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VIII.

DINOFLAGELLATA OF THE SAN DIEGO
REGION. — I. ON HETERODINIUM, A
NEW GENUS OF THE PERIDINIDAE

BY
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The investigations of the plankton of the Pacific at the San Diego Station during the past three years has brought to light a number of species belonging to the family Peridinidae which do not conform to any known genus. They all present in common a number of characters which call for the establishment of a new genus for the reception of the several species represented.

To this genus also belong seven species described by Murray and Whitting ('99) from the tropical Atlantic as members of the genus *Peridinium* to wit: *Peridinium hindmarchii*, *P. milneri*, *P. blackmani*, *P. leiorhynchum*, *P. tirostre*, *P. tripos*, and *P. doma*. *Gonyaulax triacantha* Jörg. is also to be referred to this genus. All of these species except *P. tirostre* and *Gonyaulax triacantha* have been seen by me and a fuller discussion of their structure will appear elsewhere. In the following pages the brief discussion of each is based upon Murray and Whitting's figures.

I am indebted to Miss E. J. Rigden, assistant in the summer of 1904 at the San Diego Marine Biological Station, for some of the sketches utilized in the plates accompanying this paper and also for the skill and thoroughness of her examination of the



plankton which brought to light the most of the species here discussed. The types and cotypes of the species here described for the first time are in the collections of the University of California.

Heterodinium gen. nov.

The form of the theca resembles that of *Peridinium* in the presence of a median or somewhat postmedian girdle which encircles the theca at its greatest diameter and in two antapical horns, always directed posteriorly or nearly so. The posterior margin or list of the transverse furrow is suppressed or feebly developed in comparison with the anterior one, especially at its distal end, while the anterior one, as if in compensation, is often excessively developed. The suture lines are demonstrated with great difficulty and some uncertainty in most of the species. The plates are as follows: three apicals, one left intercalary, six premedians, seven postmedians, one furrow plate, and three (?) antapicals, as shown in the accompanying text figures.

On the ventral face about midway between the apical and flagellar pores is a small pit or pore-like area in the mid ventral suture. An actual opening in this area has not been demonstrated. In the suppression of the posterior border of the girdle, in the number and arrangement of the plates and in the presence of the ventral pit on the epitheca *Heterodinium* differs from *Peridinium*, although in form and general appearance species of the two genera strongly resemble each other.

In some species and possibly generally in the genus there is a decided asymmetry to the theca brought about by a torsion of the body on the main axis in clockwise direction, looking from the posterior toward the anterior end. This is especially noticeable in the scoop-shaped forms such as *H. scrippsi*.

DETAILED DESCRIPTION.

The following is a more detailed description of the characters found in the genus. The theca is expanded in the equatorial region, with more or less well marked dorso-ventral flattening and ventral excavation near the flagellar pore. It is spheroidal,

ellipsoidal, elongated, rotund, flattened, or even scoop-shaped. The length always exceeds either diameter, and the transdiameter at the girdle equals and more often exceeds the dorso-ventral one. The greatest transdiameter is usually at the girdle but in some species the epitheca or hypotheca may exhibit a slightly greater diameter. The greatest dorso-ventral diameter is at the left of the flagellar pore.

The epitheca is usually not contracted to an apical horn though in some species a short horn is present, and in others the elongated epitheca tapers gradually from the girdle to the apical pore with more or less concavity of the lateral margins. The anterior end of the epitheca is more often broadly rounded, being dome-shaped in the rotund species and like the end of an ellipsoid or even scoop-shaped in the flattened species. In some instances, as in *H. blackmani*, the epitheca is rotund at the girdle but flattened distally. The altitude of the epitheca is usually less than the transdiameter and exceeds it in only a few cases as in *H. blackmani* and *H. hindmarchi*.

The ventral face of the epitheca is flattened and somewhat excavated, slightly in rotund species, more deeply and extensively even to the lateral margins in the dorso-ventrally compressed forms. The mid ventral face is marked by the slightly sinuous suture ridge which runs from the flagellar pore to the apex and bears midway a pit or pore-like area, a characteristic structure in the genus. This varies greatly in distinctness and in the breadth of the widened smooth suture ridge in which it is placed. The apical pore is inclined, even as much as 10° in some species, to the right and is usually well defined though rarely protuberant.

The hypotheca is usually subequal to the epitheca, being longer in *H. milneri* and *H. sphaeroideum*, and shorter in *H. blackmani*. The posterior end may or may not show a bifurcation into antapical horns. It may be broadly rounded, dome-shaped and without any antapical differentiations as in *H. sphaeroideum* and *H. doma*, with mere spinules with or without lists as in *H. milneri* and *H. murrayi*, with slight median bifurcation as in *H. whitlingae* or with typical elongated antapicals

as in *H. blackmani*. In the form of hypotheca *Heterodinium* thus exhibits a development parallel to that found in the allied genus *Peridinium*. The ventral face of the hypotheca is channeled by the longitudinal furrow plate which in many species extends anteriorly so that it indents the epitheca above the flagellar pore.

The girdle is usually submedian in position, though premedian in some species as for example in *H. milneri*, or postmedian in others as in *H. scrippsi*. The girdle is much more oblique in the flattened than in the rotund forms. In *H. whittingae* its plane is inclined ventro-posteriorly at an angle of 45° to the axis. The girdle in all species thus far observed forms a descending right spiral with a displacement accelerated distally and amounting to 1-3 times the width of the furrow. The most characteristic feature of the girdle is its incompleteness distally and the absence or slight development of the posterior ridge. The furrow is bounded anteriorly by a heavy overhanging ridge which in species thus far observed is not a ribbed fin or list but a heavy projection of the thecal wall. The posterior border is formed by a less salient ridge which becomes less prominent distally and often diverges more widely from the anterior ridge towards its distal end. The feature of a more or less deficient posterior margin of the girdle is a constant character in all species thus far observed save the imperfectly known *H. sphaeroidicum* which has, however, the ventral plates at least (the dorsal ones are not known) of the genus.

The transverse furrow is indented in the thecal wall and the flagellar pore is found at its proximal end.

