

**Redefinition of the dinoflagellate genus *Alexandrium* based on *Centrodinium*:
reinstatement of *Gessnerium* and *Protogonyaulax*, and *Episemicolon* gen. nov.
(Gonyaulacales, Dinophyceae)**

Supporting Information

**Appendix S1. Taxonomy, synonymy, plate arrangement and classification of
*Centrodinium***

1. Account of the laterally flattened species of *Murrayella* (Fig. S1)

Murray & Whitting (1899) described a slight laterally flattened biconical species under the name *Ceratium biconicum* G. Murray & Whitting from samples collected in the tropical North Atlantic. Cleve (1900) described ‘*Steiniella? punctata*’ from the mid North Atlantic waters, and commented on the affinity with *Ceratium biconicum*. The type species of *Steiniella* F. Schütt, currently known as *Gonyaulax fragilis* (F. Schütt) Kofoid (= *G. hyalina* Ostenfeld & Johs. Schmidt), is a globular species with smooth cell surface, while *Ceratium biconicum* or *Steiniella punctata* are laterally flattened species with a theca ornamented with poroids.

Kofoid (1907) proposed the genus *Murrayella* for four species: Two non-compressed species, *M. globosa* (type species) and *M. rotundata*; a biconical species, *M. spinosa* that resembles *Amphidoma*; and one laterally flattened species, *M. punctata*, for Cleve’s *Steiniella punctata*. Kofoid and Michener (1911) reclassified *M. spinosa* in the genus *Amphidoma*. The species *M. punctata* differed from the other congeneric species in the laterally compressed cell body, porulate theca, and the tabulation, with four apical and two antapical plates (Kofoid 1907).

Kofoid and Michener (1911) described *Centrodinium porulosa* without illustration as an elongated cell with a premedian cingulum and porulate theca. This suggests affinities with *Ceratium biconicum* or *Murrayella intermedia*. It is uncertain why Kofoid and Michener (1911) described this taxon as *Centrodinium*, while it resembles *Murrayella*. The publication of Kofoid and Michener (1911) is a succession of species diagnoses without illustrations. Some of the new described species (i.e., dinophysoids) were later illustrated in other Kofoid's monographs, but unfortunately illustrations of *Centrodinium porulosa* were never published. Based on the original description, we can consider that *C. porulosa* correspond to a laterally flattened species of *Murrayella*.

Kofoid (1907) commented that *Ceratium biconicum* belongs to *Murrayella*, but he did not propose the generic transfer. Later, Pavillard (1931) transferred *Ceratium biconicum* into *Murrayella*. Pavillard (1915) described without illustration *Murrayella intermedia* as intermediate between *M. punctata* and *Ceratium biconicum*. *Murrayella intermedia* was later illustrated in Pavillard (1916). Pavillard (1930) also described *Murrayella ovalis* that seems to be an aberrant or damaged cell of *Centrodinium*, close to *C. deflexum* or *C. intermedium*.

Dangeard (1927) described the genus *Goniodinium* with two species: *G. cristatum* and *G. spiniferum*. The species *G. cristatum* is non-compressed and small (48 µm long), while *G. spiniferum* is larger (100 µm) and slightly laterally compressed. *Goniodinium spiniferum* resembles *Murrayella punctata*. Loeblich and Loeblich (1966) designed *G. cristatum* as the type species of *Goniodinium*. Consequently, the type species of *Goniodinium* is not a laterally compressed species of *Murrayella*. This is relevant in case of the proposal of a genus name for the laterally compressed species of *Murrayella*.

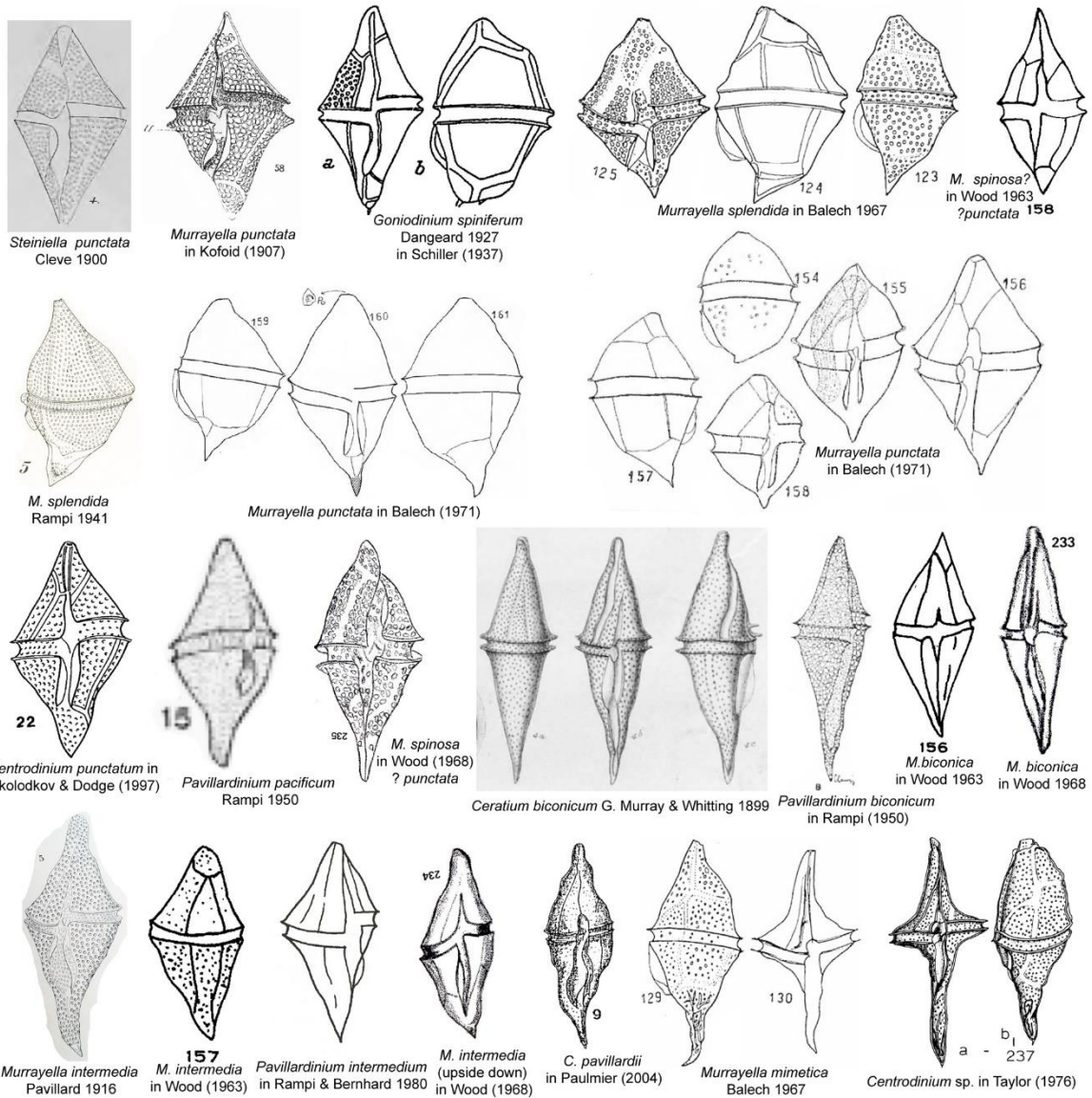


Fig. S1. Line drawings of laterally flattened species of *Murrayella* and *Goniodinium spiniferum* from the literature.

Schiller (1937) reproduced the descriptions and illustrations of the species of *Murrayella* known at the time: the type species *M. globosa*, and *M. biconica*, *M. rotundata*, *M. intermedia*, *M. ovalis*, *M. punctata* and *M. spinosa*. Schiller (1937) reported the species *Murrayella spinosa* as two independent taxa, one as a member of the genus *Murrayella* and other as *Amphidoma spinosa* [it was transferred in Kofoid and Michener (1911)]. The illustration of *Amphidoma spinosa* was correct, but the illustration of *M.*

spinosa was that of *M. punctata*, and vice versa (Schiller 1937). That confusion persisted in Wood (1963, 1968). De Toni (1936) noted that the genus name *Murrayella* Kofoid 1907 was a posterior homonym of red alga *Murrayella* Schmitz 1893, and he transferred the existing species of *Murrayella* into the new genus name *Pavillardinium* G. De Toni. At that time, the dinoflagellates were treated under the zoological and botanical codes of nomenclature, and the dinoflagellate name *Murrayella* continued in use with the description of several new species of *Murrayella* (Rampi 1941; Gaarder 1954; Wood 1963; Balech 1967).

From samples collected in the Pacific Ocean, Rampi (1941) described *M. splendida* as a laterally compressed species, and *Murrayella brianii* that resembles *Gonyaulax pacifica*. Balech (1971) reported a high variability in size for *M. punctata* that varied from 42-86 µm long, and 23-47 µm in dorso-ventral diameter, and considered *M. splendida* as a junior synonym of *M. punctata*. Rampi (1950) described *Pavillardinium pacificum* that resembles *Murrayella intermedia* or *M. punctata*. Gaarder (1954) proposed *Murrayella kofoidii* for *Amphidoma biconica*. Wood (1963) described *Murrayella australica* for a globular species, and Balech (1967) described *Murrayella mimetica*.

Sournia (1973) in his revision of the dinoflagellates listed: *Pavillardinium biconicum* (G. Murray & Whitting) Rampi [*P. biconicum* (Kofoid) Ballantine is a posterior homonym], *P. brianii* (Rampi) Sournia, *P. globosum* (Kofoid) G. De Toni, *P. intermedium* (Pavillard) G. De Toni, *P. kofoidii* (Gaarder) Sournia [= *Amphidoma biconica* Kofoid, non *Murrayella biconica* (G. Murray & Whitting) Pavillard], *P. mimeticum* (Balech) A.R. Loeblich, *P. ovale* (Pavillard) G. De Toni, *P. pacificum* Rampi, *P. punctatum* (Cleve) G. De Toni, *P. rotundatum* (Kofoid) G. De Toni, *P. spinosum* (Kofoid) F.J.R. Taylor ex Sournia, and *P. splendidum* (Rampi) Rampi.

