6, 7; WOOD 1968:30, f. 61; STEIDINGER et WILLIAMS 1970:45, t. 8, f. 22 a, b; TORIUMI 1971:65, f. 1 a, b, 2, 3 a, b, 4 a, b, 7, 8; HERMOSILLA 1973a:21, t. 3, f. 19

This species closely resembles *C. concilians* but differs from it in that the cell body is larger, the epitheca is flattened with an angular right precingular junction; a more sharply convex postmargin, and a straighter apical horn. Linear and reticular ridges have not been observed on thecae of *C. concilians* but are common on *C. gibberum*. In the original description GOURRET (1883) recognised the type and two varieties, the var. *contortum* (subsequently raised to specific status) and the var. *sinistrum*.

It is still possible to recognise two varieties of this species, the var. *gibberum* (= var. *subaequale* JÖRGENSEN) in which the right horn is only slightly curved in, and the var. *dispar* (POUCHET) SOURNIA (= var. *sinistrum* GOURRET) in which the right horn is strongly bent inwards, passing over the dorsal side of the cell body. POUCHET's varietal epithet has priority over that of GOURRET. Intermediates between the two varieties exist but are rare.

Only the var. *dispar* was observed in this material.

Stations: 13, 14, 33, 34, 37, 38, 47, 50, 62, 64, 66, 87, 100, 102, 108, 110, 143, 144, 147, 153, 162, 282, 297, 320, 323, 330, 341, 362, 371, 414, 416, 418, 419.

This variety was relatively common, but never occurred in large numbers. It was restricted to waters north of 20°S except in the west where, in common with other tropical species, its distribution extended further south. Although described as purely oceanic (STEEMANN NIELSEN 1934) it often occurred near land masses.

Many of the apparently oceanic stations are not far from island groups. It has been found to occur chiefly within the upper 50 m. (GRAHAM & BRONIKOVSKY 1944).

The species has been commonly recorded from the Indian Ocean. The records provided by WOOD (1963a) require augmentation by those of SILVA (1956a, 1960) DURAIRATNAM (1964), ANGOT (1965), SOURNIA (1966a, 1968 a, b, 1970), TAYLOR (1967), NEL (1968), SUBRAHMANYAN (1968), and ANGOT (1970).

Ceratium humile JÖRGENSEN Plate 14, Fig. 148

STEEMANN NIELSEN 1934:17, f. 34; SCHILLER 1936:390, f. 428; GRAHAM et BRONIKOVSKY 1944:27, f. 14 A; WOOD 1954:287, vix f. 208; YAMAJI 1966:97, t. 47, f. 6; SUBRAHMANYAN 1968:38, f. 64, 65; WOOD 1968:32, f. 66.

A large-bodied species resembling *C. breve* and *C. tripos*, from which it is distinguished by its long right antapical horn. low epitheca with an angular anterior profile, and flattened posterior profile, sloping strongly in relation to the girdle plane. *C. egyptiacum* HALIM is also very similar and in most respects it resembles a variant in which the left antapical horn is short, slender, and bent almost at a right angle towards the ventral side. The left antapical horn of *C. humile* may be slightly divergent or, more commonly, parallel to convergent with the cell body. Some figures show a more curved posterior profile although this may be due to tilting of the specimens. The illustrated specimen had a right antapical horn which was less divergent than usual. More often the angle is very similar to that in *C. dens* and often the cell body shape is also similar to *C. dens*.

Stations: 39, 40, 47, 58, 63, 67, 70, 71, 85, 89.

Present in moderate numbers at three coastal stations on the eastern side of the Bay of Bengal/Andaman Sea, and over a wider area in the western half of the Bay of Bengal, all during the post-N. E. Monsoon period. NEL (1968) has recorded the species from the south-western Indian Ocean, but other Indian Ocean records (in WOOD 1963a) are for the northern Indian Ocean.

According to SUBRAHMANYAN (1968) this is a neritic, warm-water Indo-Pacific species. Its type locality is in Japanese coastal waters. GRAHAM & BRONIKOVSKY (1944) reported one cell from the tropical Atlantic Ocean and STEIDINGER & WILLIAMS (1970) and WOOD

(1968) have also found it in the Atlantic Ocean. However, the species seems to occur most frequently in southern Asian waters. It has not been observed off the west coast of North America as yet.

Ceratium limulus (GOURRET ex POUCHET) GOURRET Plate 18, Fig. 182

PETERS 1932:46, t. 1, f. 6; STEEMANN NIELSEN 1934:24, f. 54; SCHILLER 1936:407, f. 448; RAMPI 1939a:307, f. 19; GRAHAM et BRONIKOVSKY 1944:35, f. 19 A; SILVA 1949:360, t. 9, f. 10; WOOD 1954:296, f. 223 a, b; KATO 1957:17, t. 5, f. 15; TRÉGOUBOFF et ROSE 1957:115, t. 26, f. 7; HALIM 1960a, t. 4, f. 14; HERRERA, MUÑOZ et MARGALEF 1955:20, f. 1, F, G; LOPEZ 1966, f. 21; YAMAJI 1966:99, t. 48, f. 4; SOURNIA 1968a:458, t. 1, f. 5; SUBRAHMANYAN 1968:56, f. 103–105; WOOD 1968:34, f. 71; RICARD 1970, t. 1, f. f.

This is a highly distinctive, flattened, short-horned species, easily separated from *C. paradoxides* CLEVE by the shape of the epitheca with two humps or strong angularities on either side of the base of the apical horn, combined with a lack of reticulation covering the body. The left antapical horn is usually outcurving or straight distally, whereas it is usually in-curving in *C. paradoxides*.

Stations: 37, 52, 92, 102, 130, 134, 288.

In accordance with STEEMANN NIELSEN's (1934, 1939a) observations the species was rare, occurring in both eutrophic (Bay of Bengal) and oligotrophic oceanic waters. It occurred at one station in the south central region below 32 °S. It has not been found to be particularly shade-loving in other studies.

The references of DURAIRATNAM (1964), TAYLOR (1967), SOURNIA (1968a, b, 1970), SUBRAHMANYAN (1968), NEL (1968), THORRINGTON-SMITH (1969), and ANGOT (1970) should be added to those provided by WOOD (1963a).

Ceratium longissimum (SCHRÖDER) KOFOID Plate 17, Fig. 175

SCHILLER 1936:413, f. 454 a, b; RAMPI 1939c:111, f. 12; — 1942:225, f. 14; GRAHAM et BRONIKOVSKY 1944:43, f. 26 A, B; WOOD 1954:299, f. 228; SILVA 1955:171, t. 9, f. 2, 3; MARGALEF 1957b:92, f. 2 c; TRÉGOUBOFF et ROSE 1957:115, t. 26, f. 11; HALIM 1960a, t. 5, f. 9; YAMAJI 1966:106, t. 51, f. 6; SUBRAHMANYAN 1968:63, f. 111, 112.

Curiously, and inappropriately, previous authors have assigned this rare species to the section *Macroceros* PAVILLARD despite its fundamental similarity to *C. schrankii* and other members of the section *Tripes*. For example, it completely lacks the posterior proximal deflection of the antapical horns (leading to an indented appearance of the posterior margin). JÖRGENSEN (1920) noted this similarity to the section *Tripes* but did not transfer it and even recent authors such as SUBRAHMANYAN (1968) have not questioned the traditional allocation. Admittedly the distinction is somewhat artificial. *C. horridum* can exhibit both types of appearance. Nevertheless allocation to the section *Tripes* seems most appropriate.

This species resembles *C. schrankii* but is much smaller with very long antapical horns sloping to the right and sub-parallel with the apical horn. JÖRGENSEN (1920) illustrated a form in which the antapical horns were strongly divergent (f. *subdivaricatum*) but this was not observed in the present material. GRAHAM & BRONIKOVSKY (1944) found that in the var. *longissimum* the horns of the Pacific strain seemed to diverge somewhat more than the Atlantic strain (or that found here), confirmed by the figure of WOOD (1954).

It also resembles *C. contortum* var. *longinum* but the latter does not have particularly long antapical horns and the left horn of the latter turns more abruptly in an apical direction shortly after leaving the body instead of curving in a smooth arc. *C. longissimum* also usually has a cell body smaller than *C. contortum*.

Stations: 31, 108, 117, 294, 319, 321.

Present at a few scattered stations in the north central Indian Ocean and one Andaman Sea station. It is known from the Mediterranean Sea, the equatorial Atlantic Ocean, Pacific Ocean, and has been found previously in the Indian Ocean by STEEMANN NIELSEN (1939a), SUKHANOVA (1962b), and SUBRAHMANYAN (1968). The former termed it a tropical, truly oceanic shade species. GRAHAM & BRONIKOVSKY (1944) found it to be "one of the most pronounced shade species encountered". It seems to occur most frequently between 200 and 100 m.

Ceratium lunula (SCHIMPER ex KARSTEN) JÖRGENSEN Plate 16, Fig. 171; Plate 18, Fig. 183

WANG et NIE 1932:305, f. 18; PETERS 1932:44, t. 2, f. 12c; STEEMANN NIELSEN 1934:23, f. 50; NIE 1936:56, f. 23 (sub *C. lunulae*); SCHILLER 1936:399, f. 439; GRAHAM et BRONIKOVSKY 1944:33, f. 17 J–N; WOOD 1954:291, f. 215 a, b; SILVA 1955:167, t. 8, f. 3–5; MARGALEF 1961b:142, f. 3/9; YAMAJI 1966:96, t. 46, f. 7, 8, 9; SOURNIA 1968a:450, f. 75, 76; SUBRAHMANYAN 1968:49, f. 82–87, t. 7, f. 33, non t. 3, f. 19 (*C. contortum*); WOOD 1968:35, f. 76; D. R. NORRIS 1969:448, f. 1, 2; STEIDINGER et WILLIAMS 1970:46, t. 10, f. 28.

The shape of the cell body is distinctive, with a sub-triangular epitheca due to only slight (or no) convexity of the upper surfaces. This, combined with the central position of the apical horn, and the widely spreading antapical horns

which do not form a smoothly arcing profile with the posterior part of the cell body, serves to distinguish the species in both its delicate and robust forms from *C. karstenii* and *C. contortum*.

SOURNIA (1968a) has explained why the taxon cannot be ascribed solely to SCHIMPER. D. R. NORRIS (1969b) has observed the apparent phagocytosis of a species of *Peridinium* by this species.

JÖRGENSEN (1911) recognised two forms: the *f. megaceros* ("magaceros" in GRAHAM & BRONIKOVSKY 1944) with a long apical horn, and the *f. brachyceros* with a short apical horn. As these conditions probably reflect only the position in a chain, the long-horned individuals being the anterior-most, these forms do not seem worth recognising. On the other hand in the "Anton Bruun" material there was a striking difference in appearance between the slender individuals and larger, more robust individuals. The latter, in fact, could be confused with robust specimens of *C. contortum* if the shape was not clearly perceived. This point is emphasised by the placement of the figures on the plates. Furthermore, although the body of the robust form is larger than the other, its horns are frequently more slender. In view of these striking differences the two taxa are here given varietal status.

C. lunula var. *lunula* (f. 171) is the smaller-bodied form with a girdle transdiameter of less than 90 μm , usually closer to 80 μm . The antapical horns are long, relatively strongly built, and are broadly divergent.

C. lunula var. *robustum* var. nov. (f. 183). This differs from the var. *lunula* in that the body is larger, usually exceeding 100 μm in girdle transdiameter. The upper epithelial surfaces are more convex. The antapical horns taper more strongly. They are often less divergent than the var. *lunula* but not always. The surface of the theca bears irregularly longitudinal ridges and strongly developed lists arise from the base of the apical horn and on the upper proximal edges of the antapical horns.

Stations: var. *lunula*: 38, 57, 62.

var. *robustum*: 31, 37, 94, 129, 134, 149, 153, 282, 287, 290, 311, 323, 325, 329, 334, 365, 398, 404, 418, 419.

The var. *lunula* was rare, occurring at only three stations, one in the Andaman Sea and two in the northern Bay of Bengal. The var. *robustum* was more common. GRAHAM & BRONIKOVSKY (1944) found the species to have a similar distribution to *C. breve* but it was more thermophilic and it has usually not been found further south than 20 °S. In the "Anton Bruun" material however, while predominantly occurring in high temperature waters, the species was also found at three stations near 30 °S (one at 35 °S). TAYLOR (1967) and NEL (1968) have also found it south of 30 °S in the southwestern sector.

It is a tropical to subtropical inter-oceanic species. In addition to those Indian Ocean records listed by WOOD (1963a) there are the following: SILVA (1956b, 1960), SUKHANOVA (1962b), TSURUTA (1963), DURAIRATNAM (1964), TAYLOR (1967), NEL (1968), SOURNIA (1968 a, b, 1970), and SUBRAHMANYAN (1968).

Ceratium paradoxides CLEVE Plate 18, Fig. 178; Plate 43, Fig. 509

STEEMANN NIELSEN 1934:24, f. 55; SCHILLER 1936:408, f. 449; GRAHAM et BRONIKOVSKY 1944:36, f. 19 B; SILVA 1955:168, t. 8, f. 6; WOOD 1963b:40, f. 147; YAMAJI 1966:99, t. 48, f. 5; TAYLOR 1967, t. 93, f. 54 (sub *horridum* GRAN); SOURNIA 1968a:458, t. 1, f. 4; SUBRAHMANYAN 1968:57, f. 106, 107; WOOD 1968:37, f. 80.

This species is similar to *C. limulus* but differs by the features listed under that taxon here. In addition *C. paradoxides* is somewhat larger, the girdle diameter ranging from 70 to 80 μm . All horns show smooth curvature to the right.

The misnamed figure provided by TAYLOR (1967) was due to a typographical error.

Stations: 14, 18, 26, 35, 61–63, 65, 99, 103, 112, 113, 125, 129, 135, 143, 144, 150, 154, 157, 161, 294, 297, 321, 326, 334, 366, 370.

Although considered a rare species it occurred fairly commonly but never in large numbers in the samples. It occurred predominantly in the western Bay of Bengal (a common pattern for "shade species") and over a wide area of the Indian Ocean.

It has been considered a "shade species" by STEEMANN NIELSEN (1934) and GRAHAM & BRONIKOVSKY (1944). It is inter-oceanic and subtropical to tropical in distribution. The references of TSURUTA (1963), TAYLOR (1967), SOURNIA (1968a, 1970), NEL (1968), and SUBRAHMANYAN (1968) should be added to those listed by WOOD (1963a) for the Indian Ocean.

Ceratium petersii STEEMANN NIELSEN Plate 15, Fig. 161

— 1934:20, f. 44; SCHILLER 1936:406, f. 446; GRAHAM et BRONIKOVSKY 1944:31, f. 16 L; WOOD 1954:296, f. 224 a, b; BALECH 1962b: 183, t. 26, f. 395–397; LOPEZ 1966, f. 25; SOURNIA 1968a:436, f. 59–61; SUBRAHMANYAN 1968:91, f. 165.

As indicated under *C. azoricum* this species may well be an extreme variant of the former. The means of distinction is also indicated under *C. azoricum* here. The specimen figured on plate 15 has less divergent horns than this species often exhibits. Like *C. azoricum* the girdle seems to be very poorly developed.

Stations: 159, 160.

These two stations were among the most southerly stations sampled. Station 160 was below 40°S, further south than the distribution of warmer water species such as *C. declinatum* and *C. euarcuratum*.

GRAHAM & BRONIKOVSKY (1944) suggested that it might be considered as a "subpolar" species except for occasional anomalous warmer incursions off the west coast of South America. They doubted that PETERS' (1932) specimens from the South Atlantic were the same as those seen by STEEMANN NIELSEN off New Zealand.

This is a first record for the species in the Indian Ocean. It is probably circumpolar in the Southern Ocean.

Ceratium schrankii KOFOID Plate 17, Figs. 176, 177

Syn.: *C. arcuatum* auct. non CLEVE sensu PETERS 1932, t. 2, f. 11c.

C. karstenii auct. non PAVILLARD sensu SCHILLER 1936, f. 431 a. Vix. SUBRAHMANYAN 1968, f. 67, 68.

C. karstenii var. *robustum* sensu SCHILLER 1936, f. 432a; SUBRAHMANYAN 1968, f. 72.

C. contortum CLEVE sensu GRAHAM et BRONIKOVSKY 1944 e.p. f. 18 L vix K.

C. contortum var. *karstenii* sensu SOURNIA 1968a, f. 71, t. 3, f. 10 (vide *C. contortum*, infra).

This name has been revived [it was formerly relegated to being a synonym of *C. arcuatum* CLEVE = *C. karstenii* PAVILLARD, now = *C. contortum* (GOURRET) CLEVE] to refer to a taxon which may or may not be considered as distinct from *C. contortum* (see comments under the latter). On the basis of published figures it appears highly probable that it intergrades with *C. contortum*. For example, JÖRGENSEN's (1920) figure of his form "α *Karstenii*" might be considered at first sight to be an intermediate. However, this is due mostly to the appearance of the horns which are somewhat heavier than is usual for *C. contortum*. A close scrutiny shows that in body shape it is very similar to fig. 184 here of *C. contortum* var. *karstenii*. It was found during the analysis of the "Anton Bruun" material, that individuals conforming to *C. schrankii* could always be readily separated from other forms assigned here to *C. contortum*. On this basis it seemed best to retain the distinction, the taxa being readily combined if found appropriate by future study.

KOFOID (1907a) considered that the features which distinguished his species from *C. arcuatum* were its subequal antapical horns (a distinction which is not particularly reliable as indicated by figures of *C. contortum* here), a wider arc of the horns, and a narrower epitheca. In addition he noted that the apical horn was not bent to the left initially as much as in *C. arcuatum*. Although he commented that the apical horn was usually short in the "Anton Bruun" material the reverse was true. This character is notoriously variable in the section *Tripes* and consequently this difference is not considered important. Also KOFOID persistently referred to the smoothly curving nature of the posterior margin, an expression which actually masks one of the most distinctive features of this taxon: a distinct flattening of the mid-posterior margin, subtle but quite definite in comparison with the strong convexity of *C. contortum*. His figures show this feature quite plainly.

In summary, then, this taxon seems to be recognisable in comparison with *C. contortum* by a combination of relatively robust antapical horns, usually subequal or with the right horn only slightly longer, narrow cell body (compared with *C. contortum* var. *karstenii*) and apical horn arising from the centre or to the left of the epitheca and bending immediately to the right rather than proceeding first to the left and then the right.

In antapical horn features it is really more like some varieties of *C. tripos*.

Stations: 32, 34, 37, 38, 42, 67, 93, 118, 125, 149, 154, 155, 161, 294, 301, 312, 313, 317, 360–362, 369, 405, 416, 420.

This distribution (N. Andaman Sea, W. Bay of Bengal, warm water areas of the Indian Ocean but absent from the 10° S region) is similar to that shown by *C. contortum* var. *karstenii* (emend.) which suggests a close affinity but at the same time argues against differences in appearance due to environmental influences on the phenotype (formae). In fact this distribution is also similar to *C. lunula*.

Because of confusion regarding identities former records are doubtful. The specimens illustrated by the authors cited in the references here were found in the eastern tropical Pacific Ocean, the Atlantic Ocean (equatorial current and southern region), and the Mozambique Channel. SCHILLER (1936) did not give localities for his specimens.

This is officially a new record from the Indian Ocean although SOURNIA (1968a) has illustrated a similar specimen under *C. contortum*. SUBRAHMANYAN's (1968) figures of *C. karstenii* might refer to this taxon but have more curved posterior margins.

Ceratium symmetricum PAVILLARD Plate 15, Figs. 152–154, 156

STEEMANN NIELSEN 1934:19, f. 40, 41; SCHILLER 1936:401, f. 441 a–d; RAMPI 1939a:306, f. 27; GRAHAM et BRONIKOVSKY 1944:29, f. 15 H–L; RAMPI 1952b:120, f. 6; MARGALEF et DURÁN 1953:42, f. 10q; WOOD 1954:292, f. 217 a–c; TRÉGOUBOFF et ROSE 1957:115, t. 26, f. 3; HALIM 1960a, t. 5, f. 1; MARGALEF 1961b:142, f. 3/10; HALIM 1963:498, f. 24, 25; LOPEZ 1966, f. 29, 30; SOURNIA 1968a:432, f. 55–57 (sub *symmetricum*); SUBRAHMANYAN 1968:51, f. 89–92; STEIDINGER et WILLIAMS 1970:47, t. 149, f. 34. Non WOOD 1968:40, f. 89 (*C. azoricum*?)

Syn.: . . . *C. gracile* (JÖRGENSEN) GOURRET . . . PETERS 1932:41, t. 4, f. 21 b, c non a vix d; SILVA et PINTO 1948:173, t. 6, f. 22; YAMAJI 1966:98, t. 47, f. 12, 13.

The name *C. gracile* (GOURRET) JÖRGENSEN for this taxon was rejected by PAULSEN (1930) because of differences in interpretation by earlier authors, and more convincingly, by GRAHAM & BRONIKOVSKY (1944) because they considered it impossible to identify the original figure precisely (GOURRET 1883, pl. 1, f. 1). The latter's argument seems reasonable and has been followed by recent monographers. At the species level *C. symmetricum* PAVILLARD has priority of *C. gracile*, the latter epithet being originally proposed at the varietal level.

GRAHAM & BRONIKOVSKY (1944) recognised three principal varieties in contradiction to STEEMANN NIELSEN's (1934) view that they blended too much to warrant recognition. These varieties are: the var. *symmetricum* (f. 154) with a relatively short apical horn and widely spread antapical horns; the var. *orthoceras* (JÖRGENSEN) GRAHAM et BRONIKOVSKY (f. 152) with closely set antapical horns and relatively short apical horn; and the var. *coarctatum* (PAVILLARD) GRAHAM et BRONIKOVSKY (f. 153, 156).

The species is closest to *C. euarctatum* and *C. filicorne* STEEMANN NIELSEN. It differs from the former in its more symmetrical posterior profile and in the smaller, relatively shorter cell body. The latter is similar in cell body shape, particularly in comparison with the var. *coarctatum*. However, the posterior horns are very widespread and relatively slender in *C. filicorne*. To date it appears to have only been found in the Pacific Ocean.

Stations: var. *symmetricum*: 112, 113, 297, 323.

var. *orthoceras*: 117, 321.

var. *coarctatum*: 17, 60, 99, 102, 113, 300, 313, 374.

The species was largely limited to the northern Indian Ocean but the var. *coarctatum*, which was the more widespread variety, also occurred at the southern end of the Mozambique Channel and in the mid-southern region near 30°S. It is a warm-water, inter-oceanic species. GRAHAM & BRONIKOVSKY (1944) considered it to be "a pronounced shade species", occurring consistently in deeper samples.

The Indian Ocean references of WOOD (1963a) require augmentation by those of SILVA (1956a), TSURUTA (1963, as *C. gracile* var. *symmetricum*), DURAIRATNAM (1964), SOURNIA (1966a, 1968 a, b, 1970), TAYLOR (1967), NEL (1968), and SUBRAHMANYAN (1968).

Ceratium tripos (O. F. MÜLLER) NITZSCH Plate 14, Figs. 147, 149–151; Plate 16, Figs. 168–170
WAILES 1928, t. 3, f. 1; MARTIN 1929:30, t. 7, f. 7; WANG et NIE 1932:304, f. 16, 17; WANG 1936:157, f. 27; SCHILLER 1936:384, f. 321a; NIE 1936:48, f. 17 A, B; WAILES 1939:44, f. 133; MARGALEF 1946, f. III 1; SILVA et PINTO 1948:172, t. 6, f. 23; KISSELEV 1950:246–248, f. 36 a–g, 49, 51, 62, 428, 431 a, b, 432 a, 432, 440, 441, 442; HASLE et NORDLI 1951, f. 3 a–k, 4 a–c, 7i, 8 a–f; MARGALEF et DURÁN 1953:40, f. 10 g–n; WOOD 1954:285, f. 205 a, b, c; LOPEZ 1955:156, f. 6; KATO 1957:15, t. 4, f. 12 a, b, 13 a, b; TRÉGOUBOFF et ROSE 1957:116, t. 25, f. 14; CURL 1959:306, f. 123; HALIM 1960a, t. 4, f. 15; CASSIE 1961, t. 7, f. 6; MARGALEF 1961a:81, f. 26j; BARTH et OSORIO 1965, f. 1 a, f, g, vix i, non b, c, d, e, h; LOPEZ 1966:330, f. 33–36, t. ("Foto") 2/1–3; YAMAJI 1966:97, t. 47, f. 1–5; HADA 1967:20; STEIDINGER et WILLIAMS 1970:47, t. 14, f. 37 a, b, t. 15, f. 38 a, b; TORIUMI 1971:65, f. 5 a, b, 6; HERMOSILLA 1973b:65, t. 33, f. 5.

Syn.: . . . *C. pulchellum* SCHRÖDER . . . CANDEIAS 1930:32, t. 3, f. 65–68; WANG 1936:155, f. 26; NIE 1936:45, f. 15 A, B; RAMPI 1939a:304, f. 21–23; SILVA et PINTO 1948:172, t. 2, f. 13; WOOD 1954:286, f. 206 a, b, c; SILVA 1956a:68, t. 12, f. 4; TRÉGOUBOFF et ROSE 1957:116, t. 25, f. 15; CURL 1959:306, f. 121; HALIM 1960a, t. 4, f. 15, 18; – 1963:498, f. 22, 23; BALLANTINE 1961:225, f. 51, 52; KLEMENT 1964:355, t. 2, f. 3; YAMAJI 1966:99, t. 48, f. 2.

C. schroederi NIE 1936:47, f. 16 A, B.

The early confusion in the recognition of this species arose from widely differing interpretations of the taxon, MÜLLER's original description not being sufficient to delimit the species precisely. Most early authors have drawn (accurately?) specimens in which the right antapical horn does not lie in a smooth arc with the posterior profile and left antapical horn, instead being bent outwards from the base (e.g. EHRENBERG 1836). The var. *balticum* SCHÜTT (and also the forma *subsalsum* OSTENFELD) is probably closest to the type variety (JÖRGENSEN 1911) and consequently that taxon should now become the var. *tripos*.

The taxonomic confusion and the infraspecific variability has been summarised by SOURNIA (1968a; see also HASLE & NORDLI 1951, and LOPEZ 1955). In brief, recent work has indicated that there is a continuum of variation linking the var. *pulchellum* (B. SCHRÖDER) LOPEZ with the var. *atlanticum* (OSTENFELD) PAULSEN (i.e. from those small specimens with a greatly reduced right antapical horn, to those larger cells with well developed, widely placed antapical horns). In addition there is a group of other varieties and forms, mostly occurring in colder or brackish waters (see JÖRGENSEN 1911, 1920 and SOURNIA 1968a). Variability in individuals forming chains, and also in cultures, has been described (summarised by HASLE & NORDLI 1951).

The following infraspecific taxa have been recognised in the present material:

C. tripos var. *atlanticum* (OSTENFELD) PAULSEN as above. The transdiameter of the cells ranges from approximately 65–90 μm .

C. tripos var. *indicum* (BÖHM) comb. nov. (basionym = *C. pulchellum* var. *indicum* BÖHM 1931b:420, f. 38 a, b), omitted by SOURNIA (1968a) although it corresponds to his fig. 43 and the present figs. 168, 169. The transdiameter of the body is relatively narrow, below 60 μm and the posterior profile is flatter than the other variants. The degree of slope with relation to the girdle plane varies greatly.

C. tripos var. *pulchellum* (B. SCHRÖDER) LOPEZ, as above, ranging from forms with a greatly reduced right horn – f. *pulchellum* (f. 147), to those with smoothly-curving antapical horns fairly widespread – f. *semipulchellum* JÖRGENSEN (f. 150).

Variants with greatly reduced horns, especially the antapical horns, are known to occur clonally and are thus not recognised formally here.

