

THE TAXONOMY OF UNARMORED DINOPHYCEAE OF SHALLOW EMBAYMENTS ON CAPE COD, MASSACHUSETTS ¹

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Several papers give brief accounts of unarmored Dinophyceae found along the eastern coast of the United States. Calkins (1902) described from Woods Hole three European species, with one as a new variety. Herdman (1924a) listed five European, sand-living species from Woods Hole. Lackey (1936) listed thirteen species, all European, in his account of Woods Hole protozoa. Martin (1929) described thirteen species, four of which were new, from Barnegat Bay. It would be expected that further study would show many more extensions of range from the east to the west side of the Atlantic. One wonders, though, whether new species would be few, as suggested by these figures, or on the contrary would be many, since studies hitherto have not been very detailed. Further, the Barnegat Bay list suggests that the shallow, estuarine type of habitat has as many species as coastal waters, since Martin's number is matched only by that of Lackey.

The following study covers twenty-six species, of which twelve are completely

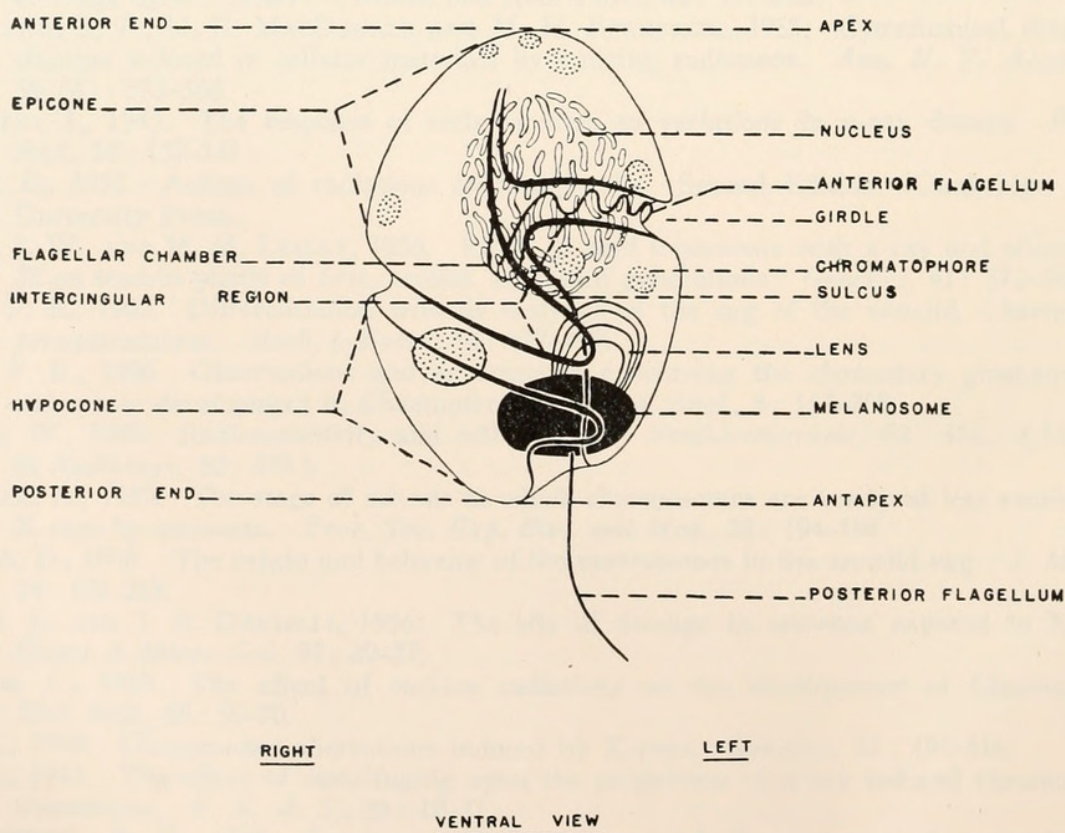


FIGURE 1. Structure of a dinophycean.

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new and nine show extensions of range from Europe. The collections which furnished the great majority of the material were from Great Pond, Falmouth Harbor, Salt Pond, and Uncatena Island Pond, all very shoal embayments on the southern shore of Cape Cod. The expectations, consequently, seem to be fulfilled.

Water samples were concentrated by centrifuging and the Dinophyceae were studied alive in water mounts. At magnifications of $\times 440$ and $\times 980$ drawings were made of specimens which had ceased to swim but showed no deformity due to approaching disintegration. Outline, girdle, and sulcus were drawn with camera lucida; the rest of the structures were drawn free-hand.

For those unacquainted with the morphology of unarmored Dinophyceae and its special nomenclature, Figure 1 illustrates the typical structure of such a dinophycean.

The species studied fall into eight genera, which may be characterized as in the following key:

KEY TO GENERA

- Girdle and sulcus rudimentary *Oxyrrhis*
- Girdle and sulcus well-developed:
 - Solitary:
 - Without ocellus and nematocysts:
 - Girdle not markedly displaced:
 - a) Girdle in anterior third of body *Amphidinium*
 - b) Girdle in central portion of body *Gymnodinium*
 - c) Girdle in posterior third of body *Massartia*
 - Girdle markedly displaced *Gyrodinium*
 - With ocellus but without nematocysts *Warnowia*
 - With ocellus and nematocysts *Nematodinium*
 - Colonial *Polykrikos*

OXYRRHIS Dujardin*Oxyrrhis marina* Dujardin

Oxyrrhis marina Dujardin in Kofoed and Swezy, 1921, p. 117, text fig. R, 3.

Oxyrrhis marina Dujardin in Lebour, 1925, p. 19, pl. 1, figs. 6a-6e.

Woods Hole area: Uncatena Island, Salt Pond; March, August, October. New Jersey; White Sea; England; brackish estuary near Nieuport, Belgium; Marseilles harbor; Genoa harbor.

This species is distinguished by the posterior position of its flagella, by the broad excavation of the posterior sulcus, divided midway by a tentacle-like lobe, and by the partial encirclement of the girdle. Other characters are its elongate ellipsoidal form and absence of chromatophores.

AMPHIDINIUM Claparède and Lachmann

KEY TO SPECIES

- Chromatophores present:
 - Chromatophore single *A. carteri*
 - Chromatophores many *A. wislouchi*
- Chromatophores absent:
 - Body stout, with rounded ends *A. crassum*
 - Body very slender, with pointed ends *A. sphenoides*