The thecal wall is made up of discrete plates, which, however, are much less easily separated and much less clearly defined than they are in other genera of the family, as for example in *Peridinium*. The sutures are marked by flattened ridges or bands or smooth tracts in which the cleavage line may be traced in some cases in young individuals. The suture bands often have a secondary reticulation of minute polygons on their surface and are best seen on a deep focus. They are differentiated on the inner as well as the outer thecal surface. The epitheca consists

of ten plates (figs. A and B) arranged as follows: three apicals about the apical pore, of which one (1) is a wide dorsal plate covering the dorsal half of the anterior end, and the other two (2, 3) are ventral and are separated from each other by the mid-ventral suture which runs from the apical to the flagellar pore. Between the dorsal and the two ventral plates are lateral sutures which in subgenera *Platydinium* and *Euheterodinium* become very heavy and much more prominent than any other sutures

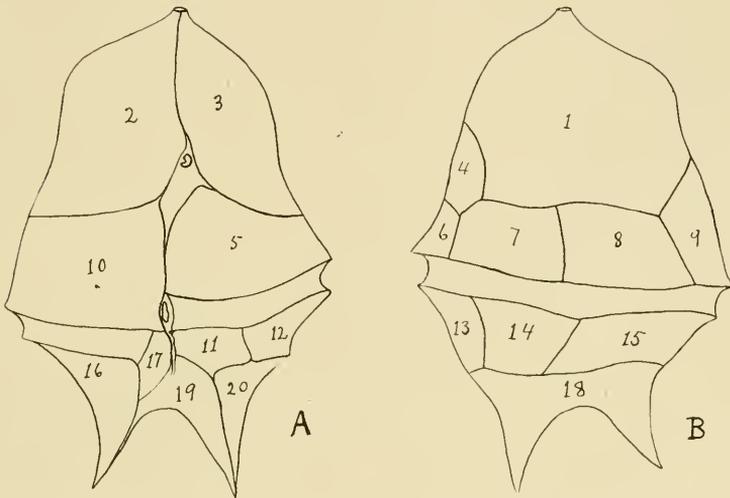


Fig. A.—Ventral view of *Heterodinium scrippsi* showing thecal plates; apicals, 1-3; premedians, 5-10; left intercalary, 4; postmedians, 11-17; antapicals, 18-20. $\times 450$.

Fig. B.—Dorsal view of same. $\times 450$.

of the theca. In some cases as in *H. scrippsi* and *H. blackmani* these lateral ridges are doubled, suggesting a narrow compressed plate, but in the more rotund species they are not doubled and there is no suggestion of the presence of such a plate. I therefore conclude that they are merely doubled margins and are not to be regarded as the margins of degenerate plates.

Anterior to the girdle is a premedian series (figs. A, B, 5-10) of 6 plates of which two are ventral (5, 10), two dorsal (7, 8),

and one each right (9) and left (6). They are not as a rule symmetrically placed because of the considerable irregularity in their size and especially because of the disturbing effect of the left intercalary plate (4) which is found between premedians 5, 6, 7 (or 6 and 7) and apicals 1 and 3. This intercalary plate is often small and in compressed species is not easily found. It is shown clearly in *H. blackmani*, but is merely suggested or not shown at all in the rest of Murray and Whitting's ('99) species. Its demonstration in all species carefully examined by me leads me to expect it in others especially since they usually show the tilting of the apical pore to the right, the slight shoulder on the left marginal outline and the asymmetrical arrangement of the premedians which attend its presence in species in which it has been demonstrated. It is greatly reduced in size in flattened species such as *H. whittingae*, and it is certainly possible that this plate may be entirely suppressed in some of the flattened species of the subgenus *Platydinium*, though no conclusive evidence to that effect is at hand.

The ventral face of the epitheca of the flattened species is formed by the two ventral-apical plates (2, 3) and the two ventral-premedians (5, 10) but in the more rotund forms the lateral-premedians (6, 9) are partially exposed in a ventral view. The left intercalary in the flattened species is dorsal in position, but in the rotund forms as *H. murrayi* and *H. doma* it appears on the left shoulder in the ventral view, and may be shifted dorsalwards so that it does not touch the ventral premedian 5.

The girdle plate has the form of a trough-like band as in *Peridinium* and appears to be variously subdivided by reticular ridges some of which may be suture lines.

The plates of the hypotheca are less clearly defined than those of the epitheca, especially on the ventral face. There are seven postmedians (11-17) adjacent to the girdle, 3 dorsal (13-15) and 4 ventral (11, 12, 16, 17) one of which (16) appears to extend to the tip of the right antapical without subdivision into anterior postmedian and posterior antapical moieties, except possibly in *H. sphaeroideum*. The separation of the adjacent postmedian (17) from the ventral median antapical is

often feebly expressed. The antapical series includes 3 plates, a single dorsal (18), a median ventral (19), and a left ventral (20). The distal end of the posterior list of the girdle usually descends on the suture between the right ventral and right latero-ventral postmedians and continues to the tip of the right antapical horn.

The boundaries of the plates on the right ventral face of the hypotheca are subject to much obscurity and considerable variation in location. The relations of the midventral plate (19) to the adjacent postmedian (17) and to the longitudinal furrow are subject to considerable variation in connection with the varying degrees of development of the posterior list of the girdle.

The longitudinal furrow is subject to considerable variation in length. It is relatively short in some species as in *H. rigdenae*, *H. sphaeroideum*, and *H. hindmarchi* where it is less than two-thirds the length of the hypotheca. In other forms as *H. tirostre* and *H. murrayi* it reaches the antapical border. It is without high membranous lists as a rule though one appears in *H. murrayi*.

The thecal wall is thin and hyaline and universally, except in apparently young individuals, reticulate with more or less irregular polygons formed by thickened ridges on the outer surface. In some species, as in *H. scrippsi*, and perhaps in certain stages of growth of other species these polygonal boundaries become so prominent as to obscure suture lines, as may be seen in Murray and Whitting's ('99) figures of *H. tirostre*, *H. murrayi*, and *H. hindmarchi*.