Stations: var. *atlanticum*: 30, 31, 34, 38–45, 54, 56, 60, 70, 100, 101, 103, 108, 135, 144, 147, 153, 162, 283, 284, 286–290, 302, 320, 326, 371, 420
 var. *indicum*: 13, 16–20, 23, 27, 31, 32, 34, 35, 37, 38, 41, 50, 54, 60, 65, 69–72, 87, 88, 90, 91, 93, 96, 99–103, 108–110, 112, 114–118, 134, 149, 150, 153, 162, 285–287, 290, 291, 294, 302, 315, 325, 327–329, 332, 334, 336, 341, 360–363, 365, 368, 370, 371, 375, 396, 419
 var. *pulchellum* f. *pulchellum*: 99, 103, 129, 134, 294, 299, 312, 320, 323, 326
 var. *pulchellum* f. *semipulchellum*: 287, 295, 341, 359, 362, 371, 413, 419

The var. *indicum* was the most widespread representative of the species, occurring in the Andaman Sea, Bay of Bengal, the Arabian Sea and at a cluster of stations at the southern end of the Mozambique Channel. It was sporadic in the central Indian Ocean, extending to 28 °S only.

The var. *atlanticum* occurred in patches, notably in the northern Andaman Sea and Bay of Bengal (both regions under river influence), and near the Gulf of Aden. Other occurrences were more scattered.

The var. *pulchellum* occurred only rarely in the northern parts of the ocean, being sporadically widespread in the western and southern regions. The f. *pulchellum* extended to 32 °S. The f. *semipulchellum* was found chiefly to the north and south of the Mozambique Channel where the other form was absent.

There have been many earlier records of the species in the Indian Ocean, WOOD's (1963a) list requiring the addition of the records of SILVA (1956a, 1960), TSURUTA (1963), DURAIRATNAM (1963), ANGOT (1965), ANGOT & GÉRARD (1966), SOURNIA (1966, 1968 a, b, 1970), TAYLOR (1967), NEL (1968), SUBRAHMANYAN (1968), THORRINGTON-SMITH (1969), and ANGOT (1970).

Family Ceratocoryaceae LINDEMANN

Members of this family all belong to one genus, typically bearing multiple strong spines limited to the hypotheca.

Genus *Ceratocorys* STEIN

This genus was the subject of a detailed study by GRAHAM (1942). In addition, the most common species, *C. horrida* STEIN was further dissected into its component plates by BALECH (1949b). GRAHAM subdivided the genus into two subgenera, both sharing the same plate formula but differing in whether or not the first postcingular plate is distinguishable from the sulcal area or not. He recognised seven species, omitting one (*C. magna*) which is recognised here. *C. alleni* TAFALL (1942), additional to those included by GRAHAM, is in all probability based on a left daughter cell of *C. gourretii* shortly after division, the antapical spines being totally lacking.

The plate formula of the genus was given by KOFOID (1910) as P, 3', 1^a, 5", 8c, 6''', 1p, 1'''''. Although excessive in the number of girdle plates this formula seems better than that given by GRAHAM (1942). Despite the latter's extensive analysis of the plates he interpreted the apical plates in a peculiar manner, giving them as (P) 2', 2^a. . . . From an examination of his and other published figures, plus the "Anton Bruun" material (chiefly with the scanning electron microscope for this purpose, e.g. fig. 529) it is concluded here that the apical arrangement can be considered as either P, 3 + 1', or P, 3', 1^a, depending on whether one interprets a small quadrangular plate at the junction of the right quadrants as an intercalary plate or a displaced apical plate. Occasionally it touches the pore plate.

BALECH's (1949b) detailed analysis was marred by unusual plate terminology. The only plate he termed as an apical plate was the apical pore plate (P here) and he reversed KOFOID's notation for those plates customarily considered to be apical plates with that for the precingular plates. LOEBLICH III (1970) has interpreted BALECH's analysis as revealing a pattern with the following formula: P, 3', 1a, 5'', 6c, 10s, 4''', 1'''''. In this action he differed from KOFOID's interpretation chiefly by lumping two small plates with the sulcals, considered by KOFOID (and here) to be postcingulars (see also GRAHAM's, 1942 discussion of the position of the small plate apparently homologous with the first postcingular plate of KOFOID), and he did not acknowledge the existence of a plate homologous to 1^P (see text fig. 1, p. 97 comparing *Heteraulacus* with the gonyaulacoid plate pattern).

Here the formula for the genus is interpreted as: P, 3' (+ 1' or 1^a), 5'', 6c, 7s (8?), 6''', 1^P, 1''''.

Ceratocorys armata (SCHÜTT) KOFOID Plate 26, Figs. 269 a, b, 272, 273

SCHILLER 1936:444, f. 486 a-c; GRAHAM 1942:40, f. 53 A-E, f. 54 A-E; MARGALEF, HERRERA, RODRIGUEZ-RODA, et LARRAÑETA 1954:92, f. 3 e, f; YAMAJI 1966:71, t. 33, f. 3; STEIDINGER, DAVIS, et WILLIAMS 1967, t. 7, f. c; STEIDINGER et WILLIAMS 1970:48, t. 15, f. 41 a, b.

Vix WOOD 1954:314, f. 243 a, b; - 1968:42, f. 95.

Non HALIM 1960a, t. 3, f. 19.

This species differs from *C. magna* chiefly in size (see latter), being much smaller. It also has much less elaborate thecal ornamentation than either *C. magna* or *C. reticulata* GRAHAM. Spines are restricted to the antapical region. There are three or four well-developed spines associated with the antapical plate. Additional small spines are associated with the ridged edges of the plates. *C. aultii* GRAHAM is also similar, sharing a similar number of antapical spines (although the latter seem to be more slender) and also in having the first postcingular plate strongly demarcated outside the sulcal groove. In *C. aultii* the sulcal region seems to be wider posteriorly and slightly curving, but GRAHAM (1942) only illustrated a megacytic specimen and so shape distinctions are difficult to make. *C. skogsbergii* GRAHAM differs chiefly in that the first postcingular is incorporated into the sulcal area (only one small quadrangular plate, the second postcingular, being visible at the junction of the left girdle end and the sulcus, instead of two). There are other differences as well.

In fig. 273 a specimen is shown in lateral view which is much more apico-antapically compressed than usual.

Stations: 29, 68, 72, 94, 97, 103, 133, 144, 283, 294, 326, 330, 331, 348, 371.

(compressed form: 23, 294)

It occurred at scattered stations over a wide area, the most southerly being station 133 at 30 °S.

The species is an inter-oceanic tropical to subtropical species with a distribution similar to *C. horrida*, only it is rarer and is supposedly less thermotolerant (GRAHAM 1942). In addition to the Indian Ocean references provided by WOOD (1963a) there are those of SOURNIA (1966a, 1967a, 1968b, 1970), and TAYLOR (1967).

Ceratocorys bipes (CLEVE) KOFOID Plate 26, Figs. 271, 276; Plate 43, Figs. 514

SCHILLER 1936:445, f. 448 A; GRAHAM 1942:43, f. 57 A-F; GAARDER 1954:16, f. 15; WOOD 1963c:16, f. 56; YAMAJI 1966:32, t. 33, f. 4; TAYLOR 1972b, t. 2, f. 12.

This small species is readily recognisable by the presence of the two bulbous posterior projections of the cell body each bearing a spine with delicate fins. Both spines arise from the antapical plate. GAARDER (1954) observed a specimen, apparently of this species, which lacked the posterior spines. Her figure, a ventral view, agrees well with other figures of this species other than the lack of spines.

Stations: 13, 20, 63, 103, 143, 150, 283.

It occurred in small numbers in the northern Indian Ocean (both the Arabian Sea and Bay of Bengal), not occurring further south than station 150 (3 °S).

This seems to be one of the most highly stenothermal members of the genus (see also *C. gourretii*), only occurring in warm temperate waters when it is carried there by intrusions of currents originating in tropical waters (e.g. the Kurosiwo off Japan). It has not as yet been found in the southern Indian Ocean. WOOD (1963a) has provided a few (three) Indian Ocean records of the species, to which his own (1963c) should be added. It is known from the Pacific Ocean in the vicinity of Japan.

Ceratocorys gourretii PAULSEN Plate 26, Figs. 274, 277

SCHILLER 1936:446, f. 488 B; GRAHAM 1942:44, f. 59 A-H; WOOD 1954:314, f. 244 a, b; SILVA 1956a:69, t. 11, f. 13; TRÉGOUBOFF et ROSE 1957:117, t. 27, f. 5; BALLANTINE 1961, f. 61 (sub *C. horrida*); WOOD 1968:42, f. 96; MARGALEF 1969b:346, f. 1 A, B; LÉGER 1972a:28, f. 13.

Vix RAMPI 1950c:246, t. 4, f. 17.

Syn.: . . . *C. alleni* TAFALL 1942:443, t. 36, f. 20, 22, 23, 26. *C. jourdanii* KOFOID 1910 . . . YAMAJI 1966:71, t. 33, f. 2; non GOURRET, 1883, (*Dinophysis jourdanii*) nec SILVA 1949:363, t. 9, f. 15.

This small species resembles *C. horrida*. It can, however, be easily distinguished by its usually smaller, rotund (but laterally flattened) body. Its length is 38–62 μm as opposed to a range of 38–97 μm for *C. horrida* (GRAHAM's size data). It possesses similar dorsal and ventral spines to *C. horrida*, except that they are never as extensive as in the latter, particularly with regard to the dorsal and ventral spines. Also it has only three antapical spines instead of the four in the latter species. As with *C. skogsbergii* the first postcingular plate is hidden within the sulcal region. The confused systematic history of *C. gourretii* has been summarised by GRAHAM (1942).* *C. alleni* TAFALL is almost certainly a left daughter cell of this species shortly after division. RAMPI (1950c) has figured a specimen purported to be *C. gourretii* but which has four antapical spines.

In one of the specimens illustrated here (fig. 274) the dorsal spine is subdivided into two spinelets. This is unusual but has been observed previously (e.g. GRAHAM 1942, f. 59 F). The other specimen is apparently a new daughter cell (left moiety), which resembles *C. kofoidii* PAULSEN (probably synonymous).

Stations: 57, 58, 61, 63, 64, 71, 98–100, 103, 108, 154.

Like *C. bipes* this is a relatively rare, high stenothermal species. In the material it occurred mostly within the northern Indian Ocean, with one record near Mauritius (st. 154). GRAHAM (1942) found that it was apparently absent from water below 22 °C. TAYLOR (ms., 1964) found it at a few stations in the southwestern Indian Ocean, apparently carried south by the Agulhas Current, and it has also been found in that locality by NEL (1968). Indian Ocean references additional to those listed by WOOD (1963a) and above are: SILVA (1956a, 1960), SOURNIA (1967a, 1968b, and 1970), and TAYLOR (1967).

Ceratocorys horrida STEIN Plate 26, Figs. 265–268, Plate 46, Fig. 529

CANDEIAS 1930:39, t. 2, f. 55 (sub *Caratocorys*); SCHILLER 1936:443, f. 485 a–c; GRAHAM 1942:38, f. 1 B, f. 47 A–E, 48 A–H, 49 A–K, 50 A–C; MARGALEF 1948b:49, f. 3c; BALECH 1949b:166, f. 1–29; RAMPI 1950c:246, t. 4, f. 20; GAARDER 1954:16, f. 16 a, b; WOOD 1954:313, f. 242 a, b; SILVA 1955:173, t. 10, f. 1–4; TRÉGOUBOFF et ROSE 1957:117, t. 27, f. 4; BALLANTINE 1961:225, f. 62 non 61; HALIM 1967, t. 1, f. 14; STEIDINGER, DAVIS et WILLIAMS 1967, t. 7, f. a, b; WOOD 1968:42, f. 97; STEIDINGER et WILLIAMS 1970:48, t. 16, f. 42 a, b; HERMOSILLA 1973a:29, t. 3, f. 1–5; TAYLOR 1973b, f. 4 c (opt. rev.).

C. horrida is one of the most common members of the tropical and subtropical dinoflagellate community. It is also highly distinctive in appearance. The only other species of *Ceratocorys* which possesses strongly extended spines on the upper part of the hypotheca is *C. gourretii* PAULSEN (see previous species for comparisons and also the comments under the genus). It has long been known that the species undergoes a drastic change in appearance as a result of cell division comparable to that found in the dinophysoid dinoflagellates. The left daughter cell receives the two large dorsal and ventral spines and has to reform the four antapical spines (fig. 266), whereas the right daughter cell has to reform the two large upper spines, initially possessing only the four antapical spines (fig. 268). GRAHAM (1942) has reported specimens which were apparently reforming all the spines, although none of this stage were observed in the "Anton Bruun" material. GAARDER (1954) has illustrated an aberrant fission product with one mature antapical spine.

Apart from the effects of division there is a great deal of variation in the length of spines. The var. *horrida* (including var. *longicornis* LEMMERMANN) has a relatively stout body with moderately long spines approximating 60–90 μm in length whereas the var. *extensa* PAVILLARD has a relatively smaller body with extremely long, divergent spines reaching more than 130 μm in length (fig. 267). KARSTEN's (1907) multiple-spined var. *africana* was probably teratological.

Stations: var. *horrida*: 13, 14, 17, 19, 21, 23, 26, 28–32, 35–38, 43, 51, 53, 56, 59–72, 85, 91–96, 98–100, 102, 103, 106, 109, 110, 113–116, 125, 135, 140–143, 150, 153, 154, 161, 282, 287, 294, 297, 301, 302, 315, 317, 322–324, 326, 327, 329, 334–336, 340, 342, 370, 413.
var. *extensa*: 64, 66.

* In contradiction to GRAHAM, but in agreement with PAULSEN (1930), *C. jourdanii* (GOURRET) KOFOID is not believed to be a synonym of *C. gourretii*. GOURRET's figure (1883, pl. 3, f. 55, as *Dinophysis jourdanii*) shows an angular, elongate body with wide girdle lists and long spines. The presence of only three, instead of four antapical spines therefore appears to be teratological, possibly due to damage, the cell being attributable to *C. horrida*. The specimens figured by SCHÜTT (1895, pl. 4, f. 20, 1–20, 4) are *C. gourretii*, as is the figure of MURRAY & WHITTING (1899, pl. 30, f. 5 a). KOFOID (1910) gave the first detailed description of the present taxon.

The var. *borrida* was very common and widespread in the northern Indian Ocean, particularly in the Bay of Bengal and Andaman Sea. It was relatively abundant at station 100. It only occurred south of 20 °S to the west and south of Madagascar. TAYLOR (ms., 1964) found it in October and January in Agulhas Current water, occurring furthest south in the former month. NEL (1968) has also found it in the south-western Indian Ocean.

GRAHAM (1942) considered this species to be a valuable indicator of tropical and subtropical water, especially as it is common (although not usually abundant) and inter-oceanic. It does not apparently tolerate water below 19 °C. It is not as stenothermal as *C. bipes* or *C. gourretii*, whose values as indicators are, however, limited by their rarity.

In addition to the Indian Ocean records mentioned above and those listed by WOOD (1963a) there are those of SILVA (1956a), TSURUTA (1963), SOURNIA (1966a, 1967a, 1968b, 1970), TAYLOR (1967), NEL (1968), THORRINGTON-SMITH (1969), and ANGOT (1970).

Ceratocorys magna KOFOID Plate 26, Fig. 270

SCHILLER 1936:445, f. 487.

Syn.: *Ceratocorys spinifera* MURRAY et WHITTING, pro parte, t. 30, f. 6d.

C. reticulata auct. non GRAHAM . . . TAYLOR 1973b, f. 6 c.

This rare species is very similar to *C. armata* but it is much larger in size, the diameter (excluding girdle lists) exceeding 125 µm whereas the same dimension in *C. armata* usually does not exceed 93 µm (more commonly near 70 µm).

KOFOID (1910) created the species for one figure (an apical view only) erroneously included by MURRAY & WHITTING with figures of the taxon now known as *Gonyaulax ceratocoroides* KOFOID. GRAHAM did not find such large specimens and consequently considered that MURRAY & WHITTING may have made an error, omitting the species from his treatment of the genus.

In the "Anton Bruun" material there were quite a large number of specimens agreeing in size with *C. magna*, and there is consequently no doubt that they exist. Whether or not they deserve distinction from *C. armata* is another question which cannot be resolved as yet. The species has strong resemblances to *C. reticulata* GRAHAM, which is also large, reaching 114 µm in diameter but the latter is not as heavily marked and the antapex of the latter is not as wide as in *C. magna*, leading to a sharper angle subtended by the sides of the hypotheca to each other.

In its strongest development of thecal ornamentation, *C. magna* bears ridges which appear almost vermiform and the plates bear broad intercalary flanges which may cover much of the face of some of the plates (cf. TAYLOR 1973b, f. 6 c).

Stations: 13, 31, 32, 38, 49, 52–54, 57, 62, 66, 68, 69, 71, 87, 91, 92, 97, 100, 101, 103.

Considering the scarcity of records by other authors the species was surprisingly common in the Bay of Bengal/Andaman Sea area. It must be noted that, as *C. reticulata* was only distinguished from *C. magna* after the primary analysis was complete, some of these records may refer to *C. reticulata*.

The species was first described from the North Atlantic Ocean and has since been recorded apparently only by TRAVERS & TRAVERS (1965) and SOURNIA (1968b) from Tuléar in the Indian Ocean.

Ceratocorys reticulata GRAHAM Plate 26, Fig. 275; Plate 43, Fig. 510

– 1942:42, f. 55 A–D.

Vix SILVA 1955:174, t. 10, f. 5–7.

Non TAYLOR 1973b, f. 6 c [= *C. magna*].

This is a large species, rivalling *C. magna* in size (and possibly being confused with it at times). It can, however, be recognised as a separate species for the present on the basis of its size (length without spines 84–98 µm, diameter without lists 86–114 µm), its very regular, close reticulation (not quite as angular as shown by GRAHAM 1942) and the narrowness of the antapex which results in the walls of the hypotheca subtending a sharper angle to each other than in *C. magna*. It is similar in its plate arrangement to *C. armata*. There are three antapical spines although SILVA (1955) reported four antapical spines, her figure being difficult to assign to this species because of lack of detail.

Station: 51.

A single specimen was found in the northern Bay of Bengal.

GRAHAM (1942) found it in both the Atlantic and Pacific Oceans in water above 20 °C. SILVA's (1955) record from Angolan waters is doubtful. She has also (1956a) recorded it from the Mozambique coast.

Family Cladopyxidaceae LINDEMANN

BALECH (1964c, 1967b) has redefined the zoological equivalent of this family (Cladopyxidae KOFOID), so that it now includes three genera: *Cladopyxis*, *Palaeophalacroma* and *Sinodinium*. The formula for the group is 3–4', 3–4^a, 7'', 6c, 5–6s, 6''', 2'''. The absence of girdle lists and the left-handed displacement are features which also unite the family. The genus *Micracanthodinium* DEFLANDRE has appendages similar to those of *Cladopyxis* but they are unbranched. It might also be assigned to this family. However the tabulation of its members has not been established as yet.

Genus *Cladopyxis* STEIN

Unlike the other members of this family *Cladopyxis* usually has three apical plates instead of four, and its most distinctive feature is the possession of elongate appendages, usually branched distally. *Micracanthodinium* DEFLANDRE is distinguished by the possession of very slender, simple appendages, lacking terminal branching. Several of the species listed under *Cladopyxis* by SCHILLER (1936) belong to DEFLANDRE's genus [e.g. *M. setiferum* (LOHMANN) DEFLANDRE (1937), *C. bacillifera* SCHILLER and probably *C. claytonii* HOLMES]. *C. quadrispina* PAVILLARD appears to be quite different, lacking a well-defined girdle and with only four spines in a sub-parallel arrangement. The latter species is of enigmatic systematic position.

A distinctive feature of the type species of *Cladopyxis* is the peculiar arrangement of the appendages, all of which arise in a single plane which lies at an angle to the girdle plane, highest on the dorsal side and lowest on the ventral side (see especially fig. 506). It might be possible to re-arrange the genera taking this feature into account, in which case KOFOID's rejected genus *Acanthodinium* might be recognised for those species in which the spines arise both dorsally and ventrally on the epi- and hypothecae. This is the case for one of the two species he originally described: *A. spinosum* KOFOID, but the other, described first, *A. caryophyllum* KOFOID, does not have this feature and is probably synonymous with *C. brachiolata*.

A curious feature of *C. claytonii* HOLMES is that the whole theca dissolves rapidly in a sodium hypochlorite solution, suggesting a possibility of further generic distinction based on the nature of the theca.

Cladopyxis brachiolata STEIN Plate 25, Figs. 255–259 a, b; Plate 43, Figs. 506–508
SCHILLER 1936:471, f. 541 a, b; RAMPI 1950c:246, f. 22; MARGALEF et DURÁN 1953:44, f. 13 k; GAARDER 1954:17, f. 17 a–j (vix b); TRÉGOUBOFF et ROSE 1957:118, t. 27, f. 14; HALIM 1960a, t. 2, f. 13; BALECH 1962b:166, t. 23, f. 364; – 1964c:28, f. 1–10; WOOD 1968:43, f. 100.

Syn.: *C. steinii* ZACHARIAS 1906:567, f. 20.

? . . . *C. caryophyllum* (KOFOID) PAVILLARD . . . SCHILLER 1936:470, f. 540; WOOD 1968:44, vix f. 101.

Cladopyxis sp., MARGALEF, HERRERA, RODRIGUEZ-RODA et LARRAÑETA 1954:92, f. 2 h.

This, the type species of the genus, has been described in detail by BALECH (1964c). GAARDER (1954) asserted that the degree of branching should not be a specific character in view of variability seen by her in North Atlantic material. Thus she believed that *C. caryophyllum*, in which the terminations of the processes are usually quadripartite, with fine "webbing" between the points, is synonymous with *C. brachiolata* in which the terminations undergo repeated branching. It had already been established by earlier authors that the tabulation of both taxa is the same. Cell division can undoubtedly influence the appearance of the cells, and probably accounts for the observation of individuals with less than five appendages, or possibly, those with less than ten. Also, in some cases one finds cells with spines in differing states of maturity (e.g. fig. 257). The small protuberance in fig. 259a may represent a new appendage beginning to develop. Fig. 256 illustrates a cell of the *C. caryophyllum* type. It can be seen that the whole cell is more robust than in the more-branched cells. The only cells observed with the scanning electron microscope were of this type.

When seen in side-view it can sometimes be seen that the postero-dorsal region protrudes from the rest of the cell body, being demarcated by a broad intercalary band (cf. BALECH 1964c, and figs. 506, 507 here).

GAARDER (1954) also included *C. spinosa* (KOFOID) SCHILLER in the synonymy of this species. However, as indicated in the introductory remarks to this genus, it was shown by KOFOID to have spines arising from precingulars 2'' and 7'', instead of being limited to 3'''–6'' on the dorsal side of the cell. It also appears to have spines on the dorsal side of the hypotheca, instead of only on the ventral side as in *C. brachiolata*.

Her suggestion probably arose from the observation of individuals similar to that in fig. 258 here. However, the latter are clearly different from *C. spimosa* and are probably immature forms of *C. brachiolata* in which all, instead of some of the spines are incompletely developed.

BALECH (1964c) has distinguished a species which is very similar to the small-bodied (length of body 26.5–35 μm), five-spined members of *C. brachiolata*, but has four small anterior intercalary plates instead of two very large ones and one smaller one. He called this species *C. hemibrachiata*. In a personal communication he has suggested that all five-spined individuals may belong to this taxon, but the few details of the tabulation of such specimens seen in this material do not seem to support this view.

The specimen figured here as fig. 255 had unusual tabulation, having several small supernumerary plates, one of which, to the right of the first apical plate, corresponds with one of the anterior intercalary plates of BALECH's species, leading to some doubt as to the permanence of these features.

Stations: 66, 70, 71, 99, 103, 109, 142, 299, 302, 305, 306, 312–315, 317, 318, 320, 332, 334.

GAARDER (1954) found that her specimens occurred only in the warmest parts of the North Atlantic Ocean. However, in the South Pacific Ocean BALECH (1962b, 1964c) found the species between 25 °S and 35 °S. In the "Anton Bruun" material, although it occurred at a few stations both in the Bay of Bengal and the Arabian Sea, it was widespread and common between 10 and 33 °S during cruise V (chiefly in March), the only period at which it occurred south of the equator. Its maximum abundance was at station 313, close to 30 °S, being one of only a few species which increased in abundance near the Subtropical Convergence Region.

The robust specimens corresponding to *C. caryophyllum* were restricted to the southern stations on the 75 °E meridian, co-occurring with the slender, more-branched forms. The smallest cells occurred at warmer stations.

Genus *Palaeophalacroma* SCHILLER

The detailed thecal study of *P. uncinatum* by BALECH (1967b) has revealed that its plate structure shows considerable affinities with the genus *Cladopyxis*, its name being misleading with regard to its systematic position. The plates of the smaller members attributed to the genus have not been determined as yet. The upper girdle edge is more prominently developed than the lower edge, the latter being poorly defined in two of the species. This is very similar to the subgenus *Sphaerodinium* of *Heterodinium*. BALECH has indicated that *Peridinium herbaceum* SCHÜTT is probably a member of *Palaeophalacroma*, making the appropriate combination.

Palaeophalacroma sphaericum sp. n. Plate 25, Figs. 261 a, b

The cells are small and approximately isodiametric (length 20 μm , transdiameter 18 μm), the surface of the theca being marked by only a few prominent ridges and scattered poroids. The girdle is demarcated only by an upper ridge showing distinct left-handed displacement at the flagellar pore site. The first apical plate and the apical pore are defined by ridges, more strongly developed on the right than on the left side. The ventral area is also bounded by ridges on both sides. It extends two thirds of the distance from the girdle to the antapex. It is narrow throughout its length.

Other plate details could not be determined. However these features are sufficient to indicate a similarity to *P. verrucosum* SCHILLER (fig. 260) and at the same time, permit distinction of the two taxa on the grounds of the more rounded shape and greater development of ridges associated with the apical plate and ventral in *P. sphaericum*. Some of the smaller cells attributed to *P. uncinatum* by SCHILLER (1931) may have been this taxon, his species now being interpreted in a distinctly different manner by BALECH (1967b; see below).

Type locality: Station 161, west of the island of Mauritius (two specimens).

Palaeophalacroma verrucosum SCHILLER Plate 25, Figs. 260 a, b
SCHILLER 1931:48, f. 49 c.

This species, not seen previously except by SCHILLER, is small, being similar in size to *P. sphaericum* sp. n. (length 18–28 μm , transdiameter 16–22 μm) but it is more ovoid in shape. The specimen observed here had a flattened antapex although this feature was not included in the original description. A further distinction between the two species is that in *P. verrucosum*, although the upper girdle ridge is clearly developed, the ridges associated with the first apical plate (apparently

very narrow) are difficult to see, and on the hypotheca there is only a single ridge passing towards the antapex to the left of the flagellar pore.

In both species the only other visible thecal structures are scattered poroids, thought by SCHILLER to project as small bumps in the case of *P. verrucosum*.

Station: 156.

A few specimens were found near 30°S in the southern Indian Ocean. The species was originally found in the Adriatic Sea and SCHILLER states that it was also found by HENTSCHEL in tropical waters of the Atlantic Ocean. There are no previous Indian Ocean records of the species.

