# Plymouth Peridinians.

By

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## I. DIPLOPSALIS LENTICULA AND ITS RELATIVES.

With Figures 1–20, Table and Diagram.

Much discussion has recently taken place over the peridinian described by Bergh (1882) as *Diplopsalis lenticula*, and certainly three distinct species have severally been designated as the original. As it is a name frequently to be found in the International Plankton lists, it is important that we should be clear as to which species we are noting, and as recent research at Plymouth has shown that all the three are common in the district it seems worth while to investigate them once more. The question is interesting also from the point of view of phylogeny, as in these species we have close relatives of *Peridinium* proper which seem to indicate the method of evolution of that genus from simpler forms with fewer plates, and from this point of view alone they are well worth study.

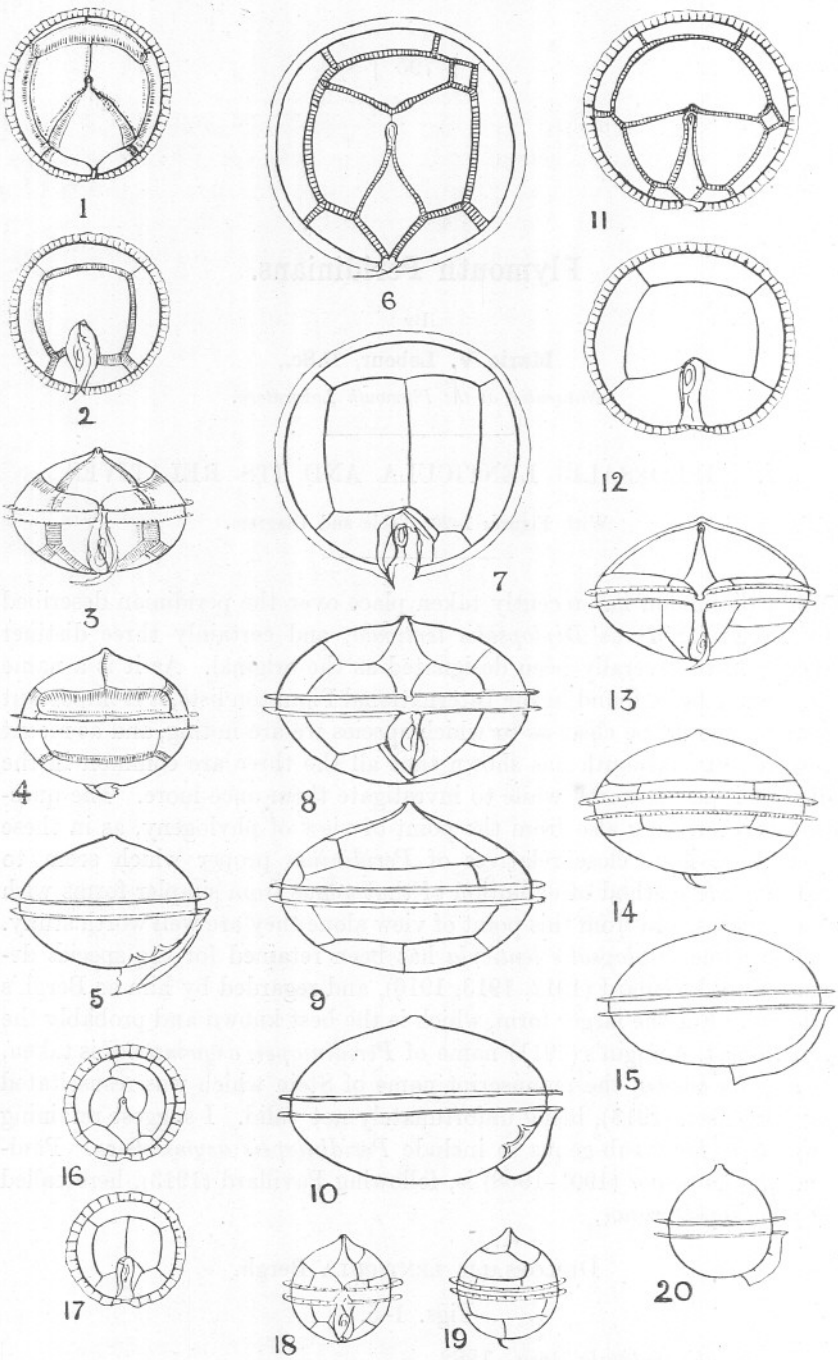
The name *Diplopsalis lenticula* has been retained for the species described by Pavillard (1912, 1913, 1916), and regarded by him as Bergh's original. For the larger form, which is the best known and probably the commonest, Mangin's (1911) name of *Peridiniopsis asymmetrica* is taken, *Diplopelta bomba*, the manuscript name of Stein which was resuscitated by Jörgensen (1913), being unfortunately not valid. I suggest retaining *Diplopelta* for a sub-genus to include *Peridiniopsis asymmetrica*. Paulsen's *forma minor* (1907–1908) is, following Pavillard (1913), here called *Diplopeltopsis minor*.

### Diplopsalis lenticula Bergh.

Figs. 1–5.

*Diplopsalis lenticula* Berg., 1882.
Stein, 1883 (Plate IX, Fig. 1).
Pavillard, 1912, 1913, 1916.

The following description is taken from the Plymouth specimens:




EXPLANATION OF FIGURES 1–20.

1–5. *Diplopsalis lenticula* Bergh. Tow-nets, 2.5.21. Eddystone-Rame. Breadth 40 $\mu$.

6–10. *Peridiniopsis* (*Diplopelta*) *asymmetrica* Mangin. Tow-nets 2.5.21. Eddystone–Rame. Breadth 66 $\mu$.

11–15. *Diplopeltopsis minor* (Paulsen). Tow-nets, 28.2.21. Breakwater. Breadth 52 $\mu$.

16–20. *Peridiniopsis rotundata* n.sp. Tow-nets, 9.6.21. Breakwater.

1, 6, 11, 16. Epitheca from top. 2, 7, 12, 17. Hypotheca from bottom.

3, 8, 13, 18. Ventral view. 4, 9, 14, 19. Dorsal view. 5, 10, 15, 20. Side view.

In Fig. 9 the central precingular is erroneously figured as one plate where it should be divided into two (3″ and 4″).

Cell lenticular, depressed, epi- and hypotheca the same shape. Apex ending in a very inconspicuous projection, on which opens the apical pore. Cell contour almost circular. Left longitudinal list conspicuous, reaching almost to the centre of the hypotheca, bent across the ventral area, its margin more or less denticulate. Right longitudinal list inconspicuous. Flagellar pore oval, on the left lower corner of the ventral area, more or less hidden by the list. Girdle not displaced, indented. Transverse list supported by very fine spines. Cell contents pink. Large pusule apparatus. Theca very finely punctuate. Sutures broadly striated, except in young forms. Epitheca with 3 apicals meeting in the centre, a fourth plate having the position of an intercalary occupying a large part of the dorsal area, 6 precingulars, the 2 connected with the dorsal plate very narrow and inconspicuous. Hypotheca with 5 postcingulars and only 1 large apical. Plate formulæ,* 4′0a 6″ 5‴ 1⁗ or 3′1a 6″ 5‴ 1⁗. Probably the latter. Reproduction by sporulation, 2 spores emerging from the cell between the epi- and hypotheca.