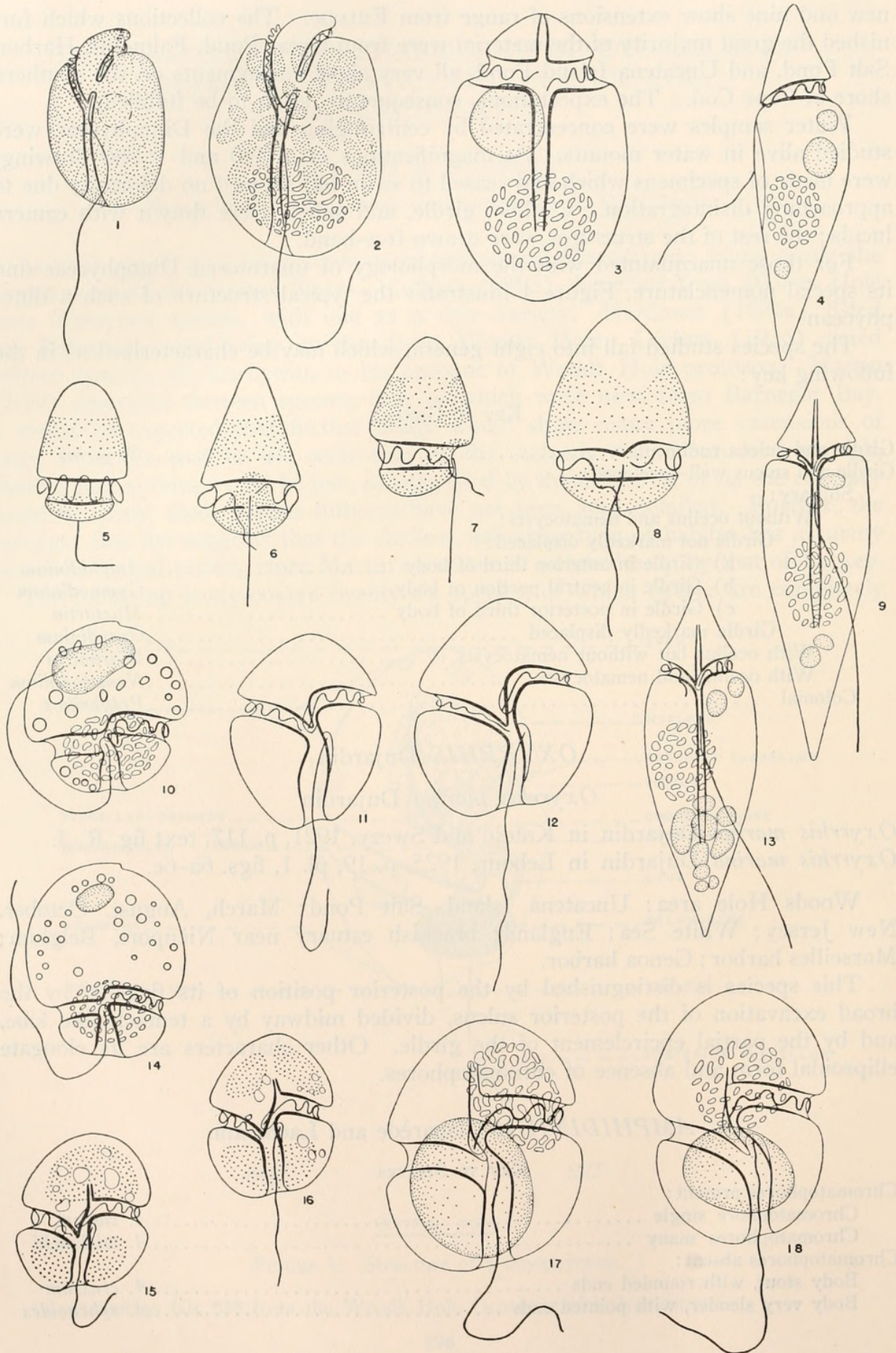


PLATE 1

Amphidinium carteri nom. nov.

(Plate 1, Figure 1)

Amphidinium klebsi Carter, 1937, p. 58, pl. 8, figs. 12, 13, 14, 15. (*non* Kofoed & Swezy, 1921).

Body dorsi-ventrally flattened, oval in outline in ventral view, elongate-elliptical in lateral view. Length 12–15 μ , width 8–9 μ . Epicone small, asymmetric, crescent-shaped in ventral view, somewhat flattened at apex; in dorsal view beak-like, rising near right margin and projecting toward left margin. Hypocone truncate-elliptical in ventral or dorsal view, asymmetric, with its right margin convex and left straight or very slightly convex, the antapex broadly rounded. Left limb of girdle starting some distance above posterior end of epicone, running in an arching course anteriorly and laterally, then extending transversely around dorsal surface of epicone, finally leading posteriorly near right margin to round posterior end of epicone, failing, however, to meet the end of the left limb. Sulcus nearer right margin, extending from posterior end of epicone in curving course to antapex. Anterior flagellum inserted at the end of the left limb of girdle; posterior flagellum inserted just below the anterior, separated from it by a "bridge" that separates girdle ends, extending 1.5 body lengths.

Chromatophore single, covering whole inner surface, often perforate, golden brown. Nucleus at posterior end of hypocone, containing short chromatin corpuscles. Pyrenoid present, in center of hypocone. Assimilate granules present or absent.

Woods Hole area: Uncatena Island; October, July. Isle of Wight, England, in brackish pool.

The species described here as *Amphidinium carteri* is identical with Carter's *A. klebsi*. It is considered an independent species since it is much smaller than the forms described as *A. klebsi* by Kofoed and Swezy (1921), Herdman (1924a), and Lebour (1925), and since it has only a single chromatophore.

Amphidinium wislouchi n. sp.

(Plate 1, Figure 2)

Amphidinium sp. Wislouch, 1924, p. 121, pl. 3, fig. 11.

Body dorsi-ventrally flattened, oval in outline in ventral view. Length 20–25 μ , width 14–16.5 μ . Epicone small, asymmetric, crescent-shaped in ventral view,

PLATE 1

- FIGURE 1. *Amphidinium carteri* nom. nov.
 FIGURE 2. *Amphidinium wislouchi* n. sp.
 FIGURE 3. *Amphidinium crassum* Lohmann
 FIGURES 4, 9, 13. *Amphidinium sphenoides* Wulff
 FIGURES 5, 6, 7, 8. *Massartia rotundata* (Lohmann) Schiller
 FIGURES 10, 14. *Massartia asymmetrica* (Massart) Schiller
 FIGURES 11, 12. *Gyrodinium metum* n. sp.
 FIGURES 15, 16. *Gyrodinium estuariale* n. sp.
 FIGURES 17, 18. *Gyrodinium glaebum* n. sp.

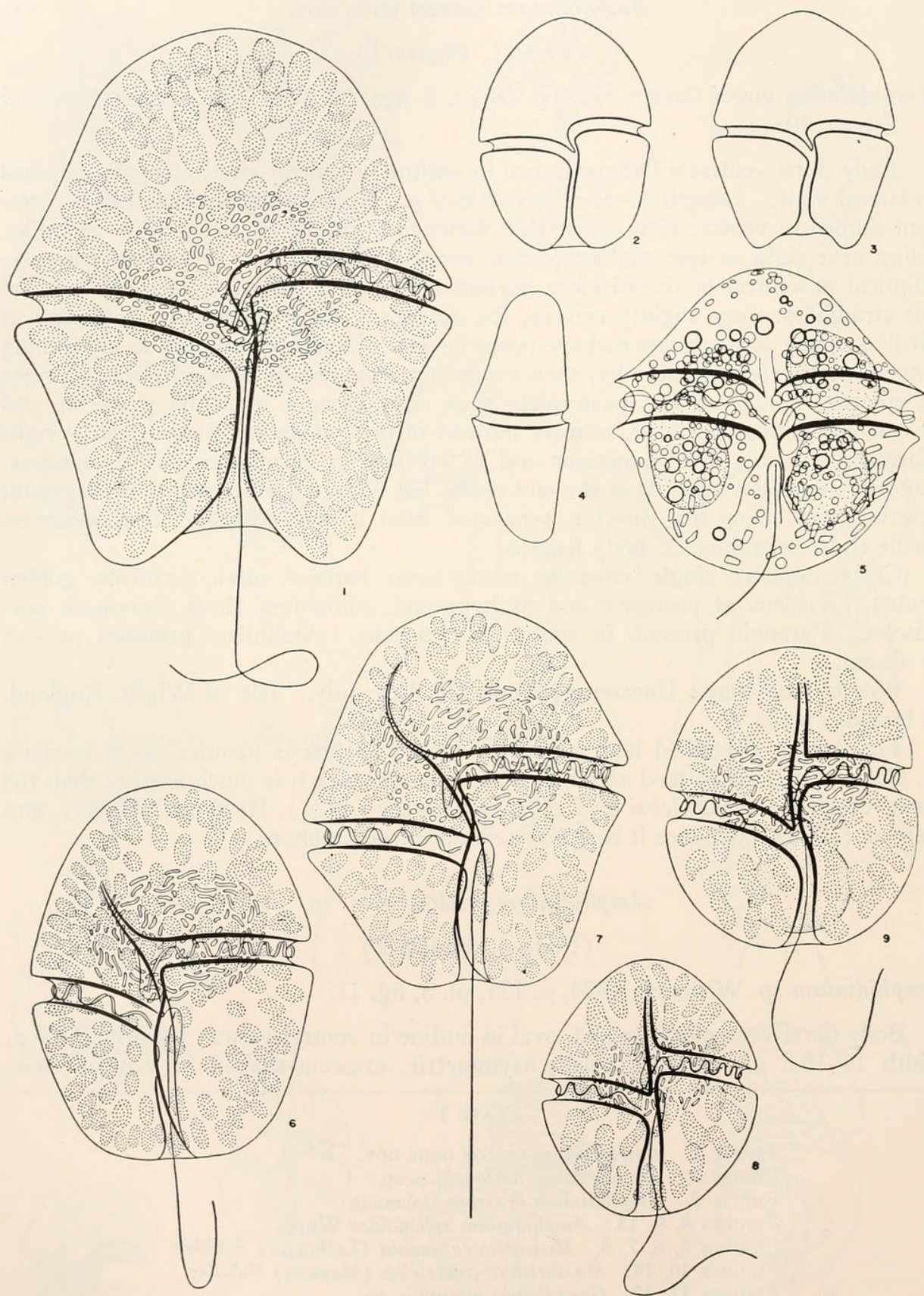


PLATE 2

somewhat flattened at apex; in dorsal view beak-like, rising near right margin and projecting toward left margin. Hypocone truncate-elliptical in ventral or dorsal view, asymmetric, with its right margin convex and left almost straight, the antapex broadly rounded. Left limb of girdle starting some distance above posterior end of epicone, running in an arching course anteriorly and laterally, then extending transversely around dorsal surface of epicone, finally leading posteriorly near right margin to round posterior end of epicone, failing, however, to meet the end of the left limb. Sulcus nearer right margin, extending from posterior end of epicone in curving course to antapex. Anterior flagellum inserted at the end of the left limb of girdle; posterior flagellum inserted just below the anterior, separated from it by a "bridge" that separates girdle ends, extending 1.5 body lengths.