Balech (1967) commented on the similarities between *Murrayella mimetica* and *Centrodinium*. Taylor (1976) illustrated *Centrodinium* sp. that resembles *M. mimetica*. Taylor (1976) classified the non-compressed species of *Murrayella/Pavillardinium* into the genus *Corythodinium* Loeblich & A.R. Loeblich, and the laterally flattened species into the genus *Centrodinium*. Taylor (1976) transferred the type species of *Murrayella*, *M. globosa*, into *Corythodinium*, and consequently he dismantled the genera *Murrayella* and *Pavillardinium*. Taylor (1976) transferred *M. biconica*, *M. mimetica*, *M. punctata* and *Pavillardinium pacificum* into *Centrodinium*, and also *M. intermedium* as *Centrodinium pavillardii* (because the name *C. intermedium* already existed). Taylor (1976) also accepted the synonymy of *Murrayella punctata* and *M. splendida* as reported in Balech (1971). Taylor did not transfer *Murrayella ovalis* into *Centrodinium* because he considered that the description was insufficient. Hernández-Becerril et al. (2010) transferred *Murrayella ovalis* into *Centrodinium*.

2. Species account of *Centrodinium* Kofoid (Fig. S2)

Cleve (1903) described *Steiniella complanata* as a cell of 270 μm long with round apices from samples collected in the Atlantic Ocean and the Mediterranean Sea. It should be noted that the typical shape of *Centrodinium* shows a truncate apex, and an acuter antapex with terminal spinules. Cleve illustrated the hypotheca as an elongated cone, while *Centrodinium* shows a conical or hemispherical hypotheca with a tubular antapical horn. Despite these imprecisions in the original line drawings, Cleve was unequivocally reporting a species of *Centrodinium*. Cleve (1903) described the new species as ‘*Steiniella? complanata*’, because he probably doubted on the placement of his new species in the genus *Steiniella*. The genus *Steiniella* F. Schütt was proposed in 1895 for *Steiniella fragilis* F. Schütt and *S. mitra* F. Schütt, and later *S. inflata* Kofoid and *S.*

cornuta Karsten (Kofoid 1907; Karsten 1907). These species of *Steiniella* are currently placed in the genera *Gonyaulax* Diesing and *Schuettiella* Balech (Balech 1988).

Kofoid (1907) erected the genus *Centrodinium* for the three species: the type *C. elongatum*, and *C. deflexum*, and he also transferred *Steiniella complanata* into *Centrodinium* without illustration. Pavillard (1931) and Rampi and Bernhard (1980) illustrated *C. complanatum* with a higher dorso-ventral diameter than in Cleve's original illustration. Like this, *C. complanatum* resembles a robust cell of *C. eminens*, being possible that Cleve's *Steiniella complanata* could be an earlier description of *C. eminens* and *C. pulchrum*.

Pavillard (1930) described *C. intermedium* with a short apical horn, and a lower ratio length/depth ratio (more dorso-ventral diameter) than other species of *Centrodinium*. The hypotheca showed a semi-circular contour while it is conical in other congeneric species. Further authors such as Balech (1962) and Rampi and Bernhard (1980) illustrated *C. intermedium* with a hemispheric hypotheca. Böhm (1933) reported *C. intermedium* with an almost more triangular contour of the hypotheca that resembles *C. complanatum* sensu Pavillard 1931. Kofoid and Michener (1911) also described without illustration *C. expansum* that could be an earlier description of *C. intermedium*.

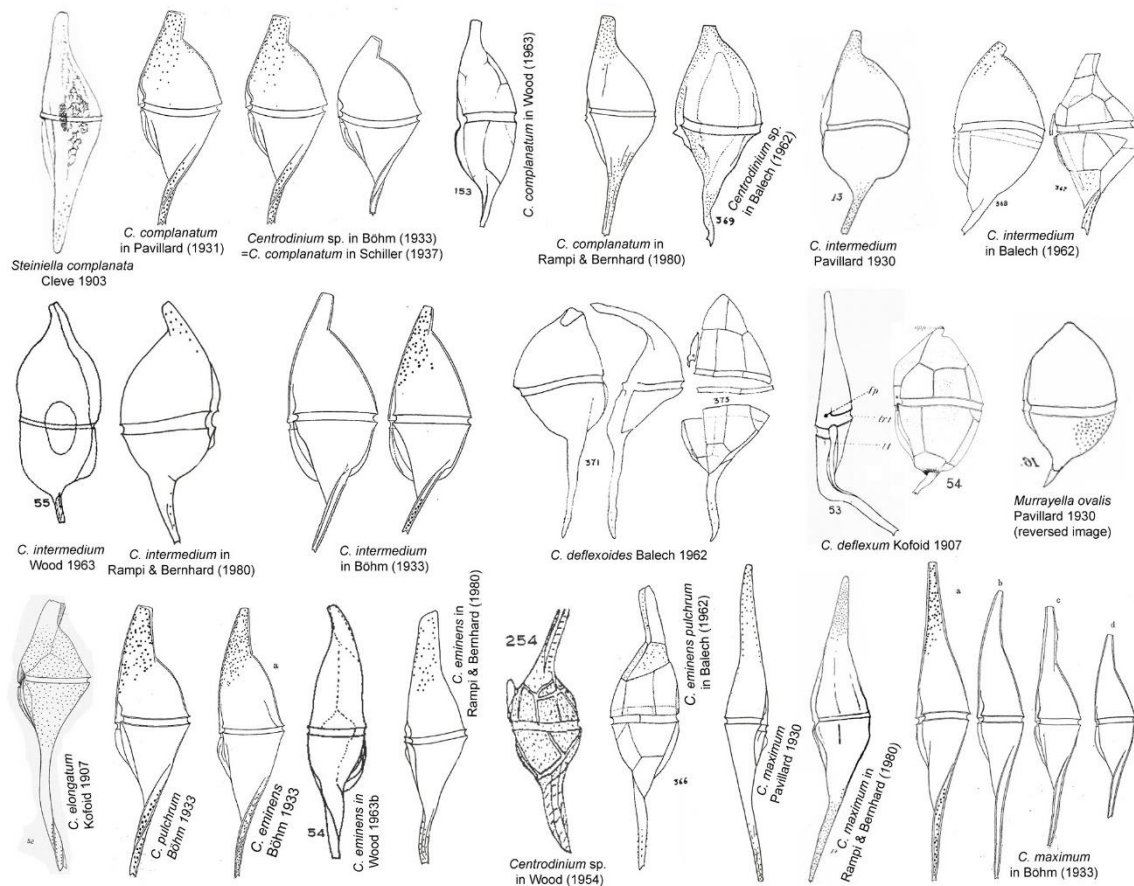


Figure S2. Line drawings of *Centrodinium* spp. from the literature.

Kofoid (1907) described *C. deflexum* with two illustrations. His illustration 53 showed the ventral view of a cell with long antapical and apical horns, while the cell in the figure 54 is apparently devoid of the apical horn and the hypotheca is hemispherical (unless Kofoid aimed to illustrate the apical horn directed towards the dorsal side). Anyway, Kofoid's figures 53 and 54 do not seem to be different views of the same species. Kofoid's figure 54 (left face) is close to *C. intermedium* because the hypotheca is hemispherical. The apical horn of *C. intermedium* is in the same plane that the cell body. In some views of *C. intermedium*, the antapical horn may appear very short because it is directed towards the ventral side, and in a different axis of the main cell body. It is unclear based on the shape of the epitheca of Kofoid's figure 53 (ventral view) if *C. intermedium* is a junior synonym of *C. deflexum*. *Murrayella ovalis* Pavillard 1930

resembles Kofoid's figure 54 (left face) of *C. deflexum*, but it lacks the apical horn and it has an antapical spine more than an antapical horn. In any case, the description of *Murrayella ovalis* is insufficiently detailed.

Kofoid (1907) described *C. elongatum* as a cell with a very short apical horn and a long antapical horn. The illustration of *C. elongatum* resembles *C. complanatum* sensu Pavillard (1931), but with a longer antapical horn. The antapical horn of *C. elongatum* is directed towards the dorsal side, while in the other species of *Centrodinium* are oriented towards the ventral side. *Centrodinium* divided by desmoschisis, with an oblique fission suture, and one of the daughter cells must regenerate a half of the theca. Consequently, one of the daughter cell has the full antapical horn from the parent cell, but an incomplete apex without an apical horn. *Centrodinium elongatum* has not been reported in the literature since the original description. Kofoid (1907) probably described *C. elongatum* based on a recently divided cell with an incomplete epitheca. *Centrodinium maximum* Pavillard 1930 is a large species with an elongated cell body, and relatively acute apices. Böhm (1933) illustrated the morphological variability of *C. maximum*, but the smaller forms seems to correspond to *C. complanatum* or *C. eminens*. *Centrodinium elongatum* could be one of the daughter cells of *C. maximum* or *C. eminens* with an incomplete epitheca and a short apical horn.

Böhm (1933) described *C. eminens* and *C. pulchrum* that mainly differed in the size. In contrast, Böhm (1933) admitted a high size variability in *C. maximum*. Schiller (1937) placed *C. pulchrum* as a form of *C. eminens*, which was followed by further authors (i.e., Balech 1962). The illustration of *C. complanatum* in Rampi and Bernhard (1980) did not significantly differ from *C. eminens*. It is uncertain whether *C. complanatum* is an earlier description of *C. eminens*. Unfortunately, Cleve's line drawings of *Steiniella complanata* was not enough detailed, and the round apices do not

correspond to the typical morphology observed in *Centrodinium*. Okolodkov and Gárate-Lizárraga (2006) considered *C. pulchrum* as a synonym of *C. complanatum*.

At the website of Algaebase <http://www.algaebase.org/>, we can find the next species names of *Centrodinium*: *Centrodinium elegans* (Pavillard) F.J.R. Taylor, *C. frenguelli* (Rampi) F.J.R. Taylor, *C. globosum* (Kofoid) F.J.R. Taylor, *C. latum* (Gaarder) F.J.R. Taylor, *C. michaelsarsii* (Gaarder) F.J.R. Taylor, *C. reticulatum* (Stein) Loeblich & A.R. Loeblich, and *C. tessellatum* (Stein) Loeblich & A.R. Loeblich. Taylor or Loeblich and Loeblich never transferred these species of *Corythodinium* into the genus *Centrodinium*.

The species *C. eminens* and *C. pulchrum* could be junior synonyms of *C. complanatum*, but the line drawings of *Steiniella complanata* in the original description differed in some aspects to the typical morphology of *Centrodinium*, especially in the rounder apices. This precludes us to propose *C. complanatum* (different from *C. complanatum* sensu Pavillard 1931) as senior synonym of *C. eminens* and *C. pulchrum*. There are reasons to consider that *C. eminens* and *C. pulchrum* are synonyms. The species *C. deflexum* in Kofoid (1907) could be an earlier description of *C. intermedium* Pavillard 1930, but the incoherencies between the two original illustrations of *C. deflexum* generates some doubts. *Centrodinium expansum* could be also an earlier description of *C. intermedium*, but there are no illustrations of that species for a comparison. The consideration of *C. deflexum* and *C. expansum* as senior synonyms of *C. intermedium* needs further research. We identify our cells as *C. intermedium* because our observations fit well with the Pavillard's original description, and the individuals were collected near the type locality. The type species, *C. elongatum*, could be a recently divided cell of *C. maximum* or *C. eminens*. The species *C. eminens* is very close to *C. maximum* and *C. elongatum*, being a good representative of the characters of the type species.