Bergh's specimens varied between 29 $\mu$ and 34 $\mu$ in length, and 40 $\mu$ to 43 $\mu$ in breadth. Pavillard's ca. 25 $\mu$ long, 45 $\mu$ broad. The Plymouth specimens vary from 33 $\mu$ to 56 $\mu$ across, the most usual breadth being from 40 to 45 $\mu$. One with 2 spores inside measured 53 $\mu$ across, each spore measuring ca. 39 $\mu$ across. The usual shape is flattened, but some from Plymouth were much rounder; these, however, were very rare.

It occurred frequently in Plymouth Sound from the region of the Breakwater, but also further out between Rame and the Mewstone and round about the Eddystone. Once (July 4th, 1921) it occurred further out, at Station E 7, Bishop's Lighthouse, Scilly Is., bearing N. by W. 8 miles (magnetic), from the surface over 40 fathoms, and once from Station N 2 (July 3rd, 1921), Wolf Rock bearing N.W. 8 miles (magnetic), at a depth of 30 metres, at the line of a rapid change of temperature, 11° (warmer water 14° above). Its natural habitat appears to be inshore, and it is most probably to be regarded as a neritic and surface form. It occurred from May to August in the Plymouth district (see table). It was found in the Clyde off Millport, inshore, from just off Keppel Pier, in August, 1921, and at Cullercoats, Northumberland, off the rocks at low water in September, 1921.

The present records are the first from the International area if we except that of Bergh. Pavillard records it from the Lake of Thau and from the Mediterranean, and in a letter (1921) tells me he has found it at Roscoff. Stein gives no special locality for this particular figure, which came either from the Baltic or from the Mediterranean.

Bergh's specimens agree with this description as to size, shape, colour

* Kofoid's (1909) system of numbering the plates is used throughout this paper.

and form and size of the left longitudinal list. The plate arrangement was not described by him. Stein (1883, Plate IX, Fig. 1) figures what he describes as a young specimen of *Diplopsalis lenticula* having 3 apicals and 5 precingulars. Although he does not figure nor describe the hypotheca of this form, the epitheca shows it to be almost certainly the species described above, the dorsal end-plate and the division of the corresponding precingular into 2 not being shown. It is extremely easy to make such a mistake, as these 2 precingulars are very narrow and in certain positions seem blended with the dorsal plate. Pavillard (1912), having rediscovered this species in the Lake of Thau, describes the dorsal plate, but not the 2 corresponding precingulars. Later (1913) he believes the dorsal plate to be non-existent. His latest description (1916) from Mediterranean specimens, gives 3 apicals, 5 precingulars, 5 postcingulars and 1 antapical, and he regards this species as identical with Bergh's, and Stein's Fig. 1, Plate IX. Through the kindness of Professor Pavillard I have been able to examine some of his Mediterranean specimens, and find the plates to be identical in number and position with those from Plymouth, the first apical being rather larger and the longitudinal list slightly more conspicuous. Moreover, Professor Pavillard tells me he has found specimens similar to those at Plymouth at Roscoff, and regards them as the same species, though possibly a variety of the Mediterranean form.

I agree with Pavillard that this species is more like Bergh's than either of the other two. The most important reason given against it is the fact that it has not as yet been found again in the locality from which Bergh's originals came (Skaggerak), whereas *Diplopeltopsis minor* is common there, and *Peridiniopsis asymmetrica* also occurs (recorded by Cleve-Euler (1917) as *Diplopsalis lenticula* Bergh, f. typica). As, however, in this last year it has been found both from the Clyde and from the Northumberland coast, it seems not unlikely that it may still be found further north and in the Skaggerak, when all difficulties would disappear.

Ostenfeld's (1901 and 1908) species, *Diplopsalis caspica*, has the same plate formula as *Diplopsalis lenticula* as given above, and certainly belongs to the same genus. The fact brought out that the genus *Diplopsalis* has 6 precingulars brings it into touch more easily with other closely related and already known forms, and the affinities are more easily seen.

### Peridiniopsis (Diplopelta) asymmetrica Mangin.

Figs. 6–10.

*Diplopsalis lenticula* Stein (Plate VIII, Figs. 12, 13, 14 and Plate IX).

Figs. 2, 3 (?) and 4.
Schütt, 1895.
Paulsen, 1907, 1908, p. 35, Fig. 44.
Meunier, 1919, in part.

*Peridiniopsis asymmetrica* Mangin, 1911 (b.c.), 1913.

*Peridinium lenticula* Paulsen, 1912, in part.

*Diplopelta bomba* Jörgensen, 1913.
Pavillard, 1913, 1916.

*Preperidinium asymmetricum* Mangin, 1913.

*Peridinium asymmetricum* Ostenfeld, 1915.

This is the largest, the best known and most widely distributed of the 3 forms in question. Mangin (1911b) completely elucidated its structure, interpreting its plate formula as 4′1a 6″ 5‴ 2⁗, the small anterior intercalary being normal to the species. Cell rather more depressed than *Diplopsalis lenticula*, but similar in shape and nearly always larger. Left longitudinal list projecting but only reaching about half-way across the radius of the cell, edge smooth, not bent over the flagellar pore. Flagellar pore on the left near the hind end of the list. Right longitudinal list inconspicuous. Girdle not displaced, indented. Transverse lists not supported by spines. Cell contents pink. Large pusule apparatus. Theca distinctly punctuate. Sutures striated, except in the very young forms. Epitheca with 4 end-plates, only numbers 1, 2 and 4 reaching to the apical pore, number 3 meeting 2 and 4 behind the apex. A very small anterior intercalary on the left side between apicals 2 and 3. 6 precingulars. Hypotheca with 5 postcingulars and 2 antapicals. A small plate, called by Mangin a supplementary postequatorial, is probably, as Pavillard suggests (1913), part of the ventral area. Reproduction as in *Diplopsalis*. Usual diameter about 80 $\mu$. Small specimens have, however, been found in the Plymouth district measuring 50–66 $\mu$. One, 84 $\mu$ across, was the largest seen and contained 2 spores. Mangin mentions 89 $\mu$ as the extreme size.

Mangin (1911c) recorded a spherical form, which he designates as *V. spherica*, and he also found a dextral variety having the plates reversed, and a variety with 3 antapicals, both the last very rare.

All the Plymouth specimens conform to the type, and agree very well with those from other localities.

It is difficult to be sure of the distribution of this species, owing to the fact that in the early records we do not know with which species we are dealing. We have, however, the following fully established records: North Sea (Northumberland coast), Swedish and Norwegian Seas, Clyde,

Irish Sea, Atlantic Ocean, English Channel, Flemish coast, Brittany coast, Mediterranean, Baltic and Boeten Straits, Calebes. It is thus widely distributed. The Plymouth records show it present from May to November, abundant in the Sound round the Breakwater and also outside from Rame and the Mewstone to beyond the Eddystone. It occurs in much the same places as *Diplopsalis*, but more frequently outside, and altogether it seems to be more abundant. This may be, however, that it is caught more frequently in the very fine nets.