Chromatophores many, elliptical, often arranged in a somewhat radiating manner, with pyrenoid as center.

Woods Hole area: Uncatena Island, Great Pond; October, March. Poland.

This species is about the same as Wislouch's *Amphidinium* sp. and is quite similar to *A. carteri* except for having many chromatophores.

Amphidinium crassum Lohmann

(Plate 1, Figure 3)

Amphidinium crassum Lohmann, 1908, p. 261, pl. 17, fig. 16.

Amphidinium crassum Lohmann in Lebour, 1917, p. 188, fig. 2; 1925, p. 31, pl. 3, figs. 2a-2c.

Body elongate elliptical, circular in cross-section. Length 23-30 μ , width 11-17 μ . Epicone very small, 0.20-0.25 the body length, broadly conical with a pointed apex; hypocone with its sides parallel in the anterior half, rounding into a broad antapex. Girdle not displaced, wide, shallow, its posterior margin wider than the anterior. Sulcus very narrow and shallow, straight, reaching from the apex to 0.66 of the length of hypocone. Flagellar chambers not seen. Anterior flagellum completely encircling body, posterior flagellum not seen.

Chromatophores absent. Nucleus close to antapex, spherical, containing short chromatin corpuscles. Brown ingested bodies and assimilate bodies common.

Woods Hole area: Great Pond, Falmouth Harbor; April, May. Baltic Sea off Kiel; English Channel; Plymouth Sound; Adriatic Sea.

Lohmann (1908) described two similar amphidiniums, *A. crassum* and *A. longum*, the second more slender and with a smaller, more pointed epicone than the first. Lebour (1917, 1925) described as *A. crassum* a type intermediate between these two in proportion of length to width, but with the "fuller" epicone of Lohmann's *A. crassum*. Lebour's type is identical with that described here.

PLATE 2

FIGURES 1, 2, 3, 4. *Gymnodinium nelsoni* Martin

FIGURE 5. *Gymnodinium lazulum* n. sp.

FIGURES 6, 7. *Gyrodinium resplendens* n. sp.

FIGURES 8, 9. *Gyrodinium aureolum* n. sp.

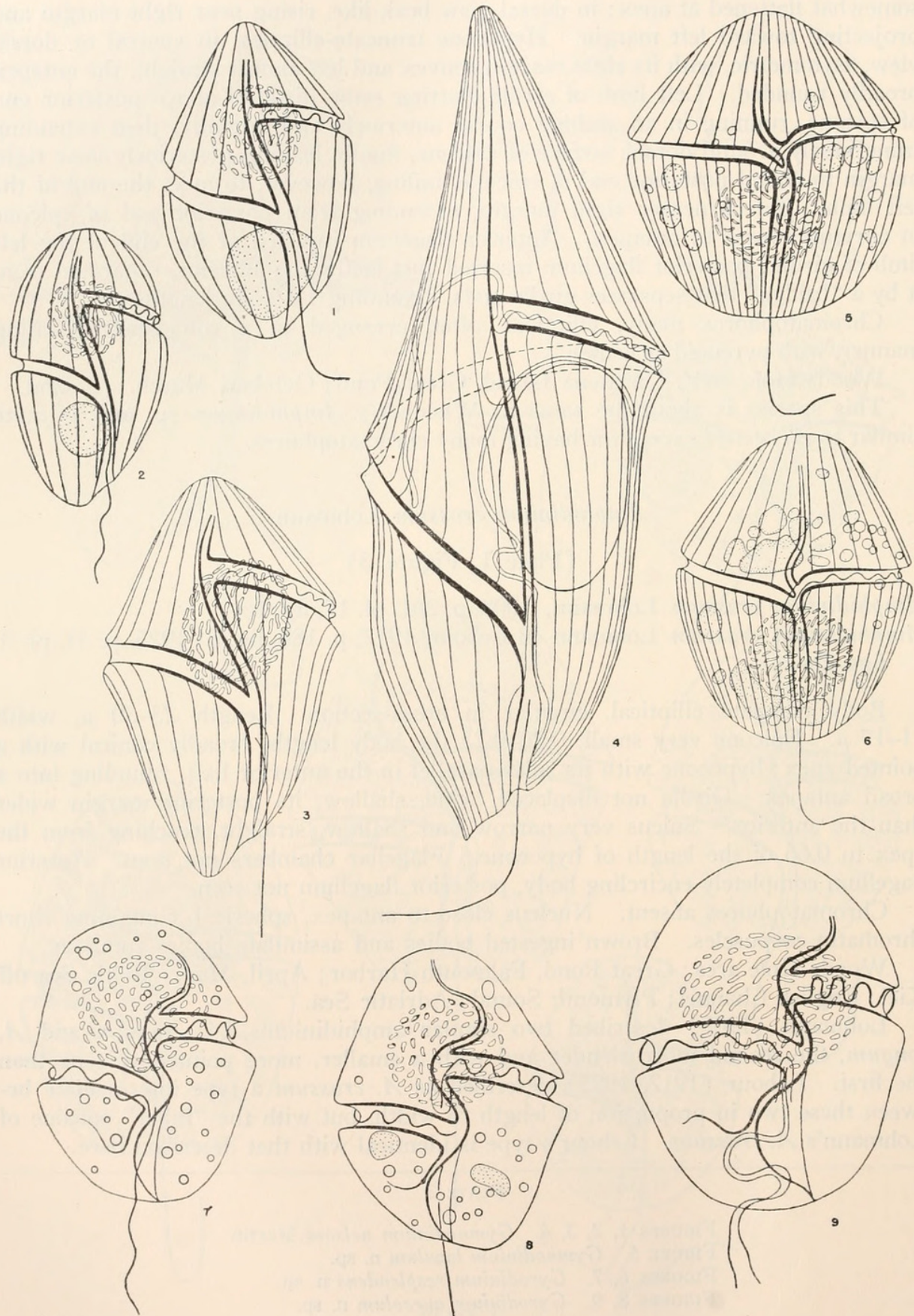


PLATE 3

Amphidinium sphenoides Wulff

(Plate 1, Figures 4, 9, 13)

Amphidinium sphenoides Wulff, 1916, p. 105, pl. 1, figs. 9a-9b.

Body cylindrical, of slender proportions, tapered posteriorly to a sharp point, tapered anteriorly more abruptly to an equally sharp point. Length 35-42 μ , width 12-13 μ . Epicone 0.20-0.25 the total length, symmetrically diamond-shaped or triangular, respectively, in ventral or dorsal view, but asymmetrically triangular in side view, with the dorsal margin more sloping than the ventral; outline contours concave. Hypocone similar but more elongate, triangular in dorsal and ventral view and more sloping along the dorsal than the ventral margin. Girdle deep, broad dorsally but narrowed ventrally, so that in side view the margins appear to converge. Sulcus narrow, running from near the apex to 0.66 the length of the hypocone. Anterior flagellar chamber a mere deepening of the left girdle end (posterior chamber not seen). Anterior flagellum encircling body; posterior flagellum somewhat shorter than the body.

No chromatophores. Nucleus midway the length of hypocone. Assimilate spherules of various sizes present or absent.

Woods Hole area: Great Pond; January. Barents Sea.

GYMNODINIUM Stein (emended by Kofoed and Swezy)

KEY TO SPECIES

Without striations:

Chromatophores present *G. nelsoni*

Chromatophores absent:

Body globular *G. lazulum*

Body laterally flattened *G. stellatum*

With striations *G. striatissimum*

Gymnodinium nelsoni Martin

(Plate 2, Figures 1, 2, 3, 4)

Gymnodinium nelsoni Martin, 1929, p. 14, pl. 3, figs. 25-26.

Body broadly fusoid, with truncate antapex, very much flattened dorsi-ventrally. Length 50-70 μ , width 38-53 μ . Epicone in ventral view sub-hemispherical to somewhat angled, its sides then straight or concave, and its apex broadly pointed. Hypocone trapezoidal, its sides convex, straight, or concave; its apex wide, emarginate to broadly indented. In lateral view dorsal contour somewhat convex, ventral contour somewhat concave; end-on view with a similar dorsal convexity and ventral concavity. Girdle narrow, deep, displaced one-two girdle widths. Sulcus not present on epicone, narrow and sigmoid in intercingular region, straight and

PLATE 3

FIGURES 1, 2, 3. *Gyrodinium dominans* n. sp.