These reticulations are often quite regular as in *H. blackmani* and along the lateral margins of the epitheca of *H. scrippsi*, or very irregular as on the ventral and dorsal faces of *H. scrippsi* and in *H. tirostre*; they may be relatively large as in *H. murrayi* or small as in *H. sphaeroideum*, with very heavy ridges as in *H. tirostre* or but faintly outlined as in *H. milneri*, or forming but a delicate network as in *H. blackmani*. In young individuals they may be entirely lacking and the presumption is that in general, individuals with partially or feebly developed reticulations have not as yet reached the stage of completed formation of the

theca. The reticulations are found also on the girdle plate and on the girdle lists and along suture lines there are frequently rows of smaller polygons. In but a few cases as in *H. murrayi* and *H. doma* are enclosing ridges so thickened by the filling in of the angles as to leave a subcircular central area. Each reticulation has typically one centrally located pore. In some species with coarse reticulations there are several pores in a single area, and frequently in all species there are minor irregularities in the number and position of the pores. Small polygons frequently lack the pores. The reticulation is evidently formed on the outer surface of the thecal wall by plasma which is extruded through the pores, for the polygons bear a definite relation to the arrangements and distribution of the pores.

The protoplasmic contents of the theca are usually hyaline and colorless, and often only partially fill the interior of the theca. The nucleus has the usual ellipsoidal form with beaded chromatin reticulum and lies near the center of the protoplasmic mass not far from the flagellar pore. It is small and is found with difficulty. No instances of diffuse reddish coloration often seen in *Peridinium* and *Pyrophacus* have been noted as yet in *Heterodinium*. Chromatophores are entirely absent in some instances, in others they are massed in spheroidal chromospheres of pale greenish yellow or deep cadmium orange color. In some cases the chromatophores are peripheral in location and of various forms. Vacuoles and pusules of varying form and distribution have been observed in the cell contents.

The dimensions of observed species are like those of *Peridinium*. The largest species thus far recorded appears to be *H. blackmani* which has a length of 225μ , and transverse and dorso-ventral diameters of 135μ and 160μ respectively; the smallest appears to be *H. sphaeroidcum* with a length of only 42μ , and transdiameter of 39μ .

The distribution of this genus from species thus far published appears to be limited, in the main, to warmer seas as shown in the following table:

Species	Latitude	Temperature C.
<i>H. blackmani</i>	7°–30° N.	25°–27°
<i>H. doma</i>	34°–39° N.	16.1°–18.9°
<i>H. hindmarchi</i>	19°–39° N.	15.6°–27.2°
<i>H. trirostre</i>	26° N.	27.2°
<i>H. leiorhynchum</i>	19°–39° N.	15.5°–24.5°
<i>H. murrayi</i>	14°–28° N.	20°–25.5°
<i>H. milneri</i>	29°–31° N.	26.9°–27.2°
<i>H. sphaeroideum</i>	San Diego 32.7° N.	14.6°–22.5°
<i>H. rigdenae</i>		
<i>H. scrippsi</i>		
<i>H. whittingae</i>		
<i>H. inaequale</i>	55°–81° N.	
<i>H. triacantha</i>		

Their vertical distribution is not known. At San Diego no individuals have been taken in the many surface catches of the tow nets made during the past few years. They have been found only in the vertical catches in from 165 to 40 fathoms to the surface. Murray and Whitting's ('99) species were all apparently from plankton collected by filtering water from ship's pumps and therefore taken some 2–3 fathoms below the surface. The absence of chromatophores or their aggregation in chromospheres observed in individuals taken at San Diego is suggestive of occurrence in deep water with diminished light. The extreme hyalinity of some species is also indicative of a deeper habitat. The excessive development of the reticulum on the theca, and the asymmetry are evidently adaptations for flotation, on the one hand by increase of friction surface, which is at least doubled in the more rugose forms, and on the other by giving a spiral course to any passive descent of the organism due to gravity, and thus prolonging its existence in the upper strata.

This is a genus of somewhat aberrant structure and is represented by relatively very few individuals in comparison with those of *Ceratium* and *Peridinium*. I regard it as a degenerate form unable to maintain itself at the surface and for some reason deficient in reproductive vigor. In comparison with the number of individuals observed the number of species is large. The known species are all well defined and observations on different individuals do not indicate as yet any noticeable intergradation.

The nearest allies of this genus are plainly in the family *Peridiniidae*, though it shows no marked structural affinities to any particular genus. The form cycle found in its species resembles that of *Peridinium* but its thecal plates are entirely different. The midventral diamond-shaped plate of the epitheca so characteristic of *Peridinium* is entirely lacking in *Heterodinium*, unless indeed the slight midventral expansion on the suture line be taken to represent a degenerate midventral which seems improbable. The excessive development of reticulations on the surface of the theca approaches that in *Protoceratium* but this genus appears to lack the midventral pit on the epitheca, and has a narrow transverse furrow which is complete distally. Its plates (see Schutt ('96)) are not known and it may prove to have a closer relationship to *Heterodinium* when these are definitely determined.

The midventral pit on the epitheca of *Heterodinium* resembles the so-called "pore" in *Poroceratium gravidum* (Gourret) but bears a different relation to the thecal plates and is probably not a homologous structure. In *Poroceratium* the "pore" lies near the middorso-ventral line in the middle of the dorsal and ventral apical plates, whereas in *Heterodinium* it lies in the suture between the two ventral apicals.

The generic distinctness of *Heterodinium* is thus beyond question and it belongs with *Ceratium*, *Peridinium* and *Protoceratium* in the sub-family Ceratiinae.

SYNOPTIC KEY TO THE SPECIES OF HETERODINIUM.

Sphaerodinium subgen. nov.

Body spheroidal, antapical horns not present or only slightly developed as spines. Epitheca rotund without stout lateral sutures.

- | | |
|--|----------------------|
| 1. With no antapical horns or spines | 2 |
| 1. With antapical spines | 3 |
| 2. Outline smooth, sutures faint, reticulations minute. <i>H. sphaeroideum</i> | |
| 2. Outline subangular, sutures prominent, reticulations coarse. <i>H. doma</i> | |
| 3. No apical horn, thecal markings faint | <i>H. milneri</i> |
| 3. Short apical horn, thecal reticulation prominent | <i>H. murrayi</i> |
| 3. Long apical horn | <i>H. triacantha</i> |

Euheterodinium subgen. nov.

Epitheca dorso-ventrally compressed, with straight, convex or concave sloping lateral margins which are usually thickened and have doubled ridges between the lateral margins of the apical plates. Antapical horns well developed. Girdle not very oblique.