3. Plate arrangement of the laterally flattened species of *Murrayella* (Fig. S3)

Kofoed (1907) described the genus *Murrayella* as: “*Oxytoxinae* with spheroidal body and medium girdle, epitheca and hypotheca nearly equal. Epitheca with 6 precingulars and 2-4 apicals and a small mid-ventral intercalary next to the longitudinal furrow. No apical pore. Hypotheca composed of 5 postcingulars one of which is the longitudinal furrow plate, and an antapical apparently of one spine-like plate”. The generic tabulation was reported as 2-4', 1p, 6'', 5''', 1''''', while Kofoed reported the tabulation 2', 1p, 6'', 5''', 2'''' for the laterally flattened species *Murrayella punctata*.

Dangeard (1927) described *Goniodinium spiniferum* with the plate formula 4' 6'', 5''', 2p, 3'''''. Balech (1967) reported the plate formula Po, 3', 1a, 6'', 6c, 5s, 5''', 2p, 1'''' for *Murrayella splendida* and *M. mimetica*. Balech (1967, p. 119-120) commented that his new species *Murrayella mimetica* could be described under the genus *Centrodinium* based on the general appearance. *Murrayella splendida* and *M. mimetica* have similar plate formula, but there are important differences in the position of the plates that conform the antapex.

The posterior hypotheca of *Centrodinium* has an antapical horn with several terminal spinules, in *Murrayella punctata* is a pointed antapex curved towards the ventral side, and in *Murrayella mimetica* is a kind of antapical horn with the distal end curved towards the ventral side. Balech (1962, 1967) illustrated the antapices of *Centrodinium deflexoides*, *Murrayella punctata* (as *M. splendida*) and *M. mimetica*. Balech (1962, p. 174) reported in the description of *Centrodinium deflexoides*: “Por debajo de 1''' and 2''' está la placa intercalar posterior con vértice inferior. Se conecta también con la antapical. Esta última es baja, angosta y tiene en la base una amplia muesca triangular que corresponde a la intercalar y al sulcus”. Balech (1962) reported one intercalary

posterior and one antapical (5''', 1p, 1''') and later he reported the hypothecal plate formula as 5''', 2'''. Balech (1962) omitted the other triangular plate in the ventral basis of the antapical horn that he illustrated in his figure 373 (see below).

Hernández-Becerril et al. (2010) reported a pore, called 'side hypothecal pore', in the SEM pictures of their figures 37 and 38 (see below). In their SEM picture of the figure 39, the apex of one cell is connected at the position of this 'side hypothecal pore' with the apex of the other sibling cell of the chain. Hernández-Becerril et al. (2010) reported line drawings of *C. pulchrum* in their figure 42, omitting the 'side hypothecal pore'. Unequivocally, that 'side hypothecal pore' is a posterior attachment pore (pap) and it's located in the posterior sulcal plate, as occurred in numerous chain-forming gonyaulacalean dinoflagellates. Consequently, the posterior hypotheca of *Centrodinium* consists of two ventro-lateral triangular plates and other plate that conforms the antapical horn that emerged from the dorsal side. The posterior sulcal plate (S.p.) located in the right face below the plates 4''' and 5''' is triangular with a pore in the anterior margin (pap, posterior attachment pore). The other triangular plate is the first antapical (1''') that is located in the left side below the plates 1''' and 2'''. The second antapical (2''') plate conforms the antapical horn.

Balech (1967) illustrated the dissociated plates of the hypotheca of *Murrayella mimetica*. The configuration of the hypothecal plates of *M. mimetica* is similar to *Centrodinium*. In the left face, the 1''' plate has an almost triangular shape. The 2''' and the posterior sulcal (S.p.) plates are in the right face. The S.p. is irregularly triangular, and the 2''' plate already forms the antapical horn. In contrast, Balech (1967) illustrated *M. punctata* with the 1''' and the S.p. plates in the left side. The posterior sulcal plate changed from the left to the right face from *Murrayella punctata* to *M. mimetica*. The 2''' plate derived to a more dorsal position and changed its morphology to conform a tubular

antapical horn. The configuration of the plates in the antapex of *M. mimetica* is identical to that in *Centrodinium*. Unequivocally, *Murrayella mimetica* is intermediate between *M. punctata* and the more flattened species of *Centrodinium*.

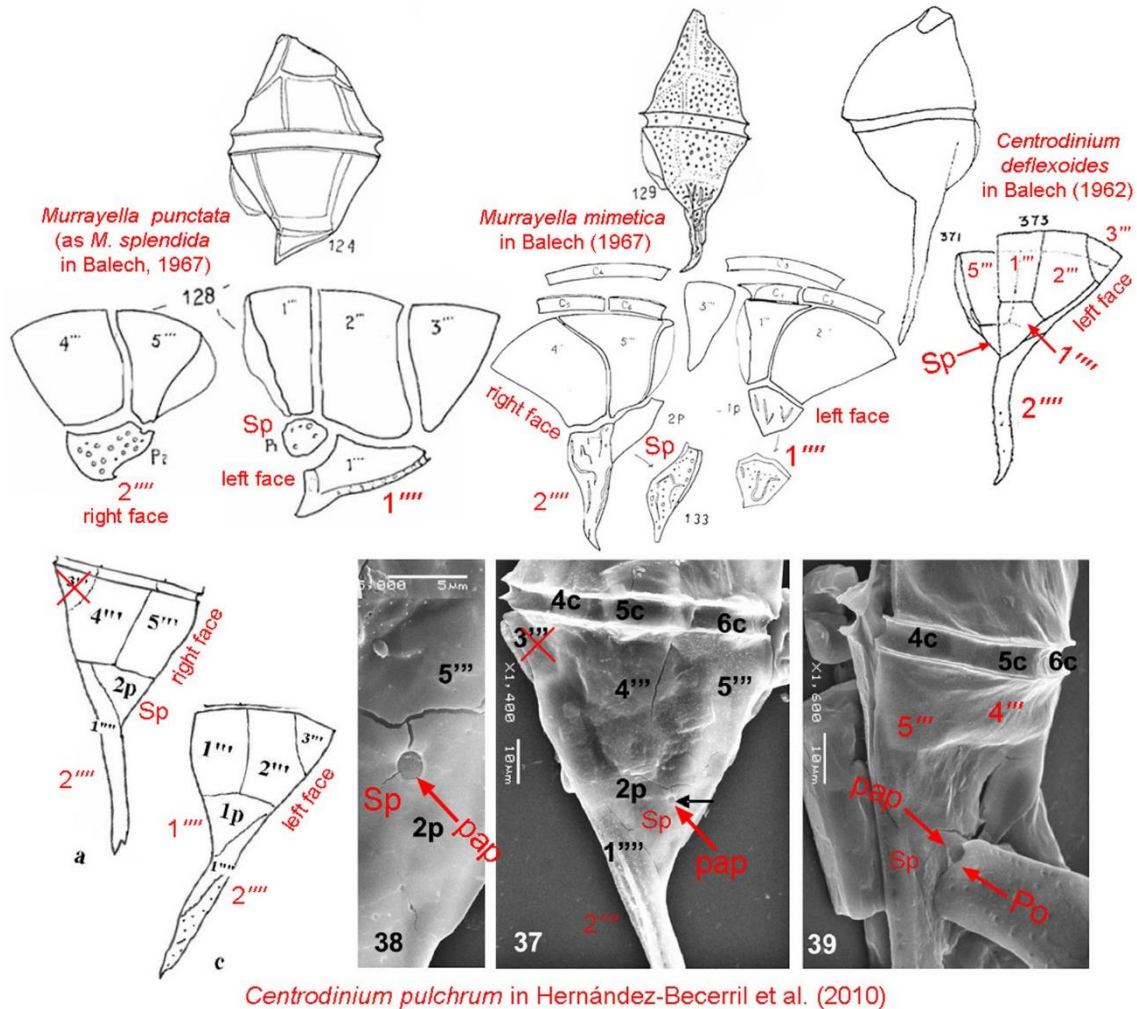


Figure S3. Images of the hypothecal plates of *Murrayella* and *Centrodinium* reproduced from Balech (1962, 1967) and Hernández-Becerril et al. (2010). The red labels correspond to interpretations of the tabulation in the present study. C1-C6 = cingular plates; pap = posterior attachment pore in the posterior sulcal plate; Po = apical pore plate; Sa = anterior sulcal plate; Sp = posterior sulcal plate; 1''-5'' = postcingular plates; 1''''-2''', antapical plates. Reproduced from: Hernández-Becerril et al. (2010) Morphology and taxonomy of the marine planktonic dinoflagellate *Centrodinium pulchrum* Böhm (Dinophyta) from the tropical Mexican Pacific, with comments on the taxonomy and distribution of the genus

Centrodinium, Phycologia, 49:5, 461-470, DOI: 10.2216/09-80.1 Copyright © International Phycological Society 2010, <http://intphycsociety.org/>, reprinted by permission of Taylor & Francis Ltd, <http://www.tandfonline.com> on behalf of the International Phycological Society.

Balech (1967, 1971) did not re-investigate the tabulation of *Centrodinium*, and he maintained the plate formula Po, 2', 3a, 7'', 5c?, 5''', 1p, 1'''' reported in his preliminary observations in Balech (1962). Balech (1962, p. 174) reported in the description of *C. deflexoides*: “6 precingulares relativamente anchas a las que se agrega en la región ventral, una muy distinta angosta, casi triangular con vértice superior, un poro cerca de la base y en ésta una muesca y pequeña apófisis unciforme. Por la diferencia de estructura y tamaño podría considerársela como una sulcal anterior muy avanzada: por el momento, sin embargo, la llamo 7'' ”. Despite this, Balech (1962) labelled the anterior sulcal as the seven precingular plate. Balech illustrated one triangular plate in the right face and other in the left face that supported the antapical horn in the ventral side. Consequently, the line drawings of Balech (1962) are illustrating a cell with the strict Kofoidian plate formula: Po, 2', 3a, 6'', 5''', 2p, 1'''' . This is closer to Balech's interpretation of the plate of *Murrayella puntacta* and *M. mimetica* on a strict Kofoidian scheme (Po, 3', 1a, 6'', 6c, 5s, 5''', 2p, 1''''), where *Centrodinium* has one additional plate in the epitheca.

