Plate Patterns of Protoperidinium spp. in Korean Coastal Waters

Hawn-Goo Yeo[1] and Eun-Young Shin[2]

[1]*Dept. of Environmental Engineering, Hanseo University, Seosan, 356-706, Korea*
[2]*Microalgal Taxonomy Institute of Korea, Seoul, 135-090, Korea*
[1]*yeohg@hanseo.ac.kr*

Abstract

Protoperidinium spp. are heterotrophic dinoflagellates in the world ocean. Although most Protoperidinium species are known to feed on diatoms and bacteria, several species feed on red tide dinoflagellate. The samples were collected from 17 locations in the neritic areas of Korea from 1990 to 2010. In the thecate dinoflagellates, the thecal plate pattern has been considered to be important criteria in their classifications. Thecate dinoflagellates with distinct epitheca and hypotheca separated by a girdle which is usually equatorial and may or may not be displaced with or without overhang. Due to this fact the shape of the theca and the arrangement of the theca were studied. The shape of first apical plate is considered an important factor. To identify the genus Protoperidinium, the shape of the first apical plate and the second anterior intercalary plate were used. Depending the shape of first apical plate, will be designated as meta(4), meta(5), para(4), para(5) or para(6). From this point of view, the genus Protoperidinium as a group of planktonic protist in the coastal area was classified.

Keywords: *Protoperidinium, thecate dinoflagellate, apical plate*

1. Introduction

Free-living marine dinoflagellates are a very old and successful haplontic group of eukaryotic microorganisms adopted to a variety of pelagic and benthic habitats from artic to tropical seas and estuaries as well as fresh to hypersaline waters. Traditionally, one of the bases of classification has been a split the division into naked (unarmoured) and thecate(armoured). The majority of other thecate dinoflagellates have a relatively small number of plates(<30), which may be quite thick and frequently are elaborately patterned. For the genera in this armored category, the taxonomic separation was based on a combination of the shape of the cell and the number and arrange-ment of the two main large thecal plates.

Species in the genus *Protoperidinium* are ubiquitous heterotrophic dinoflagellates in the world ocean, from the tropics to ice edges [1-4]. Paulsen divided the genus *Peridinium* into the subgenus groups, *Protoperidinium* and *Euperidinium* [5]. That was important in that it divided the right-handed forms from the left-handed forms, but it was not accepted as a satisfactory classification. Afterwards more satisfactory classification was brought forward by Joergensen, who divided *Peridinium* in two ways [6]. The first, according to the arrangement and form of the first apical plate; and second, according to the arrangement of dorsal epithecal plate. Afterwards the genus *Peridinium* was classified, which was important for the classification.

Saylo *et al.*, [7] discussed punctuated equilibrium and phyletic gradualism at the point of organic evolution. In recent years, biometric identification and bioinformatic studies were reported all part of the world [8-10]. Genotypic analysis of fresh water *Peridinium* speceis

was performed by Ki *et al.*, and morphological researches were done unchanged [11-12]. Molecular biological studies of *Peridinium* have done by some researchers [13-15]. Although recently more scientists observe that the arrangement of these plates are not always constant, still one arrangement is almost always typical for every species.

2. Materials and Methods

Dinoflagellates samples were collected from 17 locations near coastal areas of Korea from 1990 to 2010. Net samples were vertically and horizontally obtained using plankton net, and fixed with 4% formalin or Lugol's solution [16-18]. Some materials were collected from Lugol's solution preserved seawater samples by sedimentation method. The sampling locations are indicated in Figure 1.

This monograph is the result of the microscopic analyses. Identification of dinoflagellates in water samples was usually done by using differential interference contrast (DIC), which revealed especially well the lighted thecal structures. The microscope was a Zeiss Axioskop microscope with a Mc 80 microphotosystem. For the apparent three-dimensional image, a scanning electron microscope(JEOL JSM-840A) was used.