- | | |
|--|------------------------|
| 1. Epitheca with strongly convex sides, apex broadly rounded | |
| | <i>H. inaequale</i> |
| 1. Epitheca with straight or concave sides, apex not broadly rounded.... | 2 |
| 2. Epitheca low, its altitude about one-half the transdiameter | |
| | <i>H. rigdenae</i> |
| 2. Epitheca high, tapering, nearly equal to the transdiameter | 3 |
| 3. Left antapical bifurcated | <i>H. trirostre</i> |
| 3. Left antapical not bifurcated | 4 |
| 4. Reticulations very coarse, scantily developed | <i>H. leiorhynchum</i> |
| 4. Reticulations subregular, very delicate | <i>H. blackmani</i> |
| 4. Reticulations medium sized, very heavy | <i>H. hindmarchi</i> |

Platydinium subgen. nov.

Epitheca dorso-ventrally compressed and hollowed out ventrally, scoop-shaped. Lateral margins convex, not contracted to an apical horn. Girdle very oblique dorso-ventrally. Antapical horns present.

- | | |
|-------------------------------------|----------------------|
| 1. Antapical horns divergent | <i>H. scrippsi</i> |
| 1. Antapical horns convergent | <i>H. whittingae</i> |

Heterodinium sphaeroideum sp. nov.

Pl. 3, fig. 15.

A minute symmetrical species of spheroidal form without apical or antapical horns. The body is spheroidal or broadly ellipsoidal, the length 1.1 transdiameters. Dorso-ventral diameter equal to transdiameter. Epitheca a low dome, its altitude 0.4 transdiameters. Hypotheca exceeding the epitheca, elongated hemispherical, its altitude 0.6 transdiameters, with broadly rounded symmetrical antapex. Girdle premedian, transverse furrow indented, posterodextrotropic with very slight displacement scarcely 0.2 its width, its anterior and posterior lists equal

and the latter not deflected distally, both formed by sharp projecting ridges of the thecal wall. Longitudinal furrow short, its length less than 0.5 distance to the postmargin, broad and shallow, its distal two-thirds enlarged.

Thecal plates imperfectly known. Ventral plates of typical number and arrangement except that the right ventral postmedian (16) is not continued to the postmargin but appears to be divided into postmedian and antapical moieties. Suture lines faint, bordered by smooth structureless zones. No prominent lateral ridges. No lists or spines. Thecal wall minutely and faintly reticulate with subregular polygons with centrally located pores. Polygons relatively very numerous.

Plasma dense, heavily vacuolated, chromatophores irregular, peripherally located, greenish yellow; nucleus near flagellar pore, ellipsoidal.

Dimensions:—length, 42μ ; transdiameter, 39μ ; width of furrow, $4-5\mu$; diameter of polygons, $2-3\mu$.

Taken once in vertical haul from 165 fathoms off San Diego in June.

Although this organism does not have the deficient girdle found in other species of the genus its thecal plates, in so far as they are known, are those of *Heterodinium*.

Heterodinium doma (Murr. et Whitt.).

Peridinium doma Murray and Whitting ('99), p. 327, Pl. 30, fig. 3.

Plainly belongs to *Heterodinium* because of the clearly shown ventral pit in the central expansion of the median ventral suture. The plates are only partially shown but in the one view (ventral) given they conform to *Heterodinium* so far as shown. The girdle and furrows are also typical.

The species is characterized by the spheroidal form, submedian girdle, broadly rounded apex, entire absence of antapicals, median reticulations of subregular polygons and somewhat salient suture ridges.

Reported from the warm temperate Atlantic between 34° - 39° N.

Heterodinium milneri (Murr. et Whitt.).

Peridinium Milneri Murray and Whitting ('99), p. 327, Pl. 29, figs. 3a, b.

The characteristic *Heterodinium* structures are not clearly shown in Murray and Whitting's figures. There is only a suggestion of the midventral suture of the epitheca and a markedly deficient posterior list of the transverse furrow. The ventral pit is lacking and the plates are incompletely shown.

The species is characterized by its spheroidal rotund body, premedian girdle with wide displacement and considerable overlap of the ends of the transverse furrow, wide zones along suture lines free from reticulations, and coarsely reticulated plates. It is closely related to *H. murrayi*.

Reported from tropical Atlantic in 29°–31° N.

Heterodinium murrayi nom. nov.

Peridinium tripos Murray and Whitting ('99), p. 327, Pl. 30, figs. 4a, b.
non *P. tripos* (Müller), Ehrenberg ('33), p. 272 = (*Ceratium tripos*).

The specific name *tripos* must be rejected as it was previously introduced into the genus *Peridinium* by Ehrenberg's ('33) transfer of *Cercaria tripos* of O. F. Müller (1786) to the genus *Peridinium*. As figured by Murray and Whitting ('99) this species shows almost none of the generic characters except the very deficient posterior list of the transverse furrow. The ventral pit is questionably figured and no trace of the plates is shown. The only evidence of the presence of the left intercalary is the shifting of the apex to the right.

The species is characterized by its small size, rotund body, large and few subregular polygonal reticulations with a coarse mesh which hide the sutures and cover the whole theca. The girdle is premedian and the transverse furrow is much displaced and has considerable overhang. The apex is somewhat contracted and the antapicals bear two short finned spinules on the left and one on the right. The anterior list of the transverse furrow is membranous. There are no antapical horns.

Reported from the tropical Atlantic in 14°–31° N.

Heterodinium triacantha (Jörg).

Gonyaulax (?) *triacantha* Jörgensen ('99), p. 35.

Ceratium hyperboreum Cleve ('00), pp. 14-15, Pl. 8, fig. 5.

Gonyaulax triacantha, Paulsen ('04), pp. 21-22, fig. 5.

This form appears to belong to *Heterodinium* by reason of the reticulated thecal wall, the midventral suture of the epitheca deflected to the left, the widened distal end of the transverse furrow, and the longer right antapical spine. There is also some indication that the distal end of the posterior list of the girdle is continued in the suture on the right side of the hypotheca. None of the figures shows the ventral area or pit, or the thecal plates in full. In so far as they are indicated in Paulsen's ('04) figures, they conform to those of the genus *Heterodinium*. There are difficulties in reconciling Cleve's ('00) figures with each other, and with those of Paulsen ('04) as well as with Jörgensen's description, probably due to the fact, that, as Paulsen suggests; Cleve's figure is reversed, *i.e.*, it is a view of the ventral face as viewed through the body from the dorsal face.