FIGURE 4. *Gyrodinium spirale* (Bergh) Kofoed and Swezy

FIGURES 5, 6. *Gymnodinium striatissimum* n. sp.

FIGURES 7, 8, 9. *Gyrodinium undulans* n. sp.

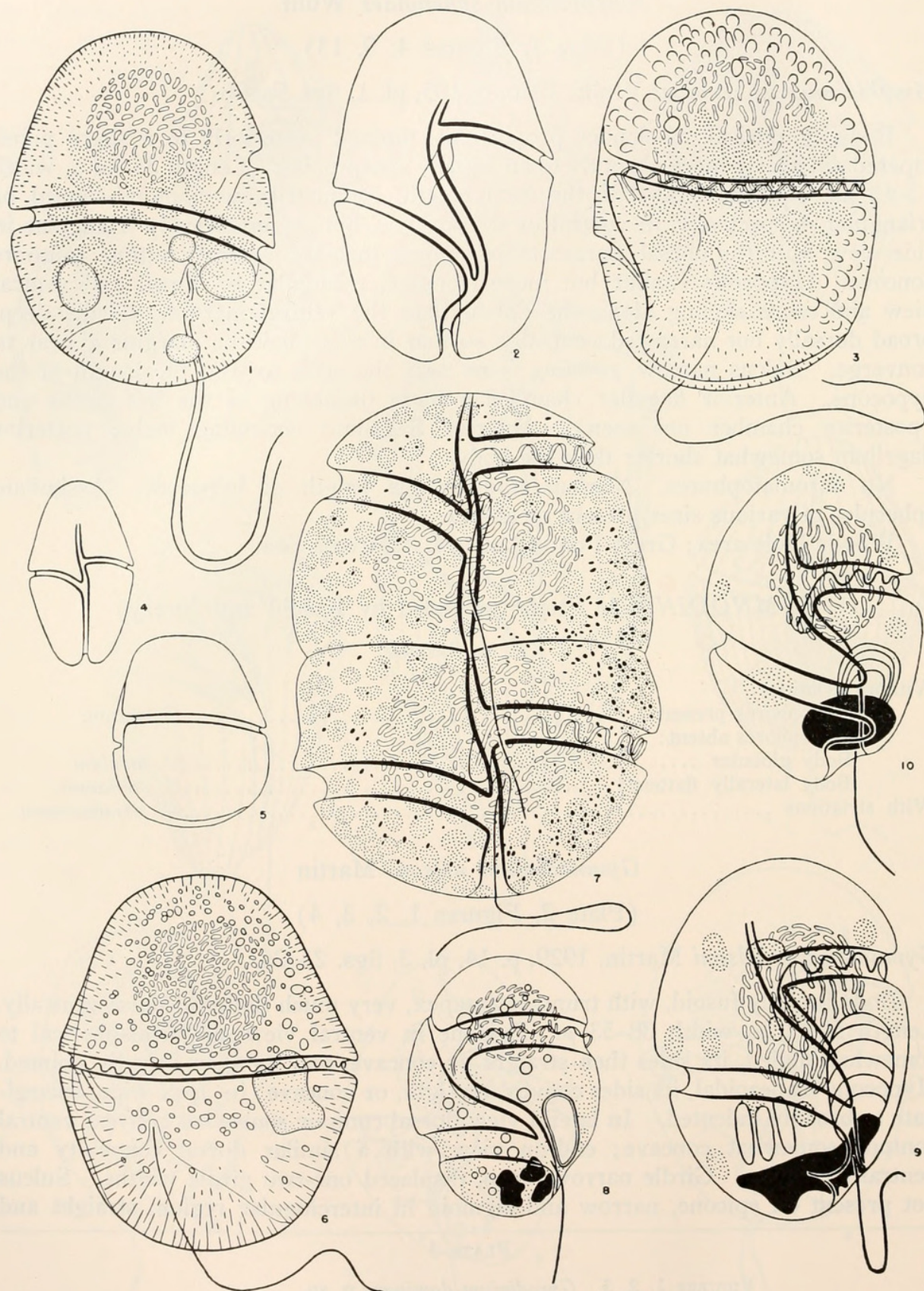


PLATE 4

somewhat wider on hypocone, widening abruptly and showing a large excavation at antapex. Anterior and posterior flagellar chambers overlapping. Anterior flagellum not completely encircling cell; posterior flagellum equal to the body length.

Chromatophores many, rich brown, elliptical, radiating from center of cell. Nucleus central, wider than long, with numberless, elongate chromatin corpuscles. Cells usually free from assimilate and ingested bodies.

Woods Hole area: Great Pond; September. Barnegat Bay, United States east coast.

G. nelsoni is distinguished from its close relative, *G. splendens* (Lebour, 1925), by having short, elliptical chromatophores instead of elongate slender ones.

Gymnodinium lazulum n. sp.

(Plate 2, Figure 5)

Body globular, circular in cross-section, epicone and hypocone subequal. Length 28–30 μ , width 30–32 μ . Epicone conical bell-shaped, with marked concavity of outline near girdle; hypocone hemispherical bell-shaped, with concavity of contours less extensive but closer to girdle than in epicone. Girdle wide, deep, without displacement. Sulcus short, narrow, and faintly defined on epicone; on hypocone abruptly widening, more so on the right than the left, its margins fading out about halfway to antapex. Girdle ends dipping in markedly to the bottom of the sulcus, deeply excavating sulcus in girdle region. Anterior flagellum inserted at opening of a pore; pore extending as small pustule from left girdle end posteriorly. Posterior flagellum inserted in trough-like depression of posterior sulcal floor. Anterior flagellum a delicate band completely encircling body; posterior flagellum short, 0.5 body length.

Chromatophores absent. Nucleus not visible. Cytoplasm clear, quite transparent, smoke blue in color. Colored spherules, grading from copper-red through orange and brown to lemon-yellow, abundant, scattered throughout cytoplasm, often clustered near girdle. Angular, crystal-like, slate-gray bodies scattered at random through hypocone. Large, brown ingested bodies common.

Woods Hole area: Great Pond; December, May.

This species was the only one studied with a clear, blue, instead of a granular, gray, cytoplasm. The array of hues of the numberless small spherules, as well as the blue of the cytoplasm, are matched by similar structures in *G. violescens* (Kofoid and Swezy, 1921).

Gymnodinium stellatum n. sp.

(Plate 4, Figures 4, 5, 6)

Body laterally flattened, elliptical in side view with sub-truncate anterior end. Length 25–47 μ , thickness 22–39 μ , width 17–25 μ . Epicone in dorsi-ventral view taller than wide, with slightly sloping sides; in lateral view as wide as tall, trape-

PLATE 4

- FIGURES 1, 2, 3. *Gyrodinium uncatenum* n. sp.
FIGURES 4, 5, 6. *Gymnodinium stellatum* n. sp.
FIGURE 7. *Polykrikos hartmanni* Zimmermann
FIGURE 8. *Warnowia parva* (Lohmann) Lindemann
FIGURES 9, 10. *Nematodinium armatum* (Dogiel) Lebour

zoidal, more sloping dorsally than ventrally. Hypocone similar to epicone in shape in dorsi-ventral view, with antapical notch dorsally; in lateral view sub-hemispherical, wider than tall. Girdle narrow, displaced 0.16–0.20 body length. Sulcus narrow, straight except for slight leftward divergence in girdle region, forming a deep hypoconal excavation with anterior limit marked laterally by a vague line running diagonally from posterior dorsal corner toward girdle region on ventral surface. Anterior flagellar chamber a long finger-like pocket extending posteriorly and somewhat dorsally; posterior flagellar chamber a narrow prolongation of hypoconal excavation, reaching almost to anterior chamber. Anterior flagellum encircling less than half the circumference, wide, band-shaped; posterior flagellum body length, sometimes double.

Chromatophores absent. Nucleus within epicone, containing elongate chromatin corpuscles. Peripheral cytoplasm with distinct radial structure. Assimilate occasionally abundant.

Woods Hole area: Salt Pond; October, December, January.

This species is very much like *Gyrodinium uncatenum* in this paper, differing principally in lacking chromatophores, in having a less displaced girdle, and a straighter sulcus. Among hitherto described species, it is similar only to *Gymnodinium bifurcatum* (Kofoed and Swezy, 1921) in its lateral flattening and deep hypoconal excavation.