Partially based on the Balech's comment on the similarity between *Murrayella mimetica* and *Centrodinium*, Taylor (1976) transferred the laterally compressed species of *Murrayella* into *Centrodinium*. Dodge (1985) reported a SEM picture of the ventral view of *Centrodinium mimeticum* (his cell seems to be closer to *C. punctatum*). In a publication on *Oxytoxum* and *Corythodinium*, Dodge and Saunders (1985) reported for

Centrodinium (probably based on a *Murrayella* species) that the plate formula was 3', 1a, 6'', 6c, s, 5''', 1p, 1'''''. Later Okolodkov and Dodge (1997) removed the anterior intercalary plate: Po, 3', 6'', 6''', 1p, 1'''''. Okolodkov and Dodge (1997) illustrated SEM pictures of left lateral and dorsal views of *C. punctatum*. Okolodkov and Dodge (1997) reported line drawings in ventral and antapical views. The sutures of the antapical plate did not match between the ventral and antapical views. Okolodkov and Dodge (1997, p. 363) described *C. punctatum* as “*Epitheca conical with blunt apex enclosing an apical pore plate with a horse-shoe shaped pore*”. This apical pore plate or an apical view of the species was not illustrated in Okolodkov and Dodge (1997). A similar apical pore was illustrated in *Murrayella punctata* in Balech (1971, his fig. 160).

4. Plate arrangement of *Centrodinium* (Fig. S4)

Kofoed (1907) described the genus *Centrodinium* as “*Ceratiinae with laterally compressed midbody contracted to an apical horn with pore...epitheca composed of apical and precingular series, 2 plates (possibly 4) in the former, and 6 in the latter...Hypotheca composed of 5 precingulars, 4 antapicals, and one dorsal intercalary...Small ventral pore above the flagellar pore*”. Kofoed erroneously reported five precingulars instead of five postcingulars. The plate formula in Kofoed (1907) is Po, 2' (or 4'), 6'', 5''', 1p, 4'''''. It is quite unusual to find a species with four antapical plates. The transversal section of the antapical horn of *Centrodinium* is triangular, and slightly twisted. Kofoed (1907) may interpret that the three faces of the antapical horn may evolve from the fusion of three plates. Kofoed described *Centrodinium* as ‘Ceratiinae’, relatives of *Ceratium/Tripos*. The apical horn of *Tripos* is composed four plates, and he may extrapolate this feature to *Centrodinium*. Kofoed (1907) did not report anterior intercalary plates in the plate formula of *Centrodinium*, but his illustration of *C. elongatum* showed

an anterior intercalary plate in the dorsal epitheca. Wood (1954) added one intercalary plate and reported the plate formula 2', 1a, ?5'' or 6'', 5''', 1p, 4''''.

Balech (1962) reported that the epitheca of *Centrodinium* is composed of two apical plates that form the apical horn, three intercalary anterior plates and seven precingulars. Balech considered the anterior sulcal plate (S.a.) as a seventh precingular plate (7''). Balech gave the plate formula Po, 2', 3a, 7'', 5c?, 5''', 1p, 1''''.

With doubts, Balech (1962) established the tabulation of the hypotheca as 5c, 5''', 1p, 1''''.

However, if we examine the sutures in Balech's figures 361, 362, and especially 373, we can observe two triangular plates at the ventral basis of the apical horn. Consequently Balech (1962) could consider the 1p and 2p plates that are below the 1''' and 5''' plates, respectively, as two posterior intercalaries, or three antapicals if we include the plate of the antapical horn.

The posterior hypotheca of *Centrodinium* consists of three plates. Three antapical plates have been interpreted in gonyaulacalean dinoflagellates such as *Pyrrhotriadinium* (formerly *Goniodoma* nom. rej. or *Triadinium*). Balech (1980) reported “*Finally in Goniodoma there is a plate which continues the sulcus slanting towards the right and which is considered a third antapical. In this case we face a difficult decision but it is not unreasonable to consider it as a posterior sulcal; one of the arguments for so doing is that its position recalls the S.p. of Gonyaulax and of other genera. Besides if it were not a sulcal it would probably be the only genus in which there is no posterior sulcal plate*”.

Balech did not find a relationship between the triangular plate in the right face of the posterior hypotheca and the sulcal posterior plate. Balech (1967) noted the resemblance between *Centrodinium* and *Murrayella mimetica*. Balech (1967, 1971) re-investigated the tabulation of *Murrayella*, but he did not examine more cells of *Centrodinium*. The arrangement of the posterior intercalary and antapical plates in *Murrayella punctata* and *M. mimetica* was different. As explained above, the plate arrangement of the hypotheca

of *M. mimetica* is similar to *Centrodinium*. The plate formula of *Centrodinium* will be Po, 2', 3a, 6'', 5''', 2p, 1'''' based on the line drawings reported in Balech (1962). A re-interpretation of the labelling of the sulcal plates based on Balech's figures of *Centrodinium* and *Murrayella* is reported in the figure S4.

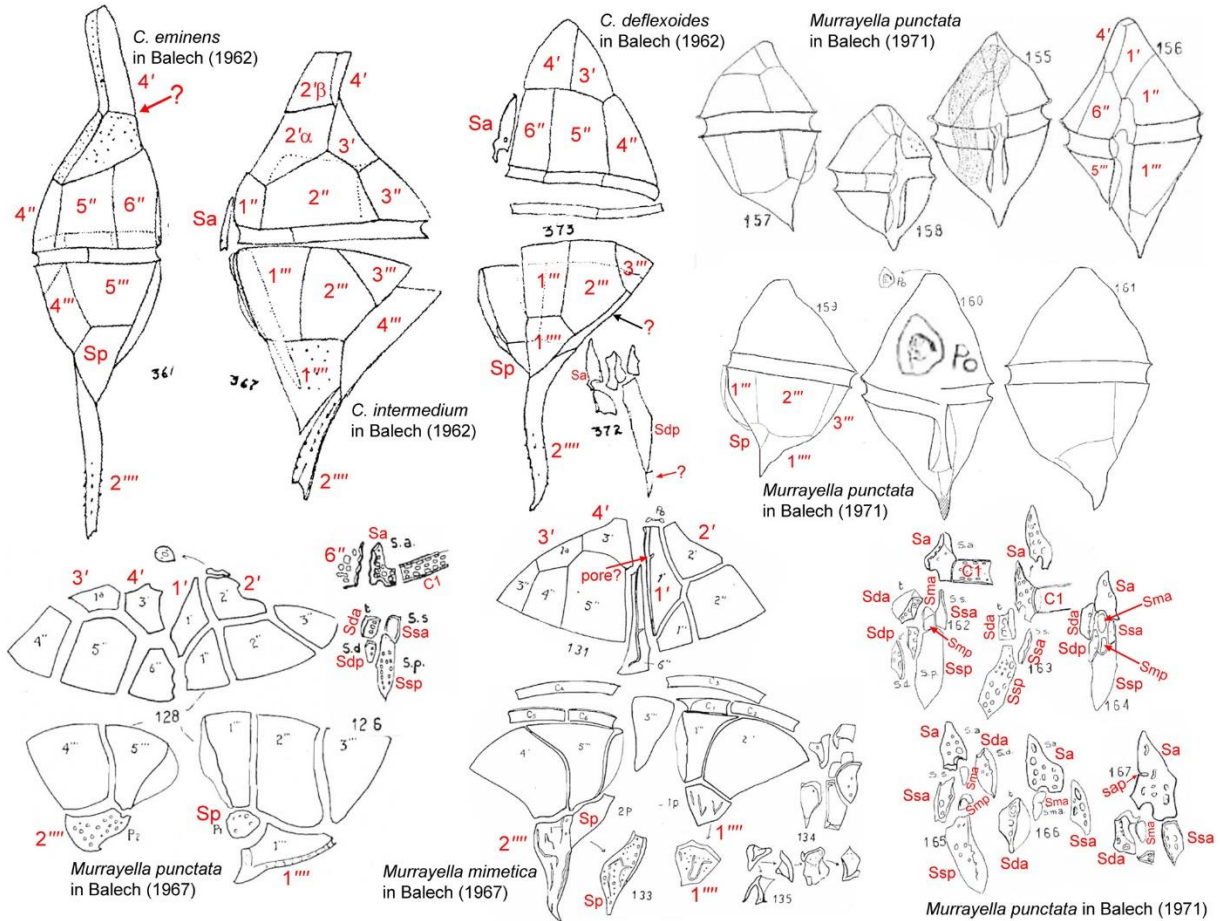


Fig. S4. Line drawings of thecal plates of *Murrayella* and *Centrodinium* from the literature. The red labels correspond to interpretations of the tabulation in the present study. 1'-4' = apical plates; 1''-6'' = precingular plates; 1'''-5''' = postcingular plates; 1''''-2'''' = antapical plates; C1-C6 = cingular plates; Po = apical pore plate; Sa = anterior sulcal; Sda = right (dexter) anterior sulcal; Sdp = right posterior sulcal; Sma = median anterior sulcal plate; Smp = median posterior sulcal; Sp = posterior sulcal; Ssa = left (sinister) anterior sulcal; Ssp = left posterior sulcal plate.

Despite the differences in the plate formula between *Centrodinium* and *Murrayella* interpreted by Balech, Taylor (1976) transferred the laterally flattened species of *Murrayella* into *Centrodinium*. The information on the plate formula of *Centrodinium* remains restricted to the preliminary study in Balech (1962). Balech (1988, p. 177) disagreed with the synonymy of *Murrayella* and *Centrodinium* proposed by Taylor (1976). Balech (1988, p. 178) commented that other genus should be created for these species of *Murrayella* that Taylor placed into *Centrodinium*. Balech (1988, p. 177) commented that his study of the tabulation of *Centrodinium* was incomplete, and he reformulated the tabulation from Po, 2', 3a, 7'', 5c?, 5''', 1p, 1'''' to Po, 2', 3a, 7'', 5c, 5''', 2'''''. He only re-labelled a posterior intercalary plate as an antapical plate. Steidinger and Tangen (1997) reproduced the Balech's plate formula for *Centrodinium*: Po, 2', 3a, 7'', 5c, ?s, 5''', 2'''''. It is evident that there is no a seventh precingular plate (7'') because the anterior sulcal is not a precingular plate, and that there are two triangular plates in the posterior hypotheca, together with tubular plate that conforms the antapical horn. *Centrodinium* has six cingular plates instead of five.