This species probably belongs in the subgenus *Sphaerodinium*, though it does not possess a spheroidal body. It is characterized by the absence of antapical horns and post indentation, concave sides of the epitheca, the developed apical horn, and the three antapical spines.

Dimensions:—length, 72-84 μ ; transdiameter, about 50 μ ; dorsal-ventral, about 45 μ .

Reported from coasts of Norway and Iceland.

Heterodinium inaequale sp. nov.

Pl. 18, figs. 9, 10.

This is a small subpentagonal species with rotund epitheca and unequal widely separated antapicals.

The body in face view is subpentagonal, the two anterior margins are quite convex, the left posterior nearly straight, the right slightly convex and the postmargin between bases of the antapicals is concave. The length is 1.2 and the dorso-ventral diameter 0.75 times the transdiameter. The epitheca is low dome-

shaped, compressed dorso-ventrally, its altitude (ventral) is 0.7 transdiameter. No apical horn is differentiated and though compressed dorso-ventrally it is not thinned down to a sharp edge at the doubled lateral sutures. The ventral face is scarcely excavated. The broad midventral suture runs from the longitudinal furrow to the apical pore swerving towards the left at the ventral pit.

The hypotheca is rotund, its altitude (mid-dorsal) 0.6 transdiameter. The antapicals are very unequal, the right is about one-half the length of the left and is abruptly incurved to an acute tip. The left is not incurved and is somewhat tapering. Its length is 0.3 transdiameter. The postmargin between the antapicals is slightly concave and is 0.4 transdiameter in length.

The plates are typical in number, the left intercalary being confined to the dorsal face. The dorsal premedians are very low, scarcely exceeding the girdle in width. The dorsal postmedians on the other hand are unusually long, and the posterior angle of the right one projects slightly beyond the margin.

The girdle is narrow and slightly oblique (15° postero-ventrally) to the equatorial plane. The transverse furrow is postero-dextrotropic with a displacement of its own width. It is scarcely indented, the thecal wall forming a slight anterior ridge, and a small posterior one which fades into the right antapical suture distally. The longitudinal furrow is narrow and short, 0.6 distance to postmargin.

The thecal wall is structureless save for scattered pores in the two individuals thus far observed. These may both be young stages and the older ones may be reticulate as are other species in the genus, but there is not the slightest evidence of reticulations on the thecal walls of these two individuals. The suture lines are light and faint. The midventral one on the epitheca is broad in the posterior half between the ventral pit and the flagellar pore, and the lateral sutures of the epitheca and hypotheca are doubled and prominent. The right dorsal premedian suture is very oblique. No fins or lists were noted.

The plasma is coarsely granular, chromatophores few, large, spheroidal, clustered near the center.

Dimensions:—length, 116–120 μ ; transdiameter, 100 μ ; dorso-ventral, 75 μ ; furrow, 8 μ in width.

Taken in vertical hauls from 40–95 fathoms to surface off San Diego in May and June.

This species is not closely related to any described species. Its asymmetry is noticeable but no other adaptations to flotation in the theca were found in the individuals examined.

Heterodinium rigdenae sp. nov.

Pl. 18, figs. 6-8.

A small pentagonal Peridinium-like species with a coarse polygonal reticulum and slight obliquity of the girdle, resembling *P. acutangulum* Lemm.

Body pentagonal in face view with straight or nearly straight subequal sides, broadly bifurcated posteriorly with short stout conical antapicals. Length 1.3 and dorso-ventral diameter 0.6 times the transdiameter. Epitheca without apical horn, the sides sloping in a straight line from the apical pore to the girdle, compressed dorso-ventrally and somewhat excavated in the mid-ventral region, lateral sutures prominent and doubled. Hypotheca also compressed, the right margin concave, the left with projecting angle at the junction of postmedian and antapical plates. Ventral face excavated. The antapical horns are short, 0.2 transdiameter in length, which is nearly equal to the slightly curved margin which separates their bases. Their ends blunt with short terminal spinule. The girdle is inclined about 15° postero-ventrally from the equatorial plane. The transverse furrow is deeply indented, more so towards its anterior than its posterior margin. It forms a descending right spiral with displacement slightly exceeding its width. Its distal end is feebly developed, the posterior ridge vanishing on the ventral face. The anterior ridge is a heavy projection of the body wall, nearly twice the height of the posterior. The longitudinal furrow is narrow and shallow, dilated posteriorly and extends from the

flagellar pore little more than 0.5 of the distance to the post-margin.

Thecal plates of the normal type. Left intercalary confined to dorsal face. Suture lines heavy, deficient on right ventral area. Thecal wall covered with irregular polygons, mostly pentagonal, larger ones each with single central pore. Polygons relatively few, 41 on dorsal apical. In young individuals faint suture lines but no polygons are found. The ventral area is found as usual at the junction of the sutures on the ventral face of the epitheca. It is unusually large and contains the anteriorly located reniform pit-like structure.

Individuals thus far observed have been very hyaline and colorless or with pale greenish yellow chromatophores, reniform or irregular in shape.

Dimensions:—length, 120–125 μ ; transdiameter, 90–92 μ ; dorso-ventral, 155 μ ; girdle width, 10 μ ; polygons, 2–10 μ .

Taken in vertical hauls from 90–100 fathoms to surface in June off San Diego.

This species resembles *H. hindmarchi* (Murr. et Whitt.) in the type of reticulations, but differs from it in its more robust form, shorter epitheca and antapicals.

***Heterodinium triostre* (Murr. et Whitt.).**

Peridinium triostre Murray and Whitting ('99), p. 327, Pl. 29, fig. 5.

This species is shown to have the typical ventral plates of *Heterodinium*, the ventral pit and the deficient posterior list of the transverse furrow which is deflected posteriorly on the right antapical horn.

The species is characterized by the presence of pointed antapical horns, the left showing a bifurcation into two apices. The epitheca is high, broadly cuneate with doubled lateral sutures. The girdle is median, the transverse furrow being displaced only its own width. The reticulations are very coarse and heavy and exhibit more than the usual irregularity in form.