Gymnodinium striatissimum n. sp.

(Plate 3, Figures 5, 6)

Body globular to elliptical, not flattened, its hypocone slightly larger than epicone. Length 29–43 μ , width 23–31 μ . Epicone conical, pointed, or somewhat truncate. Hypocone similar but more truncate, varying from tapered type with moderately sloping sides and rounded antapex to type with slightly sloping sides and broad antapex. Surface with striations, fewer on epicone (15) than on hypocone (25). Girdle narrow, rather deep, slightly displaced, with distinctive posterior flexure to end of left limb. Sulcus shallow, narrow on epicone, somewhat wider on hypocone, from near apex almost to antapex, distinguished by sharp leftward bend just anterior to girdle. Anterior flagellar chamber prolonged posteriorly. Anterior flagellum completely encircling body; posterior flagellum one body length, sometimes double.

No chromatophores. Nucleus posterior, wholly within hypocone, with elongate chromatin corpuscles. Assimilate bodies of various sizes often abundant.

Woods Hole area: Great Pond; May.

Gymnodinium striatissimum is similar in different number of striations on epicone and hypocone to the much larger *G. multistriatum*, *G. rubrum*, and *G. translucens* (Kofoed and Swezy, 1921).

MASSARTIA Conrad

KEY TO SPECIES

Without striations:

Chromatophores present *M. rotundata*

Chromatophores absent *M. asymmetrica*

With striations *M. glauca*

Massartia rotundata (Lohmann) Schiller

(Plate 1, Figures 5, 6, 7, 8)

Amphidinium rotundatum Lohmann, 1908, p. 261, pl. 17, fig. 9.*Amphidinium rotundatum* Lohmann in Wulff, 1916, p. 103, pl. 2, fig. 11.*Amphidinium rotundatum* Lohmann in Van Goor, 1925, p. 285, fig. 4.*Gymnodinium minutum* Lebour, 1925, p. 45, pl. 5, fig. 4.*Massartia rotundata* (Lohmann) Schiller in Conrad, 1939, p. 11, figs. 17–22.

Body top-shaped, circular in cross-section. Length 8–17 μ , width 6–12 μ . Epicone 2.5 times as long as hypocone, conical, with straight to gently convex sides, its apex pointed or somewhat rounded. Hypocone half as long as wide, broadly rounded, in lateral view asymmetric so that the dorsal portion is larger than the ventral one. Girdle very wide, very slightly displaced, its anterior margin overhanging and of greater diameter than the posterior margin. Sulcus not discernible. Flagellar chambers absent. Anterior flagellum up to twice the girdle circumference in length; posterior flagellum equal in length to the cell body.

Chromatophores two, yellow-brown; one band-shaped, partially encircling periphery of epicone; the other filling bottom of hypocone, extending on ventral surface to epicone. Nucleus not seen. Assimilate bodies present or absent. Pellicle occasionally present.

Woods Hole area: Great Pond, Falmouth Harbor; January to April, August, September. Barents Sea; White Sea; Baltic off Kiel; brackish estuaries near Nieuport (Belgium) and along the coast of Holland; Plymouth Sound; Adriatic Sea.

Several different populations were studied. One had straight sides to the epicone and a pointed apex. Another had convex sides to the epicone and a pointed apex. A third was rather variable, rotund in appearance, often almost colorless, with apex rounded or pointed. In a similar way this distinctive species shows considerable variation as it receives treatment from various investigators. Lohmann describes it with relatively very small hypocone, whereas Wulff describes it with relatively very much larger one. In contrast to these, which have pointed apices, Conrad's has a rounded apex. Van Goor shows a very slender form. Lohmann's and Wulff's figures show a lobed epiconal chromatophore, whereas Lebour's shows a band-shaped chromatophore.

Massartia asymmetrica (Massart) Schiller

(Plate 1, Figures 10, 14)

Gymnodinium asymmetricum Massart, 1920, p. 132, figs. 22A–D.*Massartia asymmetrica* (Massart) Schiller in Carter, 1937, p. 59, pl. 8, figs. 17–18.

Body globular, oval in outline, compressed dorsi-ventrally. Length 14–22 μ , width 13–20 μ . Epicone 0.66 body length, hemispherical, with small apical notch. Hypocone small, 0.33 body length, twice as wide as long, broadly rounded, often with slight oblique flattening in antapical region. Girdle very wide, shallow, displaced one girdle width, its anterior margin wider than posterior. Sulcus extending from girdle to antapex, widening abruptly during its course. Anterior

flagellum incompletely encircling body; posterior flagellum 1.0–1.5 body lengths.

Chromatophores absent. Nucleus almost wholly within hypocone, wider than long, containing relatively few, short, unoriented chromatin corpuscles. Large, brown ingested body and smaller assimilate bodies frequent.

Woods Hole area: Great Pond; October, January, February. Isle of Wight, England; estuary near Nieuport, Belgium.

Massartia asymmetrica is similar to *M. vorticella* (Stein) Schiller and *M. stigmaticum* (Lindemann) Schiller, which, however, contain stigmas, and to *M. glandula* Herdman, which differs, however, in its larger size (20–35 μ long) and helmet-shaped instead of hemispherical epicone. Massart's and Carter's figures of *M. asymmetrica* show somewhat greater displacement of girdle than in the specimens described here.

Massartia glauca (Lebour) Schiller

Spirodinium glaucum Lebour, 1917, p. 196, fig. 13.

Gyrodinium glaucum (Lebour) Kofoed and Swezy, 1921, p. 308, pl. 9, fig. 94, text fig. DD, 16.

Gyrodinium glaucum (Lebour) Kofoed and Swezy in Lebour, 1925, p. 54, pl. 7, fig. 4, text fig. 15.

Woods Hole area: Great Pond; October, May. Plymouth Sound; Adriatic Sea; La Jolla, California.

The specimens studied agreed closely in shape with those of Lebour and were not like Kofoed and Swezy's somewhat different form. They were, however, considerably smaller than Lebour's, 28–32 μ instead of 40–56 μ in length. This form is different from other species of *Massartia* in its striations; it is distinguished by its slender form, the slight twist to the apex, and its absence of chromatophores.

GYRODINIUM Kofoed and Swezy

KEY TO SPECIES

Without striations:

Chromatophores present:

Chromatophores 2 to 4 *G. estuariale*

Chromatophores many:

Body dorsi-ventrally flattened:

Sulcus not deflected on epicone *G. aureolum*

Sulcus deflected to right on

epicone *G. resplendens*

Body laterally flattened *G. uncatenum*

Chromatophores absent:

Sulcus sigmoid:

Epicone rounded-conical *G. metum*

Epicone hemispherical *G. glaebum*

Sulcus bisigmoid *G. undulans*

With striations:

Length 18–43 μ *G. dominans*

Length 66–96 μ *G. spirale*

Gyrodinium estuariale n. sp.

(Plate 1, Figures 15, 16)

Body ellipsoid; apex often somewhat pointed compared to broadly rounded antapex; often with slight asymmetry, the right side more convex than the left; slightly flattened dorsi-ventrally; with equal epicone and hypocone. Length 11–16 μ , width 9–12 μ . Epicone broadly conical to sub-hemispherical, the right margin often a bit more sloping than the left; hypocone hemispherical to somewhat trapezoidal, with rounded to flattened, oblique, sometimes indented antapex. Girdle deep, moderately wide, displaced 0.25–0.33 body length, strongly posteriorly bending in right limb. Sulcus slight on epicone, markedly deflected to right in intercingular area, widening, and proceeding straight to antapex on hypocone. Anterior flagellar chamber an elongate pocket diverging to right and running beneath posterior flagellar chamber which is a leftward underhollowing of sulcus between girdle ends. Anterior flagellum encircling body completely; posterior flagellum body length.

Chromatophores yellow-brown, one or two in epicone, one or two in hypocone, distinctively inset from periphery. Nucleus not seen. Assimilate bodies usually sparse.

Woods Hole area: Great Pond, Salt Pond, Uncatena Island; July, August, October to January.

Gyrodinium estuariale is very similar to *Gymnodinium vitiligo* and *Gymnodinium veneficum* (Ballantine, 1956), differing in greater displacement of girdle ends, in wider, deeper girdle and sulcus, and in an oblique, instead of symmetrically rounded, antapex. In the intercingular region the sulcus is deflected to the right (passing from anterior to posterior end) in these species, contrary to most gyrodinia. *Gyrodinium estuariale* is similar to *Gymnodinium marylandicum* (Thompson, 1947); but the latter's sulcus follows the longitudinal axis or is deflected slightly to the left.