Palaeophalacroma? sp. Plate 25, Figs. 262 a–c

A puzzling specimen was found which appears to be intermediate between *Cladopyxis* and *Palaeophalacroma* in several respects. BALECH (1967b) has shown that, in addition to the possession of processes, *Cladopyxis* also differs from *Palaeophalacroma* in the number, size and shape of certain plates. The present specimen has a plate arrangement more similar to that of *Cladopyxis* than *Palaeophalacroma* although its lack of processes precludes inclusion of it in the former genus, and its large body (length 45 µm, transdiameter 36 µm) exceeds that found in members of *Cladopyxis*. It has a superficial resemblance to *Palaeophalacroma uncinatum* SCHILLER (= *Heterodinium detonii* RAMPI 1943b, and possibly *Epiperidinium michaelsarsii* GAARDER 1954). However, in addition to being larger, the first apical plate was broader, there were only three apical plates (not all shown in the figure) instead of four, the right sulcal plate is short in the apical axis, and the posterior sulcal plate is large and posteriorly pointed, cell features resembling *Cladopyxis*.

Station: 155.

One specimen was found to the south of Mauritius.

Family Gonyaulacaceae LINDEMANN

Genus *Alexandrium* HALIM

This genus was proposed for a small species, *A. minutum*, producing red water near Alexandria, Egypt (HALIM 1960b). At the time of description it was not distinguishable from *Pyrodinium* on the basis of primary plate pattern, although HALIM compared it only to *Glenodinium*. As with earlier authors dealing with *Pyrodinium*, HALIM did not recognise the essential homology of the small plate next to the sulcus, termed by him a ventral accessory plate, with the small, so-called first precingular plate of *Gonyaulax*. HALIM's analysis of the sulcal plates differs from *Pyrodinium* and *Gonyaulax*, but apparently through incomplete dissection (see text fig. 1).

In fact this species has a primary plate pattern very similar to *Gonyaulax monilata* HOWELL, the plate corresponding to the gonyaulacoid first apical plate not reaching the apical closing platelet (the arrangement provisionally designated as 3 + 1' here).

It is suggested that both of these, plus another species, be transferred to the genus *Pyrodinium* (see under the latter for the resulting new combinations).

Much of the confusion that surrounds these taxa arises from a lack of recognition of plate homologies within the gonyaulacoid genera. A possible basic thecal pattern from which various genera may have developed has been presented elsewhere (TAYLOR 1976). Text figure 1 illustrates the similarities in basic pattern between *Heteraulacus*, *Alexandrium*, *Pyrodinium* and *Gonyaulax*.

Genus *Amphidoma* STEIN

The hypotheca of members of this genus is identical to that of *Gonyaulax*, possessing an asymmetrically placed posterior intercalary plate. However the epitheca is unlike any other member of the family. It has six apical plates and no anterior intercalary plates. The first apical plate is slender. BALECH (1971b) could find only three sulcal plates in *A. nucula* (below).

The only previous record of a member of this genus in the Indian Ocean is SOURNIA's (1972a) discovery of *A. acuminata* STEIN.

Amphidoma nucula STEIN Plate 25, Fig. 263

SCHILLER 1935:316, f. 332 a-d; SILVA 1955:154, t. 6, f. 1, 2; BALECH 1971b:35, t. 9, f. 168-174.

Syn.: *Murrayella spinosa* KOFOID 1907b:192, t. 9, f. 57.*Amphidoma spinosa* (KOFOID) KOFOID et MICHENER 1911:275; SCHILLER 1935:316, f. 333.*Gonyaulax rouchii* RAMPI 1948:4, f. 4.

This species has recently been subjected to detailed thecal analysis by BALECH (1971b). Its biconical shape is somewhat variable, the hypothecal pole sometimes appearing smoothly confluent with the central part of the cell, at other times (as here), more abruptly formed. The antapex can bear a small spinelet. The length varies from 30 to 50 μm .

A. steinii SCHILLER is very similar to this species but possesses linearly arranged pores and lacks any distinct antapical projection. In *A. acuminata* STEIN and *A. elongata* KOFOID et MICHENER the antapex is more drawn out, although one of the specimens included under *A. nucula* by BALECH approaches them in its hypothecal extension. *A. caudata* HALLDAL is distinctly different, with a conical epitheca, shallow, rounded hypotheca, and a well-developed antapical caudate process. In the absence of original or contemporary figures of the several other species described by KOFOID & MICHENER (1911), further comparisons are difficult.

Station: 327.

Only one cell was observed in a sample from near the southern tip of India. The species is known from the warmer waters of the Atlantic Ocean and the Southern Ocean. It has not been previously recorded from the Indian Ocean.

Amphidoma sp. Plate 25, Fig. 264

BALECH (1971b) has emphasised the variability in shape of *A. nucula* STEIN and, taking his comments into consideration, the illustrated specimen may correspond to a form in which the hypothecal projection blends smoothly with the broadest part of the cell. It shows a resemblance to STEIN's type figures, but the latter are too stylised to permit a detailed comparison. The specimen did not possess an antapical spinelet. The surface markings were fainter than in the specimen in fig. 263. It is smaller (length 24 μm , transdiameter 15 μm) than the size range usually given for *A. nucula*, being similar in size to *A. obtusa* KOFOID et MICHENER. The apical plate features for the latter do not agree with the present specimen, the precingular plates being described as shorter than the apical plates other than apical 1'. The specimen figured by WOOD (1963b, f. 135) may be this taxon, being similar in shape, but no size data or ventral details were provided by him.

Station: 374.

A single specimen was found near the southern African coast south of the Mozambique Channel.

Genus *Gonyaulax* DIESING[*Goniaulax* auct. nonnull.]Syn.: *Acanthogonyaulax* GRAHAM 1942:52.*Amylax* MEUNIER 1910:51.*Roulea* GOURRET 1883:63, 86.*Steiniella* SCHUTT 1895:151.*Spiniferites* MANTELL 1850:191; 1854, text figs. 77-79.*Hystriosphera* WETZELL 1933:136 (nom. nud.).

Although many of the species of this ecologically important genus are well characterised, the limits of the genus itself are more difficult to set. As can be seen from Table 3 there are several genera recognised at present which have plate formulae similar to that of *Gonyaulax*.

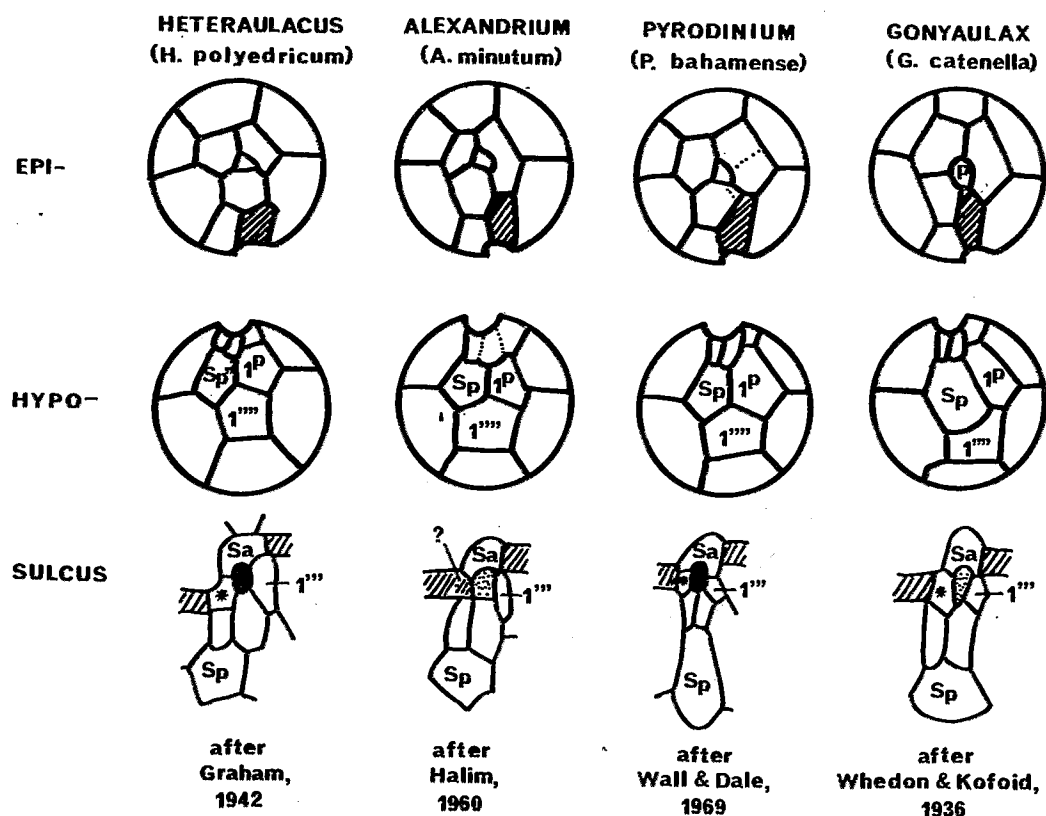
The usual, primary character of a left-handed (descending) displaced girdle is a useful criterion when combined with the plate formula. Furthermore, another feature associated with most species of *Gonyaulax* is a pronounced asymmetry in the development of the various posterior plates (Text fig. 1), probably related to the girdle distortion. Thus it appears that the plate customarily designated as the posterior sulcal plate (Sp), which is usually strongly developed in *Gonyaulax*, may be a homologue of a plate usually termed an antapical plate (as in *Heteraulacus*, which was considered to have three antapical plates by most authors until recently). From Text fig. 1 it can be seen that there seems to be a gradual transition between the Sp, 1P, 1''' arrangement and that formerly designated as 3''' (cf. TAYLOR 1976 for a more detailed account).

Table 3. The plate formula of *Gonyaulax* and related genera (contemporary, uniform interpretation).

<i>Gonyaulax</i>	P	3-4'	0-4 ^a	6''	6C	5-10S	5-6'''	1P	1''''
<i>Protoceratium</i>	P	3'	1 ^a	6''	6C+t	9S	5'''	1P	1''''
<i>Alexandrium</i>	P	3+1'	0 ^a	6''	6C(+t)	5-7S	6'''	1-2P	1''''
<i>Fragilidium</i> **	P	4'(+1'?)	0 ^a	9''(8''?)	12C	8S	7'''	1P	1''''
<i>Spiraulax</i>	P	4'	1 ^a	6''	6C	6S	6'''	1P	1''''
<i>Pyrodinium</i>	P	3+1'	0 ^a	6''	6C	6S	6'''	1P	1''''
<i>Peridiniella</i> *	P	4'	3 ^a	7''	6C	?	6(5?)'''	1P	1''''
<i>Heteraulacus</i>	P	3'	0 ^a	7''	6C	5S	6'''	1P	1''''
<i>Ceratocorys</i>	P	3'	1 ^a	5''	6C	5-10S?	4-6'''	1P?	1''''
<i>Pachydinium</i>	P	3'	0 ^a	5''	?	3S	5'''	0P	3''''
<i>Amphidoma</i>	P	6'	0 ^a	6''	6C	3S?	6'''	1P	1''''

* This genus was not figured by its originators (KOFOID & MICHENER 1911) and has not apparently been seen by others since its description. The number of postcingular plates was tentatively given for the type species. In another species to be described from the Andaman Sea elsewhere by this author only five postcingular plates are present.

** In comparing this genus with *Gonyaulax* it seems evident that BALECH's 2'''' is a homologue of the Sp, 1'''' corresponds to the usual 1P, and p is the 1'''' of *Gonyaulax*. Furthermore, his 7''' seems to correspond to a right sulcal plate. His twelfth girdle plate could also be considered a sulcal plate corresponding to that asterisked in text fig. 1, but here it is left as a girdle plate.



Text fig. 1. Plate patterns of three gonyaulacoid taxa and a possible relative (plate designations homologised).

* There are at least two or three further small sulcal-plates in the vicinity of the flagellar pore. The plate asterisked has been termed a "transitional plate" but, comparing it to the plates of *Peridinium*, it evidently corresponds to the "right accessory sulcal plate" of GRAHAM (1942).

The recognition of various parasystematic "series" within the genus has persisted since first introduced by KOFOID (1911a). The clusters of species should be either accorded the formal status of subgenera, or be raised to the level of genera. The former course seems wiser until more species have had their plate structure more fully elaborated and until their life-cycles are better known. Cyst types may prove to be useful in group recognition. At present these are known to embrace several distinctive types including smooth-walled cysts, cysts with low ridges, cysts with numerous short spines, and "hystriospheraid" cysts with a fixed number of long, branched projections corresponding to the plate arrangement of the parent theca (see WALL 1970, 1971a for a review of these types and the fossil genera they correspond to). Archeopylar (excystment pore) position and features may also be useful. For example, WALL & DALE (1969) have advocated the continued distinction of *Pyrodinium* from *Gonyaulax* partly on archeopylar features. WALL (1970) has suggested that the genus may have to be subdivided in view of the dissimilar cyst types present.

At present it appears that the generic name *Gonyaulax* DIESING (1866) may not have strict priority, as it is known that the genus *Spiniferites* MANTELL (1850, 1854) was created for fossil forms, some of which are known to be cyst stages of members of *Gonyaulax*. If it could be established that the type of *Spiniferites* [designated as *S. ramosus* (EHRENBERG) MANTELL by LOEBLICH & LOEBLICH, 1966] corresponded to the resting stage of a species of *Gonyaulax* then the former genus would have priority. However, it is apparently extinct and such evidence, other than by inference from living species, is not likely to be forthcoming. It should not be difficult to make a case for the conservation of *Gonyaulax* DIESING against *Spiniferites* MANTELL under the circumstances, although an attempt by SARJEANT (1964) to conserve *Hystriosphera* against the latter has been opposed (LOEBLICH & TAPPAN 1967) and rejected (SARJEANT 1970).

In the genus *Pyrocystis*, as recently emended (TAYLOR 1972a), the cyst stages form the dominant phase of the life-cycle, gonyaulacoid motile cells existing for less than a day (SWIFT & WALL 1972). This genus is at present united with *Dissodinium* in a separate family, the Pyrocystaceae, but the latter is probably at least diphyletic, and should be discarded.

The first authors to study the ventral area in detail appear to be GRAHAM (1942) and NIE (1947), but the latter's paper was only an abstract. He reported finding six sulcal plates in *C. diegensis*, *C. digitale*, *G. spinifera*, and *G. monacantha* but he did not illustrate their formation. Unlike *Peridinium*, *Gonyaulax* appears to be rather variable in the number and arrangement of sulcal plates although the large, curved anterior sulcal plate and the large posterior plate appear to be fairly constant.

Gonyaulax areolata KOFOID et MICHENER Plate 35, Fig. 408
— 1911:270; SCHILLER 1935:278.

The recognition of this species is difficult in view of the lack of a figure accompanying the original description. SCHILLER merely translated KOFOID & MICHENER's diagnosis into German. He did, however add a distributional detail (see below).

The present designation is based on visual reconstructions of KOFOID & MICHENER's descriptions (see also *G. minuta*, *G. pavillardii*, and *G. subulata* here). In this case the fit appears to be reasonably good. The specimen here was a bit smaller (length 34 μm instead of 40 μm). The apical horn was here opened, apparently due to ecdysis. One possible distinction between this specimen and that of KOFOID & MICHENER is the suspected presence of an anterior intercalary plate on the right ventral surface of the epitheca. However, this could not be clearly determined in the present specimen and could thus perhaps have been overlooked by KOFOID & MICHENER if indeed, it is a separate plate from the apicals. Ribs were not evident on the girdle lists. The antapical spines were not strongly developed here. They are apparently outgrowths from the margin of the ventral area. The girdle displacement is approximately one girdle width and the ends do not overhang one another. The surface of the plates is densely covered with small areolae (reticulae?).

Station: 365.

A single specimen was found in the vicinity of Tuléar, southern Madagascar. SCHILLER (1935) has recorded the species from the Indian Ocean but he did not provide any details other than "Indik". This record was omitted by WOOD (1963a). There do not seem to be any further records other than the original description from the equatorial Pacific Ocean.

Gonyaulax brevisulcatum DANGEARD Plate 36, Figs. 411–413
— 1927b:338, f. 5 a, b; SCHILLER 1935:279, f. 282 a, b.
Syn.: *Gonyaulax* spec. PAULSEN 1930:39, f. 24.
G. paulsenii GAARDER 1954:25, f. 28 a–d.
Vix *G. borealis* NORDLI 1951a:53, f. 6 a–f.

A fairly large (diameter 58–78 μm); distinctive spherical species which has, however, caused confusion, due to an apparent tendency towards plate pattern variability. Also, early figures of the species were poorly drawn. In fact, in this interpretation it is assumed that DANGEARD's (1927b) iconotype is optically reversed as, although he assigned it to *Gonyaulax* [which is characterised by left-handed (descending) displacement] he figured it as having a right-handed displacement. Optical reversals are common in the work of earlier authors and the danger is still prevalent, usually resulting from focussing through the specimen.

The species is worthy of note, for its epitheca is rather peridinoid in plate arrangement, with its three symmetrically arranged anterior intercalary plates (not shown here; see GAARDER 1954), but the hypothecal plates are typically asymmetrical in the manner distinctive for *Gonyaulax*. The greatest variability, if the interpretation here is correct, involves the sutures which normally attach on either side of the first apical plate (between the apicals and precingulars). Although these usually insert approximately mid-way between the girdle and the apex, in one specimen found here these were entirely lacking (fig. 413). GAARDER (1954) has given the plate formula of *G. paulseni* as (P), 4', 3^a, 7'', (? C, ? S), 6''', 1P, 1''''.

A further distinctive feature is the horse-shoe-shaped ridge, open to the ventral side, which surrounds the apex of the cell. It is difficult to see a distinct apical closing platelet in the area endorsed by the ridge. This ridge may serve as a convenient identification aid.

The species nearest to *G. brevisulcatum* seems to be *G. sphaeroidea* KOFOID. The latter is smaller (diameter approximately 30 μm), lacks the apical ridge, and has unusually expanded antapical portions of the sulcal lists, similar to those in *Diplopsalis*. A narrow plate which lies along the right margin of the apical plate is unusual and might be considered either another apical plate or an anterior intercalary plate (see BALECH 1962b). It is also strongly porulated, the porulae being fairly evenly spaced apart. In *G. brevisulcatum* the pores are delicate, close-set, and difficult to see under routine conditions. GAARDER's (1954) specimen described as *G. sphaeroidea* may have been *G. brevisulcatum* as it was 65 μm in diameter and had an apical eminence. She did not show epithecal plates other than the first apical plate.

NORDLI (1951a) figured a peculiarly-shaped cyst within the cells he termed *G. borealis*. The cysts resembled *Peridinium trochoideum* in general shape. A cyst was observed within one of the cells here although it did not have a peridinoid shape. It was much smaller than the mother cell. The chief distinction of the mature *G. borealis* theca seems to be its much smaller size (diameter 22–28 μm). Its plate pattern is almost identical to that given by GAARDER (1954) for *G. paulseni*. It occurs in colder waters. It may be a boreal infraspecific variant.

This taxon also shows a very strong resemblance to *Peridinium globosum* DANGEARD (1927a, commented on also by GAARDER 1954). The latter differs apparently in lacking girdle displacement and the apical ridge. The specimen figured here as fig. 412 particularly resembles the latter, but it has a displacement of approximately one girdle width. It has the apical ridge but because this is shifted more towards the ventral side it is not obvious in ventral view. The antapical view given by DANGEARD apparently shows two antapical plates unequal in size. However, such a figure, if incomplete, could be reconciled with NORDLI's gonyaulacoid hypotheca. A further difference is that although these anterior intercalary plates are present in both, they are displaced to the left side in *P. globosum*. The most difficult feature to account for is that one author would create two taxa in different genera for the same species.

In summary, the variability shown by the "Anton Bruun" specimens suggests the possibility that several taxa previously thought to be distinct may in fact, be the same, even including one assigned to *Peridinium*.

Stations: 94, 96, 98, 301.

Found at three closely-situated stations in the Bay of Bengal and one station near Mauritius. Only a few cells were seen in each sample. DANGEARD found both *G. brevisulcatum* and *P. globosum* in the eastern tropical Atlantic Ocean. MATZENAUER (1933) has recorded *G. sphaeroidea* from the Indian Ocean, but the present taxon does not appear to have been recorded from the Indian Ocean in any of its guises. However, THORRINGTON-SMITH (1969) has recorded *P. globosum* from the vicinity of Durban. It is probably a tropical, inter-oceanic species.

Gonyaulax bruunii sp. n. Plate 35, Figs. 409 a–d
 BALECH 1971b:27, t. 7, f. 125–129 sub "*G. monacantha* minor PAVILLARD?"
 Vix PAVILLARD 1916:22, t. 1, f. 8.

A small, rotund species with well-developed apical horn and strong, slender, single antapical spine arising from the right posterior margin of the posterior sulcal plate. Girdle displaced from one to two girdle widths; left-handed (descend-

ing). Plates marked only by pores. Thecal component occupying the usual first apical plate position divided into two plates by a median suture passing from the girdle to the apex. Sixth precingular plate is triangular. First post-cingular plate is small, narrowly rectangular. Posterior intercalary plate not extending as far towards the antapex as the posterior sulcal plate. Girdle and sulcal regions demarcated by strong ridges, other sutures weakly marked.

Length (without spine): 30–36 μm ; diameter 20–26 μm (includes BALECH's 1971b size data).

Plate formula: 4', 6'', 6C, 5(?)S, 6''', 1P, 1''''.

Iconotype: Plate 35, fig. 409 a–d.

Type locality: Station 404. Western Mozambique Channel, Indian Ocean.

Named for Anton Bruun and similarly for the vessel which made the cruise during which the species was discovered.

This is undoubtedly the same organism that was recently figured and described by BALECH (1971b) from the equatorial Atlantic Ocean. He also found that the plate usually considered as the first apical plate was divided into two moieties and BALECH's observations can be used to augment those given here. However, the specimens are so alike as to provide little information on variability. This agreement in appearance, combined with being apparently the only species of *Gonyaulax* to possess a divided "first apical plate", seems to be more than sufficient for the creation of a new species. There are resemblances to *G. monacantha* PAVILLARD (not present in the material) which is probably closely related, and also to *G. subulata* KOFOID et MICHENER (see comments under that species here).

The suture observed to subdivide the first apical plate is also reminiscent of the appearance of *Ensiculifera mexicana* BALECH (1967a) in which it was discovered, however, to be due to the presence of a long, delicate spine projecting from a plate in the ventral area. *Ensiculifera* seems to have a strongly peridinoid plate arrangement, including symmetrically developed antapical plates. The type species, *E. mexicana*, lacks an antapical spine.

Station: 404.

Two specimens were observed in material from a single station off the coast of Mozambique in the western Mozambique Channel region. BALECH (1971b), as indicated, found his specimens in equatorial Atlantic Ocean waters.

Gonyaulax ceratocoroides (MURRAY et WHITTING) KOFOID Plate 35, Fig. 410; Plate 44, Figs. 515, 516

SCHILLER 1935:309, f. 321 a–c; WOOD 1963c:13, f. 47; – 1968:57, f. 144.

Syn.: *Ceratocorys spinifera* MURRAY et WHITTING 1899:329, t. 30, f. 6 a, b, e non c vix d.

Acanthogonyaulax spinifera (MURRAY et WHITTING) GRAHAM 1942:53, f. 64 A–E; 65; BALECH 1962b:163, t. 22, f. 357, 358.

In the introductory comments to *Gonyaulax* it was indicated that, as a result of scanning electron microscopy, GRAHAM's (1942) claim that the taxon has 9 precingular plates is doubted. Thus the chief grounds for recognising the taxon as a separate genus fall away. Some of the results of scanning microscopy are given here on plate 44.

The species is highly distinctive in view of its well-developed fins and spines arising from the margins of the hypothecal plates. In these respects it mimics the genus *Ceratocorys* but it does not have a similar plate pattern. The scoop-like ventral-antapical opening of the sulcus is also unusual, resulting from the strong growth of the fins.

Stations: 16, 17, 52, 58, 60, 64, 99, 100, 103, 417.

Common at scattered stations in the Andaman Sea and Bay of Bengal. It was also present at one station off the east coast of Africa.

As it was not particularly rare in the Bay of Bengal material it is strange that the only previous Indian Ocean record is that of TAYLOR (1967). It is known from the type locality: the tropical Atlantic Ocean (also from the Mediterranean Sea), and from the Pacific Ocean. It is probably limited to warm-temperate to tropical waters.

Gonyaulax diegensis KOFOID Plate 35, Fig. 400

SCHILLER 1935:281, f. 285 a–i; WANG 1936:148, f. 21; RAMPI 1943a:319, f. 1; SILVA 1949:342, t. 5, f. 4; – 1952a, t. 2, f. 10; KISSELEV 1950:220, f. 389 a–d; MARGALEF et DURÁN 1953:33, f. 8 a–c; WOOD 1954:259, f. 164; – 1968:58, f. 148; HADA 1967:16, f. 27 B.

This is a distinctive, common species in many parts of the world, most similar to *G. digitale* KOFOID. It can be recognised by its more rotund shape, especially of the body of the epitheca and by the apparently invariable presence of non-reticulated margins to the plates. These are apparently not intercalary zones. The latter may be present in addition to the marginal zones. KOFOID (1911a) considered that a further distinction was a small fourth apical plate (in *G. digitale* there

are only three apical plates). A small plate was seen in the position of 4' in the present specimens, confirming the possibility of using this distinguishing feature.

Station: 35.

Found at only one station in the Andaman Sea.

It is, however, one of the more eurythermal species of the genus, being more common in temperate than in tropical waters. It has been recorded previously from the Indian Ocean by WOOD (1954, 1962 in 1963a), SUBRAHMANYAN (1958), SILVA (1956a, 1960) and TAYLOR (1967).

Gonyaulax fragilis (SCHÜTT) KOFOID Plate 36, Fig. 420

SCHILLER 1935:305, f. 316 a-h vix i; KISSELEV 1950:225, f. 394.a-2; WOOD 1954:260, f. 166; - 1968:58, f. 150. Vix RAMPI 1943a:325, f. 13 (*G. byalina?*); MARGALEF et DURÁN 1953:35, f. 8 n (*G. byalina?*); SILVA 1956a:66, t. 11, f. 10 (*G. byalina?*); BALECH 1962b:159, t. 22, f. 351 (*G. byalina?*).

This species is very similar to *G. inflata* and *G. byalina* and has probably been confused with the latter on several occasions. Seen in full ventral view the shape is distinctive, being oval with a rounded convex antapical profile (the specimen figured here is seen somewhat apically, the sulcal depression producing a bilobed antapical appearance). Although ostensibly this species could be distinguished from *G. inflata* in having three plates instead of one this distinction is doubted (see also under *G. inflata*). In fact it appears that *G. fragilis* and *G. inflata* have very similar apical plates. The first apical plate is very narrow and lies in a mid-ventral groove. Apicals two and three are situated rather symmetrically to the left and right of the elongate, well developed apical closing platelet which extends well into the dorsal surface, whereas in *G. byalina* there is a narrow plate extending down the right side of the first apical plate, making an additional fourth apical plate.

The surface markings on *G. fragilis* and *G. inflata* are very similar, with strongly developed reticulation bearing short spines at the reticular junctions on most plates. On the apical plates this is apparently reduced to short, disjunct ridges arranged in semiparallel or radiating rows. The latter structure may, however, be an immature developmental state. This author has not seen regularly parallel ridges such as those figured by SCHILLER (1935, f. 316 i), RAMPI (1943a, fig. 13), SILVA (1956a, fig. 10), or BALECH (1962b) on any specimens. Indeed, such markings, combined with a relatively broader shape, might be considered one of the distinguishing features of *G. byalina* from *G. fragilis*. The iconotype of SCHÜTT did not show any parallel ridges on *G. fragilis*. If the above authors are correct in their inclusion of linearly marked specimens, then fig. 420 here may be a small specimen of *G. inflata*. These species are evidently too imperfectly known to permit a sound decision at present, but these assignments seem the most reasonable to this author.

Stations: 301, 311, 313.

Found at only three stations; one near Mauritius and the others in the south-central region.