Reported from 26° N. in the Atlantic.

Heterodinium leiorhynchum (Murr. et Whitt.).

Peridinium leiorhynchum Murray and Whitting ('99), pp. 326-327, Pl. 29,
figs. 2a, b.

This is unquestionably a *Heterodinium* as it shows a mid-ventral pit upon the epitheca, the doubled lateral sutures and diminishing posterior list of the transverse furrow. The plates are very imperfectly shown though there is a suggestion of the left intercalary of the epitheca in the slight shoulder on the left epithecal margin, and in the incomplete suture lines of the lateral view.

The species is characterized by the somewhat differentiated apical horn, the unequal, pointed, divergent antapicals terminating in spines, the rotundity at the girdle, prominent suture ridges (incomplete in figure), smooth or coarsely reticulate thecal wall, and fenestrated lists of the girdle.

Reported from the warm temperate Atlantic from 20°-40° N.

Heterodinium blackmani (Murr. et Whitt.).

Peridinium Blackmani Murray and Whitting ('99), pp. 327-328, Pl. 29,
figs. 6a, b, c.

This superb and clearly marked species is the only one in which the left intercalary plate is shown by Murray and Whitting ('99). It is unquestionably a typical *Heterodinium* though these authors fail to show the ventral plates of the epitheca and the ventral pit characteristic of the genus. The remainder of the plates is almost completely shown. The prominent doubled lateral sutures, the short longitudinal furrow, and the posteriorly deflected posterior list of the transverse furrow stamp this species as a typical *Heterodinium*.

The species is characterized by the curved epitheca flaring to the greatly expanded equator, submedian girdle, divergent pointed antapicals. The suture lines are marked by prominent lists and the plates are reticulate with delicate subregular hexagonal polygons, which exhibit a tendency to horizontal elongation on the epitheca.

Reported from the Caribbean Sea and tropical Atlantic from 9°-25° N.

Heterodinium hindmarchi (Murr. et. Whitt.).

Peridinium Hindmarchii Murray and Whitting ('99), p. 326, Pl. 29,
figs. 1a, b.

This is plainly a *Heterodinium* as it has the characteristic ventral pit in the central expansion of the median ventral suture of the epitheca, a short longitudinal furrow and the deficient distal posterior list of the transverse furrow. The plates are not shown but the presence of the left intercalary plate is suggested in the figure.

The species is characterized by the long stout widely separated antapicals, elongated epitheca, and coarse reticulations.

Reported from tropical Atlantic from Panama to 34° N.

Heterodinium scrippsi sp. nov.

Pl. 17, figs. 1-5.

A large species with short antapicals, scoop-shaped epitheca and coarse irregular reticulations. The body is subheptangular in face view, swollen at the girdle, and with shallow posterior bifurcation. The length is 1.5 and the dorso-ventral diameter 0.7 times the transdiameter. The epitheca is long, and its altitude is about 0.8 transdiameters. The ventral face is flattened and hollowed out anteriorly and thins out laterally to the doubled suture lines on the angular margin between the apical plates. Posteriorly the epitheca flares out to meet the girdle. The lateral margins have rounded shoulders about two-thirds of the distance from the girdle to the apical pore which rises from the anterior end in a fully developed apical horn. A short ventral slot-like extension of the apical pore such as is found in *Peridinium*, follows the midventral suture for a short distance.

The hypotheca is shorter than the epitheca and in the midventral line has scarcely 0.6 its altitude. To the tip of the long left antapical is 0.75 transdiameters. It is somewhat angular, is flattened ventrally and excavated in the midventral region between the antapicals. The dorsal side has considerably more flare toward the girdle. The antapicals are short and divergent, the right being more oblique than the left. The tips are acute.

The postmargin is not set off from the inner margins of the antapicals with which it forms a fairly regular arc. The distance between the tips of the antapicals is 0.4 transdiameters.

The girdle is postmedian, reniform in cross section, though somewhat thicker on the left side, and nearly perpendicular to the main axis. The transverse furrow is deeply indented with heavy overhanging anterior list and less strongly developed posterior one which vanishes distally on the ventral suture of the right antapical horn. The furrow is wide, postero-dextrotropic with a displacement equalling its width. The longitudinal furrow is about 0.6 distance to postmargin in length and is wide and shallow.

The plates of the theca are typical, the left intercalary being almost wholly confined to the dorsal face and of small size. Both pre- and postmedians are irregular in size and arrangement. There is an unusually large ventral area in the midventral suture of the epitheca which is deflected to the left and contains the reniform ventral pit. The suture lines are well developed and are latticed in places. Hyaline lists are found on the lateral and postmargins of the hypotheca. The thecal wall including the girdle is coarsely and irregularly reticulate with well developed polygons of 3-5 sides, each with a single central pore. Near the lateral margins of the epitheca these polygons are somewhat regular and often quadrangular. There are 108 in the dorsal apical plate.

The plasma and indeed the whole organism is beautifully hyaline. There are a few subspherical greenish chromatophores and an ellipsoidal nucleus near the flagellar foramen.

Dimensions:—length, 140-155 μ ; transdiameter, 100-105 μ ; dorso-ventral diameter, 60 μ ; width of transverse furrow, 10-12 μ ; polygons 4-8 μ , rarely 12 μ .

Taken in vertical hauls from 95 fathoms off San Diego in June.

I regard *H. scrippsi* as the type species of the genus.

***Heterodinium whittingae* sp. nov.**

Pl. 19, figs. 11-13.

A large species with very oblique girdle, elliptical outline, and shallow rounded bifurcation. Body elliptical in face view with broadly rounded apical end and short incurved antapical horns which preserve the elliptical outline. The posterior bifurcation extends but one-fourth of the distance to the girdle and is broadly rounded anteriorly. The body is very much compressed dorso-ventrally, forming a sharp edge at the lateral margins. The girdle is very oblique being inclined at an angle of 45° to the main axis in an antero-dorsal to postero-ventral direction.

The length is 1.4 transdiameters and 3 times the distance between the greatest dorsal and ventral extensions which is found in the left half of the epitheca. The whole body is slightly twisted in a right spiral.