Gyrodinium aureolum n. sp.

(Plate 2, Figures 8, 9)

Body essentially globular, its dorsi-ventral outline either somewhat ellipsoidal or somewhat fusiform, slightly dorsi-ventrally flattened, with subequal epicone and hypocone. Length 27–34 μ , width 17–32 μ . Epicone hemispherical to broadly conical, sometimes slightly truncate. Hypocone similar, but usually distinctly truncate, with antapex faintly indented at times. Girdle wide, moderately deep, displaced 0.20 body length. Sulcus reaching from just behind apex all the way to antapex, with slight, left deflection in girdle region, rather narrow on epicone, wide on hypocone. Anterior flagellar chamber a posteriorly pointed, finger-shaped cavity; posterior flagellar chamber an underhollowing of left sulcal margin opposite right girdle limb. Anterior flagellum completely encircling body; posterior flagellum very long, up to two body lengths.

Numerous yellow-brown chromatophores present, elliptical in shape, usually arranged in a somewhat radiating manner. Nucleus spherical or wider than long, with elongate chromatin corpuscles.

Woods Hole area: Great Pond, Uncatena Island, Falmouth Harbor; December to April.

This species is rather similar to *Gyrodinium aureum* (Conrad, 1926). It is, however, different in its less elongate chromatophores, wider grooves, greater width for the same length, more conical outline of epicone and hypocone, and somewhat less displacement of girdle ends.

Gyrodinium resplendens n. sp.

(Plate 2, Figures 6, 7)

Body broadly fusoid, with truncate apex and antapex, moderately flattened dorsi-ventrally. Length 36–62 μ , width 32–48 μ . Epicone and hypocone similar, equal, trapezoidal in outline, their sides convex, straight, or concave; the apex somewhat rounded, the antapex with sulcal indentation. Girdle deep, moderately wide, displaced 0.20–0.25 body length. Sulcus extending onto epicone as very narrow superficial groove, diverging to right; in intercingular region narrow, vertical or left deflected; on hypocone running straight to antapex, superficially narrow but broad beneath projecting lappet of left margin. Anterior and posterior flagellar chambers elongate pockets projecting toward but not reaching each other. Anterior flagellum completely encircling body; posterior flagellum one body length.

Chromatophores oval, rich brown, radiating, many-tiered. Nucleus somewhat anterior of center, wider than long, with numerous, elongate chromatin corpuscles. Ingested bodies occasional; assimilate absent.

Woods Hole area: Great Pond; July, August.

This species is close to *Gyrodinium aureolum*. It is also quite like *Gymnodinium nelsoni*, differing in greater girdle displacement (so that it falls into the genus *Gyrodinium*), less dorsi-ventral flattening with no ventral concavity, and truncate rather than hemispherical epicone.

Gyrodinium uncatenum n. sp.

(Plate 4, Figures 1, 2, 3)

Body laterally flattened, elliptical to quadrangular in side view, elongate elliptical in ventral or dorsal view, with epicone and hypocone subequal. Length 40–54 μ , width 28–33 μ . Epicone in ventral and dorsal views helmet-shaped, taller than wide, broadly rounded at apex, its sides sloping gently, with slight concavities at girdle; in lateral view, sub-hemispherical to trapezoidal, wider than tall. Hypocone very similar but often slightly more truncate at antapex and more distinctly trapezoidal in side view. Girdle narrow, deep, displaced 0.33 body length, the right limb bending steeply posteriorly. Sulcus projecting slightly on epicone, curving to left in intercingular area, then sharply to right between right girdle end and antapex; carried across antapex all the way to dorsal side; deeply excavating hypocone, the anterior extent of excavation seen laterally as an oblique line running from dorsal end of sulcus toward ventral surface. Anterior flagellar chamber long, finger-like, projecting posteriorly and somewhat dorsally and rightward; posterior flagellar chamber a long extension of sulcal excavation, reaching nearly to anterior chamber. Anterior flagellum wide and strap-shaped, completely en-

circling body; posterior flagellum occasionally double, twice the body length; both flagella reaching all the way to the end of the chambers.

Chromatophores elongate, yellow-brown, radiating from center, leaving marginal area clear (lateral view). Nucleus spherical, in the epicone, with slightly elongate chromatin corpuscles. Crytoplasm showing vague radiating structure in peripheral region. Countless, dark assimilate bodies often present.

Woods Hole area: Great Pond, Uncatena Island; July, August, October.

This species is rendered distinctive by its lateral flattening, a rarity among gyrodinia. Very striking is the deep excavation in the hypocone, identical to that in *Gymnodinium stellatum* and *G. bifurcatum* (Kofoid and Swezy, 1921).

Gyrodinium metum n. sp.

(Plate 1, Figures 11, 12)

Body somewhat asymmetric, the right side more convex than the left, circular in cross-section, with hypocone slightly larger than epicone. Length 14.5–22 μ , width 11–16 μ . Epicone rounded-conical in outline; hypocone truncate with straight to convex sides. Girdle deeply excavated, displaced about 0.20–0.25 body length, its right limb curving steeply posteriorly. Sulcus sigmoid, not extending onto epicone, narrow in intercingular region, and wide and deep on hypocone, flattening or indenting the antapex. Anterior flagellar chamber produced inward and posteriorly; posterior flagellar chamber a mere excavation in the sulcal floor. Anterior flagellum completely encircling the body; posterior flagellum 1.5 times body length.

Chromatophores absent. Cytoplasm gray, foamy in texture. Nucleus not seen.

Woods Hole area: Great Pond; May, June, July, December, February.

This species is distinguished by the Chinaman-hat shape of the epicone. A smaller-size variant was often seen. Its features are identical except respecting size—9.5–12 $\mu \times$ 9–7 μ .

Gyrodinium glaeum n. sp.

(Plate 1, Figures 17, 18)

Body elliptical, very slightly compressed dorsi-ventrally, with equal epicone and hypocone. Length 17–25 μ , width 12–19 μ . Epicone hemispherical but slightly asymmetric, with right contour more sloping or less fully curved than left. Hypocone similar, but broader, the asymmetry more marked, the left contour more sloping or less fully curved than right, often with oblique flattening in region of sulcus end. Girdle wide, rather deep, displaced two-three times its own width. Sulcus extending slightly onto epicone, narrow and leftward diverging in intercingular region, wide and deep in a straight course on hypocone. The two flagellar chambers overlapping each other, the anterior one a pronounced, posteriorly directed excavation, the posterior one an underhollowing of left girdle margin. Anterior flagellum only partially encircling body, posterior flagellum as long as body.

Chromatophores absent. Nucleus somewhat anterior of girdle, with large and relatively few chromatin corpuscles. Large, brown ingested bodies often present, as well as small, refractive assimilate bodies.

Woods Hole area: Great Pond; July, October.

Gymnodinium variable (Herdman, 1924a) is close in shape but lacks any marked girdle displacement.

Gyrodinium undulans n. sp.

(Plate 3, Figures 7, 8, 9)

Body elliptical, somewhat dorsi-ventrally flattened with equal epicone and hypocone. Length 27–38 μ , width 21–31 μ . Epicone varying from sub-hemispherical to truncate-pyramidal, with rounded apex and straight but sloping sides. Hypocone asymmetric, truncate-pyramidal with rounded to flattened, oblique antapex, and sloping sides. Girdle wide, deep, displaced 0.20 body length, its right limb curving strongly posteriorly. Sulcus distinctive, forming a bi-sigmoid curve; very narrow on epicone, swerving leftward and then rightward to meet left girdle end, curving again to left in intercingular area and widening, then bending to right on hypocone to form large overlapping lobe, finally returning leftward to antapex. Floor of sulcus on hypocone extending straight to antapex; and right margin of sulcus “bearing away” laterally to form a swelling. Anterior and posterior flagellar chambers projecting toward, but not reaching, each other. Anterior flagellum completely encircling body; posterior flagellum one body length, occasionally double.

Chromatophores absent. Nucleus large, principally within epicone, of elongate chromatin corpuscles. Assimilate bodies sometimes in form of large blocks.

Woods Hole area: Great Pond; February, January.

Few Dinophyceae have either bi-sigmoid sulci or overlapping sulcal lobes.

Gyrodinium dominans n. sp.