Most of Stein's figures refer to this species (Plate IX, Figs. 3 and 4; Plate VIII, Figs. 12–14; Plate IX, Fig. 2, with no small intercalary and only 5 precingulars is possibly erroneous), and all are designated *Diplopsalis lenticula*. Stein has in his MSS. notebook, as he tells us, called them *Diplopelta bomba*, but on identifying them with Bergh's species gave this up in favour of *Diplopsalis lenticula*. Schütt's (1895) figures also almost certainly belong to this species, although Fig. $50_5$ agrees with Stein's Fig. 2 in having only 4 end-plates and 5 precingulars. If this be correct it must apply to another species not since rediscovered. Paulsen's (1907 and 1908) description of the larger form almost certainly refers to this species, although he takes his figure of the epitheca from Stein's Fig. 2 and describes it with 5 precingulars. Later, however (1912), he identifies it with Mangin's *Peridiniopsis asymmetrica*, which has 6 precingulars and a small left anterior intercalary. Jörgensen (1913) gives it Stein's name of *Diplopelta bomba*, in which he is followed by Pavillard. Ostenfeld (1915) relegates it with all its relatives to the genus *Peridinium*. Meunier (1919), uniting it with Paulsen's *forma minor*, regards it once more as *Diplopsalis lenticula*.

It is probably this large species which is recorded in most of the International Plankton lists. Paulsen (1912), in his summary in which he gives 4 maps of the distribution of *Peridinium lenticula* (by which name he covers both *Peridiniopsis asymmetrica* and *Diplopeltopsis minor*) in the International area, says: "It is possible that this species must be divided into two, viz. *P. lenticula* and *P. minus*, the first named being oceanic and the second neritic. They may, however, be forms of the same species and in the following they will be treated as such. They have not been separated in the Bulletins, so it is impossible to say where one and where the other has been found, they must therefore be regarded as a unity, and only in a few cases suggestions can be made as to which of them we are dealing with." After discussing the records the suggestion is made that it is probably the form *minor* that is recorded from the English Channel. As a matter of fact, as is here shown, all three species occur, but probably *Peridiniopsis asymmetrica* is the commonest, at any rate in the tow-nets. Gran (1915) records this form and the next together as *Diplopsalis lenticula*, but definitely states that it is a collective name.

DIPLOPELTOPSIS MINOR (Paulsen) Pavillard.

Figs. 11–15.

*Diplopsalis lenticula forma minor* Paulsen, 1907, p. 9, Fig. 9; 1908, p. 36, Fig. 45.

*Diplopsalis lenticula* Meunier, 1910.

*Diplopsalis sphærica* Meunier, 1910.

*Peridinium lenticulatum* Mangin, 1911a.

*Peridinium Paulseni* Mangin, 1911b.

*Peridinium Meunierii* Pavillard, July, 1912.

*Peridinium lenticula*, neritic form (=*Peridinium minus*), Paulsen, Oct., 1912.

*Diplopsalis lenticula* Jörgensen, 1913.

*Diplopeltopsis minor* Pavillard, July, 1913.

*Peridinium lenticula* Ostenfeld, 1915.

*Diplopsalis lenticula* Meunier, 1919, in part.

This little species, first described by Paulsen (1907), from the Zuider Zee, Western Baltic, Kattegat and in great masses from a fjord in the Faröes as *forma minor* of *Diplopsalis lenticula* is regarded by the Scandinavian authorities as the true *Diplopsalis lenticula*, of Bergh. Certainly its dimensions and general shape approximate to that form, but the left longitudinal list is much narrower and less conspicuous than in the form described and figured by Bergh; also it is quite smooth at the edge, not denticulated, nor curved over the flagellar pore. Moreover, it does not reach nearly to the centre of the hypotheca. The most important reason for its being regarded as Bergh's original is that so far it is the species known to occur commonly in the region investigated by him (Skaggerak). As Pavillard has discovered a species much more like the original, and it is here shown that this species occurs in the English Channel, in the Clyde and in the North Sea (off the Northumberland coast), it is not impossible that it may still be found in the Skaggerak. It seems more likely to be Bergh's form than the present one, and certainly agrees with Stein's figure (Plate IX, Fig. 1), whereas *Diplopeltopsis minor* is not figured at all by him.

*Diplopeltopsis minor* has the cell of the same shape as *Diplopsalis lenticula*. Cell contour almost circular. Left longitudinal list narrow, not denticulate, reaching not so far as the centre of the hypotheca, usually of the same width for its whole length, not bent over the flagellar pore. Right longitudinal list inconspicuous. Girdle not displaced, slightly indented. Transverse list supported by very fine spines, sometimes hardly perceptible. Cell contents pink. Large pusule apparatus. Theca

very finely punctuate. Sutures striated in the older specimens. Epitheca with 4 end-plates meeting in the centre, the first very narrow, the third occupying more than half the apical area. A small anterior intercalary plate on the left side. Seven precingulars. Hypotheca with 5 postcingulars and 1 large antapical. Plate formula 4′1a 7″ 5‴ 1⁗ or 3′2a 7″ 5‴ 1⁗. Reproduction as in *Diplopsalis*.

Paulsen's original specimens measured 52 $\mu$ to 56 $\mu$ across, Mangin's 35 $\mu$ to 49 $\mu$. The Plymouth specimens ranged from 28 $\mu$ to 45 $\mu$ across, usually over 40 $\mu$.

As in the case of *Diplopelta* it is difficult to be sure of the distribution of this species, because we do not know with which species we are dealing in the earlier records. It is known to be more neritic than *Peridiniopsis asymmetrica*, although occasionally found right out at sea in the present records. On the other hand, it is the only one of the three found in an estuarine situation (up the River Tamar).

Records of its distribution which are certain are the following : Zuider Zee, Western Baltic, Skaggerak, Kattegat, Belt Sea, fjord in the Faröes, coast of Brittany, English Channel, Barents and Kara Sea. It is thus the most northerly species of the three forms, the Brittany coast being so far its most southerly record. It is found in the Plymouth district from February to November, but only very rarely between April and October. It seems to be chiefly an Autumn and early Spring form. It occurs most frequently near the shore, but also was found outside in the Rame-Eddystone region, and on one occasion at Station E 1, 14 miles from land. All records are from the surface.

| | *Feb.* | | *April.* | | | | | *May.* | | | | *June.* | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 16 | 28 | 1 | 12 | 14 | 19 | 26 | 2 | 13 | 20 | 27 | 2 | 6 | 13 | 17 | 23 | 27 | 29 |
| | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Diplopsalis lenticula | | | | | | | | × | | | × | × | | × | | × | × | × |
| Peridiniopsis asymmetrica | | | | | | | | × | × | × | | × | × | | × | × | × | × |
| Diplopeltopsis minor | × | × | × | × | × | × | × | | | | | | | | | | × | |

| | *July.* | | | | | | | | | *August.* | | | | | | *Oct.* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 3 | 4 | 7 | 11 | 12 | 15 | 21 | 26 | 2 | 4 | 8 | 9 | 15 | 19 | 22 | 10 | 11 |
| | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 |
| Diplopsalis lenticula | × | × | × | × | | × | | × | × | | × | | × | | | | | |
| Peridiniopsis asymmetrica | | | × | × | × | × | | | × | × | | × | | × | × | × | × | × |
| Diplopeltopsis minor | | | | × | | | × | | | | | | × | | | | | |

| | *October.* | | | | | *November.* | | | | | | *December.* | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 13 | 17 | 19 | 24 | 31 | 1 | 3 | 7 | 17 | 24 | 29 | 1 | 5 | 6 | 7 | 9 | 12 | 19 |
| | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Diplopsalis lenticula | | | | | | | | | | | | | | | | | | |
| Peridiniopsis asymmetrica | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × | × |
| Diplopeltopsis minor | | | | | × | | × | | | | | | × | | × | × | × | |

Table showing distribution of *Diplopsalis lenticula*, *Peridiniopsis asymmetrica* and *Diplopeltopsis minor* in 1921 (September excepted).
1=inner grounds from the shore to Rame all over the Sound.
0=outer grounds outside Rame.