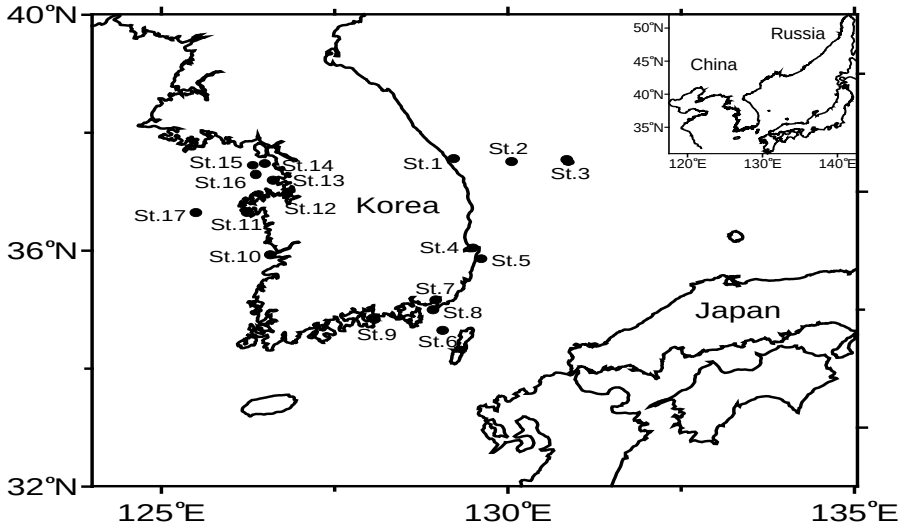


Figure. 1. A map showing the sampling locations in the coastal waters of Korea St.1 Donghae-Shi, St.2 East Sea, St.3 Ulrung-Do, St.4 Pohang, St.5 Wolsung, St.6 Korea-Strait, St.7 Masan, St.8 Jinhae, St.9 Samchunpo, St.10 Mankyung, St.11 Taean, St.12 Ahsan, St.13 Shihwa, St.14 Incheon, St.15 Youngjong-Do, St.16 Youngheung-Do, St.17 Yellow Sea

3. Morphology of Dinoflagellates

Dinoflagellates are mainly unicellular organism, the majority being flagellates or having a motile phase in their life cycle. It possesses two dissimilar flagella, typically the transverse flagellum moves in a plane at right angles to the longitudinal axis, while the longitudinal flagellum points backwards. Both flagella bear the lateral hairs, the transverse flagellum bears one row of hairs, the longitudinal flagellum two. Dinokont is where both flagella arise on the ventral side of the cell (Figure 2). The majority of cells are included in this group. The other group is desmokont which two dissimilar flagella emerge from the anterior part of the cell.

This group is Prorocentrales order. In dinokont cell as in Figure 2, the girdle may be completely equatorial with its ends meeting ventrally, or it may be displaced so that one end lies below the other.

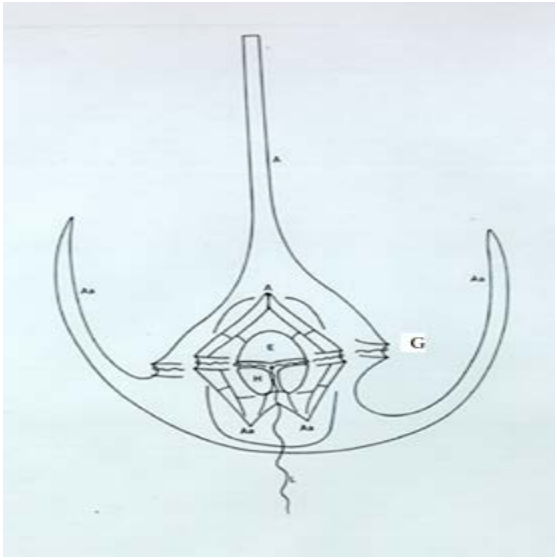


Figure 2. Diagram of dinoflagellate E:epitheca or epicone, H:hypotheca or hypocone, A:apical horn, Aa:antapical horns, L:longitudinal flagellum G:girdle(Redrawn from Drebes[19]**)**

The thecate forms may have a covering composed of three parts: epitheca(E), girdle plate covering the girdle and hypotheca(H). In armored types theca may be divided up into many plates, these of the epi- and hypotheca are arranged in variety of patterns. Although Kofoidean system has been criticized for its artificiality, it has achieved wide acceptance, due to its simplicity and usefulness. For this reason plate designations will follow the Kofoidean system.

Thecate dinoflagellates composed of epitheca, girdle and hypotheca are, divided up into plates. Apical pore are usually present. Kofoid uses the girdle as a basis and numbers the plates with reference to it in transverse series running from the left dorsally to the right.

The plates round the apex are called the apicals and designated by one acute accent mark': those round the girdle and anterior to it are called the precingulars and designated by two marks": whilst in between the apicals and precingulars there may be one or more plates which never form a complete ring and are known as the anterior and intercalaries.

The girdle itself divided several plates, it designated by c as cingular plate. The plates of the hypotheca are also in series and are indicated in the same way: those below the girdle, called the postcingulars, are designated by three mark"'; those at the antapex, the antapicals, are designated by four marks"". There may be posterior intercalaries between antapicals and postcingulars, desingnated by p. Thus the plate formula for a typical species of *Peridinium* would be 4' 3a 7" 5"' 2""(Figure 3). In addition, there are small plates in the sulcal region, forming what is known as the ventral area.