If SILVA's (1956a) record from Mozambique is transferred to *G. byalina* then this species has only been previously recorded from the Indian Ocean by WOOD (1962, in 1963a). The world distribution of this species is uncertain because of possible confusion with *G. byalina*. However, it is probably an inter-oceanic species and is restricted to tropical or warm temperate waters.

Gonyaulax fratercula BALECH Plate 35, Fig. 392

- 1964b:31, t. 4, f. 47-58; TAYLOR 1975:114, f. 8 a-e.

Vix *G. catenella?* sensu KLEMENT 1964:352, t. 2, f. 2.

This species is one of a group of closely similar chain-forming members of *Gonyaulax* (others are *G. catenella* WHEDON et KOFOID, *G. cobortricula* BALECH, *G. conjuncta* WOOD) or non-chain-formers [*G. acatenella* WHEDON et KOFOID, *G. tamarensis* LEBOUR which are nevertheless frequently found in pairs or fours. All appear to have identical plate formulae: P, 4', 0^a, 6", 6C, 7S+t, 6'''', 1P, 1'''' and differ in the size and shape of particular plates (see also comments here under *Alexandrium* for other species also very similar but which have a 3 + 1' arrangement). The distinction of these species has been extensively discussed by BALECH (1964b, 1967a, 1971b), STEIDINGER (1971) and TAYLOR (1975).

G. fratercula is intermediate in size, with a length of 32-49 µm and a diameter of 29-47 µm. It is smaller in length than *G. cobortricula* (48-55 µm) although there is an overlap in the diameters of the cells (41-47 µm). In ventral view they can be most readily distinguished by the shape of the anterior sulcal plate. In *G. fratercula*, as with many others of this group, the upper (apical) surface of the anterior sulcal plate curves in a smooth arc, indenting the epitheca with a con-

cave notch. In *G. cohorticula* the anterior sulcal plate deeply and rectangularly indents the epitheca, lacking the curving profile of *G. fratercula*. "Curtain-fin" development (closing the girdle), shown in *G. fratercula* by BALECH, is known to be a variable phenomenon (TAYLOR 1975).

Gonyaulax catenella is similar in size but is usually flattened rather than isodiametric. It is for this reason (combined with size data) that KLEMENT's specimens from the Gulf of California are tentatively attributed to *G. fratercula* although plate information on his specimens is lacking.

G. conjuncta WOOD is problematic because little information regarding the plate pattern was provided in the original description, and no indication whatever of size. In a later work (WOOD 1968) he gave the cell length as 25 μ . BALLANTINE (1961) figured and described specimens which she attributed to *G. conjuncta* but her specimens from Zanzibar were 50–63 μ m in length (equal to breadth). In view of this confusion WOOD's taxon is difficult to assess.

G. acatenella is also similar to *G. fratercula*. However, in addition to differences in the apical plates (especially 3' and 4') the epitheca is higher than the hypotheca in *G. acatenella*. The latter has been found to produce paralytic shellfish poison and to vary in the degree of development of pigmentation (PRAKASH & TAYLOR 1966).

It is possible that HALIM's (1967) specimens of *G. tamarensis* var. *excavata* from the coast of Venezuela were, in fact, *G. fratercula*, but insufficient information is available to determine this.

Stations: 16, 29, 36, 38.

A few short chains were observed at four stations, all within the Andaman Sea.

The species was originally described from the Mar del Plata in the western South Atlantic Ocean. It does not appear to have been recorded from elsewhere as yet.

Gonyaulax fusiformis GRAHAM Plate 36, Figs. 421, 422
– 1942:50, f. 63 A–G.

This is a rare tropical species, readily identifiable by reference to GRAHAM's detailed plate description. At first sight it might be confused with *Spiraulax jolliffei*, as it is similar in its biconical, fusiform shape. It is, however, more slender. Like *S. jolliffei* there is a large rectangular anterior intercalary plate on the right ventral face of the epitheca. However, there are two intercalary plates in *G. fusiformis* due to an extension of the dorsally-situated second apical plate which surrounds the right side of the apical closing platelet, thus isolating it from plates on the right side near the apex. The easiest means of recognition however, is the presence of a long, narrow, bent first apical plate in *G. fusiformis* in the customary position, the genus *Spiraulax* being recognisable by the absence of a plate in this position. *G. birostris* has much more drawn out apical and antapical horns than *G. fusiformis*.

There is a strong resemblance between *G. acuta* KOFOID et MICHENER and *G. fusiformis*. They are very similar in size and shape, girdle and sulcal features. However, as with the other species of *Gonyaulax* described by KOFOID & MICHENER (1911) a figure of their species is lacking. Consequently, their statement that there are three apical plates and no anterior intercalary plates can only be taken literally. These features can then, theoretically, serve to distinguish the species.

Stations: 33, 62, 67, 68, 103.

Found in small numbers at one station in the northern Andaman Sea and four in the western Bay of Bengal.

This species does not seem to have been found previously in the Indian Ocean. It is known from the tropical Atlantic and Pacific Oceans and appears to be relatively stenothermal and tolerant of low phosphate values (GRAHAM 1942).

Gonyaulax glyptorhynchus MURRAY et WHITTING Plate 35, Fig. 404
SCHILLER 1935:301, f. 310 a–c.
Vix WOOD 1954:260, f. 167.

This is an extremely rarely observed species although it is possible that it has been confused with the closely similar species, *G. bigblei* MURRAY et WHITTING and *G. birostris* STEIN which have been found more frequently. It is similar to *G. bigblei* in size but can be distinguished, according to the original descriptions, by the lack of girdle reticulæ in *G. glyptorhynchus* and the smoothly spinous nature of the antapical horn in *G. bigblei*. The antapical horn is hirsute in *G. glyptorhynchus*.

The main distinction between *G. birostris* and this species is the considerable difference in size. The cell body length (excluding processes) is 32–40 μm , the diameter being 23–30 μm (a combination of MURRAY & WHITTING's size information and that found here), whereas *G. birostris* is usually described as almost twice the size. For this reason WOOD's figure (above) is questioned. No size was given by him and his figure lacks a magnification. However, it is drawn almost identical in size to a figure labelled as *G. birostris*. His figures do not illustrate any clear distinction between the specimens. In a later publication (WOOD 1968) he suggested a possible synonymy between *G. birostris*, *G. bigblei*, and *G. glyptorhynchus*.

From KOFOID & MICHENER's (1911) description (no figure, but see below) *G. subulata* is also similar to *G. glyptorhynchus*. It differs most obviously in that the antapical spine is short and subulate (narrow, sharply-pointed) and the apical horn is shorter in relation to the body. Its body dimensions are similar to those of *G. glyptorhynchus*.

As with many other of MURRAY & WHITTING's figures the iconotypes are upside down. This can be readily determined by the position of the oval ventral area. Also, the apical plates were shown apparently after ecdysis as they are here. Future studies should further elucidate the relationships with *G. bigblei* and *G. birostris*. RAMPI (1952b) has provided a reasonably detailed analysis of the latter.

BALECH (1962b) considered that *G. glyptorhynchus* was synonymous with *G. birostris* but on the basis of size they have been maintained as distinct here. His description corresponds to *G. birostris* STEIN.

Stations: 51, 130.

Only two specimens were seen: one in the northeastern Bay of Bengal and the other in the south-central Indian Ocean below 30°S. It has been previously recorded from the Indian Ocean by WOOD (1962, in 1963a), TAYLOR (1967), and SOURNIA (1968b, 1970). It is apparently a very rare inter-oceanic species, recorded relatively recently from the Atlantic Ocean by GAARDER (1954).

Gonyaulax hyalina OSTENFELD et J. SCHMIDT Plate 36, Figs. 415, 416, 418, 419

SCHILLER 1935:306, f. 318 a–c; WOOD 1954:264, f. 177.

[*G. fragilis* auct. nonnull.?]

This species, originally described from the Gulf of Aden, is similar to *G. fragilis* and *G. inflata* (see also comments under both latter species). It is readily distinguishable from them by its less narrow first apical plate, the presence of a slender fourth apical plate on the right ventral surface, and the strong, parallel longitudinal ridges passing over an otherwise delicately marked theca (secondary markings consist of delicate side ridges projecting at right angles to the primary ridges and pores). It usually has a broader shape, the specimen in fig. 415 being an exception. An apical view of a dissociated, delicately developed epitheca is shown in fig. 419. The fourth apical plate can be seen as a narrow rectangle, lacking markings other than peripheral ridges. From the original figures it appears that there may be an anterior intercalary plate situated on the right ventral side, but it may be obscured by the surface markings and could not be unequivocally demonstrated here. Its presence remains a possibility, however. As noted under *Oxytoxum*, *O. gigas* KOFOID shows some surprising resemblances to this species in its plate structure, and it may in future be transferred to the genus *Gonyaulax* if the arrangement of plates is in agreement with the latter.

Secondary spines projecting out from the margins of the postcingular plates were quite commonly observed (fig. 418). A further distinctive feature appears to be the lack of strong ridges on the large posterior intercalary plate as well as the sulcal plates, although this may vary developmentally.

The specimen in fig. 415 has a slender shape, also seen in smaller specimens. Individuals down to 44 μm in length have been found, the large cells exceeding 75 μm .

Stations: 29, 30, 33, 35, 37, 38, 43, 51, 54, 57, 60, 62, 71, 93, 100, 102, 114, 118, 142, 150, 315, 322, 328, 329, 412, 417.

This was one of the more widespread dinoflagellates in the material, particularly in the northern Indian Ocean and at all seasons. It has been previously recorded from the Indian Ocean by MATZENAUER (1933) and WOOD (1962, in 1963a).

SCHILLER's (1935) error, perpetuated by WOOD (1954), indicated a northern Atlantic Ocean distribution for this species. In fact, although it has been recorded from the Pacific as well as the Indian Ocean, it does not appear to have been found yet in the Atlantic Ocean. However, it is possible that some of the Atlantic Ocean (Gulf Stream) or Mediterranean Sea records of *G. fragilis* may refer to *G. hyalina*, in which case it is an inter-oceanic, warm water species.

Gonyaulax inflata (KOFOID) KOFOID Plate 36, Fig. 417

SCHILLER 1935:308, f. 319; RAMPI 1950a:7, f. 2; MUÑOZ, HERRERA et MARGALEF 1956:76, f. 1 m, n (sub *Gonyaulax* c.f. *inflata*);

BALECH 1962b:157, t. 22, f. 343–348.

Syn.: *G. pavillardii* DANGEARD 1927b:340, f. 6 b, c.

Non *G. pavillardii* KOFOID et MICHENER 1911.

G. dangeardii (DANGEARD) SCHILLER 1935:281, f. 284; WOOD 1968:57, f. 146.

G. sp. A. MARGALEF et DURÁN 1953:35, f. 8 t-v, x, y.

This is a large, tropical species. The specimens here assigned to this species were quite similar to those figured by KOFOID and BALECH but were broader antapically. KOFOID did not provide much on which to base comparisons but BALECH has given a detailed description. The identification here is based chiefly on its large size (length 80–165 μm), and conical epitheca, combined with a hypotheca with a flattened base usually, but not always, sloping more to the left. The surface of the plates is intensely reticulated with short spines on the hypotheca, the epitheca showing only short, parallel ridges in radiating patterns in the Indian Ocean specimens. An unusual specimen is figured here. It possessed a large bulge on the left side of unknown significance. Only one specimen was seen in this state. DANGEARD's (1927b) figure did not show the first postcingular plate or posterior intercalary plate. However, it is thought that these plates, so distinctive of *Gonyaulax*, were missed due to tilting of the specimen. Also, according to KOFOID (1911a) the species is supposed to have only one apical plate. However, it is here thought that four apical plates exist, an extremely reduced first apical plate lying within the narrow mid-ventral furrow, two symmetrically arranged large apicals lying to the left and the right of the apical closing platelet and a smaller dorsal closing plate. BALECH (1962b) also found four apical plates plus the apical closing platelets.

From supplementary observations made here an affinity with *G. fragilis* and *G. byalina* becomes evident. The surface markings are similar, and the extremely narrow first apical plate, demarcated by strong ridges is common to both. So also is the narrow, slit-like apical closing platelet extending well onto the ventral side, and the symmetrical appearance of the second and third apical plates (see comments here under *G. fragilis*).

Station: 286.

Three specimens were observed at one station near the Gulf of Aden.

This is a new record for the Indian Ocean under any of the names listed above. The species is known from the Atlantic Ocean, the Spanish coast, and the Pacific Ocean. It is probably an inter-oceanic, warm water species.

Gonyaulax kofoidii PAVILLARD Plate 35, Figs. 393, 394

SCHILLER 1935:285, f. 288; RAMPI 1943a:320, f. 4; SILVA 1949:343, t. 5, f. 8, 9; WOOD 1954:260, f. 168 a-c; — 1968:59, f. 151.

Although observed fairly often, this species has been only rarely illustrated. The occurrence of apical ecdysis is evidently common, the cec with apical plates gaping apart being often observed (as here, fig. 393, the specimen being almost identical to that of KOFOID 1911a, pl. 14, f. 30).

The species is perhaps most similar to *G. pacifica* (fig. 395) but it can be readily distinguished by its much smaller size (length without spine 90–110 μm , — 150? WOOD 1968), the more tapering shape of its hypotheca, a smaller degree of dorso-ventral flattening (considerable in *G. pacifica*), and closer set pores. There are numerous other differences, especially in the ventral region.

Due to a few instances when individuals were seen forming ecdysal cysts, and the co-occurrence of individuals of one cyst type in a sample with numerous cells of *G. kofoidii*, it was possible to describe the cysts formed by this species (fig. 394). The cyst wall is smooth with an apical projection and a slight trace of a girdle depression but no structure corresponding to the antapical spine (as is present on the cyst of *G. pacifica*, fig. 397).

Stations: 15, 41, 43, 54, 64 (cysts only at 37, 38, 47, 56).

Fairly common at stations in the Bay of Bengal (also at one station in the Andaman Sea).

The species has been previously recorded from the Indian Ocean by WOOD (1954, 1962 in 1963a), SILVA (1956a), SOURNIA (1966a, 1968b, 1970), and ANGOT (1970). It is a cool-temperate to tropical inter-oceanic species.

Gonyaulax milneri (MURRAY et WHITTING) KOFOID

Plate 35, Fig. 401; Plate 44, Figs. 517 a-c

SCHILLER 1936:522, f. 612 a-c; RAMPI 1952a:108, f. 11; WOOD 1963b:37, f. 133; — 1968:59, f. 152.

The species has apparently only been originally illustrated four times before, once in the type description (as *Gonio-*doma* milneri* MURRAY et WHITTING 1899), once by RAMPI and twice by WOOD. For this reason it is figured here both as a line drawing and in scanning electron micrographs.

It is highly distinctive and unlikely to be confused with any other species of *Gonyaulax*. At first sight it does resemble a member of *Heteraulacus* (= *Goniodoma*) but the tabulation on the epitheca is like that of many *Gonyaulax* species. The theca is strongly developed, with numerous close-set pores and with ridges, lists, and spines marking the plate sutures. Neither MURRAY & WHITTING nor RAMPI illustrated the termination of the first apical plate short of the girdle, but this feature has been confirmed here several times.

Ecdysis for this species is unusual for the genus *Gonyaulax* in that it is probably lateral rather than apical (observations of MURRAY & WHITTING and original).

Stations: 101, 116, 294, 302, 332.

Found in small numbers at a few scattered stations including the Bay of Bengal, Arabian Sea, equatorial waters, and one station south of Mauritius.

The species has only been recorded from the Indian Ocean by WOOD 1962, in 1963a). It is known from the tropical Atlantic and Pacific Oceans and also from the Mediterranean Sea.

Gonyaulax minuta KOFOID et MICHENER Plate 35, Fig. 402

— 1911:271; SCHILLER 1935:287; WOOD 1968:59, f. 154.

Syn.: *G. minima* MATZENAUER 1933:450, f. 17; vix SCHILLER 1935:287, f. 291 a, b, vix 292 c—c; KISSELEV 1950:221, f. 383 a, b, vix c—c; WOOD 1954:264, f. 179; — 1968:59, f. 153.

The original description, as with others in the same work, lacks an illustration. Consequently its recognition is subjectively interpretive although in this case WOOD (1968) has provided a figure.

It is a very small species of the "polygramma group" (length 14–30 μm). It bears resemblances to *G. polygramma*, *G. pavillardii*, and *G. turbynei* but is smaller. Markings other than weak linear ridges are difficult to see. MATZENAUER (1933) figured only pores in addition to the faint longitudinal ridges and WOOD's specimen apparently only had pores. There is a slight apical eminence. WOOD's specimens apparently had a well-developed apical horn although this was not evident in the present specimens.

Details of the plate pattern are as yet lacking. MATZENAUER's original figures did not clearly distinguish between linear ridges and sutures and WOOD's figure is only a ventral view. The present material was not suitable for detailed analysis.

WOOD (1968) has distinguished between *G. minima* and *G. minuta* and his figures do, indeed, suggest a difference not evident in his, or the original descriptions. The antapex of his figure of *G. minima* is flattened and slopes strongly to the left, whereas *G. minuta* is figured with an evenly rounded antapex. Furthermore, the sulcus is shown to flare posteriorly in the former taxon. Future study is required to affirm these differences.

Station: 411.

A few specimens were found at one station in the Mozambique Channel.

The species has only been recorded once since its initial description (from the eastern tropical Pacific Ocean) by WOOD (1968, from the Straits of Florida). However, *G. minima* was first described from the Indian Ocean (MATZENAUER found it to be an abundant nano-plankton species) and subsequent Indian Ocean records of the latter comprise those of WOOD (1954, 1962 in 1963a), DURAIRATNAM (1964), and SUBRAHMANYAN & SARMA (1967).

Gonyaulax ovalis SCHILLER Plate 35, Fig. 405

.... SCHILLER 1935:289, f. 296 a—d.

The specimen illustrated agreed closely with SCHILLER's description and figures although it is somewhat smaller (length 30 μm) than the length (48–52 μm) given. SCHILLER has indicated that MATZENAUER's (1933) *G. ovata* from the Indian Ocean may be synonymous. However, *G. ovata* was not shown to possess an apical horn whereas *G. ovalis* has a distinct, short, abruptly attached horn resembling the "affixed" type in *Peridinium*. The theca of *G. ovalis* is distinctively thick in appearance.

Station: 405.

Found only at one station in mid-Mozambique Channel. It has apparently been observed previously in the Mediterranean Sea and in the southern sector of the Pacific Ocean (HASLE 1969) although, if MATZENAUER's taxon is synonymous, then it has also been observed in the Indian Ocean.

cave notch. In *G. cobortricula* the anterior sulcal plate deeply and rectangularly indents the epitheca, lacking the curving profile of *G. fratercula*. "Curtain-fin" development (closing the girdle), shown in *G. fratercula* by BALECH, is known to be a variable phenomenon (TAYLOR 1975).

Gonyaulax catenella is similar in size but is usually flattened rather than isodiametric. It is for this reason (combined with size data) that KLEMENT's specimens from the Gulf of California are tentatively attributed to *G. fratercula* although plate information on his specimens is lacking.

G. conjuncta WOOD is problematic because little information regarding the plate pattern was provided in the original description, and no indication whatever of size. In a later work (WOOD 1968) he gave the cell length as 25 μ . BALLANTINE (1961) figured and described specimens which she attributed to *G. conjuncta* but her specimens from Zanzibar were 50–63 μ m in length (equal to breadth). In view of this confusion WOOD's taxon is difficult to assess.

G. acatenella is also similar to *G. fratercula*. However, in addition to differences in the apical plates (especially 3' and 4') the epitheca is higher than the hypotheca in *G. acatenella*. The latter has been found to produce paralytic shellfish poison and to vary in the degree of development of pigmentation (PRAKASH & TAYLOR 1966).

It is possible that HALIM's (1967) specimens of *G. tamarensis* var. *excavata* from the coast of Venezuela were, in fact, *G. fratercula*, but insufficient information is available to determine this.

Stations: 16, 29, 36, 38.

A few short chains were observed at four stations, all within the Andaman Sea.

The species was originally described from the Mar del Plata in the western South Atlantic Ocean. It does not appear to have been recorded from elsewhere as yet.

Gonyaulax fusiformis GRAHAM Plate 36, Figs. 421, 422
– 1942:50, f. 63 A–G.

This is a rare tropical species, readily identifiable by reference to GRAHAM's detailed plate description. At first sight it might be confused with *Spiraulax jolliffei*, as it is similar in its biconical, fusiform shape. It is, however, more slender. Like *S. jolliffei* there is a large rectangular anterior intercalary plate on the right ventral face of the epitheca. However, there are two intercalary plates in *G. fusiformis* due to an extension of the dorsally-situated second apical plate which surrounds the right side of the apical closing platelet, thus isolating it from plates on the right side near the apex. The easiest means of recognition however, is the presence of a long, narrow, bent first apical plate in *G. fusiformis* in the customary position, the genus *Spiraulax* being recognisable by the absence of a plate in this position. *G. birostris* has much more drawn out apical and antapical horns than *G. fusiformis*.

There is a strong resemblance between *G. acuta* KOFOID et MICHENER and *G. fusiformis*. They are very similar in size and shape, girdle and sulcal features. However, as with the other species of *Gonyaulax* described by KOFOID & MICHENER (1911) a figure of their species is lacking. Consequently, their statement that there are three apical plates and no anterior intercalary plates can only be taken literally. These features can then, theoretically, serve to distinguish the species.

Stations: 33, 62, 67, 68, 103.

Found in small numbers at one station in the northern Andaman Sea and four in the western Bay of Bengal.

This species does not seem to have been found previously in the Indian Ocean. It is known from the tropical Atlantic and Pacific Oceans and appears to be relatively stenothermal and tolerant of low phosphate values (GRAHAM 1942).

Gonyaulax glyptorhynchus MURRAY et WHITTING Plate 35, Fig. 404
SCHILLER 1935:301, f. 310 a–c.
Vix WOOD 1954:260, f. 167.

This is an extremely rarely observed species although it is possible that it has been confused with the closely similar species, *G. highlei* MURRAY et WHITTING and *G. birostris* STEIN which have been found more frequently. It is similar to *G. highlei* in size but can be distinguished, according to the original descriptions, by the lack of girdle reticulæ in *G. glyptorhynchus* and the smoothly spinous nature of the antapical horn in *G. highlei*. The antapical horn is hirsute in *G. glyptorhynchus*.

Gonyaulax pacifica KOFOID Plate 35, Figs. 395, 397; Plate 40, Fig. 482
 SCHILLER 1935:290, f. 297; GRAHAM 1942:48, f. 62 A-L; RAMPI 1943a:321, f. 3; SILVA 1949:343, t. 5, f. 7; MARGALEF, HERRERA,
 RODRIGUEZ-RODA, et LARRAÑETA 1954:91, f. 3d; WOOD 1954:261, f. 170 a, b; TAYLOR 1969:165, t. 1, f. 1, 2.
 Syn.: *Steiniella cornuta* KARSTEN 1907:348, t. 53, f. 7.
Murrayella briani RAMPI 1941a:60, t. 2, f. 1.

A distinctive, very large (for the genus), highly flattened species. The flattening is asymmetrically dorso-ventral. It is somewhat similar to *G. kofoidii* but the latter does not exceed 110 μm , whereas *G. pacifica* ranges in length (without spine) from 115 to 167 μm . Furthermore, in *G. pacifica* the porulation is more delicately developed and widely spaced. Broad intercalary bands are usually present between the apical and precingular plates. GRAHAM (1942) has carried out a detailed dissection of the theca.

During the examination of the "Anton Bruun" material the observation of unusual delicate internal plates surrounding the nucleus prior to and during cyst formation was considered of sufficient interest to warrant separate publication (TAYLOR 1969). A cyst is also shown here (figs. 397, 482). It differs from that of *G. kofoidii* in being longer and bearing a distinct antapical projection, as well as by internal details.

Stations: 18, 31, 32, 36, 37, 57, 62-66, 71, 94, 95, 99, 100, 102, 103, 108, 112, 117, 131, 161, 294, 300, 315, 322, 326.

This was the commonest member of *Gonyaulax* in the material, particularly in the western Bay of Bengal. It was scattered throughout the oceanic region, occurring as far south as 35°S. The species has been previously recorded from the Indian Ocean by KARSTEN (1907), WOOD (1954, 1962 in 1963a), SILVA (1956a), DURAIRATNAM (1964), TAYLOR (1967), and SOURNIA (1966a, 1968b, 1970). It is known also from the Pacific and Atlantic Oceans and the Mediterranean Sea. It is a warm-temperate to tropical inter-oceanic species.

Gonyaulax pavillardii KOFOID et MICHENER Plate 35, Fig. 403
 - 1911:271; SCHILLER 1935:290.
 Non *G. pavillardii* DANGEARD 1927b.

As with *G. areolata* and *C. minuta* this identification is based on a reconstruction from KOFOID & MICHENER's description due to the lack of an iconotype. This identification is more tentative because the present specimen measured only 31 μm x 30 μm whereas the original description was based on larger material (48 μm x 44 μm). Other features were, however, quite similar.

The predominantly linear markings are common to most members of the "polygramma group" (KOFOID 1911a) and in fact, it is doubtful if *G. pavillardii* can be satisfactorily separated from *G. turbynei* into which it may blend. It shares the same roundly oval posterior plate with *G. turbynei*. The latter species has a fairly distinctive arrangement of the first apical plate but the description of *C. pavillardii* is not detailed enough to make comparisons, simply stating that it is narrow and widened posteriorly.

Stations: 26, 371.

Found at one Andaman Sea station and one off the coast of Mozambique.

This species has not been previously recorded from anywhere other than the type locality (eastern tropical Pacific Ocean) although, if it is indeed distinct, it has probably been confused with *G. turbynei*.

Gonyaulax polyedra STEIN Plate 35, Fig. 396
 SCHILLER 1935:291, f. 299 a-f [+ SOBRINO 1918, f. 1, 2, t. 2, f. 1-4 (t. 3, f. 1, 2), CONRAD 1926:94, t. 2, f. 37]; RAMPI 1943a:321, f. 14;
 KISSELEV 1950:222, f. 386; NORDLI 1951b:207, f. 1 a-f; MARGALEF et DURÁN 1953:33, f. 8 f-i; WOOD 1954:261, f. 171 a, b; EVITT
 1964, f. 2 (sub. *polydrea*); WALL 1967, f. 6 A; WALL et DALE 1967, t. 1, f. N, O; WALL, GUILLARD et DALE 1967, f. 1, 2; WALL et DALE
 1968b:271, t. 1, f. 17, 18, t. 3, f. 3-6; WOOD 1968:60, f. 156; WALL 1971a, t. 2, f. 7, 8, 9.
 Vix MARGALEF, DURÁN et SAIZ 1955:97, f. 5 n.
 [*G. polyedra* auct. nonnul.]

A distinctive, angularly-shaped species. It resembles *G. milneri* in possessing a flat antapex, but other resemblances between the two species are minor. The surface of the theca is evenly and strongly porulated with faint reticulation also present. A peculiar epithelial tabulation has been figured by WALL (1967) in which two intercalary plates are produced as a result of being pushed away from the apex.

One type of cyst is spherical with numerous fairly short spines (NORDLI 1951b) and resembles *Lingulodinium machaerophorum* (DEFLANDRE et COOKSON) WALL (1967, WALL, GUILLARD & DALE 1967). However, it can also produce a cyst with a smaller body and longer, fewer spines.

The species is usually strongly luminescent. Aspects of its physiological periodicity have been examined by SWEENEY (1969). Ultrastructural features have been described by SWEENEY & BOUCK (1966), and SCHMITTER (1971). Its association with "red water" blooms, fish kills, and toxicity has been discussed by KOFOID (1911a), NIGHTINGALE (1936), and SCHRADIE & BLISS (1962), amongst others. Its potential as a food source has been described by PATTON et al. (1967).

Station: 109.