In the table the records are divided into those from the Sound and up the Tamar, as far as Rame (marked 1 for " inside records " in the table) and those from outside the sound from Rame Head and on a level with it outwards (marked 0 for " outside records " in the table).

Mangin records a reversed form having the anterior intercalary on the right, and a symmetrical variety with 2 anterior intercalaries, 1 right and 1 left. The symmetrical form is also figured by Meunier (1913) as *Diplopsalis lenticula*, and a spherical form called by him *Diplopsalis spherica* and afterwards united with *D. lenticula*. He gives, however (1913), only 5 precingular plates, following Paulsen in his original description, but later (1919) he describes it as having 6, the seventh having probably been overlooked. Amongst the Plymouth specimens is a very flat variety, having the first apical extremely narrow, which is very like Meunier's figure, but with the asymmetrical intercalary. Also almost spherical forms were found. The longitudinal list is also variable, but never reaches the dimensions, nor has the form which is present in *Diplopsalis lenticula*.

We thus have the 3 species in the Plymouth district, each of which has been regarded as the original *Diplopsalis lenticula* of Bergh. Giving the preference to Pavillard's species one goes upon its evident resemblance in size and form, as Bergh described no plates ; but besides this resemblance its presence in the English Channel, and also in the Clyde and North Sea off the Northumberland coast, makes it much more probable that it may be found in Bergh's original locality. The fact that it had not before been found further North and West than the Mediterranean seemed to put it out of account in the International lists, and it was inferred that all records referred either to the large form *Peridiniopsis asymmetrica* or the *forma minor* of Paulsen, *Diplopeltopsis minor*, see Paulsen (1912). The latter being the species commonly found where Bergh obtained his specimens most of the Scandinavian authorities (Paulsen, Ostenfeld, Jörgensen) believe it to be the original. As we can only go by its colour, size and shape, it is impossible to be sure ; but the fact that the left longitudinal list is short and narrow and without denticulations at its edge, and also does not reach nearly so far as the centre of the hypotheca, makes it correspond with the original description less exactly than Pavillard's species. Mangin, who regards *Peridiniopsis asymmetrica* as the original of Bergh, is not supported by others except when it is regarded as one species with *Diplopeltopsis minor*. It agrees only in colour and shape with Bergh's species, and as it is very much larger and as the plates distinctly differ from both the smaller forms it does not seem likely that it is identical with either.

The fact brought forward by Pavillard (1913) that Stein figured two distinct species as *Diplopsalis lenticula* is evidently quite correct, and as Stein was the first to figure any plate structure, strictly speaking one of his forms must be kept as *Diplopsalis lenticula*. It seems only natural that we should take the smaller form which corresponds more with Bergh's species, and as this is seen to be similar to Pavillard's from the Mediterranean and also to the Plymouth specimens, it is right that we should regard this as *Diplopsalis lenticula* rather than the other very much larger form, or the smaller *Diplopeltopsis minor*, which was not figured by Stein at all.

Whilst investigating these species many small peridinians were found, which in their size, shape and colour resemble *Diplopsalis pillula* Ostenfeld (1908) and *Diplopsalis minima* Mangin (1911c), but on closer enquiry all were found to differ and a surprising variety of plate arrangement was found. On account of their small size it was not always possible to be certain of the plates, although they are all closely related to *Diplopsalis* and its near allies. One species, however, was carefully investigated and found to be unlike any other in the fact that there was a very large dorsal plate, anterior intercalary or third apical, which curved round to the front and touched apical 1, the latter instead of being diamond-shaped has on the left a third side, so that in shape (but not in its relation to precingular 2) it resembles the first apical in the section Metaperidinium (Jörgensen) of *Peridinium*. The plate formula is 4′0a 6″ (?) 5‴ 2⁗, or 3′1a 6″ (?) 5‴ 2⁗, the number of precingulars being apparently 6, but their complete elucidation was so difficult that on the left side there is a slight doubt as to their number. Bearing this in mind, it will be taken as 6, lacking further observations, and it would thus belong to the genus *Peridiniopsis*. I propose for it the name *Peridiniopsis rotunda*, and give herewith a short description of it :—

PERIDINIOPSIS ROTUNDA n. sp.

Figs. 16–20.

Cell almost spherical, sometimes slightly depressed, sometimes higher than broad. Left longitudinal list conspicuous but not reaching to the centre of the hypotheca, edge smooth. Girdle broad, not displaced, slightly indented. Transverse list supported by conspicuous spines set far apart. Cell contents pink. Large pusule apparatus. Sutures in older specimens broadly striated. Cell diameter 22 $\mu$ to 28 $\mu$. Epitheca with 3 apicals meeting at the centre, a fourth plate, third apical or anterior intercalary, having a dorsal position and coming round to the front on the left side, joins the first apical which has a third straight side

where it is in contact with this dorsal plate. 6 (?) precingulars. Hypotheca with 5 postcingulars and 2 antapicals. Plate formula 4′0a (or 3′1a) 6″ (?) 5‴ 2⁗.

Distribution in all parts of Plymouth Sound and occasionally outside in centrifuged water samples.

It is interesting that the outline of this species might easily represent Ostenfeld's *Diplopsalis pillula*. The shape and size are almost identical. It is therefore absolutely untrustworthy to go by the outline only. Van Breemen's specimen from the Aral Sea (1905) might just as well represent this species (see Paulsen, 1908, p. 37).

Other very small forms with outline exceedingly like *Diplopsalis pillula* and *D. minima* and the present species showed the plate structure of *Diplopsalis lenticula* and *Diplopeltopsis minor*, and were apparently young forms of these. At least three more of similar size and shape were found, but with different plate structure. They have not yet been fully worked out. Owing to the fact that *Diplopsalis pillula* and *D. minima* are exceedingly small and have not been recorded by other observers, it is difficult to be quite certain of their plate structure. It seems almost possible that they may be found to have 6 precingular plates instead of 5, as these can be so narrow dorsally that they are easily overlooked. It is noteworthy that they both have 2 antapicals. For want of further knowledge of their structure these two are left out of account in the following survey.