The epitheca is very much flattened anteriorly and somewhat excavated on the ventral face, forming in fact a thin sheet which expands posteriorly as it meets the oblique girdle. The hypotheca is likewise flattened and excavated ventrally about the longitudinal furrow. The lateral postmedian plates form a posteriorly projecting tooth on the left margin.

The girdle forms a descending right spiral with slight displacement equalling its width. Its distal end is much widened, the posterior border becoming low and deflected posteriorly into the ventral suture of the right antapical horn. The longitudinal furrow is short and narrow. The flagellar pore is found as an elliptical opening at its proximal end.

The thecal wall is thin, delicate and hyaline with light suture ridges except in the case of the lateral sutures between the apicals which are doubled and heavy, as are also the lateral sutures on the hypotheca. The plates are normal, the left intercalary being restricted to the dorsal face. The surface, including that of the girdle plate, is everywhere covered with a reticulum of irregular polygons, each with a single central pore. In the several specimens thus far observed the reticulum has been very light and delicate. The polygons are relatively numerous, 97 having been recorded on the dorsal apical plate.

The plasma is exceedingly hyaline and coarsely vacuolated and its total amount is relatively very small. The nucleus is minute (12μ), spheroidal and centrally located, and there is one pale chromosphere of similar size and form adjacent to it. This is a large species, 180μ in length, 140μ in transdiameter and 60μ in greatest dorso-ventral extension. Polygons $5-12\mu$ in diameter.

Taken in vertical catch from 85 fathoms to the surface off San Diego in July.

LITERATURE CITED.

Cleve, P. T.

- :00. Notes on some Atlantic Plankton-organisms. Kongl. Svensk. Vetén.-Akad. Handl. Bd. 34, No. 1, 34, 22 pages, 8 plates.

Ehrenberg, C. G.

- '34. Dritter Beitrag zur Erkenntniß grosser Organization in der Richtung des kleinsten Raumes. Abh. Akad. Wiss. Berlin, 1833, pp. 145-336, Taf. 1-11.

Joergensen, E.

- '99. Protophyten und Protozoen im Plankton aus der norwegischen Westküste. Berg. Mus. Aarb. 1899. No. VI, pp. 1-112, I-LXXXIII. 5 plates.

Müller, O. F.

1786. Animalcula Infusoria fluviatilia et marina. Pp. LVI, 365, 50 Taf.

Murray, G., and Whitting, F. G.

- '99. New Peridiniaceae from the Atlantic. Trans. Linn. Soc., London. Botany (2), Vol. V, pp. 321-342, Tables I-IX, Pls. 27-33.

Paulsen, O.

- :04. Plankton Investigations in the waters round Iceland in 1903. Medd. Comm. Havunderzög. Bd. I, No. 1. 41 pages, 11 figures, 2 maps.

Schütt, F.

- '96. Peridinales. Engler und Prantl's Nat. Pflanzenfamilien. I Teil, Abth. b, pp. 1-30, 43 figs.

EXPLANATION OF PLATES.

PLATE 17.

- Fig. 1.—*Heterodinium scrippsi* ventral view. $\times 725$. *ap. p.*, apical pore;
fl. p., flagellar pore; *l. f.*, longitudinal furrow; *v. a.*, ventral
area; *v. p.*, ventral pit.
- Fig. 2.—Dorsal view of same. $\times 420$.
- Fig. 3.—Oblique view of left side of same. $\times 420$.
- Fig. 4.—Diagrammatic apical view of same. $\times 420$.
- Fig. 5.—Reticulations adjacent to posterior list of transverse furrow.
 $\times 2725$.

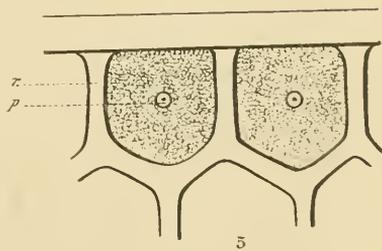
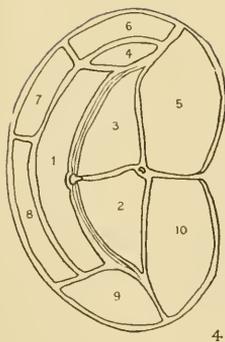
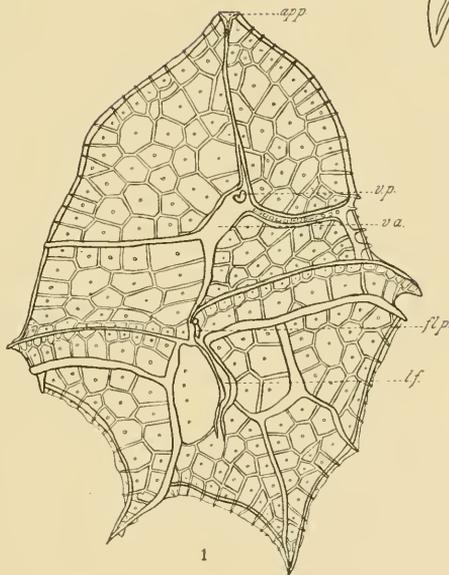
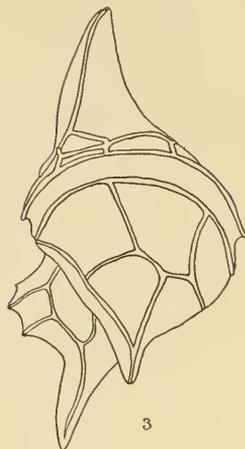
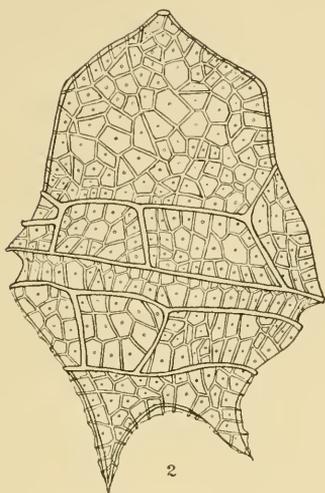


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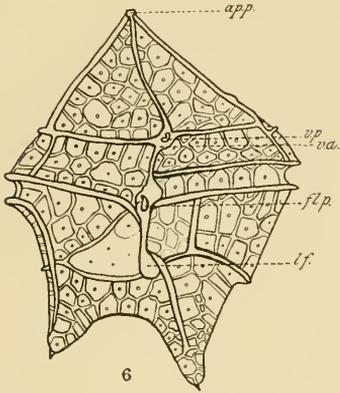
Fig. 6.—*Heterodinium rigdenae*, ventral view. $\times 410$. *ap. p.*, apical pore;
fl. p., flagellar pore; *l. f.*, longitudinal furrow; *v. a.*, ventral
area; *v. p.*, ventral pit.