(Plate 3, Figures 1, 2, 3)

Body broadly fusiform, circular in cross-section, epicone and hypocone subequal. Length 18.5–43 μ , width 10–22 μ . Epicone and hypocone conical to rotund-conical, their sides varying from convex to straight. Both epicone and hypocone occasionally with slight concavities near girdle. Surface with continuous striations, the number the same on epicone and hypocone, between 7 and 10 across ventral face. Girdle of moderate depth and width, displaced 0.25–0.33 body length. Sulcus sigmoid, deflected to left 0.25 transdiameter in intercingular region, reaching halfway up epicone, extending to posterior margin of hypocone on left side of antapex. Anterior flagellar chamber a posteriorly directed, finger-like projection from left end of girdle. Posterior flagellum inserted at posterior end of girdle (flagellar chamber not seen). Anterior flagellum not completely encircling body; posterior flagellum short, 0.50 body length.

Chromatophores absent. Nucleus anterior, in epicone, containing elongate, oriented chromatin corpuscles.

Woods Hole area: Great Pond, Falmouth Harbor, Salt Pond; April, July, August, October to December.

Gyrodinium dominans is an ally to three very similar species of *Gyrodinium*: *G. pingue* (Schütt, 1895, as *Gymnodinium spirale* var. *pinguis*; Wulff, 1916, as

Spirodinium varians; Kofoid and Swezy, 1921; Lebour, 1925), *G. obtusum* (Schütt, 1895, as *Gymnodinium spirale* var. *obtusum*; Kofoid and Swezy, 1921; Lebour, 1925), and *G. fissum* (Kofoid and Swezy, 1921). The chief distinction is the flexure of the sulcus in *G. dominans*, contrasting with the comparative straightness of the sulcus in the other three.

Gyrodinium spirale (Bergh) Kofoid and Swezy

(Plate 3, Figure 4)

Gyrodinium spirale (Bergh) Kofoid and Swezy, 1921, p. 332, pl. 4, fig. 43, text fig. DD, 14.

Gyrodinium spirale (Bergh) Kofoid and Swezy in Lebour, 1925, p. 56, pl. 8, fig. 1.

Body slender fusiform; circular in cross-section; somewhat twisted on its longitudinal axis; with epicone longer but narrower than hypocone. Length 66–96 μ , width 30–38 μ . Epicone narrowly conical, convex or straight along left and dorsal contours. Hypocone with sides parallel anteriorly, convex posteriorly; its antapex pointed, excentric, to right of ventral, longitudinal axis; with sulcal notch to left of antapex. Surface with continuous striations, 8–13 on epicone, 15–20 on hypocone. Girdle narrow, rather shallow, displaced more than 0.33 the body length, its right limb curving strongly posteriorly. Sulcus very narrow, from somewhat behind apex to left girdle end as a heavy line, a very narrow but distinct groove between girdle ends, widening and deepening from right girdle end to antapical notch. Anterior flagellum inserted at opening of a pustule, which is composed of a short, sac-shaped portion, extending posteriorly, and of a long, thread-like portion, extending somewhat anteriorly, then laterally, finally posteriorly along right contour to region of right girdle limb. Posterior flagellum likewise inserted at opening of a pustule having a long, thread-like extension anteriorly and leftward to region of left girdle limb. Anterior flagellum following girdle 0.33 or less of girdle length. Posterior flagellum short, about 0.25 of body length.

Chromatophores absent. Nucleus elongate-ellipsoidal on left side (ventral view), in intercingular area, without apparent structure.

Woods Hole area: Great Pond, Falmouth Harbor; December, April, May, August. Baltic Sea; Norway; Port Erin, Ireland; Plymouth Sound; Adriatic Sea; La Jolla, California; Indian Ocean; coast of Australia.

The organism defined here agrees closely with those described by Kofoid and Swezy and by Lebour. Distinctive characteristics are the slender form, twist of body, greater dorsal than ventral curvature, and a longer epicone than hypocone.

WARNOWIA Lindemann

Warnowia parva (Lohmann) Lindemann

(Plate 4, Figure 8)

Pouchetia parva Lohmann, 1908, p. 264, pl. 17, fig. 23.

Body elliptical, circular in cross-section, slightly tapered posteriorly, epicone somewhat larger than hypocone. Length 22.5–30 μ , width 15–18 μ . Epicone

hemispherical, hypocone similar but narrowed toward antapex and with sulcal indentation along left contour. Girdle shallow but very wide, displaced 0.50 the body length, with strongly descending right limb. Sulcus narrower than girdle, extending in sigmoid path from apex to antapex, bending from right margin toward center anterior to girdle, diagonal across ventral face between girdle ends, recurving from left margin toward center posterior to girdle. Anterior flagellar chamber an elongate pocket from left end of girdle limb, the posterior flagellar chamber not seen. Anterior flagellum not encircling body completely; posterior flagellum short, 0.33 body length.

Yellow bodies, resembling chromatophores in color and peripheral position but unlike in large size and irregular shape, sparse anteriorly but abundant posteriorly. Nucleus anterior, with elongate, oriented corpuscles. Melanosome near antapex, black, diffuse and spreading, or ellipsoidal and globular. Lens simple without evident laminations, projecting anteriorly on left side from melanosome. Nematocysts absent. Cell often within a pellice. Assimilate bodies frequent.

Woods Hole area: Great Pond; July. Baltic off Kiel.

The organism studied here is probably a close match to Lohmann's *Pouchetia parva*, but Lohmann showed no girdle and sulcus. It is close to *Nematodinium armatum*, but the tapered hypocone, large irregular chromatophores, absence of nematocysts, and cyst differentiate it, as well as the characteristics mentioned under *N. armatum*.

NEMATODINIUM Kofoid and Swezy

Nematodinium armatum (Dogiel) Lebour

(Plate 4, Figures 9, 10)

Pouchetia armata Dogiel, 1906, p. 36, pl. 2, figs. 48-49.

Nematodinium armatum (Dogiel) Lebour, 1925, p. 71, pl. 10, figs. 5a-5b

Nematodinium armatum (Dogiel) Lebour in Martin, 1929, p. 19, pl. 2, figs. 5-7.

Body elliptical, with equal epicone and hypocone. Length 33-53 μ , width 20-33 μ . Epicone evenly rounded, slightly asymmetric in ventral view, its right margin more sloping than the left; hypocone also slightly asymmetric with more sloping left than right side, the antapex either somewhat pointed and off-center, or, usually, obliquely truncate. Girdle deep, moderately wide, displaced 0.33 the body length, with strongly descending right limb. Sulcus extending from near apex in a sigmoid path to antapex, widening on the oblique margin of antapex, a portion of it curving sharply to the right, delimiting a knob-like protuberance on ventral face of the hypocone. Anterior flagellar chamber an elongate pocket from left end of girdle limb (posterior chamber not seen). Posterior flagellum one body length (anterior flagellum not fully studied).

Chromatophores yellow, circular or subcircular, few, and scattered. Nucleus large, anterior, of elongate chromatin corpuscles. Melanosome near antapex, black, diffuse and spreading, or ellipsoidal and globular. Lens single with concentric laminations, projecting anteriorly on left side from melanosome. Nematocysts present or absent, in region of right girdle limb.

Woods Hole area: Great Pond; August. Barnegat Bay, New Jersey; Plymouth Sound; Naples.

Some of the specimens were of full, ellipsoidal proportions, as in Dogiel's figure. Some were more slender, though not quite so slender as in Lebour's Figure 5a. Some had a slight tapering of hypocone and pointed antapex as in Martin's figures. They are all intermediate between the smaller *Warnowia parva* (Lohmann, 1908) without rightward curvature of sulcus on hypocone and with comparatively wider, shallower furrows, and the larger *Nematodinium lebourae* (Schiller, 1933; Kofoed and Swezy, 1921, as *N. armatum*), with rightward curvature of sulcus on hypocone and with comparatively greater transverse displacement of the sulcus.

POLYKRIKOS Bütschli

KEY TO SPECIES

Chromatophores present:

Body cylindrical *P. hartmanni*

Body laterally flattened *P. lebourae*

Chromatophores absent *P. schwartzi*

Polykrikos hartmanni Zimmermann

(Plate 4, Figure 7)

Polykrikos hartmanni Zimmermann, 1930, p. 436, figs. 8-9.

Colony cylindrical in form with rounded ends, consisting of two zooids, delimited by a slight constriction. Length 60-68 μ , width 42-47 μ . Epicone often smaller than hypocone in anterior zooid but equal to hypocone in posterior zooid. Girdles wide, rather shallow, displaced twice their width. Sulcus continuous from apex to antapex, roughly straight, narrowed at the constriction between zooids and in intercingular regions. Sulcus produced inward as anterior and posterior flagellar chambers, which extend posteriorly and anteriorly, respectively, their diverging ends overlapping. Anterior flagella incompletely encircling zooids; posterior flagella about 0.66 as long as the colony.