Only a single specimen was seen in the "Anton Bruun" material, occurring in the southeastern Arabian Sea. It is apparently of rare occurrence in the Indian Ocean, having been observed previously from this area only by MATZENAUER (1933) and WOOD (1962, in 1963a). On the other hand it is a common summer species off the California coast where it also shows a markedly neritic distribution. It commonly occurs in the latter region in summer in sufficient numbers to cause "red water" with occasionally associated outbreaks of marine fauna mortality. Although recorded several times from the Atlantic Ocean and the Mediterranean Sea it does not seem to occur in abundance there. It can be considered an inter-oceanic, warm-temperate to tropical species with a preference for neritic waters.

Gonyaulax polygramma STEIN Plate 35, Fig. 398

SCHILLER 1935:292, f. 300 a-j, 301 g, h (+ WAILES 1928:3, t. 3, f. 26-28); WAILES 1939:28, f. 74, 81; RAMPI 1943a:323, f. 8; MARGALEF 1948b:47, f. 11; SILVA 1949:342, t. 5, f. 5, 6; KISSELEV 1950:222, f. 391 a-c; WOOD 1954:261, f. 172 a-c; MARGALEF et DURÁN 1953:33, f. 8j; MARGALEF 1957a:47, f. 1m; STEIDINGER 1968:1, f. 1 a-c, 2-6, 8, 9, 10 a-c, 11-13, 14 a-c; WOOD 1968:60, f. 157; RICARD 1970, t. 2, f. n; HERMOSILLA 1973b:58, t. 31, f. 12-16.

Vix TAYLOR 1962:237, t. 1, f. 1-5; GRINDLEY et TAYLOR 1964:111, f. A. (? = *G. reticulata* KOFOID et MICHENER).

In its maturely developed state this species is distinctive with a stout apical horn, strongly developed subparallel, linear ridges, a strongly areolated theca and very slight overlap of the ends of the girdle. The posterior plate of the ventral area is shallowly depressed and widest at its antapical end. One to several spinelets, sometimes bearing a small list, are usually present along the antapical edge of the posterior plate. TAYLOR (1962) has indicated that there is an apparent progression in size and complexity of thecal development among members of the genus assigned by KOFOID (1911a) to the parasystematic "polygramma group". However, the main species to cause distinction problems are *G. minima* MATZENAUER and *G. turbynei* MURRAY et WHITTING, because of the possibility of confusion with immature cells of *G. polygramma*, and *G. reticulata* KOFOID et MICHENER (which was never illustrated). The other species of the group, *G. kofoidii*, *G. pacifica*, and *G. scrippsae* are not particularly similar to *G. polygramma*. *G. rostrata* DANGEARD is based on an inverted individual which was evidently involved in ecdysis. The ventral area plates appear to be distorted, causing judgement difficulties (see comments here under *G. minuta* KOFOID et MICHENER).

STEIDINGER (1968) has indicated that the specimens from a "red water" bloom figured by TAYLOR (1962) and GRINDLEY & TAYLOR (1964) are different from the usual concept of *G. polygramma*, a well-developed apical horn being absent. Also, the reticulation of the theca was very pronounced. She suggested that these specimens probably corresponded to the description of *G. reticulata*, an opinion with which this author concurs. Although no figures of the latter are available it seems that the figures of TAYLOR (1962) and GRINDLEY & TAYLOR (1964) may serve as illustrations of it. On the other hand, this does not resolve the problem of whether *G. reticulata* deserves separate recognition from *G. polygramma*. It appears to represent an extreme variant in a cluster of somewhat similar taxa which may or may not be distinguished at the species level. Smooth-walled cysts with an apical protuberance and slight depressions corresponding to the girdle and sulcus are produced by apical ecdysis.

Stations: 24, 34, 35, 37, 38, 52, 69, 72, 96, 103, 104, 130, 153, 154, 291, 294, 305, 341, 344.

This was the second most common representative of the genus in the material (after *G. pacifica*). It occurred at scattered stations over most of the area although, like *G. pacifica*, it was apparently absent in the Mozambique Channel region during the period of sampling (cruises VII and VIII). It was never abundant although, like *G. polyedra*, it has occasionally formed blooms dense enough to produce "red water" and marine fauna mortalities (NISHIKAWA 1901; PRAKASH & SARMA 1964; LEWIS 1967; but probably not the blooms reported by GRINDLEY & TAYLOR 1962, 1964 - see above). It does not seem to produce a specific toxin of the mussel-poison type. Blooms require temperatures above 17-20 °C.

Indian Ocean records of the species are frequent (see WOOD 1963a plus KARSTEN 1907; SILVA 1956a, 1960; DURAIRATNAM 1964; PRAKASH & SARMA 1964; TRAVERS & TRAVERS 1965; SOURNIA 1966a, 1968b; LEWIS 1967 and TAYLOR 1967). It is an inter-oceanic temperate to tropical species.

Gonyaulax subulata KOFOID et MICHENER Plate 35, Fig. 407

- 1911:270; SCHILLER 1935:303.

Syn.: *G. sp. B.* MARGALEF et DURÁN 1953:35, f. 81; DURÁN, SAIZ, LOPEZ-BENITO, et MARGALEF 1956:69, f. 2b.

G. buxus BALBCH 1967a:106, t. 6, f. 100-107; SILVA 1968:38, t. 7, f. 14-17.

This is another case (see *G. areolata*, *G. minuta*, and *G. pavillardii*) where one of the "Anton Bruun" taxa showed resemblances to an unillustrated description of KOFOID & MICHENER. Here the general thecal details corresponded well with the original description, including the size (length including spine 51–58 μm , 47 μm in original; diameter 25–28 μm , 27 μm in original) the girdle being displaced approximately 1–1.5 girdle widths with none or slight overlap of the ends. The apical horn resembles that of *G. glyptorhynchus* but it is not as long. It was approximately 10 μm in length, the plates gaping apart, presumably due to ecdysis. In the figures by the other authors cited the apical horn is shown with closed plates. BALECH (1967a) has given a detailed description of the species while under the understandable impression that he was creating a new species.

The antapex of the cell can be symmetrically conical, the subulate (narrow, awl-shaped) spine being central in location (MARGALEF & DURÁN 1953), or it can arise more from the right side of the antapex (other figures, including that here). It seems most closely related to *G. bruunii* sp. n. and *G. glyptorhynchus*.

The plate boundaries are hard to see. The first apical plate is somewhat displaced towards the left side. The sixth precingular plate is quadrangular. The plates are covered with fine, irregularly reniform markings and pores.

Station: 162.

Only a few specimens were found in the vicinity of Mauritius.

The species has been found in the Gulf of Mexico and on the Spanish coast, in addition to its discovery by KOFOID & MICHENER in eastern tropical Pacific Ocean material. Consequently it is probably an inter-oceanic, warm-temperate to tropical species. It has not been found previously in the Indian Ocean.

Gonyaulax turbynei MURRAY et WHITTING Plate 35, Fig. 399

SCHILLER 1935:299, f. 307 a, b; RAMPI 1943a:324, f. 12; KISSELEV 1950:224, f. 388 a–d; WOOD 1954:263, f. 175; – 1968:61, f. 161; SILVA 1955:153, t. 6, f. 14, 15; BALECH 1971a:164, t. 35, f. 689–691, t. 36, f. 692–694.

Vix MARGALEF et DURÁN 1953:35, f. 8s; MARGALEF 1969a, f. 3G.

SCHILLER's specimen (1935, f. 307b), like a surprising number of other figures of *Gonyaulax* in his monograph, is upside down. The species differs from *G. polygramma* in being smaller (not exceeding 50 μm in length), lacking an apical horn, and having less pronounced ridges. A reticular meshwork may or may not be strongly developed. The specimen illustrated here is very similar in development to the iconotype. Specimens less than 32 μm in length (if any) are likely to be confused with the smaller members of the "polygramma group" such as *G. minima* MATZENAUER. *G. scrippsae* is also similar but possesses a distinct overlap of the displaced ends of the girdle, one result of which is that the sixth precingular plate is triangular instead of quadrangular in shape.

TAYLOR (1962) and STEIDINGER (1968) have discussed the problem of distinguishing between immature members of *G. polygramma* and *G. turbynei*. So has KOFOID (1911a). He suggested that STEIN's (1883, t. 4, f. 19) small, highly striated specimen may be an immature form of *G. turbynei* and proposed the name *G. turbynei* forma *longistriata* for it. BALECH (1971a) has provided some details of the plate formation of the species.

Stations: 63, 374.

Rare, at two stations, one off the east coast of India and the other off the east coast of Africa. It has been previously recorded from the Indian Ocean by SCHRÖDER (1906), MATZENAUER (1933), WOOD (1954), and TAYLOR (1967). It is known from the tropical and southern Atlantic Oceans, the Mediterranean Sea, and the equatorial, eastern and western Pacific Ocean. It does not usually occur in large numbers.

Genus *Protoceratium* BERGH

Due to the strongly developed reticulation on the thecae of all members of this genus it has been difficult to determine plate patterns. This can only be effectively achieved by the dissection of the theca. The formula for the genus given by SCHILLER (1936) is 1–3', 0^a, 6'', 6''', 0–1P, 1–3'''''. He stated that an apical pore was absent although it is obviously present in one of the figures he included (his fig. 339 a) and it is definitely present in *P. spinulosum* observed here (pl. 36, fig. 414). An apical plate was mentioned by KOFOID & MICHENER (1911). WALL & DALE (1968a) found at least two different types of cysts in *P. reticulatum* which resemble fossils ascribed to the genus *Operculodinium*. Both types are spiny.

It is difficult to know whether the detailed pattern of *Protoceratium reticulatum* (CLAPARÈDE et LACHMANN) BÜTSCHLI (the type species) has been determined or not. Recently REINECKE (1967) has described what she considered to be a new species of *Gonyaulax*, *G. grindleyi*, providing full details of the tabulation. The plate pattern is unquestionably compatible with the genus *Gonyaulax* (P, 3', 1^a, 6'', 6C+t, 9S, 6''', 1P, 1'''''). However, there are also very strong resemblances to *P. reticulatum* (a resemblance also noted by LOEBLICH III 1970 who referred to REINECKE's taxon only under the latter name) and the cysts she found are identical with one type observed by WALL & DALE (1968). Transferral of the type species to another genus places other members of *Protoceratium* in a taxonomically nebulous position which will have to be resolved in the future.

Precise observational techniques make it possible to assign a species more readily to a recent, precisely defined taxon, than to an older, more equivocally described taxon. Unless the step is taken to recognise an old taxon in its presumed newly detailed guise, the result of this process is the disappearance of many species from the literature with the loss of the literature which was applied to them. Whether or not such a process is desirable is an entirely subjective problem. It would certainly be alleviated if type specimens rather than type figures (iconotypes) were available, although dissection requirements still could not be met. VON STOSCH (1969) has described features of a culture of *G. grindleyi*.

This author agrees with LOEBLICH III (1970) that *G. grindleyi* is probably the same taxon that some authors have called *P. reticulatum*. However, whether this was true for the original description can never be absolutely resolved. The lack of future records of *P. reticulatum* by authors applying critical plate criteria would be strongly supportive of their union, considering that the latter has been commonly recorded from temperate waters. BALECH (1971a) has accepted REINECKE's species without reference to a resemblance to *Protoceratium*.

Only one specimen of another species was found in the "Anton Bruun" material. A few of the sutures on the ventral surface were visible, but the remainder were masked by the heavy thecal ornamentation and an attempt to dissect it was unsuccessful.

Protoceratium spinulosum (MURRAY et WHITTING) SCHILLER
— 1936:326, f. 340.

Plate 36, Fig. 414

Vix HALIM 1960a, t. 3, f. 20 (sub *Prorocentrum*, lapsus pennae).

The present observations appear to be the first since the specimen was examined by MURRAY & WHITTING (1899). It can be distinguished from all other members of the genus by the very strong, knob-like spines which project out from virtually all intersections of the strong network of ridges covering the theca. The height of the ridges is approximately 6 μm . In addition to the spines and ridges there are delicate hyaline lists which stretch arc-like between adjacent spines. The girdle lists are formed in a similar fashion. The girdle is closer to the anterior end of the cell than the posterior end. Fine pores are present in the thin "areolae" of the theca.

This specimen resembled the type specimen very closely. The size range known at present is (type specimen in brackets): length 78 (58) — 56 μm , diameter 80 — (50) μm . HALIM's (1960a) drawing from Villefranche-sur-Mer in the Mediterranean does not contain sufficient detail to be certain if it represents this species or not. The strength of spine development is not indicated clearly. It was close in size to the type specimen (length 58.5 μm , diameter 50.7 μm).

Stations: 34, 101, 117, 133.

Single individuals were observed at stations in the Andaman Sea, the Bay of Bengal, and at 30°S in the southern central Indian Ocean.

The species has only been definitely recorded from the northern Atlantic Ocean (28°N) although if HALIM's (1960a) designation is correct it also occurs within the Mediterranean Sea.

Genus *Pyrodinium* PLATE

This genus was first thought to differ from *Gonyaulax* by the presence of 5 instead of 6 postcingular plates (e.g. by SCHILLER 1935), but a subsequent study of the type species, *P. babamense*, by WALL & DALE (1969) found that it had the usual small gonyaulacoid first post-cingular plate. The latter study, plus that of BUCHANAN (1968) have shown that *P. babamense* has an essentially similar plate pattern to some members of *Gonyaulax* but differs in the nature of cyst archeopyle (a complex "2A + 6P" type instead of a simple precingular archeopyle), and by the so-called first apical plate

not reaching the apical closing platelet. This plate pattern seems to be intermediate between that of *Heteraulacus* and *Gonyaulax* (see text fig. 1 here, and TAYLOR 1976).

In fact, two species which have been assigned to *Gonyaulax* (*G. monilata*, *G. balechii*) and the single species of HALIM's (1960b) genus *Alexandrium*, also share this condition in which the plate corresponding to the gonyaulacoid first apical plate does not reach the apex, being indistinguishable in plate pattern from *Pyrodinium* at generic level detail. Details of the cysts of these species are unknown at present, and the sulcal plate details seem incompletely determined in *A. minutum*, but it is this author's opinion that the three taxa above (plus the genus *Gessnerium* which has been shown to be based on the optically reversed theca of *Gonyaulax monilata*) should be transferred to *Pyrodinium*. Cyst features, when determined, will test this conclusion.

At present the plate pattern for *Pyrodinium* can be given as P, 3-4 + 1', 0², 6'', 6c, 5s, 6''', 1P, 1'''''. New combinations proposed here are:

Pyrodinium monilatum (HOWELL) comb. nov.

Basionym: *Gonyaulax monilata* HOWELL 1953:153, f. 1-5.

Syn.: *Gessnerium mochimaensis* HALIM 1967 ex HALIM 1969b:619.

Gessnerium monilata (HALIM) LOEBLICH III 1970:903 (892).

Pyrodinium balechii (STEIDINGER) comb. nov.

Basionym: *Gonyaulax balechii* STEIDINGER 1971:183, f. 1 A-D.

Pyrodinium minutum (HALIM) comb. nov.

Basionym: *Alexandrium minutum* HALIM 1960b:102, f. 1 a-j.

The genus appears to have a close affinity to some of the thin-walled *Gonyaulax* species possessing minimal girdle displacement, e.g. *G. catanella* WHEDON et KOFOID, *G. acatenella* WHEDON et KOFOID and *G. tamarensis* LEBOUR and others attributed to the parasystematic "catanella" (STEIDINGER 1971) or "tamarensis" groups (TAYLOR 1975), and it is interesting that paralytic shellfish poison production is found in some members of both.

Pyrodinium schilleri (MATZENAUER) SCHILLER Plate 35, Fig. 406

- 1935:314, f. 330 a-c; TAFALL 1942:442, t. 36, f. 21, 24, 25, 27, 28.

Syn.: *Gonyaulax schilleri* MATZENAUER 1933:449, f. 16 a-c.

This species was first described by BÖHM (1931a) from the Persian Gulf. It apparently differs from *P. babamense* in lacking the large lateral lists extending from the girdle lists to the antapical spine (on both sides, closing the antapex completely). Also it was originally thought to have five apical plates instead of the 3 + 1' of *P. babamense*. As a result of the observations of TAFALL (1942) and here, the species is known to usually occur with a 4 + 1' configuration. As in the latter species the left antapical spine (associated actually with the sulcal list) is much longer than the right spine. Cell division can create temporarily short-horned specimens such as that figured by MATZENAUER (1933) in ventral view. The original specimens were noticeably flattened apico-antapically, but the "Anton Bruun" specimens did not exhibit such strong flattening and neither did those of TAFALL from the eastern tropical Pacific Ocean.*

Station: 18.

Two specimens were observed in a sample from the Andaman Sea near Phuket, Thailand.

The species is also known from the Persian Gulf and the Red Sea as well as the eastern Pacific Ocean.

Pyrodinium sp. ? Plate 36, Figs. 423 a-d

At first sight the individual illustrated resembles *P. balechii*. However, closer examination reveals differences which, combined with the poor resolution of ventral plates, do not permit such an identification.

The chief differences are: the presence of weak ridges on the epitheca as well as the hypotheca; the large sixth pre-cingular plate (more like *P. minutum*); the narrow, vertically elongate first postcingular plate (also like *P. minutum*); the peculiarly situated fourth postcingular plate, surrounded by the third and fifth pre-cingulars which have a common suture beneath it (rather like *Amphidiniopsis* WOLOSZYNSKA), the possibility of two posterior intercalary plates (or one elongate

* STEIDINGER et al. (1967) say that some cells have characters of both *P. schilleri* and *P. babamense*, but do not specify which *P. babamense* has been reported to produce shellfish poison in New Guinea (MACLEAN 1973).

plate reaching as far dorsally as the antapical plate) and the flattened antapex. Also, the epitheca is not as large as the hypotheca.

The cell's dimensions were: length 31 μm ; diameter 28 μm .

Station: 365.

Found at an inshore station near Tuléar, Madagascar. Only one specimen was seen.

Genus *Spiraulax* KOFOID

Syn.: *Spiraulaxina* LOEBLICH III 1970:904 (892)

Although the plate formula of this genus falls within the compass of *Gonyaulax* DIESING, KOFOID (1911b) and GRAHAM (1942) considered that the absence of a plate homologous to the peridinoid and gonyaulacoid first apical plate (usually extending mid-ventrally from girdle to apex) was sufficient to distinguish it from other fusiform gonyaulacoid taxa with a single antapical horn and "scooplike" ventral area (e.g. *G. fusiformis* GRAHAM). The presence of a large anterior intercalary plate situated on the right ventral face of the epitheca, instead of the dorsal face, is unusual but is also present in *Gonyaulax fusiformis* GRAHAM, and possibly in *G. byalina* OSTENFELD et SCHMIDT.

A confused nomenclatural situation has arisen over the interpretation of early descriptions, leading to the proposal of three generic names and two species names, for possibly only one, or at the most two taxa. Consequently an explanation is necessary.

MURRAY & WHITTING (1899) figured a new species which they called *Gonyaulax jolliffei*. It was fusiform in shape, illustrated upside down (as were all their figures of fusiform *Gonyaulax* species, a feature curiously uncorrected by SCHILLER 1935), and their figure was evidently of a theca that had undergone apical ecdysis, the apical plates gaping apart similar to fig. 424 here. Their figures showed no first apical extending from the apex to the girdle, thus corresponding to *Spiraulax*. However, they also showed no signs of an anterior intercalary plate.

KOFOID (1911b) assumed that the anterior intercalary plate had been overlooked by MURRAY & WHITTING (1899), a not unreasonable assumption in view of numerous other omissions and stylistic interpretations by them. However, he should not, perhaps, have been as certain as his treatment suggested. His generic description was based on a detailed analysis of his own material and also corresponded to an earlier figure by ENTZ (1905). In accordance with his view that his taxon and that observed by MURRAY & WHITTING (1899) were the same he used *Gonyaulax jolliffei* as a basionym (although not terming it such), creating the new combination *Spiraulax jolliffei* (MURRAY et WHITTING) KOFOID.

GRAHAM (1942) disagreed with KOFOID's conclusion, considering that the forms observed by MURRAY & WHITTING were a different taxon to that described by KOFOID. He did not, however, have evidence for this other than MURRAY & WHITTING's figures, having only observed specimens corresponding to KOFOID's material. Consequently his creation of a new name, *Spiraulax kofoidii* GRAHAM, for KOFOID's material and his own (thus making this the type of the genus) was precipitate. As no author has yet found specimens corresponding to MURRAY & WHITTING's illustration his action seems inappropriate.

The situation has been further complicated by LOEBLICH III (1970) who, on the basis of GRAHAM's opinion, has created a new genus, *Spiraulaxina* LOEBLICH III, for the taxon observed by GRAHAM (1942) and KOFOID (1911b). The only reason given for this action is: "As noted by GRAHAM 1942, p. 54, *Spiraulax kofoidii* is not congeneric with *Spiraulax jolliffei* (MURRAY & WHITTING) KOFOID, 1911, hence *Spiraulaxina* gen. nov. is proposed for GRAHAM's species."

To summarise the situation: KOFOID created a new genus, *Spiraulax*, as the result of observations on material which may or may not be conspecific with *G. jolliffei* MURRAY et WHITTING. The description of the genus provided by KOFOID in fact excludes MURRAY & WHITTING's material if their figures are taken literally in that a dextro-ventrally situated anterior intercalary plate (1^a) is considered one of the generic criteria. If, with modern observational techniques, the existence of a taxon corresponding precisely to MURRAY & WHITTING's description can be demonstrated, then *S. jolliffei* KOFOID is not synonymous with *G. jolliffei* MURRAY et WHITTING. This has not occurred as yet and in the opinion of this author, is unlikely to. However, should such an eventuality arise, and only then, the problem can be solved either by use of GRAHAM's new name (*Spiraulax kofoidii*) or by careful stress of authorship of names, as above.

The creation of a further new genus, the type of which is *Spiraulaxina kofoidii*, seems unwarranted and confusing for it embraces the material and figures essential to the description of *Spiraulax* by KOFOID (1911b).

Until such time as specimens corresponding to MURRAY & WHITTING's figures are convincingly demonstrated to exist, especially with regard to the absence of an anterior intercalary plate on the right ventral side, this author recommends provisional acceptance of KOFOID's judgement and its consequences (see treatment of *Spiraulax jolliffei* below). The absence of a mid-ventral apical plate extending from the apex to the ventral area, together with the single, right anterior intercalary plate, seem sufficiently distinctive to warrant the separation of *Spiraulax* KOFOID from *Gonyaulax* DIESING.

If specimens corresponding to MURRAY & WHITTING's figures are discovered it would seem best to adopt GRAHAM's new name: *Spiraulax kofoidii*, for the type of the genus *Spiraulax*.

Spiraulax jolliffei KOFOID Plate 36, Fig. 424

[? *Spiraulax jolliffei* (MURRAY et WHITTING) KOFOID] . . . SCHILLER 1935:312, f. 328 a-c; RAMPI 1943a:326, f. 16; MARGALEF 1948b: 47, f. 1m; WOOD 1954:265, f. 181; HALIM 1967:751, t. 7, f. 100; WOOD 1968:128, f. 399.

Syn.:? *Gonyaulax jolliffei* MURRAY et WHITTING 1899:324, t. 28, f. 1 a, b.

Spiraulax kofoidii GRAHAM 1942:55, f. 66 A-G.

Spiraulaxina kofoidii (GRAHAM) LOEBLICH III, 1970:904.

[Orthographic variants: *jollifei* (SCHRÖDER 1906; SCHILLER 1935; HALIM 1967), *jolliffei* (KARSTEN 1907)]

The criteria for the recognition of this commonly observed tropical species, together with its confused systematic history have been extensively discussed in the comments under the genus here. The genus is monospecific to date.

Stations: 53, 54, 61, 95, 98, 100, 103, 108, 161, 302, 326, 405, 420.

Common but not abundant at scattered stations in the Bay of Bengal, the eastern Arabian Sea and the west-central Indian Ocean. The majority of the stations were oceanic rather than neritic.

GRAHAM (1942) has indicated that the Indian Ocean records of SCHRÖDER (1906) and KARSTEN (1907), both referring to *Gonyaulax jolliffei* although providing no figures, should not be accepted. On the other hand he did accept MATZENAUER's (1933) Indian Ocean record. Other Indian Ocean records are those of WOOD (1962, in 1963a), SILVA (1956a), and SOURNIA (1966a as *S. jolliffei*, and 1967a, 1968b as *S. kofoidii*). The species is also known from the tropical oceanic areas of the Atlantic and Pacific Oceans.

Family Gymnodiniaceae LEMMERMANN

Members of this family all lack a theca composed of obvious plates, have ventrally inserted flagella, and lack ocelli, tentacles or cnidocysts. The degree of torsion or displacement of the girdle (left-handed) is variable.

Genus *Amphidinium* CLAPARÈDE et LACHMANN

This genus is distinguished arbitrarily from *Gymnodinium* by the location of the girdle within the anterior third of the body. The majority of members of the genus are benthic and/or sandloving, usually exhibiting either dorso-ventral or lateral flattening. The less well-known planktonic species seem to usually lack flattening (subgenus *Rotundinium* KOFOID et SWEZY).

Amphidinium sp. Plate 37, Fig. 434

This species could not be identified with certainty due to the lack of structural detail remaining from preservation. It most closely resembles several small species of LOHMANN's in size, e.g. *A. crassum* and *A. longum*, but the former has an acute epicone and a rounded hypocone, and the latter, although it has a similar hypocone to the present species, has a much smaller, acute epicone. The cell's length was 23 μm and its diameter 13 μm .

Station: 287.

It was found in the Gulf of Aden.

Genus *Balechina* LOEBLICH et LOEBLICH

The genus name was proposed by the above authors (1966) as a replacement for the subgenus *Pachydidinium* PAVILLARD on raising it to generic status. At the latter level it became a junior homonym for the genus *Pachydidinium* PAVILLARD. Recognition of *Balechina* as distinct from *Gymnodinium* is followed here in view of the thick, semi-rigid amphiesma possessed by the former. The amphiesmal vesicles are easily distinguishable with the light microscope in the former genus, but are only seen with difficulty in the latter. The thick amphiesma apparently allows members of *Balechina* to be more adequately preserved with routine commercial formalin than *Gymnodinium*.

The semi-rigidity of the amphiesma of *Balechina* may be due to the deposition of a flexible or fibrous material but none have been examined with the electron microscope as yet. Unlike members of the Ptychodisceaceae there is no distinct envelope ("pellicle") penetrated by a single large flagellar aperture. Instead the two flagella arise from widely separated entry points (the latter being visible even when the flagella have been shed). The transverse flagellum arises within the sulcus from its customary origin near the proximal left end of the girdle, the longitudinal flagellum arising from a point further down the sulcus, directly over the nucleus in the two species observed here.

The apparent strength of the amphiesma of *Balechina* is also of interest with regard to the existence of fossilised *Gymnodinium*-like species with a thick, ridged covering. These have been referred to the genus *Dinogymnium* EVITT and have been assumed to be cysts.

Balechina coerulea (DOGIEL) comb. nov. Plate 37, Fig. 443, Plate 40, Fig. 481

Basionym: *Gymnodinium coeruleum* DOGIEL 1906:35, t. 2, f. 46, 47; KOFOID et SWEZY 1921:197, f. Z 4; KOFOID 1931:10, t. 1, f. 5; SCHILLER 1932:344, f. 349 a, b; STEIDINGER et WILLIAMS 1970:51, t. 22, f. 68 a, b.