Fig. 7.—Dorsal view of the same. $\times 410$.

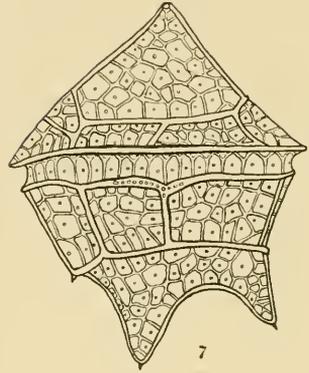
Fig. 8.—View of left side of same. $\times 410$.

Fig. 9.—Ventral view *H. inaequalis*. $\times 420$. Abbreviations as in fig. 6.

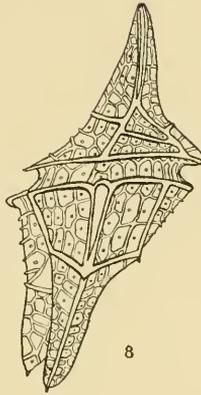
Fig. 10.—Oblique view of right side of same. $\times 420$.



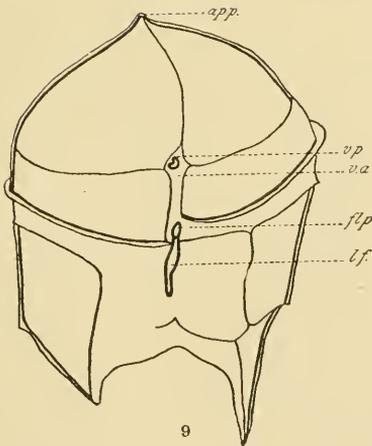
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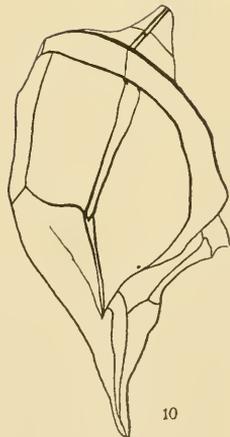
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PLATE 19.

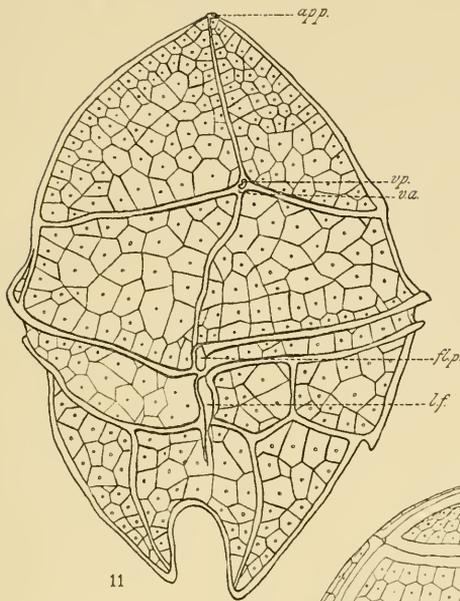
Fig. 11.—Ventral view of *Heterodinium whittingae*. $\times 420$. *ap. p.*, apical pore; *fl. p.*, flagellar pore; *l. f.*, longitudinal furrow; *v. a.*, ventral area; *v. p.*, ventral pit.

Fig. 12.—Dorsal view of same. $\times 420$.

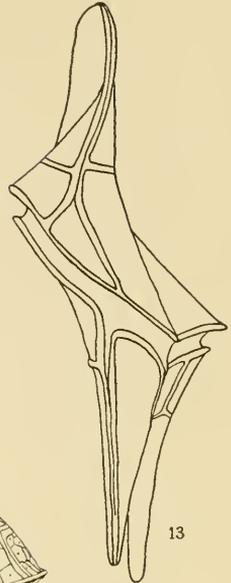
Fig. 13.—View of right side of same. $\times 420$.

Fig. 14.—Optical section at girdle of same. $\times 420$.

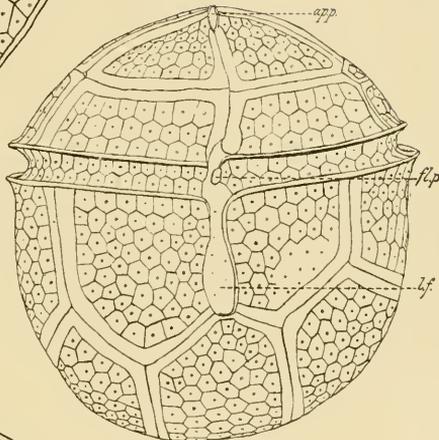
Fig. 15.—Ventral view of *H. sphaeroides*. $\times 1500$.



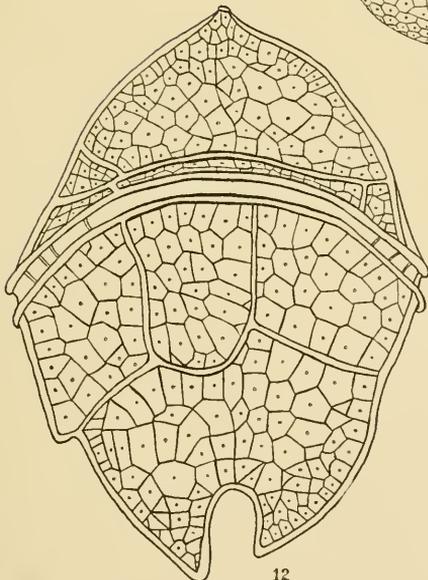
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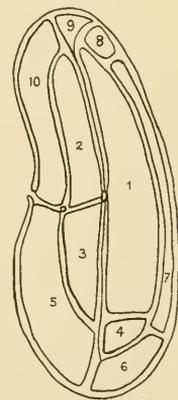
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