At the ultrastructural level, dinoflagellates have a common thecal or cell covering structure that, along with their flagellar and nuclear characters, differentiates them from the other algal

groups. The theca can be smooth and relatively unornamented, as in some *Gymnodinium*, or it can constitute a cell wall of polysaccharide plates with spines and flanges.

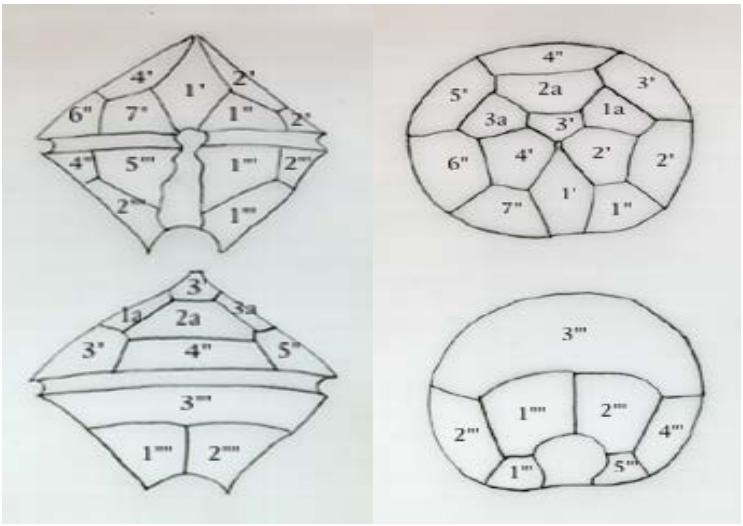


Figure 3. Diagram of Numbering of Plates of *Protoperidinium* (Redrawn from Lebour [20])

4. Family Protoperidiaceae F. J. R. Taylor [21]

Body is typically globular, lenticular, pyriform, rarely peculiarly flattened, and generally provided with two antapical spines or horns. Two or three circular rows of plates are compressed in the epitheca. Hypotheca consists of a circular row of postcingular plates which are rarely single but typically two, bilaterally arranged. Thecates with polygonal cellulose plates: (apicals, precinulars, cingulars, postcigulars, antapicals), alternatively the cell sheds old theca(ecdysis), cell division occurring in a naked or encysted state.

Key to genera

1a. No apical pore is formed with two antapical plates----------4
1b. An apical pore is typically formed with two antapical plates----------2

2a With 2-3 anterior intercalaries, morphology varied, four apical plates---
----------*Protoperidinium*
2b. With 1-2 anterior intercalarie, 1st apical plate usually rhomboidal, three apical plates----------3

3. 1a plate smaller than 2a----------*Diplopsalopsis*
4. Three apical plates are exceedingly small in size, lying in the ventro-median region----------*Gotious*

4.1. Genus *Protoperidinium*

Small to large cell of varied shape. Thecate dinoflagellates with distinct epitheca and hypotheca separated by a girdle which is usually equatorial and may or may not be displaced, with or without overhang.