There is no doubt about the fact that in these species we have a very large variety in the number of plates, and it seems probable that amongst them we have forms comparable to those from whence sprang *Peridinium*. All the investigators seem to be agreed that they are closely related to *Peridinium* and form a series leading up to it. Are they to be regarded as primitive or degenerate forms ? It seems to be the prevailing opinion that they are more primitive than *Peridinium*. All are symmetrical cells, lenticular to spherical in shape, girdle not displaced, with the left longitudinal list more or less produced, pink in colour with a large pusule apparatus, and with fewer plates than *Peridinium*.

At the present time, besides *Diplopsalis*, *Peridiniopsis* and *Diplopeltopsis*, there are species known which are closely related to *Peridinium*, some with only 2 anterior intercalaries (*Peridinium monospinium*, *P. minutum*), which have been separated as *Archæperidinium* Jörgensen, and with only one anterior intercalary, separated as *Diplopsalopsis* Meunier, Pavillard emend (*P. orbiculare*). These are all recognised by Pavillard as genera in his very interesting survey of *Diplopsalis* and its related genera (1913), and Paulsen (1907–1908) had already arranged them in order although regarding them all as *Peridinium*. Jörgensen (1913), whilst separating them into genera, suggests that they

might just as well be regarded as sub-genera, stating that it entirely depends on the variability, if any, of the plates. Mangin (1911) regards the groups as based too much on variable plates, as he shows that the intercalaries may vary from 1 to 2 in *Diplopeltopsis minor* and the antapicals from 2 to 3 in *Peridiniopsis asymmetrica*. It is quite true that the intercalaries may vary from 1 to 2 in a species, for besides Mangin's and Meunier's examples the present writer has found a specimen of *Peridinium orbiculare* with a small right anterior intercalary in addition to the usual left one. The variation from 2 antapicals to 3 is, however, surely to be regarded as a sport rather than a true variety, as *Peridinium* always has 2, and in all the thousands of examples examined of *Peridinium* and its near relatives this is the first to be recorded with 3 antapicals.

The genera so far proposed have the following plate formulæ (as usually designated) :—

*Diplopsalis*, 4′0a (or 3′1a) 6″ 5‴ 1⁗.

*Peridiniopsis*, 4′0a 6″ 5‴ 2⁗.

*Diplopelta*, 4′1a 6″ 5‴ 2⁗.

*Diplopeltopsis*, 4′1a 7″ 5‴ 1⁗.

*Diplopsalopsis*, 4′1a 7″ 5‴ 2⁗.

*Archæperidinium*, 4′2a 7″ 5‴ 2⁗.

*Peridinium*, 4′3a 7″ 5‴ 2⁗.

I should suggest that starting with *Diplopsalis* (which has 4 plates in the epitheca besides the 6 intercalaries, 5 postcingulars and 1 antapical) we have a forward movement in three directions, one of which leads to *Peridinium* proper :—

*Firstly*, through *Peridiniopsis* to *Diplopelta* where the antapical first splits as in *Peridiniopsis*, then a small left intercalary appears as in *Diplopelta*. In this case the so-called third apical of *Diplopelta* is apparently homologous with the dorsal plate (intercalary or third apical) in *Diplopsalis*.

*Secondly*, through *Diplopeltopsis* to *Diplopsalopsis* where the precingulars increase to 7, a left intercalary appears as in *Diplopeltopsis*, and then the apical splits as in *Diplopsalopsis*.

*Thirdly*, through the so-called *Diplopsalis acuta* Entz fil and *Archæperidinium* to *Peridinium* proper, in which while there is still only one antapical a small apical appears anterior to the large dorsal plate. In this fresh-water species* Entz (1904) describes this dorsal plate splitting

* So far only this fresh-water species is known with this particular plate formula.

into 2 and so leading up to *Archæperidinium*, in which there is a small third apical and 2 anterior intercalaries, the antapicals now being 2, and finally *Peridinium* proper where there are 3 anterior intercalaries.

In this scheme I have purposely taken away *Diplopsalopsis* (type *D.*

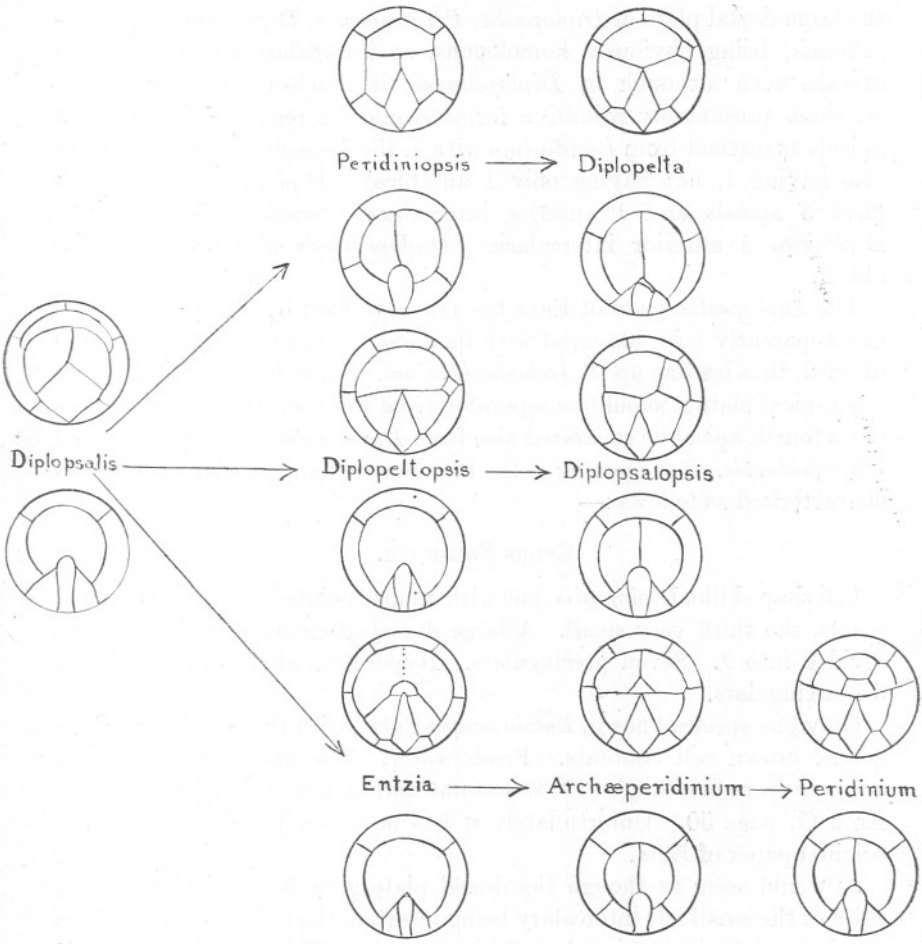



DIAGRAM ILLUSTRATING THE SUGGESTED RELATIONSHIP OF *DIPLOPSALIS* WITH THE ALLIED GENERA

*orbiculare*) from the direct line to *Peridinium*, because the dorsal plates appear to be homologous with the dorsals of *Diplopeltopsis*, *Peridiniopsis* and *Diplopelta*, and with the large anterior intercalary of the *Diplopsalis acuta* of Entz, and thus also homologous with the 2 anterior intercalaries of *Archæperidinium*. If this be so then the third apical in the *Diplopsalis acuta* of Entz and of *Archæperidinium* and of

*Peridinium* proper must be of later origin than the 2 intercalaries, and the so-called third apical of *Diplopsalopsis orbiculare* is not homologous with the third apical of *Peridinium*. For this reason it would be advisable to remove *Diplopsalopsis* from *Peridinium*, as it is apparently out of the direct line although closely related. Also, it would be advisable to regard the large dorsal plate of *Diplopsalis*, *Peridiniopsis*, *Diplopelta* and *Diplopeltopsis*, being obviously homologous, as intercalaries and not third apicals, even although in *Diplopeltopsis* it touches the apex. Thus all these presumably primitive forms would be regarded as having 3 apicals as distinct from *Peridinium* with 4, the *Diplopsalis acuta* of Entz also having 4, but having only 1 antapical. *Diplopsalis* would then have 3 apicals and 1 anterior intercalary, *Peridiniopsis* the same, *Diplopelta* 2 anterior intercalaries, *Diplopeltopsis* and *Diplopsalopsis* also 2.