A large (length usually more than 200 μm), distinctive species. DOGIEL (1906) figured two shapes, one with a much more conical epicone than the other. KOFOID & SWEZY (1921) selected the more rounded figure for their treatise. Later KOFOID (1931) and STEIDINGER & WILLIAMS (1970) have shown that in living cells the epicone is distinctly conical. A roundly conical shape has been seen by this author (unpublished) in living cells from Villefranche-sur-Mer, in the Mediterranean Sea. Living cells are not usually as acutely pointed as that figured here. The most distinctive feature of the species, the strong blue peripheral pigmentation located in granules, is not a constant feature, brownish pink or green cells being commonly mixed with blue individuals. The blue is rapidly bleached in formalin preservation. The large nucleus is situated in the hypocone. The specimen observed had ingested diatoms.

The species resembles *G. gracile* (which has a larger hypocone in relation to the epicone) and *G. costatum* (which has a length exceeding 150 μm). The descending girdle is shared by many large species of this genus and there is a strong possibility that several of them are conspecific.

Station: 59.

One cell was found in the north-central Bay of Bengal. This is the first record of the species from the Indian Ocean. It has been observed previously in the Mediterranean Sea, Japan and the Gulf of Mexico.

Balechina marianae sp. n. Plate 37, Fig. 442, Plate 40, Fig. 480

Syn.:? *Gymnodinium* J. STEIDINGER et WILLIAMS 1970:52, t. 23, f. 72.

This taxon, not previously named, can be readily distinguished from all other members of the genus by the presence of a strong, apically-situated mamilla or boss. The amphiesma resembles that present in *B. coerulea* being strongly vesiculated with linear ribs superimposed upon the vesicular reticulation. The length is 115–120 μm , and the transdiameter 70–76 μm . The apical region lacks strong reticulation. The girdle is deeply impressed and displaced left-handedly by one-fifth to one-quarter of the transdiameter. The heights of the epi- and hypocone may be subequal but can be altered by cell division. For example, in the specimen of STEIDINGER & WILLIAMS the hypocone was longer than the epicone, probably being a posterior daughter cell shortly after division. Their specimen had a narrower anterior epicone than that observed in the "Anton Bruun" material. The nucleus is situated in the hypocone. Various accumulation bodies are present. The species is probably phagocytic.

The species is named in recognition of tireless assistance provided during the author's researches by MARIAN E.W. SLATER.

Station: 55.

Two cells were found in the north-central Bay of Bengal, not far from the locality for *B. coerulea* in the material.

STEIDINGER & WILLIAMS' (1970) specimen was from the eastern Gulf of Mexico during the "Hourglass" cruises. Other specimens have been observed by this author in Mediterranean Sea material collected from Villefranche-sur-Mer in September, 1972, co-occurring with *B. coerulea* (unpubl. obs.).

Genus *Gymnodinium* STEIN

Under *Balechina* it has been indicated that members with a thickened outer region exhibiting delicate areolation, and often ridges, have been recently elevated from subgeneric (*Pachydidinium*) to separate generic rank. Such cells tend to preserve considerably better with formalin than those with thinner outer layers assigned to the genus *Gymnodinium*, and consequently it is not surprising that only one cell of the latter type was found in the "Anton Bruun" samples. There is clearly a great need for a future study of living material from tropical waters to augment the preliminary study of NORRIS (1966), in order to get a better idea of the representation of this and other fragile genera.

Gymnodinium sp. Plate 37, Fig. 435.

This medium sized cell, length 58 μm , diameter 35 μm , lacking appreciable flattening, was very similar to *G. herbaceum* KOFOID in KOFOID & SWEZY (1921, p. 220, f. Y, 17, pl. 4, f. 44). It had a similar ovoid body and was very similar in size to that of the original material (length 55 μm) from Naples in the Mediterranean Sea. The main difference was that the striations, reported for the surface of the hypocone only, could not be seen.

A large accumulation body was located at the anterior end. KOFOID & SWEZY (1921) reported that this species and its close relatives, e.g. *G. ravesceus*, all possess chloroplasts but ingest small cells.

Station: 296.

It was found south of the Seychelle Islands during cruise V.

Family Heteraulacaceae LOEBLICH et DRUGG

[Syn.: Goniodomaceae LINDEMANN; Heteraulaceae LOEBL. et DRUGG]

A new family name was necessary when it was discovered that the name of the type genus, *Goniodoma* STEIN, was invalid (DRUGG & LOEBLICH 1967; LOEBLICH & DRUGG 1968a, b).

In the introductory comments to the Gonyaulacaceae attention was drawn to the ease with which the gonyaulacoid plate pattern and the pattern of *Heteraulacus* could be compared and possibly derived from one or other (most probably the gonyaulacoid from the heteraulacoid, the latter possessing little distortion from a radially symmetrical arrangement).

To this author the two families appear to be very closely related, and could, perhaps, be united.

Only one genus of this family was found in the material. The other, *Goniodinium* P. DANGEARD, is of doubtful systematic position, one of its two species probably being referable to *Centrodinium* (see later).

Genus *Heteraulacus* DRUGG et LOEBLICH

Syn.: *Goniodoma* STEIN non ZELLER

Of the seven species given by SCHILLER (1936) under this genus, only two: *H. polyedricus* (POUCHET) DRUGG et LOEBLICH and *H. sphaericus* (MURRAY et WHITTING) LOEBLICH III, can be readily recognised. Two, described by KOFOID & MICHENER (1911), have never been illustrated and have not been identified by subsequent authors. It is possible that this may occur in the future, as has been done for several of their *Gonyaulax* species here. *Goniodoma ostensfeldii* PAULSEN was later (1949) transferred by its author to *Gonyaulax*, but the plate pattern given by him in the latter

work differs markedly from that in the original figures. *Goniodoma striatum* MANGIN lacks a clear diagnosis and there was no figure of a full ventral view and so, despite its linear markings, it cannot be recognised with certainty. *Goniodoma lacustre* LINDEMANN, for which no figure was given in SCHILLER, was suggested to be a species of *Glenodinium* but appears to be closer to *Fragilidium*. *Goniodoma depressum* GAARDER (1954) may be a good species, but *G. concavum* GAARDER is a life-cycle stage of *Pyrocystis noctiluca*. SILVA (1956b, 1969) has partially determined the plates of two further species of the genus.

Heteraulacus polyedricus (POUCHET) DRUGG et LOEBLICH Plate 28, Figs. 291–294; Plate 43, Fig. 513
– 1967:183.

Syn.: *Goniodoma polyedricum* (POUCHET) JØRGENSEN . . . CANDEIAS 1930:19, t. 1, f. 28, 29; SCHILLER 1936:438, f. 479 a–c; GRAHAM 1942:46, f. 60; NIE and WANG 1942:65, f. 1 A–K, f. 2 A–D; MARGALEF 1948a:21, f. 2, 3, 4; SILVA 1949:341, t. 5, f. 1; KISSELEV 1950:256, f. 446; RAMPI 1950c:245, f. 10; MARGALEF et DURÁN 1953:44, f. 13 a; WOOD 1954:313, f. 241 a–c; TRÉGOUBOFF et ROSE 1957:117, t. 27, f. 2; HALIM 1960a, t. 3, f. 14; – 1967:729, t. 4, f. 53, 54; BALLANTINE 1961:225, f. 58–60; WOOD 1963b:42, f. 154; STEIDINGER, DAVIS et WILLIAMS 1967, t. 9, f. a; WOOD 1968:62, f. 163.

G. acuminatum STEIN et auct. nonnul. . . . WANG et NIE 1932:295, f. 7, 8.

Heteraulacus acuminatus (EHRENBERG) DIESING . . . STEIDINGER et WILLIAMS 1970:53, f. 76 a–f.

This is a very common tropical species, and as indicated in the introduction, it may have a long geological history. GRAHAM and NIE & WANG (1942) have provided detailed plate analyses of the species. It is characterised by its angular shape, with a flattened antapex.

Megacytic growth produces wide pore-free bands, modifying the shape of some plates, and, as can be seen in the antapical view shown in figure 294 b, the fins usually accompanying the sutures may not coincide with all the plates after megacytic growth.

Stations: 13–15, 17–19, 25, 26, 28, 30–35, 37, 38, 42, 43, 49, 51, 52, 54–58, 60–63, 65, 66, 68–71, 90–92, 96–98, 100, 101, 103, 106, 109–111, 114–116, 125, 129, 130, 133–135, 141, 144, 147, 148, 150, 154, 161, 162, 286, 287, 290, 291, 294, 295, 299, 305, 314, 315, 317, 320, 337, 339, 344, 374, 419.

The earliest fossil record of this species is the Lower Eocene of Northern Germany (MORGENROTH 1966). It is a cosmopolitan tropical to subtropical species.

The records of SILVA (1956a, 1960), TAYLOR (1967), SOURNIA (1968b), and NEL (1968) can be added to those listed by WOOD (1963a) for the Indian Ocean.

Heteraulacus sphaericus (MURRAY et WHITTING) LOEBLICH III Plate 28, Fig. 290
– 1970:904.

Basionym: *Goniodoma sphaericum* MURRAY et WHITTING 1899:325, t. 27, f. 3 . . . SCHILLER 1936:439, f. 480 a–d; NIE et WANG 1942:66, f. 3 A–D; RAMPI 1950c:245, f. 18; MARGALEF et DURÁN 1953:44, f. 13 d–g; SILVA 1956a:68, t. 11, f. 12; TRÉGOUBOFF et ROSE 1957:117, t. 27, f. 3; HALIM 1960a, t. 3, f. 13 a, b, c; WOOD 1968:62, f. 164; HADA 1970:18, f. 16.

This species is readily distinguished from *H. polyedricus* by its rounded shape, lacking the angularity of suture junctions found in the latter. It is usually smaller (diameter 35–52 μm), but there is an overlap in the size range of the two species. There is a displacement of the first precingular plate so that it reaches further apically than the seventh precingular plate beside it, and it is triangular in shape instead of rectangular. The latter can also be found in megacytic specimens of *H. polyedricus*, however, (cf. plate 28, f. 293). A ventral pore may be present on the epitheca, but it could not be seen in the specimen figured here.

Stations: 35, 36, 39, 59, 60, 68, 93, 95, 97, 100, 103.

It is a rare inter-oceanic species. WOOD (1963a) lists three Indian Ocean records of the species, to which should be added those of SILVA (1956a, 1960).

Family Heterodiniaceae LINDEMANN

Genus *Heterodinium* KOFOID

This is a distinctive, rarely encountered genus limited chiefly to tropical waters. A few species (e.g. *H. rigdenae*, *H. blackmanii*) extend into warm temperate regions. BALECH (1962b) modified KOFOID & ADAMSON's (1933) plate formula by reducing the number of postcingular plates to 6''' from 7''' so that it is at present characterised by a plate formula of P, 3', 1^a, 6'', 6C (? S), 6''', 3''''.

In addition a ventral pore plate is present. The ventral pore, usually situated in the mid-ventral face of the epitheca, is surrounded by a ridge which often forms a query-like shape.

A feature of this genus of ecological interest is the predominance of records of occurrence below 100 m or deeper (see KOFOID & ADAMSON 1933; GAARDER 1954). This may explain its apparent rarity in the material of other expeditions where sampling has not extended deeper than 100 m. The predominance of records in the western half of the Bay of Bengal in January, the western Arabian Sea and north of the Seychelles may be related to vertical movement of water (see general discussion of the distribution of "umbriphilic" species).

Heterodinium agassizii KOFOID Plate 23, Fig. 229
KOFOID et ADAMSON 1933:86, t. 10, f. 4-8, t. 16, f. 27; SCHILLER 1936:342, f. 369; HALIM 1967:730, t. 4, f. 55-57.

This is one of the highly reticulated members of the flattened subgenus *Platydinium*. It appears closest to *H. fides* KOFOID but differs in that the profile of the epitheca in ventral (or dorsal) view is smoothly rounded with only slight concavity above the girdle. HALIM's (1967) specimen is equivocal in this respect but does exhibit other features (below) similar to *H. agassizii*. Also the antapical horns are relatively longer and less divergent. Most of the surface areolae have a single prominent pore near the centre in both species. Both also have distinctly serrate marginal fins surrounding the hypotheca.

Station: 103.

Only one specimen of this species was found in the Bay of Bengal. This is a new record from the Indian Ocean. It has been found previously in the tropical Pacific and Atlantic Oceans, and the Mediterranean and Caribbean Seas. Like most other species of the genus it has been considered a deep euphotic or subeuphotic species (KOFOID & ADAMSON 1933). In GAARDER's (1954) Atlantic samples it was present in hauls from 200-100 m and 200-0 m.

Heterodinium blackmanii (MURRAY et WHITTING) KOFOID Plate 23, Fig. 225
KOFOID et ADAMSON 1933:74, t. 9, f. 1-4, 7, t. 15, f. 25; SCHILLER 1936:340, f. 367 non 366; BALECH 1962b:154, t. 21, f. 341, 342.
Non WOOD 1954:267, f. 184 a, b (= *H. curvatum* KOFOID)

One of the largest species (length usually greater than 200 μm) of the subgenus *Heterodinium* (elongate, tapering epitheca; antapical horns well developed). It is most closely related to, if not conspecific with (SCHILLER's suggestion) *H. curvatum* KOFOID. BALECH (1962b) has discussed the distinction of these two taxa at length. The simplest means of recognising them: the more curved epitheca (sinistral), narrower, more acute antapical horns, and reduced reticulation of the latter were consistent in the present material, lending to the continued distinction of the taxa in this report (although *H. curvatum* was not observed).

Stations: 109, 134.

Found singly at a station off the west coast of India and in the south central Indian Ocean close to 27°S. The species has been recorded previously from the Indian Ocean by SCHRÖDER (1906) and KARSTEN (1907). The latter found it, between 5°N and 30°S. Although rare, this species is one of the commonest members of the genus. KOFOID & ADAMSON's (1933) data suggested a preference for deeper waters but KARSTEN's records were from the upper 15 m (except for one haul from 200 to 0 m). The species is inter-oceanic and may not be as obligately stenothermal as many of the warm temperature species.

Heterodinium doma (MURRAY et WHITTING) KOFOID ? Plate 23, Fig. 236
KOFOID et ADAMSON 1933:30, t. 1, f. 8, 9, t. 15, f. 3; SCHILLER 1936:331, f. 346; RAMPI 1941a:56 vix t. 1, f. 6; BALECH 1962b:150, t. 20, f. 329.

One of the more elaborately reticulated members of the sphaerodally-shaped subgenus *Sphaerodinium*, this taxon resembles other species which lack antapical spines or horns and in particular *H. schilleri* PAVILLARD and *H. sphaeroideum* KOFOID. The former is much smaller (length 20 μm) and the latter has a distinctly larger hypotheca than epitheca with little or no displacement of the girdle.

The specimen illustrated here in some respects appears intermediate between *H. doma* and *H. sphaeroideum*. It is the same size as the former and has a larger epitheca than hypotheca. However, the girdle displacement is less than that shown by other authors, and the right proximal region of the girdle is not as overhung by the epitheca. BALECH's (1962b) specimen has an unusual concave antapical end.

Station: 65.

Found at one station close to the continental shelf in the western Bay of Bengal.

The species has been previously recorded from the Indian Ocean by WOOD (1954, 1962 in 1963a). It is known from the tropical Pacific and Atlantic Oceans.

Heterodinium fides KOFOID Plate 23, Fig. 228

KOFOID et ADAMSON 1933:90, t. 11, f. 2, 4, 6, t. 16, f. 28, t. 19, f. 56–58; SCHILLER 1936:343, f. 370 a, b.

This species closely resembles *H. agassizii* KOFOID (see comments under the latter, here). In addition to shape distinctions it also tends to be smaller. Little further information can be added. The specimen observed here was very similar to the type specimen.

Station: 109.

A single specimen was observed at this station off the west coast of India from which *H. blackmannii* was also recorded.

A further new record for the Indian Ocean. KOFOID & ADAMSON (1933) considered this species as stenothermal and subeuphotic in distribution in the eastern tropical Pacific Ocean.

Heterodinium globosum KOFOID Plate 23, Fig. 231

KOFOID et ADAMSON 1933:45, t. 4, f. 1–4, t. 15, f. 10; SCHILLER 1936:333, f. 353; RAMPI 1941a:58, t. 1, f. 2, 5; – 1969b:324, t. 4, f. 2; BALECH 1962b:152, t. 20, f. 331, 332.

Syn.:? *H. gracile* BÖHM 1936:33, f. 12 d/1–3.

? *H. leiorhynchum* sensu RAMPI 1939b:463, f. 1; – 1941a:59, t. 1, f. 7, 8; – 1952b:116, f. 2; TRÉGOUBOFF et ROSE 1957:114, t. 24, f. 14; HALIM 1960a:191, t. 2, f. 25.

This medium-sized, spherical species is relatively distinctive with its rotund body, short apical horn gradually tapered from the epitheca and unequal antapical horns. Reticulation is usually irregularly and somewhat sparsely developed. Broad intercalary bands are usually present. Curiously KOFOID & ADAMSON's description referred to the right horn being "a bit shorter". All their figures of this species however, show the right horn is considerably shorter than the left; in fact, more so than the specimen illustrated here.

There is difficulty in treating descriptions of Mediterranean specimens attributed to *H. leiorhynchum* (MURRAY & WHITTING) KOFOID. Those of RAMPI (1939b, 1941a and 1952b) and HALIM (1960) resemble *H. globosum* although are not quite as spherical in body shape. This interpretation seems to originate from a comment of PAVILLARD's (pers. comm. to RAMPI) that the original figures by MURRAY & WHITTING (1899) are undoubtedly somewhat stylised. KOFOID & ADAMSON (1933) recognised both taxa although their figure of *H. leiorhynchum* lacks the detail of their other analyses. They considered the presence of distinct antapical spines as indispensable for the recognition of the latter. To this author the taxon which most resembles *H. leiorhynchum* in shape is *H. spiniferum* KOFOID et MICHENER. However, it lacks the antapical spines and instead possesses a spinous fin between the bases of the antapical horns. The specimens termed *H. leiorhynchum* by RAMPI and HALIM also lack these antapical spines. As these Mediterranean specimens therefore differ from *H. leiorhynchum* and seem to correspond to *H. gracile* BÖHM (1936) the latter name may be the most appropriate if distinction from *H. globosum* is maintained.

The present specimens closely resemble the type specimen of *H. globosum* and consequently that is the name applied here.

Stations: 56, 64, 289.

Observed at two stations in the northern Bay of Bengal and one near the Gulf of Aden. This is a further new record for the Indian Ocean. The species is known from both the tropical Atlantic and Pacific Oceans and probably occurs in the Mediterranean Sea.

Heterodinium inaequale KOFOID Plate 23, Fig. 233

KOFOID et ADAMSON 1933, t. 16, f. 32; SCHILLER 1936:344, f. 372 a, b non c; RAMPI 1950a:9, f. 6.
 Syn.: *H. laticinctum* KOFOID . . . KOFOID et ADAMSON 1933:95, t. 10, f. 3, t. 16, f. 30, t. 18, f. 52–55.

This member of the subgenus *Platydinium* is recognisable by its rounded epitheca, lack of reticulation, sharp, unequal incurved antapical horns and serrated antapical fin. There seems to be little doubt that, as suggested by SCHILLER (1936), *H. laticinctum* KOFOID & ADAMSON is a large, robust form (total length 145 μm) of *H. inaequale*. SCHILLER also considered *H. pavillardii* (PAVILLARD) KOFOID & ADAMSON as synonymous. The latter is smaller, with antapical horns which are less incurved. However, if this is considered as synonymous then it seems unreasonable to maintain the identity of *H. asymmetricum* KOFOID & ADAMSON which also has a less incurved left antapical horn and has, in addition, a right horn which is reduced almost to a vestige. At present the best course seems to be to retain the specific distinction of *H. pavillardii* and *H. asymmetricum* until intermediate forms are demonstrated. *H. laeve* KOFOID & MICHENER is also similar but has long, curved antapical horns, the left still somewhat longer than the right horn.

Station: 412.

Only one specimen was observed from Nosy-Bé (Madagascar). The species has not been previously recorded from the Indian Ocean although WOOD (1954) has recorded *H. asymmetricum* from the Southern Ocean. It is known from the Pacific and Atlantic Oceans and the Mediterranean Sea.

Heterodinium mediocre (KOFOID) KOFOID et ADAMSON Plate 23, Fig. 234

– 1933:102, t. 16, f. 36, t. 19, f. 59–65, t. 21, f. 74; SCHILLER 1936:345, f. 375 a–c non 376.
 Syn.: *H. gesticulatum* forma *mediocris* KOFOID.

In many respects the specimen illustrated here is intermediate between *H. mediocre* and *H. gesticulatum* KOFOID. It is designated as the former because the epitheca is roundly symmetrical, the antapical horns are widely divergent, and the sinistral lobe (bulge on the left side of the hypotheca) is less marked than in typical members of *H. gesticulatum*. On the other hand it differs from the variability described by KOFOID & ADAMSON by the presence of a “bald” apical plate (1') and wide intercalary bands (both features of *H. gesticulatum* but probably variable), and lack of denticles along the antapical margin. The type specimen of *H. gesticulatum* exhibited a sloping of the epitheca towards the left which was not evident in the specimens in this material.

The recognition of *H. mediocre* forma *sinistrum* (KOFOID & ADAMSON) as an infraspecific variant by SCHILLER does not seem consistent with his recognition of *H. deformatum* (KOFOID) KOFOID & ADAMSON at the specific level (see comparative comments under *H. sinistrum* here). Probably both should be considered as infraspecific variants, but then *H. mediocre* may prove to be more appropriately considered as an infraspecific variant of *H. gesticulatum* as KOFOID suggested originally. For the present the specific recognition of each taxon seems to be the wisest path.

Station: 287.

A single specimen was observed at the entrance to the Gulf of Aden.

H. mediocre has not been recorded from the Indian Ocean previously although TAYLOR (1967) recognised *H. gesticulatum* in the southwestern Indian Ocean. It was originally described from the eastern tropical Pacific Ocean.

Heterodinium milneri (MURRAY et WHITTING) KOFOID Plate 23, Fig. 232

KOFOID et ADAMSON 1933:41, t. 3, f. 1, 2, 4–6, t. 15, f. 8; SCHILLER 1936:333, f. 351 a, b; HERRERA, MUÑOZ, et MARGALEF 1955:18, f. 1 E; BALECH 1962b:151, t. 20, f. 330; – 1971a:160, t. 32, f. 668, 669.

Vix RAMPI 1939b:463, f. 3; – 1941a:57, t. 1, f. 10; TRÉGOUBOFF et ROSE 1957:114, t. 24, f. 16; WOOD 1963b:39, f. 142.

Syn.: *Peridinium milneri* MURRAY et WHITTING 1899:327, t. 29, f. 3 a, b.

Non *Goniodoma milneri* MURRAY et WHITTING 1899:325, t. 27, f. 2 a, b, c, d.

This is a small spheroidal species, only 50 to 87 μm in length. SCHILLER provides a length of 130 μm , but this appears to be an error not agreeing with the dimensions of KOFOID & ADAMSON (1933), RAMPI (1941a), BALECH (1962b) or the present specimens. The species differs from *H. murrayi* KOFOID by its shorter apical horn, shorter antapical spines (4 instead of 3 although only 3 are obvious), and reduced reticulation. In both species there is a greatly displaced girdle and the body of the epitheca is shorter than the hypotheca.

In this species the ventral pore is very inconspicuous and is situated close to the apex. Also, the plate pattern on the ventral face of the epitheca is anomalous, presumably due to the girdle displacement although other species with strong displacement, *H. murrayi* and *H. obesum* KOFOID maintain the conventional arrangement of precingulars, apical plates, and ventral pore (plate).

SCHILLER (1936) erroneously cited *Goniodoma milneri* as the original binomial. In MURRAY & WHITTING (1899) both *Peridinium milneri* and *Goniodoma milneri* are described as distinct taxa. The former was transferred to *Heterodinium* by KOFOID and the latter to *Gonyaulax*, also by KOFOID (see here under *Gonyaulax* for details).

Station: 101.

A single specimen was observed at this station off the east coast of India.

The species is known from the tropical Atlantic and Pacific Oceans and the Mediterranean Sea. It was the commonest species of *Heterodinium* found by GAARDER (1954) in "Michael Sars" Atlantic Ocean material. It has not apparently been observed previously in the Indian Ocean.

Heterodinium rigdenae KOFOID Plate 23, Figs. 227, 230

KOFOID et ADAMSON 1933:78, t. 5, f. 4, t. 15, f. 16, t. 17, f. 42-47; SCHILLER 1936:337, f. 360 a-d; BALECH 1962b:153, t. 21, f. 336-338; WOOD 1963c:15, f. 49.

In its most reticulated state this species is readily recognisable. It is most close to, if not conspecific with, *H. crassipes* SCHILLER. The latter's only obvious difference is the large fin which extends between the antapical horns (noted by KOFOID & ADAMSON). An extreme variant, thought to be this species, is shown in fig. 230. It totally lacked surface reticulation and the antapical horns were more divergent than the variability previously known. It was present in the same sample as the other specimen illustrated.

Stations: 35, 71, 100, 116, 142, 294.

Although by no means common this was the most highly represented member of *Heterodinium* in the material. It occurred at scattered stations in the Bay of Bengal, Andaman Sea, and at three stations in the northern Indian Ocean (cruises I, II, and V).

It has been previously recorded from the Indian Ocean by KARSTEN (1907) and WOOD (1962, in 1963a). It is one of the most eurythermal members of the genus, occurring in warm-temperate as well as tropical waters. It was the commonest species in "Albatross" Pacific Ocean material examined by KOFOID & ADAMSON (1933).

Heterodinium sinistrum KOFOID et ADAMSON Plate 23, Fig. 235

- 1933:105, t. 16, f. 34, t. 21, f. 78.

Syn.: *H. mediocre* forma *sinistrum* (KOFOID et ADAMSON) SCHILLER 1936:346, f. 376.

In the comments under *H. mediocre* the alternative treatments of this taxon (infraspecific or specific) and others closely similar (*H. gesticulatum*, *H. deformatum*) have been discussed. *H. sinistrum* represents a variant in which the left antapical region of the hypotheca has become elongated and the epitheca slopes towards the right. *H. deformatum* represents the other extreme, with great reduction of the left side.

Station: 313.

Observed at one station in the south central Indian Ocean near 30°S.

This taxon has only been previously recorded from the eastern tropical Pacific Ocean.

Heterodinium whittingae KOFOID Plate 23, Fig. 226

KOFOID et ADAMSON 1933:92, t. 16, f. 29; SCHILLER 1936:343, f. 371; GAARDER 1954:32, f. 35 a, b; MARGALEF 1969a, f. 4 A-C; RAMPI 1969b:326, t. 4, f. 1; LÉGER 1973a:20, f. 6.

A distinctive, large, flattened species with large well-developed reticulations and sharp, inwardly-curved antapical horns. It is not likely to be confused with other species. Its closest resemblance (superficial) is with *H. scrippsii*, from which it is readily distinguished by being much more flattened, and in the shape of its antapical horns which curve outwards in *H. scrippsii*.

Station: 334.

Found at only one station in the northern Indian Ocean (southern Arabian Sea). This is a first record for the Indian Ocean. The species is relatively eurythermal, being found in warm temperate as well as tropical waters in the Pacific and Atlantic Oceans.