5. Problems in the interpretation of the plate formula of *Centrodinium* by Hernández-Becerril et al. (2010)

Hernández-Becerril et al. (2010) investigated the plate arrangement of several cells of *C. pulchrum* by light and scanning electron microscopy. These authors reported the plate formula as 3', 3a, 6'', 6c, 5s, 5''', 2p, 1'''''. This implies that the apical pore plate is absent, and there is a new apical plate when compared to Balech's plate formula. Their interpretation of the plate arrangement of *Centrodinium* has several problems.

The plates of *Centrodinium* are thin and hyaline, and the cells are highly laterally flattened. During the light microscopy observations of empty thecae, we must take care

because we can focus on the outer theca, or we can be observing the inner part in the other face of the theca (observing the inner theca). The light microscope or the lens of the camera may reverse the image, giving a specular (optically reverse) image of the cell. The SEM pictures did not provide specular images. Obviously there are not internal views of the theca because the cells are not transparent for the SEM. The theca of *Centrodinium* is fragile, the sutures between the plates are faint, and the cells can be damaged during the sample treatment for SEM. We have to be careful interpreting the tabulation from cracked or broken thecae and to confuse artificially-induced fissures with the true sutures between the thecal plates.

5.1. The additional apical plate (Fig. S5)

Hernández-Becerril et al. (2010) illustrated four cells identified as *Centrodinium pulchrum* by SEM. They reported three apical plates in the apical horn, and three anterior intercalary plates. Balech (1962) stated that the apical horn of *Centrodinium* was exclusively composed of two apical plates. Hernández-Becerril et al. identified a tiny fragment of theca near the apex as a new plate labelled as 2'. This adds a new plate in the epitheca that is only reported in their figure 31 of the cell labelled DUHB-*Centrodinium* 4. The theca of the individual DUHB-*Centrodinium* 4 was highly damaged, partially broken and with a cracked surface as reported in their figures 35, 36 and 39. It seems that one of these fissures of the theca was interpreted as a suture, and this induced to Hernández-Becerril et al. to propose the new plate 2' in their figure 31. The proposal of this questionable new apical plate is strongly risky based on a single observation in a highly deteriorate theca. In the figure 31, there is other fragment of the plate adjacent to this doubtful plate 2' that was not labelled as an additional apical plate. This questionable new plate 2' changed the plate formula because the adjacent posterior plate that forms the apical horn is then labelled as an intercalary plate. In addition, any tiny plate near the apex

could be interpreted as the ventral apical plate (X) or canal plate that can suggest an artificial affinity with some Peridinales.

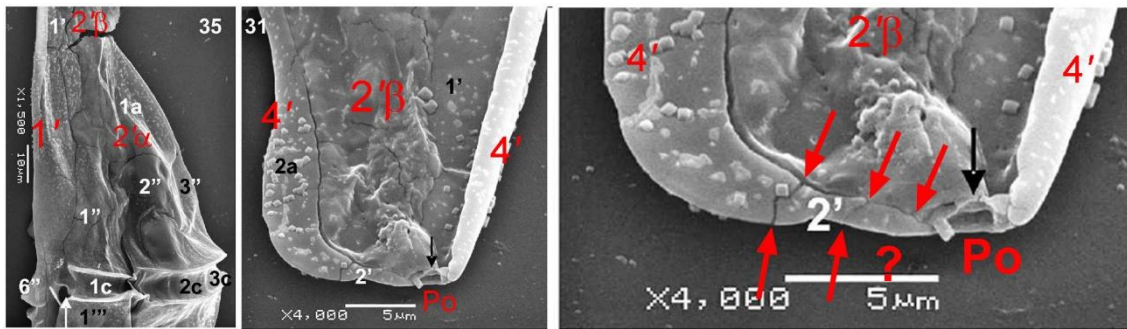


Fig. S5. SEM pictures of the individual labelled DUHB-*Centrodinium* 4 in Hernández-Becerril et al. (2010). Note the cracked and broken theca. The red arrows point fissures in the apex that were interpreted as thecal sutures and a new apical plate. The red labels correspond to interpretations of the tabulation in the present study. Reproduced from: Hernández-Becerril et al. (2010) Morphology and taxonomy of the marine planktonic dinoflagellate *Centrodinium pulchrum* Böhm (Dinophyta) from the tropical Mexican Pacific, with comments on the taxonomy and distribution of the genus *Centrodinium*, Phycologia, 49:5, 461-470, DOI: 10.2216/09-80.1 Copyright © International Phycological Society 2010, <http://intphycsociety.org/>, reprinted by permission of Taylor & Francis Ltd, <http://www.tandfonline.com> on behalf of the International Phycological Society.

5.2. *The other epithecal plates* (Fig. S6)

Hernández-Becerril et al. (2010) reported three intercalary plates. In their figure 8, the large intercalary plate in the dorsal epitheca is labelled as 3a plate. In the figure 16 that shows the same view, the same large intercalary plate in the dorsal epitheca is labelled as 1a plate. Hernández-Becerril et al. reported the right face of the epitheca in their figure 29. The left side of the epitheca is reported in the SEM picture of their figure 35, but the

theca is too damaged to discern the sutures of the thecal plates. The line drawings in Hernández-Becerril et al. seems to be based on the left epitheca of the tabulation of the figure 16 (LM image). However, there are serious doubts because the sutures in the left epitheca (Fig. 42c) seem to be partially a specular image of the right epitheca. There is one large anterior intercalary plate in the dorsal side of each line drawing (left and right faces) that, in fact, are the same plate. The plate labelled as 3a in the figure 42a (right face) is the same that the plate labelled as 1a in the figure 42c (left face).

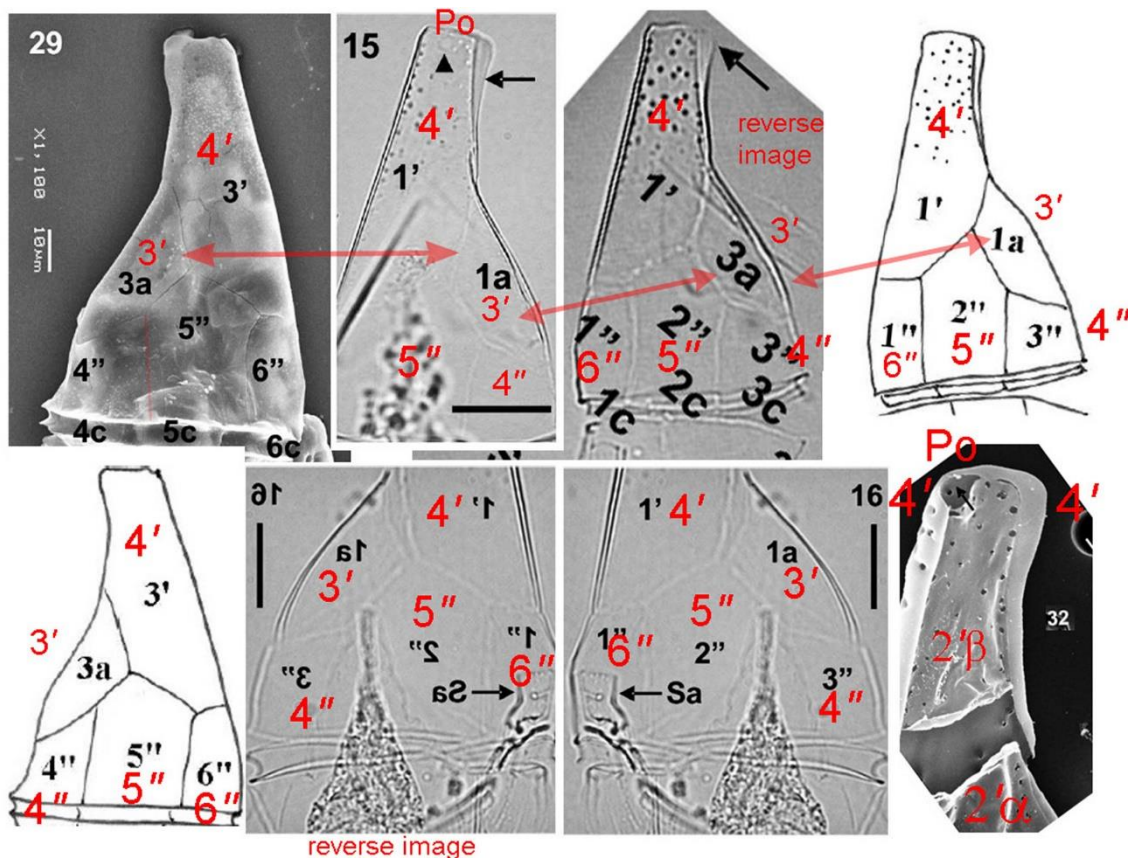


Fig. S6. Different images of the epitheca in Hernández-Becerril et al. (2010). Two images have been optically reverse (mirror-image) to facilitate the comparison. The red labels correspond to the interpretation of the tabulation in the present study. Reproduced from: Hernández-Becerril et al. (2010) Morphology and taxonomy of the marine planktonic dinoflagellate *Centrodinium pulchrum* Böhm (Dinophyta) from the tropical Mexican Pacific, with comments on the taxonomy and distribution of the genus *Centrodinium*,

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5.3. *The pore in the apex* (Fig. S7)

Hernández-Becerril et al. (2010) in their figure 15 (LM image) pointed a pore near the apex labelled as ‘side pore’. This ‘side pore’ is also reported in their figure 33 (SEM). In the plate formula, Hernández-Becerril et al. (2010) omitted the presence of the apical pore plate (Po). This pore may correspond to the Po missing the cover or closing platelet or canopy (cp).

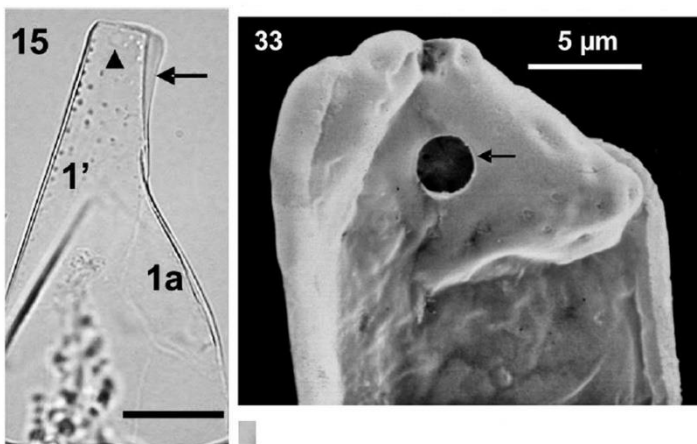


Fig. S7. Images of the ‘side pore’ in the apex of *Centrodinium pulchrum* in Hernández-Becerril et al. (2010). Reproduced from: Hernández-Becerril et al. (2010) Morphology and taxonomy of the marine planktonic dinoflagellate *Centrodinium pulchrum* Böhm (Dinophyta) from the tropical Mexican Pacific, with comments on the taxonomy and distribution of the genus *Centrodinium*, Phycologia, 49:5, 461-470, DOI: 10.2216/09-80.1 Copyright © International Phycological Society 2010, <http://intphycsociety.org/>, reprinted by permission of Taylor & Francis Ltd, <http://www.tandfonline.com> on behalf of the International Phycological Society.