The *Diplopsalis acuta* of Entz has not been seen by the writer, but it has apparently been observed with its dorsal plate (anterior intercalary) divided, thus leading up to *Archæperidinium*. Since, however, it has only 1 antapical plate it should be separated from *Peridinium*, and on account of its fourth apical be separated also from *Diplopsalis*, *Diplopeltopsis* and *Diplopsalopsis*. I suggest for it the new generic name of *Entzia*, which is characterised as follows :—

Genus *Entzia* n.g.

Cell shaped like *Diplopsalis*, but with a more pointed apex. Four apical plates, the third very small. A large dorsal intercalary, which may be divided into 2. Seven precingulars. Hypotheca with 1 antapical and 5 postcingulars.

Only one species known, *Entzia acuta* (Entz), with the characters of the genus, brown cell contents. Fresh water. The above description is adapted from Schilling's (1913) account and figures of *Diplopsalis acuta* Entz fil, page 50. Unfortunately it has not been possible to see the original paper of Entz.

It would seem as though the dorsal plate grew so unwieldy that, in spite of the small left intercalary being inserted, the only way to progress was by a plate developing dorsally at the apex. This once accomplished the line to *Peridinium* was well established.

The above is a suggestion only, but assuming this theory to be correct then *Diplopsalopsis* must be removed from *Peridinium* unless we make the genus, already overweighted, to include all these primitive forms. Even Mangin's *Preperidinium*, proposed for these last, does not meet the case, as it removes *Archæperidinium* from *Peridinium*, and places it amongst forms obviously not so closely related. I should suggest regarding the intercalaries as variable within the genus, the apicals, ant-

apicals and precingulars as constant generic features. In this way *Archæperidinium* would be a sub-genus of *Peridinium*, *Diplopelta* a sub-genus of *Peridiniopsis*, and *Diplopsalis*, *Diplopeltopsis*, *Diplopsalopsis* and *Entzia* would be separate genera, thus :—

Genus DIPLOPSALIS Bergh, plate formula 3′1a 6″ 5‴ 1⁗.

*Diplopsalis lenticula* Bergh.

*Diplopsalis caspica* Ostenfeld.

Genus PERIDINIOPSIS Lemmermann, plate formula 3′1–2a 6″ 5‴ 2⁗.

Sub-genus PERIDINIOPSIS, plate formula 3′1a 6″ 5‴ 2⁗.

*Peridiniopsis Borgei* Lemmermann.

*Peridiniopsis rotunda* n. sp.

Sub-genus DIPLOPELTA Jörgensen, plate formula 3′2a 6″ 5‴ 2⁗.

*Peridiniopsis* (*Diplopelta*) *asymmetrica* Mangin.

Genus DIPLOPELTOPSIS Pavillard, plate formula 3′2a 7″ 5‴ 1⁗.

*Diplopeltopsis minor* (Paulsen).

Genus DIPLOPSALOPSIS Meunier, plate formula 3′2a 7″ 5‴ 2⁗.

*Diplopsalopsis orbiculare* (Paulsen).

Genus ENTZIA n.g., plate formula 4′1–2a 7″ 5‴ 1⁗.

*Entzia acuta* (Entz fil).

Genus PERIDINIUM Ehrenberg, plate formula 4′2–3a 7″ 5‴ 2⁗.

Sub-genus PERIDINIUM, plate formula 4′3a 7″ 5‴ 2⁗.

*Peridinium depressum* Bailey, etc.

Sub-genus ARCHÆPERIDINIUM Jörgensen, plate formula 4′2a 7″ 5‴ 2⁗.

Peridinium (Archæperidinium) monospinum (Paulsen).

" " minutum Kofoid.

" " excentricum Paulsen.

" " thorianum Paulsen.

Several fresh-water species are here omitted, not being known to the writer.

I have added *Peridinium excentricum* to the sub-genus *Archæperidinium*; the plates have the same number, and owing to the greater growth of the second anterior intercalary the fourth precingular is pushed to the left side. It certainly belongs to the section Orthoperidinum as Jörgensen (1913) suggests, and Pavillard (1916) confirms. *Peridinium thorianum* also seems to belong to *Archæperidinium*.

This brings us to the fact, noted by Jörgensen, that all these forms here

discussed which lead to Peridinium belong to the section Orthoperidinium. If *Diplopsalis* is a primitive form then we can trace a definite progress to *Peridinum*, section Orthoperidinium. All the forms considered being of the Orthoperidinium type, therefore unless *Peridinium* had two separate origins Orthoperidinium must be more primitive than Metaperidinium. Barrows (1918), in his very interesting memoir on the significance of skeletal variation in the genus *Peridinium*, is of the opinion that Metaperidinium is the more primitive, his chief reason being that the precingulars 1 and 7 are probably of later origin than the others, as they are of smaller size, and in Metaperidinium they are smaller than in Orthoperidinium, owing to the left-hand extra face, and in Paraperidinium both are smaller, owing to the two extra faces, the first apical being a hexagon. Paraperidinium is thus in his opinion the most primitive, Orthoperidinium the most advanced. Now Barrows himself assumes that *Peridinium* arose from a form with fewer plates. We do not at present know of any form with a first apical shaped like Para- or Metaperidinium with only 5 precingulars from which a *Peridinium* could be derived, but we have *Diplopeltopsis* and *Entzia* with the precingulars 1, 2, 3, 5, 6, 7, shaped like the 6 in *Diplopsalis* and *Peridiniopsis*, with those touching the first apical quite as small as any in Metaperidinium. There seems little doubt here that the fourth apical has been formed between 3 and 5, the original 3 and 4. I should suggest, therefore, that it is more likely that the fourth precingular is the latest of the precingulars in *Peridinium* and not the first and seventh, and that Orthoperidinium is more primitive than Metaperidinium. The fact that in the several species which I have named *Peridiniopsis rotunda* we have a first apical of the same shape as in Metaperidinium is interesting, and suggests a further field for enquiry.

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## II. EXUVIELLA PERFORATA GRAN FROM THE ENGLISH CHANNEL.

With Figures 1–9.