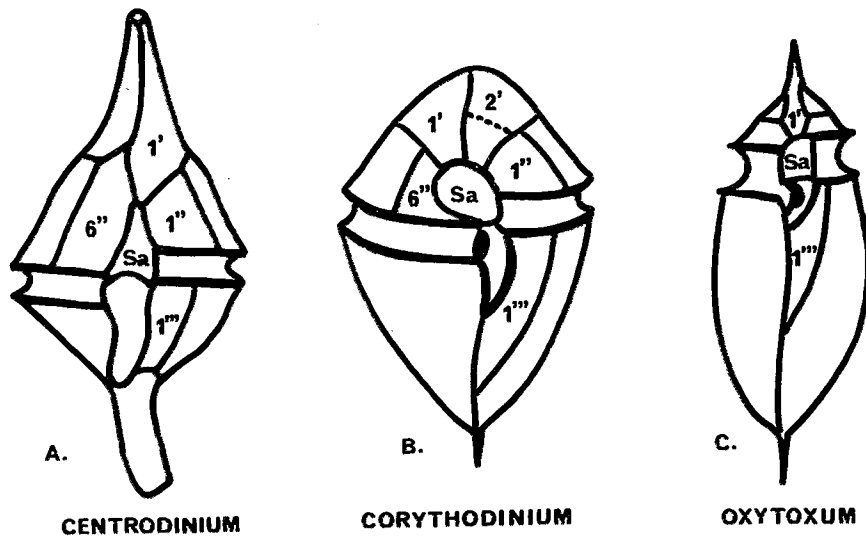
Family Oxytoxaceae LINDEMANN

Conventionally this family has been regarded as consisting of two genera, *Oxytoxum* STEIN and *Pavillardinium* (KOFOID) DE TONI (= *Murrayella* KOFOID). They have been separated almost solely by the position of the girdle (whether it is anterior or submedian in position respectively). Plate information on many of the taxa has been lacking or incomplete due to their rarity and/or small size. The rare psammophilic genus *Adenoides* BALECH, also apparently a member of the family, has a tabulation of 1', 4'', 5c, 5s, 5''', 5P, 1'''' (BALECH 1956).

Recently it has become evident that a) the genus *Centrodinium* KOFOID shows strong resemblances to some members assigned to *Pavillardinium* ("Group A"); b) *Pavillardinium* has grown to include two rather dissimilar groups, one of which resembles *Centrodinium* ("Group A") and the other, some members of *Oxytoxum* ("Group B"); and c) *Oxytoxum* has come to include at least two dissimilar groups, one of which (originally described as the genus *Pyrgidium* STEIN) shows resemblances to the "Group B" of *Pavillardinium* above, and the other is more distinctively separate.

In other words, as information on the above genera has increased, and further species have been added, the generic limits as originally proposed have become increasingly inappropriate. Here attention is drawn to new criteria which can be readily observed and applied to recognise three generic groupings which seem to be more realistic to this author. In the process it has been found that the revised schema requires the reinstatement of STEIN's (1883) genus *Pyrgidium*, although with the epithet substituted by *Corythodinium* LOEBLICH et LOEBLICH III, and the dismantling of *Pavillardinium*.

Details are given below under each genus. Text figure 2 illustrates the chief features by which each can be recognised in ventral view. All members of this family share a tendency towards left-handed displacement of the girdle with accompanying torsion effects. Torsion and displacement is least in *Oxytoxum*, moderate and involving the hypotheca mostly in *Centrodinium*, and strongest, effecting both the epi- and hypotheca, in *Corythodinium*. In all three genera the sulcus notches the hypotheca strongly (strongest in *Centrodinium* and least in *Oxytoxum*) and in two the anterior sulcal plates invade the epitheca strongly. In *Centrodinium* the anterior sulcal plate is subtriangular and in *Corythodinium* it is large and obovate.



Text fig. 2. Ventral views of the three principal genera of the Oxytoxaceae recognised here. Note the differences in the form of the ventral area (not all plates are shown) and the anterior sulcal plate (Sa).

Genus *Centrodinium* KOFOID

Syn.: *Murrayella* KOFOID pro parte; *Pavillardinium* KOFOID pro parte.

When this genus was first described KOFOID (1907b) indicated its probable affinity with *Ceratium*. This allocation has become increasingly doubtful with time. KOFOID's figures indicated only a few plate sutures on the left side and only one ventral view was given, illustrating the considerable lateral flattening of the genus and the presence of an elongate

sulcal furrow, but showing none of the plates on the ventral side. Nevertheless, KOFOID provided numbers of plates for each series [2(- 4'?), 6'', 5''', 1P, 4''''].

Unfortunately he referred to "five precingulars" on the hypotheca, undoubtedly intending to refer to postcingulars judging from the context in which the error appeared (he had already given the number of plates on the epithecal series, and an intercalary plate on the hypotheca was termed a "dorsal intercalary"). This led SCHILLER (1936) to give the number of precingular plates as 5". WOOD (1954) later suggested the possible presence of an anterior intercalary plate ("1a?") although he gave no reason for this. His figure is too imprecise to clearly determine the plate formulation and is probably inverted.

BALECH (1962b) also considered the question of plates. On the basis of both left and right-side observations on four species from the Pacific Ocean he concluded that the plate formula ought to be altered to 2', 3^a, 7'', 5C?, 5''', 1P, 1''''; a drastic revision but not too surprising in view of the difficulty in observing the plates. Unfortunately, he did not detail the appearance of any of the plates as seen in ventral view.

A more serious complication became evident in one of BALECH's later (1967a) studies although there were earlier indications of the problem. He noted a strong resemblance to *Centrodinium* in his detailed analysis of the plates of a new species, *Murrayella mimetica*. However, he considered that the difference in plate formula (3', 1^a, 6'', 6C, 5''', 2P, 1''''), combined with a smaller size and strongly-developed thecal markings with pores covering the whole surface of the theca, was sufficient to warrant separation from *Centrodinium*. The plate formula was similar to that which he had established for other species of *Pavillardinium* (although this did not include the type species of the latter).

Under *Corythodinium* the problem of the recognition of the genus *Pavillardinium* (= *Murrayella*) has been discussed in detail. The type species of the latter has been included in *Corythodinium*. Here some other members formerly assigned to *Pavillardinium* (and which now are in a nebulous systematic position because of the removal of the type and their own inability to conform to the criteria of *Corythodinium*) are believed to correspond closely to *Centrodinium* and are consequently transferred to it. If desired two subgenera (one exhibiting lateral flattening and posterior torsion, and the other not) could be recognised although there does not seem to be much to be gained from this at present.

As now proposed the genus *Centrodinium* can exist as either strongly or only moderately flattened (laterally) species. All have girdles exhibiting left-handed displacement, the displacement usually not being more than one girdle width. The anterior sulcal plate is distinctively shaped, being fairly narrow and subtriangular with one apex pointing towards the anterior of the cell. The sixth precingular plate is often long and narrow, often being acute at its apical end. The posterior sulcal region is always displaced towards the right side at its lower end and in those members most similar to the type species (*C. elongatum* KOFOID) the antapex of the cell is drawn out and has obvious torsion. It is also often distally bent towards the cell's left.

In addition to those species usually assigned to the genus the following taxa have been transferred:

- Centrodinium biconicum* (MURRAY et WHITTING) comb. nov. [basionym = *Ceratium biconicum* MURRAY et WHITTING 1899:323, t. 27, f. 4 a-c; Syn. *Murrayella biconica* (MURRAY et WHITTING) PAVILLARD 1931:98, t. 3, f. 15; *Pavillardinium biconicum* RAMPI 1948:937, f. 8]
- Centrodinium pavillardii* nom. nov. [basionym = *Murrayella intermedium* PAVILLARD 1916:44, t. 2, f. 5; a new combination is prevented by *C. intermedium* PAVILLARD 1930]
- Centrodinium mimeticum* (BALECH) comb. nov. [basionym = *Murrayella mimetica* BALECH 1967a:117, pl. 8, fig. 129-132, pl. 9, f. 133-135]
- Centrodinium pacificum* (RAMPI) comb. nov. [basionym = *Pavillardinium pacificum* RAMPI 1950a:10, f. 15]
- Centrodinium punctatum* (CLEVE) comb. nov. [basionym = *Steiniella punctata* CLEVE 1900c:18, pl. 8, fig. 4 cf. BALECH 1971b:34, pl. 8, fig. 154-158, pl. 9, f. 159-167 = *M. punctata* (CLEVE) KOFOID, ? *M. splendida* RAMPI 1941a, *Pavillardinium splendidum* (RAMPI) RAMPI 1950a]

In addition the following taxa are also probably referable to *Centrodinium*:

- Murrayella ovalis* PAVILLARD 1930:12, f. 16; - 1931:98, pl. 3, f. 16 (insufficient detail).
- Murrayella* sp. BALECH 1962b:187, pl. 24, f. 374.
- Unidentified sp. BALECH 1962b:188, pl. 23, f. 365.
- Goniodinium spiniferum* P. DANGEARD 1927b:337, f. 3 a-c (anterior sulcal detail not shown).

Centrodinium sp. Plate 24, Figs. 237 a–c

[? *Centrodinium mimeticum* (BALECH) comb. nov.]

The specimen shows many resemblances to *Centrodinium mimeticum* (BALECH) comb. nov. and also strengthens the proposed ties of taxa of the latter type to *Centrodinium*. It exhibits strong lateral flattening, with a broader epitheca than hypotheca, the poorly-demarcated plates being recognisable more by their pore-free intercalary zones than by sutures. There is a long, narrow sulcus with delicate fins, and an elongated posterior end drawn out into a horn exhibiting a twisted (descending) appearance. A few of the sutures are associated with strong ridges. The plate pattern could not be fully established on the right side and so only those details shown in the figures here are known. The plate details show many resemblances to *C. mimeticum*, especially in the arrangement of the plates on the ventral side of the epitheca although BALECH did not observe distinct torsion in the posterior part of the cell. Also, there are some other puzzling anomalies (perhaps arising from erroneous observations here). The most striking is that in the "Anton Bruun" specimen there was a median dorsal longitudinal suture (associated with a girdle suture) on the hypotheca, whereas BALECH found a plate (3'') to be centrally situated in that position. The size here is compatible with the range given by BALECH (length 93–127.5 μm ; transdiameter 37.5–50 μm).

Station: 103.

A single specimen was observed from the Bay of Bengal in the vicinity of Madras. BALECH's specimens were from the Gulf of Mexico.

Genus *Corythodinium* LOEBLICH et LOEBLICH III emend. nov.

Syn.: *Pyrgidium* STEIN 1883; *Murrayella* KOFOID 1907b; *Pavillardium* DE TONI 1936; *Oxytoxum* STEIN pro parte.

This genus was created by STEIN (1883, p. 20 as *Pyrgidium*) for five species considered by him to be similar to *Oxytoxum*. These were *P. constrictum*, *P. mitra*, *P. reticulatum*, *P. sceptrum*, and *P. tessellatum*. His description, as in the case of *Oxytoxum*, was based on inverted specimens (so that his references to the epi- and hypothecae were reversed) and his depiction of the thecal plates was relatively incomplete although excellent for the time. LOEBLICH & LOEBLICH (1966) have designated *P. tessellatum* STEIN as the type of the genus, also providing the name used here in view of preoccupation of STEIN's epithet by a genus of gastropods and of lichens. Of the five original species included by STEIN, *P. mitra* and *P. sceptrum* are now excluded as a result of the emendation below.

As generic characters STEIN drew attention to the presence of five plates on the "Vorderleib" (now known to be five postcingulars on the hypotheca) of which that associated with the sulcus (the "Mundbasal") was shorter and narrower than the others. An antapical spine was present ("Frontstachel"). The hypotheca was strongly indented below the flagellar pores, forming a well-defined sulcus. He considered that the epitheca consisted of five precingulars and one apical plate. Three of these species were large, relatively broad, with low, wide epithecae, lacking apical spines (*P. constrictum*, *P. reticulatum*, and *P. tessellatum*) whereas the other two had apical spines (long in *P. sceptrum*, very small in *P. mitra*). *P. reticulatum* was figured only from the dorsal side. One of the species he assigned to *Oxytoxum*, *O. diploconus* showed strong resemblances to the group of three species above but was figured only in side view, and he made no comment as to this resemblance. The side view was sufficient to show that it had a descending, displaced girdle (one girdle width).

As the genus had been formulated by STEIN it intergraded completely with *Oxytoxum*, due to the common possession of an anteriorly displaced girdle and the deep notch in the hypotheca associated with the sulcus. Due to the inclusion of *P. mitra* and *P. sceptrum* in the genus there was also a complete morphological gradient towards the small rounded members of *Oxytoxum* and towards the elongate members with terminal spines such as *O. scolopax*. Consequently it seemed quite reasonable for later authors to "sink" *Pyrgidium* into *Oxytoxum*, PAULSEN (1908) considering it to be a subgenus, and SCHÜTT (1896) and SCHILLER (1936) referring to it as a section of *Oxytoxum*.

KOFOID (1907b) created a new genus *Murrayella* (pre-occupied by a genus of the red algae: *Murrayella* SCHMITZ) the type of which (*M. globosum* KOFOID) was very similar to the "group of three" in STEIN's work but it had the girdle submedian in position.

Of the other species assigned by him to this genus *M. spinosa* KOFOID was shown later to be synonymous with the type species of *Amphidoma* (BALECH 1971b), and *M. punctata* (CLEVE) KOFOID is here transferred to *Centrodinium*, leaving only *M. rotundata* KOFOID, which because of the lack of a ventral view, cannot be properly treated here.

Pavillardinium (as *Murrayella* was renamed by DE TONI) has continued to be recognised by either of its names, with species being added to it periodically. In the process it has become evident that there are two rather dissimilar units within *Pavillardinium*, one resembling the type species and the other resembling *Centrodinium* (see comments under the latter for further details of those members now transferred to it). Action has been taken here to hopefully clarify this situation, and make it more realistic, by down-grading the very arbitrary criterion of girdle position and focussing on a hitherto neglected feature of the theca, easily visible, which seems to this author to be an important character. As a result the genus *Pyrgidium* sensu lato has been resurrected, including three of its original species, one of which is the type (*P. tessellatum* STEIN) and the genus *Pavillardinium* DE TONI (= *Murrayella* KOFOID) sensu stricto has been "sunk" into *Corythodinium*.

The characters now considered to be important in the delimitation of *Corythodinium* emend. are:

Relatively robust species, rounded or broadly elongated, lacking "affixed" apical spines (although the epitheca may rise to a pointed cone) but usually possessing an antapical spine. The epitheca often shows signs of dextral torsion, with the plates displaced accordingly. In a few species the epitheca may be laterally flattened and raised into a crest. The girdle is strongly developed, lacking lists, with right-handed (descending) displacement of one or more girdle widths. The proximal ends of the girdle may overlap slightly. Both the epitheca and the hypotheca are strongly notched by the sulcus. The anterior sulcal plate is unusually large and usually obovate (sometimes pentangular) with the narrower end closer to the flagellar pore(s). The thecal plates are usually strongly reticulated and poroid, and intercalary bands may develop.

The plate formula of the type species is 3', 2^a, 6'', 5C, ? S, 5''', 1'''' but the range of variation within the genus cannot be established clearly as yet. *C. belgica* (MEUNIER) comb. nov. has four apical plates, no intercalary plate and only five precingular plates. *C. globosum* (KOFOID) comb. nov. has an anterior intercalary plate on the ventral side. As emended the genus includes the following taxa (with references to recent detailed descriptions, if available, and basionyms where new combinations are involved):

- C. belgicae* (MEUNIER) comb. nov. [basionym = *Oxytoxum belgicae* MEUNIER 1910, pl. 16, f. 38–41; cf. BALECH 1971a:167, pl. 36, f. 695–703]
- C. biconicum* (KOFOID) comb. nov. [basionym = *Amphidoma biconica* KOFOID 1907a:311, pl. 32, f. 50–52, = *Murrayella* KOFOID; GAARDER 1954:34, f. 40 a–c]
- C. carinatum* (GAARDER) comb. nov. [basionym = *O. carinatum* GAARDER 1954:35, f. 42 a, b]
- C. compressum* (KOFOID) comb. nov. [see below]
- C. constrictum* (STEIN) comb. nov. [basionym = *Pyrgidium constrictum* STEIN 1883, t. 5, f. 15–18]
- C. cristatum* (KOFOID) comb. nov. [basionym = *O. cristatum* KOFOID 1907b:188, p. 10, f. 64, cf. BALECH 1962b:170, pl. 19, f. 290, 291]
- C. curvicaudatum* (KOFOID) comb. nov. [basionym = *O. curvicaudatum* KOFOID 1907b:189, pl. 10, f. 61]
- C. diploconus* (STEIN) comb. nov. [basionym = *Oxytoxum diploconus* STEIN 1883, pl. 5, f. 5; cf. BALECH 1971a:166, pl. 36, f. 704]
- C. elegans* (PAVILLARD) comb. nov. [basionym = *Oxytoxum elegans* PAVILLARD 1916:43, pl. 2, f. 4; cf. BALECH 1971b:31, pl. 8, f. 138–141]
- C. frenguelli* (RAMPI) comb. nov. [basionym = *O. frenguelli* RAMPI 1941a (1943?):65, pl. 2, f. 2; note that MARGALEF's 1969a, fig. 3J is optically reversed]
- C. globosum* (KOFOID) comb. nov. [see below]
- C. latum* (GAARDER) comb. nov. [basionym = *O. latum* GAARDER 1954:36, f. 43; BALECH 1962b:170, t. 19, f. 292–294, 297–301]
- C. michaelsarsii* (GAARDER) comb. nov. [basionym = *O. michaelsarsi* GAARDER 1954:37, f. 44; figure incomplete; determination by GAARDER's comparisons to *O. tessellatum* and *O. elegans*]
- C. recurvum* (KOFOID et MICHENER) comb. nov. [basionym = *O. recurvum* KOFOID et MICHENER 1911:288 – no figures; determination by comparison with *O. cristatum*]
- C. reticulatum* (STEIN) comb. nov. [basionym = *Pyrgidium reticulatum* STEIN 1883, t. 5, f. 14; cf. BALECH 1971b:31, pl. 7, f. 135–137]
- C. tessellatum* (STEIN) LOEBLICH et LOEBLICH III 1966:23. [type, cf. BALECH 1971b:30, pl. 70, f. 130–134]

Not all the taxa above necessarily deserve separate recognition, some no doubt being synonymous. The following indeterminate taxa are probably also assignable to *Corythodinium*: *M. rotundatum* KOFOID (1907b), *O. brunellii* RAMPI (1939b), and *O. areolatum* RAMPI (1941a, also in HERRERA, MUÑOZ & MARGALEF 1955, f. 1 L), *Oxytoxum* sp. BALECH (1971a, pl. 36, f. 708–713).

Pyrgidium mitra STEIN and *P. sceptrum* STEIN are excluded from the genus, remaining within the genus to which they are now assigned (*Oxytoxum* STEIN). *Murrayella australica* WOOD is probably a species of *Amphidoma*.

Corythodinium compressum (KOFOID) comb. nov. Plate 24, Fig. 254
Basionym: *Oxytoxum compressum* KOFOID 1907b:188, t. 10, f. 63; . . . SCHILLER 1936:461, f. 522; WOOD 1963b:44, vix f. 162 a, b.

This species resembles *C. carinatum* (GAARDER) comb. nov. so closely that they are probably synonymous although GAARDER (1954) found both species in her material. The name, *C. carinatum*, refers to a strong lateral flattening of the epitheca into a crest whereas this is not mentioned for *O. compressum*. However, it should be noted that this would not be evident when the cells are seen from the side or three-quarter view as shown here or in KOFOID's original figure. In size the taxa are similar with a total length of 90 to 115 μm including a strong, sharply-pointed antapical spine, curving ventrally, 12 to 16 μm in length. *C. cristatum* (KOFOID) is also similar in size and shape although the epitheca is relatively larger. It is flattened laterally, as in *C. carinatum*, but is curved over in a hook apico-dorsally.

The constriction on the hypotheca of *C. constrictum* (STEIN) comb. nov. serves to distinguish it from *C. compressum* and it is also smaller (total length approximately 75 μm).

Station: 53.

Only one specimen was observed. The station was in the northern Bay of Bengal. This is a rare species which has only been previously recorded from the Indian Ocean by WOOD (1962, in 1963a) and SOURNIA (1968b). It was originally described from the eastern tropical Pacific Ocean.

Corythodinium globosum (KOFOID) comb. nov. Plate 24, Figs. 238 a, b
Basionym: *Murrayella globosa* KOFOID 1907b:191, t. 9, f. 56.
Syn.: *Pavillardinium globosum* (KOFOID) DE TONI RAMPI 1950a:9, f. 21.

This is a distinctive, rarely observed species. It is readily identifiable by the presence of an unusual anterior intercalary plate which is situated on the ventral epithecal surface in such a way that it intrudes between the first apical plate (displaced to the right upper quadrant of the epitheca as in other members of this genus) and the very large anterior sulcal plate, almost cutting off contact. Intercalary bands seem to be commonly developed in this species, making the precise position of the sutures difficult to locate although the plates themselves are very evident, with strong reticulation.

It is not yet known if any other members of *Corythodinium* also possess the ventrally situated anterior intercalary plate.

Station: 61.

Only one specimen was found. It occurred in the northwestern Bay of Bengal. The species was originally described from the eastern tropical Pacific Ocean. It has not apparently been previously recorded from the Indian Ocean.

Genus *Oxytoxum* STEIN

Some of the early confusion regarding this taxon has been explained in the comments under *Corythodinium*. Although STEIN created the latter as a separate genus two of the five species originally assigned to it exhibited intermediate features, leading later authors to include *Corythodinium* (using STEIN's epithet: *Pyrgidium*) under *Oxytoxum*. As now reinstated the genus *Corythodinium* can be recognised from *Oxytoxum* by the possession of a large obovate or pentangular anterior sulcal plate which invades the epitheca strongly, and also by the strong left-handed girdle displacement. In *Oxytoxum* the anterior sulcal plate (often bounded by thickened edges) only indents the epitheca slightly, if at all, and the girdle shows only slight signs of displacement. All members of *Oxytoxum* have an anteriorly situated girdle with a relatively small epitheca, whereas the epitheca is relatively larger in *Corythodinium* (broader across its base) and

the girdle may be either median or anterior in position. It should be noted that *O. gigas* KOFOID is not a member of *Oxytoxum* but instead belongs to *Gonyaulax*. It is highly probable that it is synonymous with *G. mitra*.

As indicated earlier, *Oxytoxum* exhibits the least signs of torsion in the family, and the sulcus notches the hypotheca only slightly. The plate pattern is very poorly known, existing formulae having been derived from the larger members now transferred to *Corythodinium*. Recently BALECH (1971a) has partially dissected the epithecal plates of *O. scolopax*. In the present work some superficial details of the flagellar pore region of the same species have been illustrated with the aid of the scanning electron microscope (fig. 5:12). The presence of what appears to be a vestigial list to the right of the flagellar pore is interesting in the light of the description of a new species here in which a list (perhaps its homologue) is clearly developed (*O. lativelatum* sp. n.).

The resemblance of the genus to *Oxyphysis*, discussed by KOFOID (1926), appears to be superficial as the latter is apparently a good dinophysoid genus.

Two species of *Oxytoxum* described recently by RAMPI (1969a), *O. tonollii* and *O. margalefii*, do not conform with the proposed criteria for the recognition of the genus. It is suspected that they may be inverted members of *Amphidoma* (see comments under the latter).

Oxytoxum crassum SCHILLER Plate 24, Fig. 242
– 1936:459, f. 518 a, b; WOOD 1968:88, f. 251.

This identification is somewhat tentative because the present specimen (only one seen) had an acute rather than ovoidly rounded antapex. Small apical and antapical spines are present, although the latter are only faintly shown in one of SCHILLER's figures and not in the other. They are, however, mentioned in his text.

The sutures are very strongly marked by ridges, especially on the epitheca. SCHILLER stated that five apical and five precingular plates are present although only four apical plates could clearly be seen here (a figure which fits other members of the genus). The flagellar pore is very evident.

This species resembles *O. mitra* STEIN but is apparently much smaller. STEIN (1883) did not give a size in his original description but from his magnification data (given as ranging from 450 to 690 X) the length can be presumed to be between 70 and 110 μ m.

Station: 319.

Found at a central Indian Ocean station on cruise V. This is a new record for the Indian Ocean. The species was first described from the Adriatic Sea and has since been recorded from the Straits of Florida.

Oxytoxum globosum SCHILLER Plate 24, Fig. 247
– 1936:458, f. 515 a, b; RAMPI 1969b:327, t. 4, f. 4.
Non WOOD 1963c:17, f. 59.

This is a very small, rotund species. The Indian Ocean specimens were only 12–14 μ m in length. RAMPI (1969b) reported a length of 15 μ m and SCHILLER's original figure calculates to 17 μ m. A small apical papillum is present and SCHILLER also described a small antapical spine although the latter could not be observed in the Indian Ocean material. *O. ovum* GAARDER is similar in general appearance but it is much larger (40 μ m in length).

Station: 315.

Only two specimens were observed at a southern central Indian Ocean station on cruise V. Although WOOD (1963c) has recorded the species from the eastern Indian Ocean his figure cannot be referred to this species, possessing a subglobular epitheca with a diameter of approximately half that of the hypotheca instead of approximately two thirds. Consequently, this appears to be a new record for the Indian Ocean. It was originally described from the Adriatic Sea.

Oxytoxum laticeps SCHILLER Plate 24, Fig. 249
– 1936:461, f. 523; WOOD 1954:46, f. 170; – 1963b:46, vix f. 170; HASLE 1960:37, f. 31; WOOD 1968:90, f. 260.

SCHILLER's original figure only showed the dorsal side with no details of thecal surface structure. Consequently, HASLE's identification was based only on shape and size. The epitheca is broad, low and evenly convex. In the original description and in the present specimens an apical spine was lacking, although HASLE has figured a small apical spine. HASLE's specimens had a fairly strongly displaced girdle (left-handed, descending) but this was not as great in the present

material and is not shown at all in WOOD's figures. The size range, as presently known, is: length 15–25 μm ; diameter 9–15 μm .

The species differs from *O. mediterraneum* SCHILLER in possessing a posterior spine and lacking strong, linearly arranged pores. It is also similar to *O. viride* SCHILLER which has (according to the interpretation here) a different ventral area construction (see fig. 248). *O. punctulatum* RAMPI (1952a) also lacks a posterior spine, has a wide sulcal region, and has closely set rows of punctae similar to *O. mediterraneum*. It has a wider epitheca than *O. pachyderme*.

Station: 374.

Only a few specimens were observed at a station off the southern African coast. It was originally described from the Adriatic Sea and has been found in the Coral Sea, the eastern tropical Pacific Ocean, the Indian Ocean (WOOD 1963b), and the tropical Atlantic Ocean. It is apparently a surface species.

Oxytoxum lativelatum sp. n. Plate 24, Figs. 240 a, b

A small rotund species; the epitheca much smaller than the hypotheca, subglobular with small crenulations marking the upper girdle ridge. Girdle diameter approximately one quarter of the maximum diameter; height approximately one-fifth to one-quarter of the total cell length. The hypotheca is roundly lenticular with an acutely pointed antapex. The broadest region is near the mid-point of the cell. Its surface is finely reticulated. Its walls appear to be thicker than the remaining theca. The plate pattern is not known as yet. The first postcingular plate is narrow, only reaching halfway to the antapex.

A strongly developed but transparent fin arises from the right side of the flagellar pore. It extends slightly onto the epitheca. There is also an internally projecting spine (into the cell body) which arises near the flagellar pore. Length: 28 μm ; maximum diameter 18 μm .

Iconotype: Plate 24, fig. 240 a, b.

Type locality: Southern Indian Ocean; 31° 58'S, 59° 51'E.

No species of *Oxytoxum* have as yet been described bearing a fin of the type depicted here (see *O. semicollatum* sp. n. for a different type) although it is possible that such structures may have been missed due to their transparency. As indicated under *O. scolopax* the latter has a vestigial structure of similar type and position and this may be relatively common in the genus. The inwardly-projecting curved spine associated with the flagellar pore is also unusual.

This species has resemblances to two species described by RAMPI but differs from them in the presence of the flagellar fin and spine. In fact, the figure of *O. minutum* RAMPI (1948, fig. 5) from the subtropical Pacific Ocean shows a structure which may be a fin although no mention of it was made in the text. In any case his species is easily distinguishable due to its broad epitheca and antapically rounded hypotheca. In shape *O. lativelatum* is very similar to *O. spinosum* RAMPI (1941a, fig. 15; HALIM 1960a, pl. 3, fig. 24) and it is possible that RAMPI missed the fin. He only illustrated the species in ventral view. His type material was somewhat smaller (length 20 μm) than *P. lativelatum*.