Chromatophores circular, small, numerous, yellow-brown in color. Nuclei always two, with elongate chromatin corpuscles. Several long nematocysts often, but not always, present in region just below anterior girdle. Innumerable black granules may fill peripheral cytoplasm of whole colony or may be restricted to posterior end.

Woods Hole area: Great Pond; August. Adriatic.

Slight differences between our specimens and Zimmermann's are the smaller size of ours (Zimmermann's 80-120 $\mu \times$ 55-75 μ) and the yellow-brown instead of yellow-green chromatophores. *Polykrikos barnegatensis* (Martin, 1929), also composed of two cells, is close to *P. hartmanni* but has a single nucleus and a more elliptical outline.

Polykrikos schwartzi Bütschli

Polykrikos schwartzi Bütschli in Kofoed and Swezy, 1921, p. 400, text fig. F, 4.

Polykrikos schwartzi Bütschli in Lebour, 1925, p. 67, pl. 10, figs. 2a-2b, text fig. 16c.

Woods Hole area: Great Pond; August. Arctic near Iceland; off coast of Norway; Skagerack; Baltic off coast of Denmark; Baltic off Kiel; North Sea off

Helgoland; Plymouth Sound; Atlantic off Concarneau, France; Mediterranean off French coast.

This species is distinguished by its many cells (zooids), averaging about eight, with four nuclei; by its cylindrical form; and by the absence of chromatophores.

Polykrikos lebourae E. C. Herdman

Polykrikos lebourae E. C. Herdman, 1924b, p. 60, fig. 6.

Polykrikos lebourae E. C. Herdman in Lebour, 1925, p. 68, pl. 10, fig. 3.

Woods Hole area: Salt Pond, beach sand; November. Port Erin, Ireland, in sand.

This species is quite distinctive in its lateral flattening. It has eight cells, two nuclei, and yellow-brown chromatophores. It is recorded from beach sand at Woods Hole by E. C. Herdman.

DIAGNOSES OF NEW SPECIES

Amphidinium carteri n. sp.

Corpus dorsali-ventraliter compressum, a fronte visum ovale; epicono minuto, asymmetrico et rostroformi; hypocono truncato-elliptico; sulco prope marginem dextrum, leniter curvato; chromatophoro uno, parietali, perforato, fulvo. Longitudo 12–15 μ , latitudo 8–9 μ . United States, in loco dicto Great Pond, Barnstable County, Massachusetts.

Amphidinium wislouchi n. sp.

Corpus simile *Amphidinio carteri* sed paullo majus; chromatophoris multis, ellipticis, paululum radiatim ordinatis. Longitudo 20–25 μ , latitudo 14–16.3 μ . United States, in loco dicto Great Pond, Barnstable County, Massachusetts.

Gymnodinium lazulum n. sp.

Corpus globosum; epicono conico vel campaniformi; hypocono hemispherico vel campaniformi; sulco tenui; corpore sine striis; chromatophoris absentibus; cytoplasmate pellucido, subcaeruleo, saepe cum multis corporibus multi-coloratis. Longitudo 28–34 μ , latitudo 30–32 μ . United States, in loco dicto Great Pond, Barnstable County, Massachusetts.

Gymnodinium stellatum n. sp.

Corpus lateraliter compressum; epicono quadrangulato et hypocono hemispherico; extremis cinguli 0.17 longitudinis corporis transpositis; sulco a vicinitate apicis ad cavernam profundam hypoconi extendente; corpore sine striis; chromatophoris absentibus; structura cytoplasmatis exterioris perspicue radiata. Longitudo 25–47 μ , latitudo 22–39 μ , crassitudo 13–25 μ . United States, in loco dicto Salt Pond, Barnstable County, Massachusetts.

Gymnodinium striatissimum n. sp.

Corpus globosum vel ellipticum; epicono et hypocono conico, aculeato, vel truncato; cingulo angusto, flexuram posterioram extremi sinistri habente; sulco a vicinitate apicis ad antapicem extendente; corpore cum striis, in hypocono pluribus quam in epicono ornato; chromatophoris absentibus. Longitudo 29–43 μ , latitudo 23–41 μ . United States, in loco dicto Great Pond, Barnstable County, Massachusetts.

Gyrodinium estuariale n. sp.

Corpus ellipticum, paululum asymmetricum, margine dextro convexiore quam margine sinistro; epicono late conico vel sub-hemispherico; hypocono hemispherico; extremis cinguli 0.25–0.33 longitudinis corporis transpositis; sulco ad latus dextrum inter extrema cinguli multum deflecto; corpore sine striis; chromatophoris fulvis, 2–4, paulum intra peripheriam positus. Longitudo 11–16 μ , latitudo 9–12 μ . United States, in loco dicto Great Pond, Barnstable County, Massachusetts.

Gyrodinium aureolum n. sp.

Corpus globosum; epicono et hypocono hemispherico vel conico; extremis cinguli 0.33 longitudinis corporis transpositis; sulco a vicinitate apicis ad antapicem extendente; corpore sine striis; chromatophoris multis, fulvis, plerumque omnibus plus minusve radiatim ordinatis. Longitudo 27–34 μ , latitudo 17–32 μ . United States, in loco dicto Great Pond, Barnstable County, Massachusetts.

Gyrodinium resplendens n. sp.

Corpus late fusiforme, apice et antapice truncato, dorsaliventraliter compressum; extremis cinguli 0.20–0.25 longitudinis corporis transpositis; sulco in epicono angusto, tenui; ad latus dextrum curvato, in hypocono profundo et recto; corpore sine striis; chromatophoris multis, fulvis, radiatim ordinatis. Longitudo 36–62 μ , latitudo 32–48 μ . United States, in loco dicto Great Pond, Barnstable County, Massachusetts.

Gyrodinium uncatenum n. sp.

Corpus lateraliter compressum, a late visum ellipticum vel quadrangulum; extremis cinguli 0.33 longitudinis corporis transpositis, parte dextra ad antapicem multum curvata; sulco in epicono tenui, ad sinistram prope extremitatem posteriorem cinguli deflecto; hypocono excavationem profundam antapicis prae-hente; corpore sine striis; chromatophoris luteo-fuscis, elongatis, radiatim ordinatis; cytoplasmate circa peripheriam structuram radiatam habente. Longitudo 40–54 μ , latitudo 28–33 μ . United States, in loco dicto Uncatena Island, Barnstable County, Massachusetts.

Gyrodinium metum n. sp.

Corpus paulum asymmetricum, latere dextro convexiore quam latere sinistro; epicono conico, multo latiore quam hypocono; hypocono truncato, multo longiore quam epicono; cingulo profundo, extremis cinguli 0.20–0.25 longitudinis corporis

transpositis; sulco S-curvato, in epicono absente, in hypocono lato; corpore sine striae; chromatophoris absentibus. Longitudo 14.5–2 μ , latitudo 11–16 μ . United States, in loco dicto Great Pond, Barnstable County, Massachusetts.

Gyrodinium glaebum n. sp.

Corpus ellipticum, paulum asymmetricum; epicono hemispherico, hypocono late hemispherico; cingulo lato, extremis cinguli 2–3 latitudinibus cinguli transpositis; sulco in epiconum vix extendente, in hypocono lato et profundo; corpore sine striis; chromatophoris absentibus. Longitudo 17–25 μ , latitudo 12–19 μ . United States, in loco dicto Great Pond, Barnstable County, Massachusetts.

Gyrodinium undulans n. sp.

Corpus ellipticum; epicono subhemispherico vel truncato-pyramidali; hypocono truncato-pyramidali; extremis cinguli 0.20 longitudinis corporis; sulco in duo S-formata curvamina facto, margine sinistro in hypocono marginem dextrum superposito; corpore sine striis; chromatophoris absentibus. Longitudo 27–38 μ , latitudo 21–31 μ . United States, in loco dicto Great Pond, Barnstable County, Massachusetts.

Gyrodinium dominans n. sp.

Corpus fusiforme; epicono et hypocono conico; extremis cinguli 0.25–0.33 longitudinis corporis transpositis; sulco S-curvato, in epiconum extendente, in hypocono ad marginem sinistrum prope antapicem extendente; corpore cum striis, 7–10 a ventrale viso in epicono et hypocono; chromatophoris absentibus. Longitudo 18.5–43 μ , latitudo 10–22 μ . United States, in loco dicto Great Pond, Barnstable County, Massachusetts.

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SUMMARY

1. Unarmored Dinophyceae were collected from very shallow embayments on the south shore of Cape Cod, Massachusetts.
2. Twenty-six species, distributed in eight genera, were studied. Twelve were considered as new species and nine showed extensions of range from Europe.

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