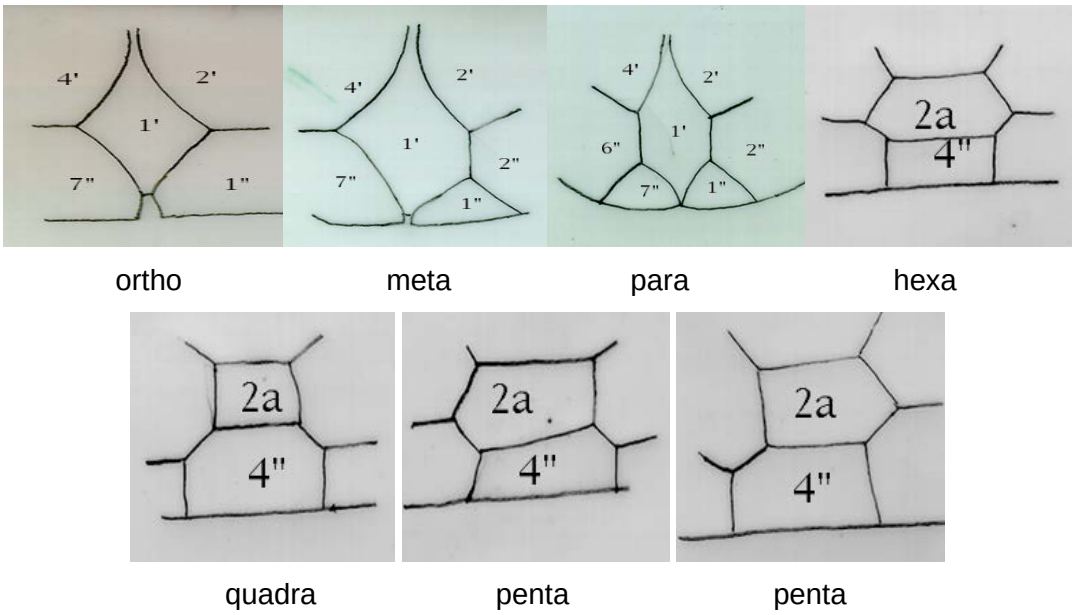
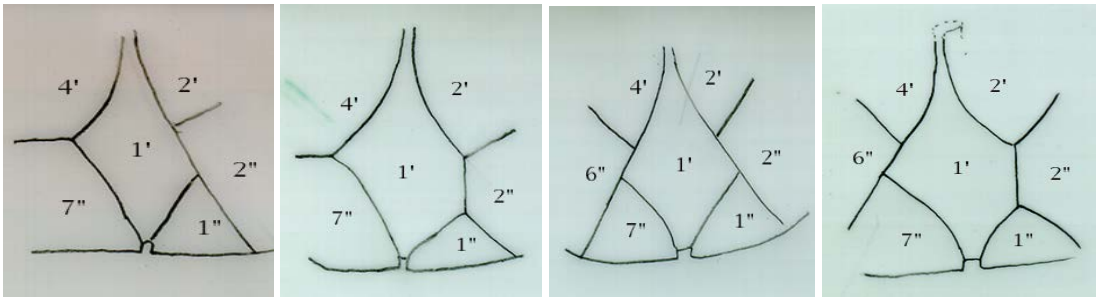


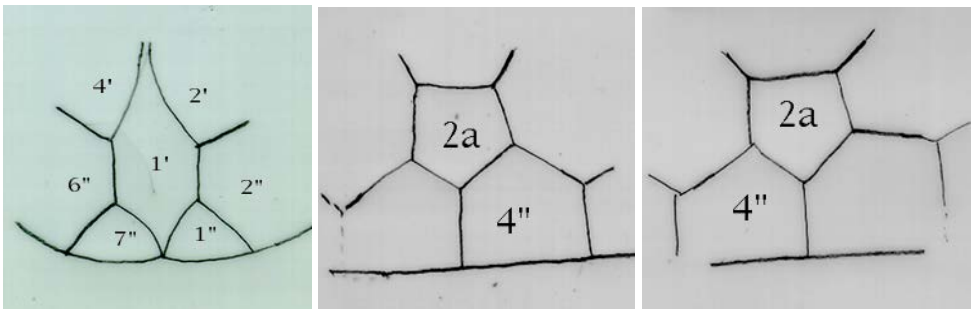
Figure 4. Diagram Showing Arrangement of the First Apical Plate and Second Anterior Intercalary Plate

Chromatophores and chloroplasts are usually absent. Only two anterior intercalary plates belong to subgenus *Archeoperidinium*. Paulsen divided the genus *Peridinium* into the subgenus group, as *Protoperidinium* and *Euperidinium*, it divided the right-handed forms from the left-handed forms[5]. Afterwards brought by Joergensen [6], who divided *Peridinium* in the first place according to the arrangement and form of the first apical plate, and secondly according to the arrangement of dorsal epithecal plate(Figure 4).

4.1.1. Meta(4), hexa(4), hexa(5) and Unipes Group

The shape of the first apical plate is meta but actually the shape of the first apical plate is 4 sided, even though they meet 5 plates(2', 1". 2", 7", 4') so I would like to designate the plate pattern of this species as meta(4) meaning it has a 4 sided first apical plate with meta: meaning they meet 5 plates. In the same way it is possible to designate the para group of *Protoperidinium*. Species have the hexa as a first apical plate, but they have only four sided plates, so it could designate the plate as hexa(4). Hexa means the first apical plate meets 6 plates, (4) shows four sided the first apical plate shape (Figure 5).





para(6) unipes unipes

Figure 5. Diagram Showing Arrangement of the First Apical Plate and the Shape of First Apical Plate and Second Anterior Intercalary Plate of Unipes Group

When observed the second anterior intercalary plate, the species including hexa and quadra, they are easy to identify, because they shows clear plate pattern. For the penta group, it has two kinds of the penta group. There is a regular penta group species, but most of the penta group is usually included in unipes group, unipes group's 2a shape is like an upsidedown pentagon. There is a regular shape of penta, but only a few. For example *Protoperidinium punctulatum* and *Protoperidinium claudicans.* This could distinguish each species in an easy way to observe the plate pattern. The typical plate formula is 4', 3a, 7", 3c, 5"', 2"".