There are also strong resemblances in shape to *O. sphaeroideum* STEIN var. *sphaeroideum* but the latter lacks the antapical spine in addition to the fin and internal spine (cf. SCHILLER 1936, p. 452, fig. 498).

Station: 157.

Three specimens, all similar in size and shape, were found at this single southern Indian Ocean station.

Oxytoxum nanum HALLDAL Plate 24, Figs. 245, 246
– 1953:56, f. 20.

This species is similar to *O. variabile* SCHILLER but differs from it by its broader girdle, and by the epitheca being displaced slightly to the left. It is not as variable as the latter, the "Anton Bruun" specimens all being relatively similar in size (total length ranges from 20–26 μm). The body is curved, being ventrally concave in its posterior part. The sulcus distinctly notches the hypotheca.

Stations: 156, 289, 291, 305, 310, 358, 365, 366, 370, 371, 374, 404, 407.

As with other small *Oxytoxum* species, the use of nets for sampling probably results in severe under-representation. In the present case the distribution exhibited is nevertheless interesting. With the exception of a few northern and southern (to 38°S) open ocean stations, mostly on cruise V, it was recorded frequently from a cluster of closely set stations in the southern half of the Mozambique Channel and also a bit further south. These latter stations were predominantly close to either the African or Mascarene coasts.

It was originally described from Weather Ship M (66 °N) in the North Atlantic Ocean where it was common and at times achieved a concentration of 8500 cells per litre. It does not appear to have been observed since then although it has possibly been confused with *O. variabile*. It must be strongly eurythermal, and is a surface species in the North Atlantic.

Oxytoxum pachyderme SCHILLER [valid. nov.] Plate 24, Fig. 250
 Basionym: *O. pachyderme* SCHILLER 1936:460, f. 519 "ad interd." WOOD 1963b:48, vix. f. 168.

SCHILLER's description of this taxon is invalid by the International Code of Botanical Nomenclature (Art. 34) because of the temporary status which he gave to it. Rather than create an unnecessary new name SCHILLER's description is here formally established.

The species is small (length 18–30 μm ; upper limit derived from WOOD). SCHILLER did not give a size in the text but his magnification for the figure indicates a length of 24 μm . It is relatively rotund with a low, convex epitheca and a relatively wide girdle. There is a small antapical spine and a less conspicuous apical spine. The specific epithet refers to the thick appearance of the wall. There are, however, several other species with equally thick walls. WOOD (1963b) made no reference to, nor illustrated the thick nature of the wall.

The present specimen is not as broad as that of SCHILLER, and the epitheca was slightly wider.

Station: 312.

Two specimens were observed in a single sample from a southern central Indian Ocean station (32 °S). It was originally described from the Adriatic Sea and WOOD found it in the Coral Sea. It has not been recorded previously from the Indian Ocean.

Oxytoxum parvum SCHILLER Plate 24, Fig. 239
 – 1936:464, f. 531; WOOD 1963b:48, f. 177; – 1968:92, f. 267; HERRERA et MARGALEF 1963:78, f. 24q; RAMPI 1969b:328, t. 4, f. 3.
 Syn.:? *O. tenuistriatum* RAMPI 1941a:63, t. 2, f. 14.

The specimen illustrated here is essentially intermediate in features between the description of SCHILLER and that of RAMPI's taxon above. It was 43 μm in length (*parvum*: 36 μm ; *tenuistriatum*: 52 μm) with a short-spined, somewhat globose epitheca. *O. parvum* was originally shown to have a slightly more developed apical spine than this specimen whereas *O. tenuistriatum* has a slightly shorter spine. The theca (of both) is marked by longitudinal costae as well as finer rows of pores. An interesting feature exhibited by both SCHILLER's specimen and the present one was a prominent round inclusion in the posterior part of the cell. They probably are accumulation bodies.

In the indentation of the epitheca by the sulcus the specimen also resembled *O. longiceps* SCHILLER which is also similar to *O. parvum* but is larger (length 66 μm). GAARDER (1954) found specimens which bridged the size range of *O. parvum* with *O. longiceps* (length of her specimens 45–65 μm) although indentation of the epitheca by the sulcus was lacking. Perhaps this taxon will also be shown to be synonymous (*O. parvum* having priority) in the future.

Station: 18.

A single specimen was found at a station in the southern Andaman Sea near Phuket Island. The species is known from the Mediterranean Sea, the tropical Atlantic Ocean, the western Pacific Ocean, and WOOD (1962, in 1963a) has recorded it from the eastern Indian Ocean.

Oxytoxum scolopax STEIN Plate 24, Figs. 252, 253; Plate 43, Fig. 512
 SCHILLER 1936:453, f. 502 a–c; RAMPI 1939b:465, f. 16; – 1941a:63, t. 2, f. 9; KISSELEV 1950:259, f. 449; RAMPI 1952a:113, f. 1; WOOD 1954:315, f. 245; SILVA 1956a:69, t. 11, f. 14; TRÉGOUBOFF et ROSE 1957:118, t. 27, f. 8 A, B; SILVA 1958:32, t. 3, f. 7; CURL 1959:306, f. 124; HALIM 1960a, t. 3, f. 26; HERRERA et MARGALEF 1963:78, f. 24 r; YAMAJI 1966:107, t. 51, f. 16; STEIDINGER, DAVIES, et WILLIAMS 1967, t. 6, f. f; TAYLOR 1967, t. 91, f. 38; WOOD 1968:93, f. 270; STEIDINGER et WILLIAMS 1970:54, t. 27, f. 87; BALECH 1971a:166, t. 36, f. 705–707; SOURNIA 1972a:155, f. 10.

This is one of the commonest members of the genus. With its elongate shape (length 70–120 μm), sharp, prominent spines on both the apex and antapex, and bladder-like swelling at the base of the antapical spine it is distinctive. *O. scepterum* (STEIN) SCHRÖDER is not as slender and lacks the posterior swelling.

From the accompanying electron micrographs it can be seen that there is a slightly developed fin on the right side of the flagellar pore. It is probably this fin which is developed much further in *O. lativelatum* sp. n. The micrographs also give a good visualisation of the surface structure of the theca. Some details of the epithecal and girdle plates have been elucidated

by BALECH (1971a). The sheath-like structure found associated with one of the cells (fig. 253) could have been produced either by the cell or by an organism which had ingested and then egested it.

Specimens from the cold southern station (308) were more robust than those in warmer waters.

Stations: 71, 98, 99, 108, 308, 315.

Although not common this species was very widely distributed, being one of the few to be found south of 40 °S in the Subtropical Convergence region near the Islands of Amsterdam and St. Paul.

The species is inter-oceanic. Although it appears to prefer warmer waters it can also apparently tolerate cold-temperate conditions.

GAARDER (1954) found the species to be scattered throughout the "Michael Sars" Atlantic Ocean material she examined.

In addition to the records listed by WOOD (1963a) the species has been recorded previously from the Indian Ocean by SILVA (1956a), ZERNOVA (1962), TSURUTA (1963), TAYLOR (1967), SUBRAHMANYAN & SARMA (1967), NEL (1968), and SOURNIA (1968b, 1970, 1972a) and ANGOT (1970).

Oxytoxum semicollatum sp. n. Plate 24, Fig. 241

Cells small with a reduced epitheca one fifth of the total length; girdle relatively wide, one quarter total length; hypotheca widest just below the girdle, antapex acute. Thecal surface porulate. Plate pattern not yet resolved. The species is distinguished by a delicate lower girdle list projecting anteriorly, not outwards, higher on the right side than on the left side. Sulcal area indents hypotheca but not epitheca.

Length: 19–20 μm ; maximum diameter 12 μm (2 specimens).

Iconotype: Plate 24, fig. 241.

Type locality: Coast of Mozambique; 24° 42'S, 35° 23'E.

O. lativelatum sp. n. is the only member of the genus *Oxytoxum*, other than this species, which possesses a well developed list and in addition to considerable differences in cell body features, the lists are organised completely differently. In the case of *O. lativelatum* it is situated perpendicularly adjacent to the flagellar pore whereas it can be considered a homologue of a girdle list in this case.

When dealing with such delicate structures there is always the possibility that they are in fact parts of previously described species which have been missed by previous authors. The present species shows strong resemblances in shape to *O. sphaeroideum* STEIN var. *steinii* OSTENFELD et PAULSEN but is apparently considerably smaller (judging from STEIN's magnifications as no size is given by SCHILLER 1936). MARGALEF & DURÁN (1953, f. 2 X) have figured a small specimen which may be the present species as it possesses an upwardly-directed "spine" arising from the left side of the lower girdle rim. This is the opposite side to the fin reported here, but this may be the result of optical reversal or variability in the feature.

Station: 371.

After extensive searching of the material only two specimens could be found in one sample from the coast of Mozambique (August, 1964).

Oxytoxum subulatum KOFOID Plate 24, Figs. 251 a, b
SCHILLER 1936:465, f. 535; WOOD 1954:316, f. 250; MARGALEF 1961b:142, f. 3/11.

Vix BALECH 1962b:168, t. 19, f. 295, 296.

Syn.: *O. milneri* auct. non MURRAY et WHITTING . . . RAMPI 1941a:68, t. 2, f. 4; — 1952a:112, t. 1, f. 3; KISSELEV 1950:260, f. 453; TRÉGOUBOFF et ROSE 1957:118, t. 27, f. 13; HALIM 1960a, t. 3, f. 23; BALECH 1962b:169, t. 19, f. 284, 285; YAMAJI 1966:107, t. 51, f. 15; LÉGER 1971a:30, f. 12.

Vix WOOD 1963b:46, f. 173.

This is a large species. It most closely resembles *O. challengeroides* KOFOID (which is shorter, not exceeding 80 μm , largely due to the lack of a long apical process, but also differing by a less tapered antapex), and also apparently, *O. milneri* MURRAY et WHITTING. The latter could be synonymous but on the other hand, it probably belongs to a separate genus (*Corythodinium*).

The species are similar in size (length, *O. m.* 110–131 μm , *O. s.* 124–142 μm), and shape. The chief superficial distinction seems to be the canula-like, truncated tip to the epitheca of *O. subulatum*, that in *O. milneri* being sharply

pointed, the epitheca also being more smoothly conical. The narrow portion of the epitheca is shifted towards the ventral side in *O. subulatum*. Much of the difficulty in making a decision arises from the fact that MURRAY & WHITTING (1899) only illustrated their specimen from the dorsal side, and KOFOID (1907b) only illustrated *O. subulatum* from the right side. Here BALECH's (1971b) interpretation of MURRAY & WHITTING's species is used for its recognition. As a result it has been assigned to the genus *Corythodinium* due to the presence of the large anterior sulcal plate indenting the epitheca. HASLE's (1960) specimen appears to have been the same taxon as BALECH's, but she did not illustrate the ventral details of her specimen.

Station: 99.

It was only found at one station in the southwestern Bay of Bengal. The species has only been found in the Indian Ocean once before (see WOOD 1963a). It was originally described from the eastern tropical Pacific Ocean and has been found by WOOD (1954) in the western Pacific Ocean and by MARGALEF (1961b) in the Atlantic Ocean off the coast of northwestern Africa.

Oxytoxum variabile SCHILLER Plate 24, Figs. 243, 244
 – 1936:455, f. 505 a, b; HASLE 1960:38, f. 34 b–d vix a; WOOD 1963b:49, f. 183; RAMPI 1969b:330, t. 3, f. 8, 9.
 Syn.: *O. gracile* SCHILLER 1936:455, f. 506.

This small species exhibits a strong degree of variation, particularly in size, its reported dimensions (combined from the above sources) being: length 14–26 μm (30 μm in WOOD 1963b), diameter 5.5–12 μm . HASLE (1960) considered that its variability may also include *O. gracile* SCHILLER (which has a less convex lower girdle surface and more concave sides to its epitheca). On the basis of observations on the "Anton Bruun" material this synonymy appears to be reasonable. Delicate reticulation has been seen on the theca of some specimens.

O. nanum HALLDAL is also similar but is retained as separate here on the basis of the relatively broader, less excavated girdle, asymmetrically placed epitheca (displaced to the left), and strong linear markings (figs. 245, 246).

Stations: 157, 327, 336, 365, 374, 404, 407.

Recorded in small numbers from scattered central and western Indian Ocean stations, including the Mozambique Channel. It was apparently absent from the Bay of Bengal although, due to its small size, it is quite possible for it to not be retained by nets. Using closing bottles HASLE (1960) found that it achieved numbers up to 4000 cells per litre in equatorial Pacific Ocean samples, and was common at all depths to 300 or 400 m. It is clearly an important tropical species requiring sedimentation or centrifugation techniques to fully assess its abundance and distribution. It has been previously recorded from the Indian Ocean by WOOD (1962, in 1963a). Other records include the Mediterranean Sea, the tropical Pacific Ocean, and the Tasman Sea.

Oxytoxum viride SCHILLER Plate 24, Fig. 248
 – 1936:456, f. 510 b; WOOD 1968:94, f. 276.

A small (length 17–20 μm) species with rounded epi- and hypotheca. The epitheca is relatively well-developed being approximately one-fifth to one-quarter of the cell length. There is a small spinule at the tip of the hypotheca and (in the present material only) an inconspicuous apical projection may also be present. The most striking feature, visible even in formalin-preserved material several months after collection, is the presence of numerous small, bright-green chloroplasts (yellow-green in formalin). In ventral view, shown here for the first time, the girdle appears to be interrupted at the flagellar pore.

Station: 335.

A single specimen was observed at a station in the southern Arabian Sea.

The species has only been seen previously by SCHILLER (Adriatic Sea), GAARDER (1954, eastern tropical Atlantic Ocean), and WOOD (Strait of Florida).

Family Peridiniaceae EHRENBERG

This family is here represented by the genera *Diplopsalis* BERGH, *Peridiniopsis* LEMMERMANN, *Peridinium* EHRENBERG and *Zygabikodinium* LOEBLICH et LOEBLICH III.

Genus *Diplopsalis* BERGHSyn.: *Dissodium* ABÉ, partim.

This is the earliest described member of a group of spheroid to lenticular genera similar to *Peridinium*, but having for the most part, only three apical plates instead of four (see Table 4). In several, including *Diplopsalis* sensu stricto, there is only one antapical plate, instead of two as in *Peridinium*. The genus *Entzia* LEBOUR has four apical plates but has only one antapical plate. Nevertheless most authors have included it with *Peridinium*.

The history of this group is extremely confused, largely due to the fact that the earliest figures lacked tabulation (being difficult to see when the cell contents are present), and tabulational details are the chief means by which they are presently separated. Also, the effects of individual variability are still not well understood.

The genera can only be handled in the manner followed by the consensus of modern authors, building on the detailed studies of PAVILLARD (1913), LEBOUR (1922) and NIE (1943). The latter authors have summarised the historical confusion surrounding the genera.

A recent major development has been the proposal by BOURRELLY (1968a, b) to discard the genus *Glenodinium* because of the impossibility of defining its type species and the very differing interpretation which it has been given by many authors. This has partly arisen from the tendency to use *Glenodinium* as a convenient label for species whose tabulation was not elaborated fully or, in some instances, not at all. BOURRELLY has put all of the members with only one anterior intercalary plate into the genus *Peridiniopsis* in view of an analysis of the type species of the latter genus (BOURRELLY 1968b). This seems to be a sound suggestion to the present author, provided that *Peridiniopsis* is limited to those taxa with two antapical plates, thus already separating it from *Diplopsalis* (see below). Steps should be taken to have *Glenodinium* EHRENBERG declared a nomen confusum or nomen ambiguum (Botanical Code, articles 69, 70) and to allocate the species to other readily definable genera.

Further confusion has arisen due to differences between the Botanical and Zoological Codes (see Introduction). LOEBLICH III had asserted (1970, p. 905) that the genus *Diplopsalis* BERGH is pre-occupied by SCLATER's subgenus of birds, a view which is acceptable to the zoologist but not to botanists. If the principal is accepted that only names valid according to both codes may be used for dinoflagellates, ABÉ's name *Dissodium* should be used. This is unfortunate due to the possibility of confusion with *Dissodium* PASCHER. LOEBLICH III (1970) has indicated that members of *Diplopsalis* have two antapical plates. This reflects NIE's (1943) broader interpretation of the genus. Here the majority of these taxa would be considered to belong to the genus *Peridiniopsis*.

The subdivision in the table is logical and reflects the strictest recent interpretation of the genera. *Diplopsalis* is here limited to those species with only one antapical plate, as stressed by BALECH (1967a). However, how meaningful it is after variability is taken into account is unknown.

The large dorsal anterior intercalary plate of *Diplopsalis* can touch the apical pore in some cases (e.g. Pl. 28, fig. 298), thus theoretically altering the epithecal plates from 3', 1^a, 6'' to 4', 0^a, 6''. Allowance for such minor variability must clearly be made before creating new taxa. NIE (1943) considered that the anterior intercalary plates and the antapical plates were liable to variability, whereas the apical, precingular, post-cingular, cingular and sulcal plates were more conservative. Thus he did not distinguish *Peridiniopsis* from *Diplopsalis*.

Another point to be stressed is that there should not be a great inconsistency in the criteria used for generic recognition here and in *Peridinium*. In the latter a difference in the number of anterior intercalary plates is of subgeneric rather than generic significance, if no other differences are also present. While this is chiefly an arbitrary matter, the use of differing magnitudes of distinction among such closely related taxa does not seem logical.

From the table it can be seen that *Diplopsalis* and *Peridiniopsis* share the peculiarity of having only six precingular plates (the rest having seven) but differ in the presence of only one antapical plate in the former as well as in the number of cingular plates. *Zygabikodinium* and *Diplopsalopsis* have a combination of 3', 7'', differing only in the number of antapical plates. *Entzia* and *Peridinium* both have a 4', 7'' combination, also differing primarily in their antapical plate number.

Diplopsalis lenticula BERGH Plate 28, Figs. 298, 299

LEBOUR 1922:795, f. 1-5; - 1925:99, t. 15, f. 1 a-c; NIE 1943:10, f. 9-13; WOOD 1954:222, f. 86 a-c; TRÉGOUBOFF et ROSE 1957: 109; t. 23, f. 6 A, B; MARGALEF et MORALES 1960:5, f. 2 d; YAMAJI 1966:79, t. 37, f. 1; WALL et DALE 1968a:279, f. 7, t. 4, f. 19; STEIDINGER et WILLIAMS 1970:49, t. 18, f. 51.

Vix MARTIN 1928:23, f. 11–13 (*D. lebourae?*); HADA 1967:16, f. 26; WOOD 1968:54, f. 132.

Non WANG et NIE 1932:296, f. 9; SILVA 1952a:35, t. 3, f. 1, 2 vix 3.

Syn.: *Glenodinium lenticula* (BERGH) SCHILLER 1935:103, f. 95 a–h; KISSELEV 1950:136, f. 217 a–z, 220 a–B, non 218 a–B, nec 219 a–B.
Dissodium lenticulum (BERGH) LOEBLICH III 1970:905.

This is the type species of the genus, and although tabulation was not indicated in the original figures it is now accepted as having three apical plates, one large, symmetrical, dorsal anterior intercalary plate, six precingular plates (early figures, such as that of PAVILLARD 1913, often showed five, the mid-dorsal suture being omitted), five post-cingular plates and only one antapical plate. The cells are lenticular in shape, varying in transdiameter from 32–68 μm (usually less than 55 μm). KISSELEV (1935) created a forma *globularis* for those with a more spherical shape, later transferring it along with the f. *lenticula* to *Glenodinium*.

Fig. 298 shows an unusual epitheca in that it is more dorso-ventrally compressed than usual, and because of a dorsal shift of the apical pore, it looks as if it has four apical plates rather than three plus an intercalary plate. LEBOUR (1922) also found such variants occasionally.

WALL & DALE (1968a) have found that the cysts are spherical, with a smooth surface and a large apical archeopyle.

D. lebourae (NIE) BALECH is similar, being initially described as a variety of the above, but has been separated because of its spherical shape, sometimes even longer than broad, shape, large size (usually greater than 57 μm , but there is overlap with the above) and particularly prominent left sulcal list.

Stations: 94, 95, 101, 103, 104, 105.

The species was found only at a few stations in the west-central Bay of Bengal. However it was abundant at two of these (94, 101). Only two of the stations coincided with the distribution of the morphologically similar taxon, *Peridiniopsis asymmetrica*.

WOOD's (1963a) list of Indian Ocean records includes references to *Peridiniopsis asymmetrica* which should not be combined with *D. lenticula* (e.g. BALLANTINE 1961). Nevertheless there are still numerous records of the species from the Indian Ocean, SILVA's (1956a) and TAYLOR's (1967) references being additional to those listed by WOOD. It is evidently thermotolerant, being found in both cold-temperate and tropical waters. LEBOUR (1922) considered it to be a neritic species.

Table 4. Plate formulae of *Diplopsalis* BERGH and related genera.

<i>Diplopsalis</i> s. str. (= <i>Dissodium</i> ABÉ)	3'	1 ^a	6''	3C	6S	5'''	1''''
<i>Peridiniopsis/Oblea</i> * (= <i>Diplopelta</i> , <i>Glenodinium partim</i>)	3'	1–2 ^a	6''	3–6C	6S	5'''	2''''
<i>Zygabikodinium</i> (= <i>Diplopeltopsis</i>)	3'	1–2 ^a	7''	3C	4S	5'''	1''''
<i>Diplopsalopsis</i>	3'	2 ^a	7''	?	?	5'''	2''''
<i>Entzia</i>	4'	2 ^a	6–7''	3C	?	5'''	1''''
<i>Peridinium</i>	4'	2–4 ^a	7''	3–6C	4–7S	5'''	2''''

**Oblea* BALECH (1964b) has a similar formula to *Peridiniopsis* but has been distinguished from it in view of the strongly lateral displacement of the principal (largest) anterior intercalary plate.

Genus *Peridiniopsis* LEMMERMANN

Syn.: *Diplopelta* JÖRGENSEN; *Glenodinium partim*; *Dissodium* ABÉ partim.

This genus is very similar to *Diplopsalis*, differing by its possession of two antapical plates instead of one. The type species, *P. borgei* has six cingular plates, but the marine species seem to have only three (NIE 1943), an interesting parallelism to the marine and freshwater species of *Peridinium*. NIE (1943) did not distinguish between members with two antapical plates and those with one and consequently many of the species he described belong, in actuality, to *Peridiniopsis*. The following are here transferred:

Peridiniopsis hainanensis (NIE) comb. nov. [basionym: *Diplopsalis hainanensis* NIE 1943:13, f. 20–25]

Peridiniopsis pingii (NIE) comb. nov. [basionym: *Diplopsalis pingii* NIE 1943:16, f. 26–31]

Peridiniopsis excentrica (NIE) comb. nov. [basonym: *Diplopsalis excentrica* NIE 1943:17, f. 32–36]

LOEBLICH III (1970) followed NIE's broader interpretation, but transferred them all to *Dissodium* ABÉ in view of his assertion that *Diplopsalis* is pre-occupied.

In Table 4 it has been indicated that the genus *Oblea* shares the same tabulation but the single anterior intercalary plate is displaced very strongly to the left side of the epitheca [e.g. *O. rotunda* (LEBOUR) BALECH]. For further comments, see the discussion under *Diplopsalis*.

Peridiniopsis asymmetrica MANGIN Plate 28, Figs. 296 a, b; Plate 45, Figs. 520 a–c
LEBOUR 1922:798, f. 6–10; – 1925:101, t. 15, f. 3 a–c; WAILES 1928, t. 3, f. 9–12; – 1939:29, f. 83 A–D; BALLANTINE 1961:219, f. 18–20.

Syn.: . . . *Glenodinium lenticulum* forma *asymmetrica* (MANGIN) SCHILLER 1935:105, f. 97 a–c (non f, g, vix h); KISSELEV 1950:136, f. 219 a–β.

Diplopsalis lenticula forma *asymmetrica* (MANGIN) STEIDINGER, DAVIS et WILLIAMS 1967, t. 6, f. d; STEIDINGER et WILLIAMS 1970: 49, t. 18, f. 52.

Diplopsalis asymmetrica (MANGIN) LINDEMANN 1928:91; NIE 1943:14, f. 1–8; SILVA 1958:29, t. 2, f. 8–10; MARGALEF 1964, f. 2B; YAMAJI 1966:79, t. 37, f. 2.

Dissodium asymmetricum (MANGIN) LOEBLICH III, 1970:905.

Diplopelta asymmetrica (MANGIN) BALECH 1964b:22.

As NIE (1943) has remarked, this is probably the largest, most widely distributed and best known member of the *Diplopsalis/Peridiniopsis/Zygabikodinium* group. Its tabulation is that usual for the genus. The first anterior intercalary plate is small, rhomboid, and displaced to the left side, the second anterior intercalary being much larger and almost mid-dorsal. The body shape varies from lenticular to round, and the transdiameter can reach 95 μm. Typically the girdle lists lack supportive spines.

P. hainanense is perhaps the closest species to it, having only one anterior intercalary plate instead of two. In *P. excentrica* the apical plates are reduced in size, the second anterior intercalary plate being very large and covering most of the epitheca. *P. pingii* is much smaller, having a transdiameter of 40–45 μm.

Stations: 15, 17–19, 21, 24, 25, 28, 30, 32, 34, 35, 39, 40, 42, 48, 49, 51, 52, 62, 64, 65, 69, 71, 72, 87, 90, 92, 95–98, 105, 129, 130, 133, 144, 147, 148, 156, 285–287, 291, 310, 312, 359, 362, 366, 369, 371, 375, 415, 418, 420.

This was the commonest of the lenticular taxa, and was also one of the commonest species in the material. Although found as far south as 38°S it was generally absent from the central Indian Ocean and also, with the exception of the Gulf of Aden, from the Arabian Sea. In the Bay of Bengal it occurred chiefly at neritic stations (except those of lowest salinity), and it was widespread throughout the Andaman Sea. It was common both north and south of the Mozambique Channel, but was not found in the central channel at the time of cruise VIII (October).

The species is cosmopolitan, tolerating both cold-temperate and tropical conditions. It has been found on several occasions previously in the Indian Ocean, although WOOD (1963a) listed the records under *Diplopsalis lenticula* and erroneously included MATZENAUER's (1933) and SUBRAHMANYAN's (1958) records under "*Diplopsalis minor*."

Genus *Peridinium* EHRENBERG

This is one of the largest genera of thecate dinoflagellates and various attempts have been made to subdivide it into subgroupings or other genera. For example, one of the earliest attempts was that of PAULSEN (1908) who recognised two subgenera: *Proto-peridinium* (BERGH) OSTENFELD in which the girdle displacement is right-handed and antapical horns are lacking; and *Euperidinium* GRAN, with left-handed girdle displacement and often with antapical horns. This simple subdivision was soon seen to be insufficient to handle the ever-increasing number of species, and JØRGENSEN (1913) produced a new system which was based on the shape of the first apical plate, (four-sided: *Orthoperidinium*; five-sided: *Metaperidinium*; six-sided: *Paraperidinium*), three groups being subdivided further into various sections. Although his major groups are not used, many of his sections are still recognised, and his emphasis on the first apical plate was incorporated by later authors (principally PAVILLARD 1916, PETERS 1928, PAULSEN 1930, SCHILLER 1935, ABÉ 1936a and PAULSEN 1949) into a system using a combination of the features of the first apical plate plus the second (mid-dorsal) anterior intercalary plate, expressed in abbreviated jargon such as "ortho-quadra", "meta-penta" etc. (see text fig. 3), together with more general features such as the shape of the body, girdle displacement, presence or absence of antapical horns and spines, etc.