In centrifuging samples of sea water from Plymouth Sound and some of the stations outside, some interesting forms of *Exuviella* were found. These are all minute, the largest measuring 22 $\mu$ in length, and consequently are easily overlooked, although one at least is abundant during the summer months. This species, which is the commonest *Exuviella* in the Plymouth district, has been identified as *Exuviella perforata* Gran, described by him from the North Sea (1915), and is a new record for the English Channel. As it appears to be very little known and its structure is unusual in several particulars, the following notes are not without interest.

In 1915 Gran (page 99, Fig. 7) describes and figures *Exuviella perforata*, a new species from the North Sea at a depth of 0–20 metres, occurring in the eastern part with a density of 100–760 specimens per litre. It is roundish oval or nearly circular in shape, measuring 22·5–25 $\mu$ long and 21–22·5 $\mu$ wide, with a broad girdle and thick shell (thickness of cell 14–17 $\mu$). The character, however, that gives it peculiar distinction is the depression in the centre of each valve, as Gran puts it, "with a sharply confined point-shaped perforated deepening in the centre." This separates it from any previously known species of *Exuviella*. The cell contents owing to contraction could not be described in detail, but in a footnote it is stated that living specimens from Arendal in March, 1914, had brown chromatophores. Cleve-Euler (1917) records an *Exuviella*, which he says may be *E. perforata* Gran, as occurring frequently in the Skaggerak, from 0 to 100 metres.

Schiller (1918) describes several new species of *Exuviella* from the Adriatic and Gulf of Naples. Of these *Exuviella bisimpressa* (page 258,

Fig. 11) appears to agree very well with Gran's description and figures. He shows, however, a distinct striation of the girdle, and did not see for certain any perforation in the central depression, although he thinks there appears to be a pore present. Special stress is laid on the twisted flagellar pore, the opening of which is described as being directed sideways. Schiller found three yellow-brown chromatophores in his species. Length 22–27 $\mu$, breadth 18–21 $\mu$. Found in the Adriatic from May to June from 0 to 20 metres, maximum of 180 in a haul at 20 metres; and in August and September from 10 to 150 metres, maximum of 170 at 150 metres. This was the only *Exuviella* found below 100 metres.

There seems no reason to separate the two species, therefore Gran's name must be kept: *Exuviella perforata* Gran=*Exuviella bisimpressa* Schiller.

In the Summer of 1921 a small *Exuviella* agreeing well with Gran's species was found commonly in centrifuged water samples and very fine tow-nets from Plymouth Sound and the surrounding waters. Although casually noticed in former years it was not properly investigated and usually apparently overlooked. The dimpling-in of the centre of each valve characterises the species and when cleared each valve is seen to have this cone-shaped indentation, which occurs exactly in the same position as the pyrenoid described from other species of *Exuviella* (Klebs 1912, Pouchet 1883), where there is no such indentation in the valve. No pyrenoid, however, was observed in the present species. The indentation appears in surface view as a small dark spot in the centre of the valve. No perforation was actually seen, although it is possible that one may be present.

The valves come close together in the centre of the girdle zone as figured by Schiller. This zone may or may not be striated. In the smaller forms, ca 19 $\mu \times 16$ $\mu$, it usually appears to be smooth; in the larger, presumably older forms, ca 22 $\mu \times 19$ $\mu$, it is distinctly striated. The margin of each valve is ornamented with one row of poroids, occurring inside the striations when these are present. This ornamentation is not mentioned by Schiller, but is indicated by faint dots in Gran's lower left-hand figure. It seems to be characteristic of the species, but once a small form occurred, 16 $\mu \times 14$ $\mu$ (Plymouth Sound, 2.6.21), which was destitute of these markings and was further abnormal in that one valve had its cone-like structure facing outwards instead of inwards, and anteriorly there were two distinct but very minute spine-like projections in the flagellar region of the same valve (Figs. 5 and 6). This abnormal form is here regarded as belonging to *Exuviella perforata*, although further investigation into more specimens may show it to be a different species.

An interesting feature in *Exuviella perforata* is the structure of each

valve in the region of the exit of the flagella. In all my specimens one valve was excavated at the anterior end as though a bite had been taken out of it; the other, which bore vestiges of very minute spines, was provided with a projection fitting into the excavation in its companion valve. This projection was perforated by 2 pores, presumably for the exit of the 2 flagella (Figs. 3 and 4). Such a structure has not, so far as I know, been described in any *Exuviella*, and no mention of it is made by Gran and Schiller.

The living specimens showed two somewhat irregular bright yellow-brown or almost completely yellow chromatophores, each one pressed against the inner surface of the valve face, leaving a space in the central part of the cell surrounded by the girdle area. Three chromatophores, such as Schiller describes, were never observed (Figs. 1 and 2).

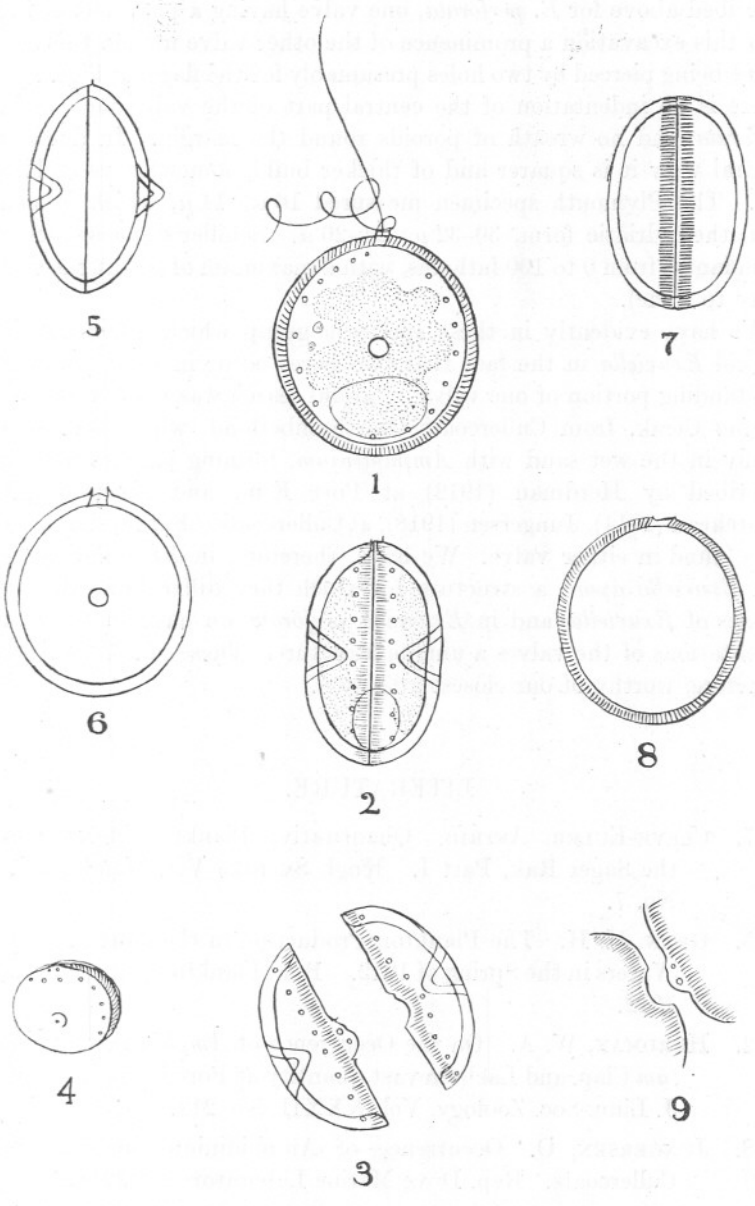
The longitudinal flagellum was held straight out in front, and the transverse flagellum moved rapidly horizontally. The healthy cell moved spirally forward with an occasional backward jerk. The nucleus which stained as a typical peridinian nucleus was situated at the hind end of the cell. The theca stained a faint blue-violet with chlorzinc-iodine.