5.4 *The hypothecal plates* (Fig. S8)

The figures 8 and 18 in Hernández-Becerril *et al.* (2010) apparently reported the left face of the hypotheca. In both figures, the 3''' plate is not visible because that implies a highly curved plate in this highly laterally flattened species. The 3''' plate is only visible in the left side. The hypotheca in the line drawing of the figure 42c needs to be corrected to remove the 3''' plate.

Hernández-Becerril *et al.* (2010) illustrated a SEM picture of *C. pulchrum* (their figure 37) with a pore near the margin of one of the two triangular plates adjacent to the basis of the antapical horn. These authors named this pore as 'hypothecal pore' in a plate identified as the second posterior intercalary plate (2p). This 'hypothecal pore' is also visible in two LM pictures (their figures 8 and 18), but this time in a plate labelled as 1p. These authors confused the right and left faces of the hypotheca, and the plates are mislabeled in the LM images of the figures 8 and 18. Gonyaulacalean dinoflagellates such as *Alexandrium* may have a pore, named posterior attachment pore (pap), often near the anterior-right margin of the posterior sulcal plate and connected to the margin by a narrow canal (Balech 1995). Hernández-Becerril *et al.* illustrated *Centrodinium* as a chain-forming species. The anterior and posterior attachment pores are the connection sites of a cytoplasmic strand between the sibling cells of a chain.

The triangular plate in the right hypotheca of *Centrodinium pulchrum* containing the posterior attachment pore is the posterior sulcal plate. As Balech (1980) reported for *Pyrrhotriadinium* (as *Goniodoma*, nom. rej.), there are no three antapical plates because one of these antapical plates is the posterior sulcal plate displaced towards the right side.

The plate formula in Hernández-Becerril *et al.* (2010) is reported as 3', 3a, 6'', 6c, 5s, 5''', 2p, 1'''' . If we include the apical pore plate, we discard the mysterious tiny apical

plate, and we consider that the triangular plate with the posterior attachment pore in the right hypotheca is the posterior sulcal plate, then the strict Kofoidian plate formula will be Po, 2', 3a, 6'', 6c, ?s, 5''', 2''''.

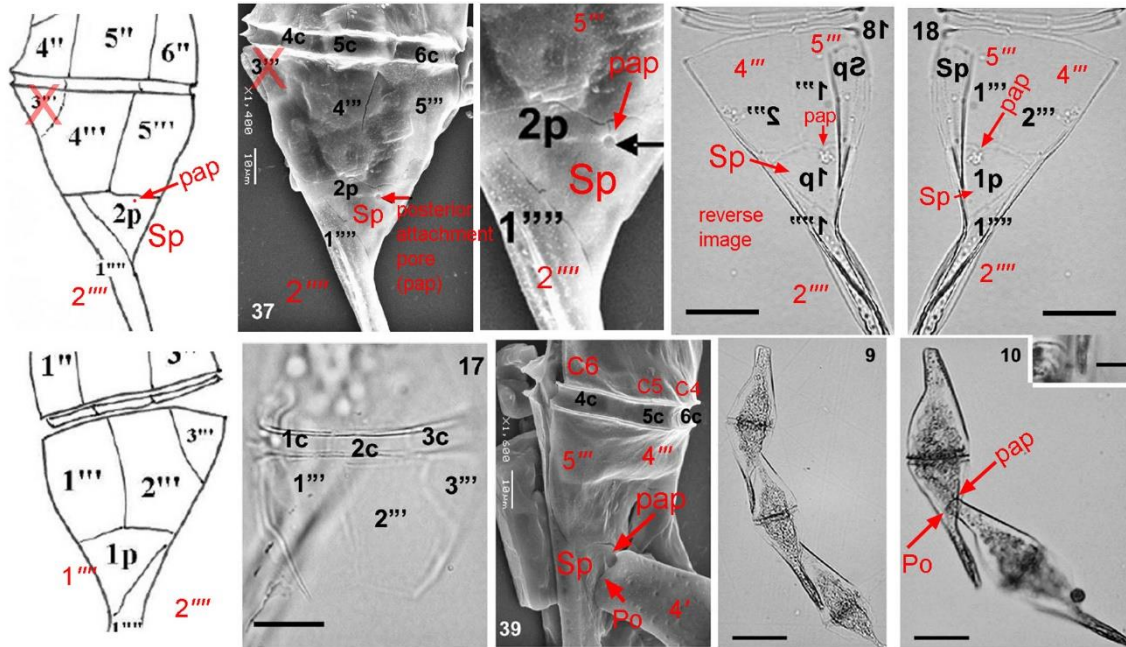


Fig. S8. Different images of the hypotheca of *Centrodinium pulchrum* in Hernández-Becerril et al. (2010). One image has been optically reversed (mirror-image) to facilitate the comparisons. The red labels correspond to the interpretation of the tabulation in the present study. pap = posterior attachment pore in the posterior sulcal plate; Po = apical pore plate; Sp = posterior sulcal plate. Reproduced from: Hernández-Becerril et al. (2010) Morphology and taxonomy of the marine planktonic dinoflagellate *Centrodinium pulchrum* Böhm (Dinophyta) from the tropical Mexican Pacific, with comments on the taxonomy and distribution of the genus *Centrodinium*, *Phycologia*, 49:5, 461-470, DOI: 10.2216/09-80.1 Copyright © International Phycological Society 2010, <http://intphycsociety.org/>, reprinted by permission of Taylor & Francis Ltd, <http://www.tandfonline.com> on behalf of the International Phycological Society.

6. Problems in the interpretation of the plate formula of *Centrodinium* by Li et al. (2019) (Fig. S9).

Li et al. (2019) provided new morphological data of *Centrodinium punctatum*. They consider the plate 3' that does not reach the apex as an intercalary anterior plate (1a). Consequently the epithecal plate formula is Po, 3', 1a, 6''. This is due to these authors follow a strict Kofoidian scheme, although from the plate is apical from an evolutionary point of view, and the consideration as an intercalary plate only add confusion.

The main problem is the mislabeling of the lateral posterior sulcal plates that also induce the error in the tabulation of the hypotheca. Li et al. (2019, p. 173) reported “The right posterior sulcal plate (Sdp) and left posterior sulcal plate (Ssp) were narrow and more than twice as long as they were wide (Fig. 6D). The posterior sulcal plate (Sp) was narrow, symmetrically hexagonal, extended into the hypotheca without reaching the antapex (Fig. 6D)”.

In the schematic drawing of the tabulation, Li et al. (2019, p. 177, figure 8C) illustrated the right (Sdp) and left posterior sulcal (Ssp) with a similar length. This is not evident in their Figure 6C-D where the left posterior sulcal plate is several times large than the right pair. The narrow plate is the left posterior sulcal, but Li et al. misidentified it as the left posterior sulcal as the posterior sulcal. There is no a visible suture in the most antapical border of the plate Ssp In their figure 6D (see below Figure S9). As consequence, these authors misidentified the other hypothecal plates. The elongated sulcal plate (Sp) sensu Li et al. (2019) correspond to the left sulcal posterior plate, the second antapical plate is the sulcal posterior and the posterior intercalary plate is the second antapical plate. The hypothecal tabulation proposed by Li et al. (2019) as 5''', 1p, 2'''' is in fact 5''', 2'''' that is common for all the members of this family of dinoflagellates. Unfortunately, Li et al.

(2019) did not carry out a study using plate dissection. As shown in this study, one of the lateral posterior sulcal plates in always larger than the other pairs in the species of *Centrodinium* spp. The different length of these plates was also noted in the plate dissections of *C. punctatum* by Balech (1967, 1971) (See Figure S9).

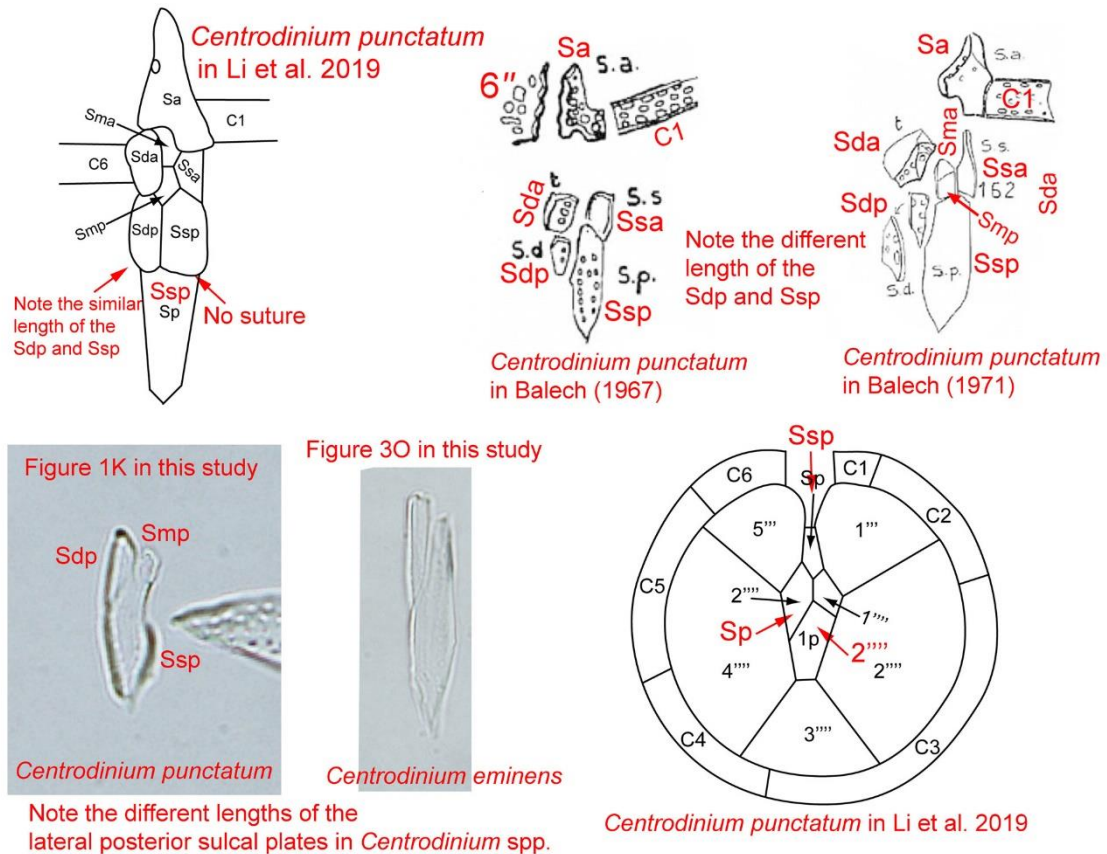


Fig. S9. Different images of the sulcus and hypotheca of *Centrodinium punctatum* in Balech (1967, 1971) and redrawn from Li et al. (2019) and. The red labels correspond to the interpretation of the tabulation in the present study.