Meta(4)--a lot of sp. included in meta(4)
Meta(5) (1)*Protoperidinium unipes* group.
(2) *Protoperidinium globulus* group.
Para(4)---a lot of species
Para(5)---only two species.
Para(6)---only one --two(?) species.

4.2. Key to Subgenus

1a. Only two anterior intercalary plates----------*Archeoperidinium*
1b. Three anterior intercalary plates----------*Protoperidinium*

4.3. Subgenus *Archeoperidinium*

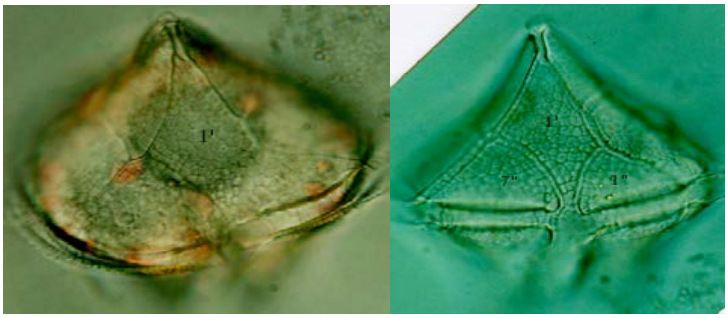
This genus include species only two anterior intercalary plates. From Korean coastal water, two species are included subgenus *Archeoperidinium*: *Protoperidinium minutum Protoperidinium valgus*

5. Plate Pattern of Genus *Protoperidinium*

5.1. The First Apical Plate and Meta Group

When the genus *Peridinium* and *Protoperidinium* were observed, it could be seen that each species had the same plate pattern. For example, when *Protoperidinium conicum* was preserved, the shape of the first apical plate and the secondary anterior intercalary plate were the same each time, even though they were of different varieties or forms of the same species

due to the shape of cell. For example, in the meta groups of the *Protoperidinium divergence* or *Protoperidinium crassipes*(Figure 6), the shape of the first apical plate is meta but the actual shape of the first apical plate is 4 sided, even though they meet 5 plates(2', 1". 2", 7", 4'). Thus, I would like to designate the plate pattern of this species as meta(4) meaning it has a 4 sided first apical plate with meta: meaning they meet 5 plates.



P.crassipes P. divergence

Figure 6. Photomicrographs of both Species showing Meta(4)

5.2. Plate Pattern of Para Group

In the same way it is possible to designate the group of paraperidinium. Another species is the *Protoperidinium pellucidum* var. *stellatum*(Figure 7). This species has the hexa as first apical plate, but they only have a four-sided plate, so it could designate the plate as hexa(4). Hexa means that the first apical plate meets 6 plates, (4) shows that the shape of the first apical plate is four sided.

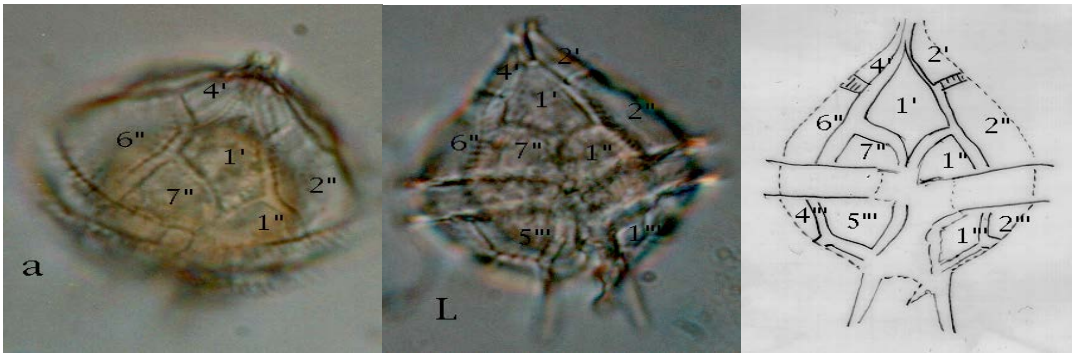


Figure 7. The Plate Pattern of *P. pellucidum* var. *stellatum*

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Authors

Hwan-Goo Yeo
August 1992: Seoul National University, Department of Oceanography, Ph.D
March 1996-current: Hanseo University, Department of Environmental Engineering, Professor

Eun-Young Shin
February 1999: Seoul National University, Department of Oceanography, Ph.D
March 1999-current: Microalgal Taxonomy Institute of Korea, Researcher