Only once were more than two chromatophores seen, and in that case division was apparently taking place. The cell, 19 $\mu$ long, contained two very much smaller valves and four chromatophores. Further observations on this dividing form are unfortunately lacking.

This little *Exuviella* is widely distributed, and occurs abundantly from June to October, and sparingly in the winter. From close inshore in the region of the Breakwater it extends to beyond the Sound, round by the Mewstone and Eddystone, and was also found at Stations E 1 (14 miles from the Breakwater), E 2 (half-way between Plymouth and Ushant) and E 7 (ca 22 miles south of the Lizard). It is, therefore, well distributed on the west side of the Channel. Most of the samples examined were from the surface, but in some of the water-bottle samples it occurred at 5, 10 and 20 fathoms. It was found inside some of the planktonic animals examined for food, such as copepods, larval decapods and tintinnids.

Assuming that we are correct in regarding the Plymouth species as identical with *Exuviella perforata* of Gran and *Exuviella bisimpressa* of Schiller, we now have its distribution known still further, ranging from the Adriatic and English Channel to the North Sea and the Skaggerak, and further investigation will probably find it in other localities.

Once only from below the Laboratory, 16.6.21 (surface), another species of *Exuviella* occurred. This is probably the *Exuviella apora* of Schiller (1918, p. 258, Fig. 12). It differs from it, however, in having the margins striated. The valves anteriorly have exactly the same structure as is




FIGURES 1–9.

1. Exuviella perforata, valve view
2. ,, ,, ventral view.
3. ,, ,, anterior end of disarticulated valves.
4. Exuviella perforata, side view showing anterior end.
5. Exuviella perforata, abnormal form.
6. ,, ,, ,, ,,
7. Exuviella apora, ventral view.
8. ,, ,, valve view.
9. ,, ,, anterior ends of valves.

described above for *E. perforata*, one valve having a piece out of it and into this excavation a prominence of the other valve fitting, this prominence being pierced by two holes presumably for the flagella (Figs. 7 to 9). There is no indentation of the central part of the valve face, as in *E. perforata*, and no wreath of poroids round the margin. In dorsal and ventral view it is squarer and of thicker build, somewhat resembling a nut. The Plymouth specimen measured 16 $\mu \times 14\ \mu$, which is smaller than the Adriatic form, 30–32 $\mu \times 21$–26 $\mu$. Schiller's species occurred abundantly from 0 to 100 fathoms, with a maximum of 860 at the surface (May to June).

We have evidently in these species a group which differs from the typical *Exuviella* in the fact that two pores occur in front piercing an outstanding portion of one valve. Careful search was made in *Exuviella marina* Cienk. from Cullercoats, Northumberland, which occurs commonly in the wet sand with *Amphidinium*, forming patches with it as described by Herdman (1912) at Port Erin, and Storrow (1913), Whitehead (1914), Jungersen (1918), at Cullercoats ; but no similar pores were found in either valve. We have, therefore, in *Exuviella perforata* and *Exuviella apora* a structure by which they differ from all typical species of *Exuviella*, and in *Exuviella perforata* we have in the central indentations of the valves a unique structure. These small species are, therefore, worthy of our closest attention.

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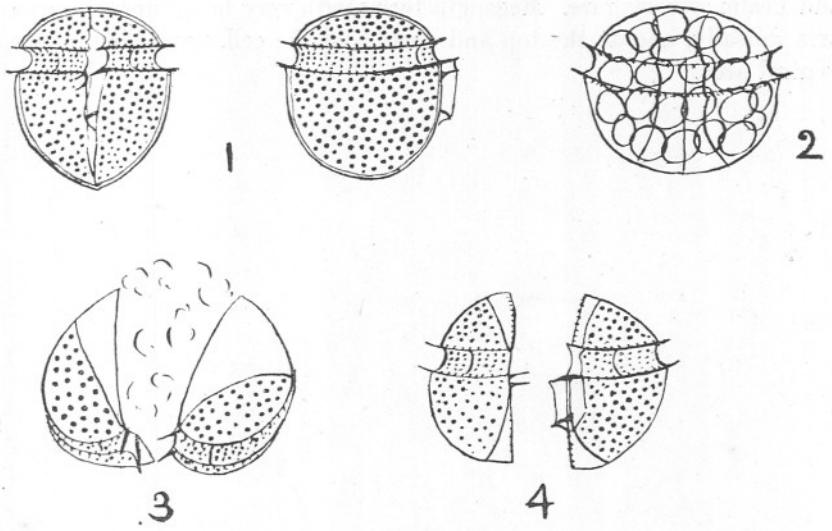
## III. A NEW SPECIES OF PHALACROMA.

With Figs. 1–4.

In centrifuged water and in very fine tow-nets there sometimes occurred an extremely small species of *Phalacroma*, which appears to be new. Six specimens in all were found in May, July and August, 1920 and 1921, from Plymouth Sound, in the region of the Breakwater, Cawsand Bay,




FIGURES 1–4. *Phalacroma pulchella* n.sp.

1. Normal individual, ventral and side views.
2. Megacytic form, showing refractive contents of cell.
3. Megacytic form with contents bursting out after treatment with eau de Javelle—seen from above.
4. Separated valves of megacytic form, ventral view.

1 from v. fine tow-net, Cawsand Bay, 5.8.20; 2–4 from Eddystone, W. ½ mile, 9.8.21.

Knap Buoy, Eddystone Grounds and once from the Yealm estuary. It is smaller than any known species of Phalacroma, is perfectly colourless, and measures from 21 $\mu$ to 33 $\mu$ in length. The cell is full of large refractive bodies (Fig. 2), similar to those often seen in *Dinophysis rotundata*. When not about to divide (Fig. 1) it is slightly flattened from side to

side, but it is more usual to see megacytic forms getting ready for division when there is a large median area added, so that the cell is broader than long. This median part is without sculpture and is thrown off after division. I propose for this little species the name *Phalacroma pulchella*, of which the following is a diagnosis :—

*Phalacroma pulchella* n.sp.

Cell not much compressed, almost circular in side view, with conspicuous epitheca and broad girdle. Left longitudinal membrane reaching about half-way down the hypotheca. Theca covered with small poroids, which are continued on to the girdle. Transverse lists supported by fine spines. Longitudinal groove extending for a short way along the epitheca. Cell contents colourless, usually with large refractive bodies. Length 0·021–0·033 mm. Habitat Plymouth Sound, Eddystone Grounds and Yealm estuary, rare. Megacytic forms with very broad unsculptured area dorsally, and at the top and bottom of the cell, narrowing at the ventral area.