7. Synonymy of *Centrodinium* and *Murrayella*

The relationship between *Centrodinium* and the laterally flattened species of *Murrayella* have been a matter of controversy (Taylor 1976, Balech 1988). Kofoid (1907) described the genera *Centrodinium* and *Murrayella* as members of the family Ceratiaceae

(*Ceratium*, *Triplos*) and the Oxytoxaceae (*Oxytoxum*, *Corythodinium*), respectively. Kofoid (1907) proposed *Murrayella* for four species with different morphologies (globular, biconical and laterally flattened) that were later placed into three distinct genera. Fifteen other species of *Centrodinium* or laterally flattened species of *Murrayella* were further described, in almost all cases without studies of the plate arrangement. Balech (1962) did a preliminary study of the plate arrangement of *Centrodinium*. He observed that the apical horn unequivocally consisted of two apical plates (1'-2'), and there were three anterior intercalary plates (1a-3a). Balech reported seven precingular plates (1''-7'') despite recognizing that the seventh precingular had the morphology of an anterior sulcal plate. Balech's line drawings showed a tubular plate that forms the antapical horn supported in the ventral side by two triangular plates. Despite this, Balech reported the hypothecal plate formula with one antapical (1''') and one posterior intercalary (1p) plate, which suggests a missing plate. Thus, Balech (1988) reported the plate formula of *Centrodinium* as Po, 2', 3a, 7'', 5c, 5''', 2''', but the line drawings in Balech (1962) suggests the formula Po, 2', 3a, 6'', 6c, ?s, 5''', 2p, 1'''' in an strict Kofoidian scheme.

Balech (1967, 1971) did a more complete study of the tabulation of *Murrayella punctata* (= *M. splendida*) and *M. mimetica*. He reported the plate formula as Po, 3', 1a, 6'', 6c, 5s, 5''', 2p, 1'''''. This time, Balech (1967) described the ventral plate with a posterior sinus as the anterior sulcal plate instead of the seventh precingular plate. Balech found three plates in the posterior hypothecae of *M. punctata* and *M. mimetica*, but with an important difference. In *M. punctata*, there were two plates in the left face that Balech labelled as the first antapical and one of the posterior intercalary plate, while in *M. mimetica* there is only one plate in the left side (see Appendix S1 in the Supplementary material). Independently of the labelling, it is evident that there is a plasticity in the

position of the plates among the species of *Murrayella*. Balech (1967, p. 119-120) commented that based on the general appearance *M. mimetica* could be described under the genus *Centrodinium*. The plate arrangement of *M. mimetica* has intermediate characteristics between *Centrodinium* and *Murrayella*, supporting the relationship between these genera. *Murrayella mimetica* as well as *Centrodinium* share an almost triangular plate in the left face, and other in the right face and the plate of the antapical horn. Balech considered the posterior sulcal plate displaced towards the right face as a posterior intercalary plate. Taylor (1976) transferred the laterally flattened species of *Murrayella/Pavillardinium* into *Centrodinium*. Balech (1988) disagreed and considered that *Murrayella* and *Centrodinium* should remain as independent genera. Dodge (1985) provided a SEM picture of the lateral view of a cell identified as *C. mimeticum*. In a publication on *Oxytoxum*, Dodge and Saunders (1985) commented that the plate formula of *Centrodinium* (probably based on a *Murrayella* species) was 3', 1a, 6'', 6c, s, 5''', 1p, 1'''''. Subsequently, Okolodkov and Dodge (1997) modified the plate formula for *C. punctatum* as Po, 3', 6'', 6''', 1p, 1''''', removing the anterior intercalary plate and adding a postcingular plate. Hernández-Becerril et al. (2010) provided LM and SEM pictures of several cells of *C. pulchrum*. There are numerous mislabelings in the designation of the plates induced by optically reversed LM pictures (see Appendix S1 in the Supplementary material). Based on a single deteriorated theca, Hernández-Becerril et al. (2010) assumed that one of the tiny fragments of theca of the apical horn corresponded to an additional apical plate. They provided the plate formula 3', 3a, 6'', 6c, 5s, 5''', 2p, 1''''', without apical pore plate.

The molecular data reveal that *Centrodinium eminens* and *C. intermedium*, highly laterally flattened species with apical and antapical horns and smooth thecae, are very closely related to *C. punctatum* (formerly *Murrayella punctata*), a moderately flattened

species with pointed apices and a porulate theca (Figs 4, 5). The three species of *Centrodinium* cluster as a sister group of the non-compressed species *Alexandrium affine* and *A. gaarderae* (Figs 4, 5, S1). *Centrodinium punctatum* appears as an intermediate stage between non-compressed species lacking pointed apices or horns (i.e., *Alexandrium*), and the more highly flattened species of *Centrodinium* with horns.

The cell compression and development of horns in *Centrodinium* is accompanied with a plasticity in the plate arrangement. It is commonly accepted that the species of a given genus share a similar plate formula. Following a strict Kofoidian scheme, *C. punctatum* and the more flattened species of *Centrodinium* have different plate formulae and consequently belong to distinct genera. Splitting *Centrodinium* into distinct genera is not supported in the molecular phylogenies (Figs 4, 5). The cell flattening is dorso-ventral in most of the pelagic peridinioid and gonyaulacoid dinoflagellates, while *Centrodinium* is laterally compressed. *Centrodinium punctatum* represents then an earlier stage towards the cell flattening. Three plates are clearly in contact with the apical pore plate in *C. punctatum*. The anterior extension of the third apical plate (3') and partially the first apical plate (1') began to be hindered by the overlap growth of the fourth (4') and second apical (2') plates (Fig. 1). The apical horn in the more flattened species of *Centrodinium* (*C. eminens*, *C. intermedium*) is due to the anterior growth of plates 2' and 4', which hindered the anterior elongation of plates 1' and 3' (Figs 2, 3). From an evolutionary point of view, these four plates belong to the apical series, although two of them can be classified as anterior intercalary plates in a strict Kofoidian scheme. We are generally more flexible in the position of the plates in other species. *Alexandrium minutum* has cells in which the first apical plate may or may not reach the apical pore plate (Balech 1989). We accept the plate formula 4' and 6'' for *A. minutum*, while the plate formula of cells from the same population is 3' and 7''. The gonyaulacoid genera *Coolia*, *Ostreopsis* and *Gambierdiscus*

have three plates surrounding the Po, but the plate formula is often reported with four apicals assuming that the first apical is placed in the precingular plate series as suggested by Besada et al. (1982). The position of the first apical plate changes along the life cycle of the gonyaulacoid genus *Fragilidium* (Amorim et al. 2013). These examples support that a strict Kofoidian scheme of tabulation does not reflect the nature of these plates. The plate 4' of the highly flattened species of *Centrodinium* is long, thick, and flat. The plate 2' should be also long. This feature is solved with the split of the thin plate 2' into two plates (Fig. 3D). The split of epithecal plates have been reported in other gonyaulacoid dinoflagellates such as *Coolia* or *Gambierdiscus* (Loeblich and Indelicato 1986, Jeong et al. 2012, Gómez et al. 2016a). The pointed antapex of *C. punctatum* has evolved into an antapical horn in the more flattened species of *Centrodinium* (Figs 1-3). The antapical horn is composed of a single tubular plate that emerges from the dorsal side. In the ventral side, the antapical horn is supported by two lateral triangular plates (Fig. 6F). The equivalent plates in *C. punctatum* are the posterior sulcal and the first antapical plates (Fig. 6E). The lateral flattening forced the displacement of the posterior sulcal and first antapical plates towards the right and left faces, respectively. In *C. punctatum*, the right posterior lateral plate is longer than the left pair, while reverse in the more flattened species of *Centrodinium* (Figs 1-3, 6E-F).

The posterior sulcal plate of numerous species of *Alexandrium* is characterized by a posterior attachment pore linked to the plate margin by a channel (Balech 1995). This pore is visible in the triangular posterior sulcal plate in the right face of *Centrodinium* (Figs 2F, 3R-S), as illustrated in Hernández-Becerril et al. (2010, their figures 36-37). Three antapical plates (or 2p, 1''') has been reported for *Pyrrhotriadinium* (Balech 1979, see Appendix S1 as Supplementary material for a discussion on the nomenclature of *Pyrrhotriadinium*). Balech (1980) reported that the posterior sulcal plate displaced

towards the right side has been traditionally mistaken for an antapical or posterior intercalary plate. *Centrodinium* as well as the other gonyaulacoid relatives have two antapical plates. The second antapical plate is placed in the dorsal side and formed the antapical horn, and the first antapical and the posterior sulcal have evolved into triangular plates that support the antapical horn at its ventral basis (Figs 2E, 3S, 6F). The plate arrangement of *Centrodinium* is similar to its gonyaulacoid relatives, just with some morphological modifications as result of the cell elongation and lateral flattening.

8. Suprageneric classification of *Centrodinium* (Fig. S10)

Kofoid (1907) began the diagnosis of *Centrodinium* as: “Ceratiinae...” that suggests an affinity with gonyaulacalean dinoflagellates of the family Ceratiaceae (*Ceratium* and *Triplos*). Kofoid (1907) began the diagnosis of *Murrayella* as “Oxytoxinae...” that suggests an affinity with the peridinioid dinoflagellates of the family Oxytoxaceae (*Oxytoxum*, *Corythodinium*). Gómez et al. (2016) and Gómez (2018) provided recent studies of the taxonomy and classification of the Oxytoxaceae. Kofoid’s plate formula for *Centrodinium* [Po, 2' (or 4'), 6", 5"', 1p, 4'''] is different from his plate formula for *Murrayella punctata* (2', 1p, 6", 5"', 2''', apical pore plate absent).

Kofoid (1907) did not establish any relationship between *Centrodinium* and *Murrayella*. Kofoid and Michener (1911) described two species of *Centrodinium* without illustration. The description of *Centrodinium porulosa* seems to correspond to a species of *Murrayella*, and even Kofoid and Michener (1911, p. 287) reported in the description of *C. porulosa* “approaching *Murrayella* in some respects”. This is the first mention of a relationship between *Centrodinium* and *Murrayella*. Kofoid and Michener (1911, p. 268) placed the two new species of *Centrodinium* in the family Oxytoxinae (Oxytoxaceae), while previously Kofoid (1907) described *Centrodinium* as ‘Ceratiinae’.

Lindemann (1928) placed *Centrodinium* and *Ceratium* in the Ceratiaceae, and *Murrayella* and *Oxytoxum* in the Oxytoxaceae. Schiller (1937, p. 432) reported the ‘Familie Centrodinium Kof.’ for *Centrodinium*, and he placed *Murrayella* in the Oxytoxaceae. The zoological family ‘Centrodinidae Kofoid’ is cited in Chatton in Grassé (1952, p. 354) for *Centrodinium*, while *Murrayella* was placed in the Oxytoxidae. Vozzhennikova (1965) also used the botanical family Centrodiniaceae Kofoid. In contrast, Loeblich (1970, p. 880) reported ‘Family Centrodiniaceae Schiller 1937’ that reappeared in other classifications (Sarjeant 1974; Tappan 1980). It is unclear whether Kofoid or Schiller proposed a family for *Centrodinium*.

Balech (1967, p. 117) reported that *Oxytoxum* and *Murrayella* differed in the tabulation and the position of the sulcus. Balech (1967, his figure 131) illustrated *Murrayella mimetica* with a notch in the right side of the plate 1' that could be interpreted as ventral pore in the plate 1'. It should be noted that this ventral pore is a characteristic of numerous species of gonyaulacalean dinoflagellates (i.e., *Alexandrium* Halim). Kofoid (1907) described the genus *Centrodinium* with “small ventral pore above the flagellar pore”. This ventral pore, present in *Murrayella* and *Centrodinium*, is a pore with a thin channel connecting to the right margin of the anterior sulcal plate.

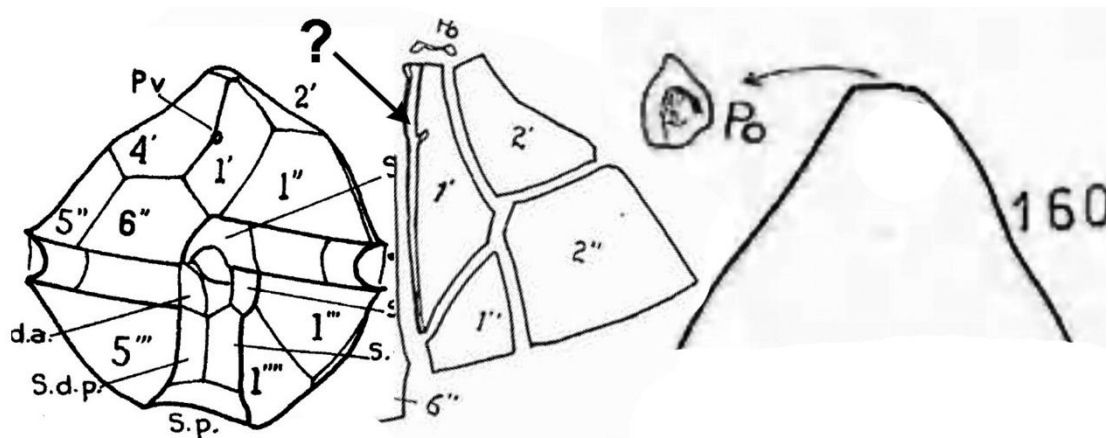


Fig. S10. *Alexandrium* in Balech (1995) and *Murrayella mimetica* in Balech (1971). The arrow points a notch in the first apical of *M. mimetica*.

The morphology of the apical pore is a diagnostic character in dinoflagellates. Dodge and Okolodkov (1997, p. 363) reported for *Centrodinium punctatum*: “*apex enclosing an apical pore plate with a horse-shoe shaped pore*”. Balech (1971, p. 34) reported in the description of *Murrayella punctata*: “*La placa Po es bastante grande, oval pentagonal con un poroide grande y generalmente otro pequeño*”. The apical pore plate of *Alexandrium* has a fishhook, comma or oval-shaped pore that is covered by the cover or closing platelet or canopy (cp). Some species, especially the chain-forming taxa, showed an additional round pore that is the anterior attachment pore (aap) (Balech 1995). In the chain-forming species of *Alexandrium*, the anterior attachment pore in apical pore (Po) of one cell is connected to the posterior attachment pore (pap) in the sulcal posterior (S.p.) plate of the sibling cell (see Fig. S8).

Loeblich (1982) placed *Oxytoxum*, *Pavillardinium* and *Centrodinium* in the Oxytoxaceae. Anomalously, Loeblich (1982) omitted *Corythodinium*, a genus that he erected in 1966 for one species of *Oxytoxum*. Dodge (1984) placed *Oxytoxum*, *Corythodinium* and *Centrodinium* in the Oxytoxaceae. Later, Dodge and Saunders (1985) considered *Corythodinium* as synonym of *Oxytoxum*, and excluded *Centrodinium* from Oxytoxaceae. Sournia (1986) placed *Oxytoxum*, *Corythodinium* and *Centrodinium* in the Oxytoxaceae. Balech (1988, p. 178) considered that *Centrodinium* and the laterally flattened species of *Murrayella* should be placed in a family other than the Oxytoxaceae. Taylor (1987) and later Steidinger and Tangen (1997) placed *Oxytoxum*, *Corythodinium* and *Centrodinium* in the Oxytoxaceae. In contrast, Fensome et al. (1993) restricted the Oxytoxaceae to *Oxytoxum* (they considered *Corythodinium* as a synonym), and placed

Centrodinium in the Gonyaulacales as family uncertain. Dodge and Okolodkov (1997) placed *Centrodinium* in the Oxytoxaceae, while they reported in the page 363: "*the only grounds for retaining Centrodinium in the Oxytoxaceae would seem to be its shape, particularly its pointed apex and antapex*". The molecular phylogeny of *Oxytoxum* and *Corythodinium* is reported in Gómez et al. (2016).

Hernández-Becerril et al. (2010) proposed the new family Centrodiniaceae for *Centrodinium* (including all the laterally flattened species of *Murrayella*) and placed it in the Peridiniales. Hernández-Becerril et al. did not discuss whether the family Centrodiniaceae was already proposed by Kofoed or Schiller. It is uncertain whether Kofoed or Schiller accomplish with the requirements to propose a new family for *Centrodinium* in the Zoological Nomenclature. If the family is valid in the Zoological Nomenclature, then this family is valid in the Botanical Nomenclature as explained in the example 5 of the article 45 of I.C.N. (International Code of Nomenclature for Algae, Fungi, and Plants). We are unable to clarify whether Kofoed or Schiller proposed a family for *Centrodinium* following the formal requirements.

Gómez (2012) placed *Centrodinium* in the family Goniodomataceae within the Gonyaulacales. He divided this family into two subfamilies, one for *Gambierdiscus*, *Goniodoma*, and other subfamily for *Alexandrium*, *Centrodinium*, *Coolia*, *Ostreopsis*, *Pachydinium* and *Pyrodinium*. Gómez (2012) used the family name Goniodomataceae Lindemann 1928 with priority over Ostreopsidaceae Lindemann 1928, Triadiniaceae Dodge 1981, Yeseviidae Özdikmen 2009, and Centrodiniaceae Hernández-Becerril et al. 2010. Gottschling and Elbrächter (2015) proposed to conserve the name *Scrippsiella* against *Goniodoma*. The proposal 2382 was recommended and the name *Goniodoma* was rejected (Prud'homme van Reine, 2017). According to the article 18.3 of the I.C.N: A name of a family based on an illegitimate generic name is illegitimate. The proposal 2383

to reject the name Goniodomataceae by Elbrächter and Gottschling (2015) was recommended (Prud'homme van Reine, 2017). *Peridinium acuminatum* is the type of *Goniodoma*, *Heteraulacus* and *Yesevius*. Kretschmann et al. (2015) proposed that *Peridinium acuminatum* is the peridinioid *Scrippsiella acuminata* (Thoracosphaeraceae, Peridinales). For the gonyaulacalean species previously placed in *Goniodoma*, Kretschmann et al. (2015) proposed the use of *Pyrrhotriadinium* Nakada 2010, with the type species *Pyrrhotriadinium polyedricum* (Gonyaulacales) and basionym the gonyaulacalean *Peridinium polyedricum* Pouchet. Dodge (1981) proposed the genus *Triadinium* and the family Triadiniaceae with *Triadinium polyedricum* as type species, and cited *Peridinium acuminatum* Ehrenberg as basionym. Nakada (2010) reported “Note that a substitute name for Triadiniidae Dodge (or Goniodomidae) is currently unnecessary, because this taxon may be classified in a family with available name (e.g. Pyrophacidae =Pyrophacaceae, Ostreopsidae = Ostreopsidaceae)”. In the molecular phylogenies, *Pyrrhotriadinium polyedricum* is not closely related to the Pyrophacaceae (*Pyrophacus*). *Pyrrhotriadinium* clustered as basal in the clade of *Fukuyoia* and *Gambierdiscus*, and as a sister group of *Alexandrium* (Gómez et al. 2015). The phylogenetic trees of the ribosomal DNA sequences of the type of Ostreopsidaceae, *Ostreopsis*, showed sequences with long branches, and it is difficult to determinate with high support the relationship of *Ostreopsis* and the other gonyaulacalean relatives (Gómez et al. 2017). We cannot establish if *Pyrrhotriadinium* should be placed in the Ostreopsidaceae, and then the proposal of a new family name as ‘Pyrrhotriadiniaceae’ could be superfluous. If *Centrodinium* is a member of this gonyaulacalean family of *Pyrrhotriadinium*, then Goniodomataceae, Triadiniaceae or Yeseviidae needs to be replaced by another name. Ostreopsidaceae, Centrodiniaceae or an alternative name for a gonyaulacalean species of Goniodomataceae/Triadiniaceae/Yeseviidae are the

candidates. The family Centrodiniaceae in Hernández-Becerril et al. (2010) was proposed as a peridinioid dinoflagellate based on a re-description of the genus with numerous errors. It is unclear if the family Centrodiniaceae was proposed before because the names ‘Centrodiniaceae Kofoid’ and ‘Centrodiniaceae Schiller’ have been reported in the literature (Grassé 1952, Vozzhennikova 1965, Loeblich 1970, Sarjeant 1974, Tappan 1980). At the present, the molecular phylogeny cannot be resolved if both *Centrodinium/Alexandrium* sensu lato and *Ostreopsis* should be placed in the Ostreopsidaceae.

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