POLYMORPHINIDAE FROM THE UPPER CRETACEOUS OF ENGLAND

by TOM BARNARD

ABSTRACT. Various Cretaceous species of Polymorphinidae have irregular fistulose end-chambers. Similar forms occur from the Jurassic to Recent. The Upper Cretaceous fistulose forms are considered to be abortive offshoots from either the chief smooth species or from the rarer ornamented forms. Their taxonomic significance and occurrence is discussed.

MEMBERS of the family Polymorphinidae are closely related to the Lagenidae (or Nodosariidae), possessing similar wall-structures, chamber-shapes and apertures, and differing only in the arrangement of the chambers. In the Lagenidae the chambers are usually arranged in a uniserial order, with the main axis being either straight, curved, or even planispiral, whereas in the Polymorphinidae the chambers are arranged in a spire about a vertical axis, but placed at angles about this axis.

Their morphological development and suggested evolution was dealt with by Cushman and Ozawa (1930) in a monograph of Recent and Tertiary forms. A classification was put forward based on the arrangement of the chambers in a large number of specimens, widely distributed both in space and time.

It would appear that the smooth, primitive forms, *Globulina* and *Guttulina*, have not only a long geological history, but also a wide distribution in various rocks. Some genera, particularly those occurring in Tertiary rocks and Recent oceans, are restricted in their distribution, becoming highly selective and specialized. Many of these species are greatly restricted in both vertical and horizontal range. Smooth forms appear to have long ranges, whereas ornamented genera do not range widely. This may be an illusion primarily due to the difficulty in differentiating between the smooth genera and species. It is clear that overlap occurs in many early 'species' of *Guttulina* and *Eoguttulina*, and specific determination is difficult.

It appears from the study by Cushman and Ozawa (1930) that although the family Polymorphinidae made its first appearance during the Trias, and the Jurassic forms representing the genus *Eoguttulina* were of an extremely simple plan, it was not until the Cretaceous that any generic diversity occurred. This view is oversimplified, for great diversity of form does occur in the Jurassic. Individual variation in the arrangement of the chambers is well seen in specimens from the Lias, Oxford Clay, and Kimeridge Clay of England. Many variants show a chamber arrangement identical to that in forms which do not appear as definite genera until late in the Cretaceous. However, whereas the Cretaceous species become well established, most of the Jurassic variants are short-lived and do not persist.

Most of the genera belonging to this family were represented before the end of the Cretaceous. Throughout the Jurassic and Cretaceous the species generally had their chambers arranged at angles around a vertical axis, and this, together with the shape of the chambers, tended to produce globular or fusiform tests. However, in Tertiary times

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some forms (and occasional abnormal specimens from the Cretaceous) tended to have the chambers arranged biserially.

Although members of the Polymorphinidae occur sporadically throughout the Mesozoic rocks of England, they are generally rare except at scattered horizons where they may be extremely abundant.

The author has not observed any species with irregular or fistulose end-chambers occurring in Jurassic rocks, although they are recorded by Terquem (1864). Apparently fistulose forms do not occur until the Cretaceous. Many such forms have been recorded from the Lower and Upper Cretaceous rocks of both Europe and America, and specimens are also rare throughout Tertiary to Recent times.

Bullard (1953), in a paper on the 'Polymorphinidae of the Cretaceous (Cenomanian) Del Rio Shale' from Texas, records a number of fistulose forms and suggests that '. . . all the various modes of growth known to the family, such as free, attached, fistulose, tubulose, and racemose are represented in the Del Rio fauna. This evidence suggests that the family had reached a mature stage in its development long before the Tertiary. . . . The extensive development of the Polymorphinidae by Del Rio time reflects a rapid expansion of the family during the Washita. . . .' Tappan (1940, 1943) recorded eight species from the Duck Creek Formation (basal Washita), and ten from the Grayson Formation, whereas nineteen are recorded from the Cenomanian. This rapid increase in development also occurs throughout the Albian of southern England and is continued into the Cenomanian, although the big increase in number of species recorded from America is probably due to the setting up of many new species, which are, in fact, just variants of well-established forms. Little account of the variation has been taken in assigning specimens to species.

Bullard suggests by her naming that fistulose forms are new species and not variants of well-established, and often long-ranged, species. *Globulina fistulosa* Bullard (p. 342), although rare in the Del Rio Formation, differs from its contemporary species *Globulina lacrima* Reuss only in having a fistulose end-chamber. Also *Pyrulina cylindroides* (Roemer) appears to have a similar relationship to the fistulose *Pyrulina longa* (Tappan). From the foraminiferal occurrence charts of the Del Rio Formation it is apparent that in most cases the forms occur together in pairs, and their ranges are contemporaneous for the whole formation, except that the smooth forms have longer ranges, as might be expected.

The present author believes that fistulose forms, as well as many attached forms belonging to this family, are abortive variants of smooth, or in rare cases ornamented species, and should not be regarded as true species, for they are of sporadic occurrence and do not appear to have become firmly established. At certain horizons, however, the abnormal forms greatly increase in number, momentarily in time, and this may be due to internal or external environmental factors.

In the Albian of England as with the Washita of America, a number of fistulose forms occur, but in England the lithology is constant and does not appear to reflect any change in environment. Fistulose specimens also occur in the Cenomanian in England, and here with the rapidly changing lithologies it would be easy to invoke environmental changes to produce aberrant forms.

Throughout the Turonian and Senonian, fistulose forms occur rarely and sporadically until the *Belemnitella mucronata* zone, where a distinct shallowing of the sea took place,

as reflected by the more arenaceous nature of the Chalk. In some ways the residues from Chalk samples and the organic content resemble the Lower Cenomanian.

The continued shallowing of the *mucronata*-chalk is shown by the Maestrichtian of Holland. Here an abundance of various species of polymorphinids occurs, often with fistulose forms. In order to make the evolutionary history of the Polymorphinidae more complete, specimens have been figured from certain horizons within the Dutch sequence.

At other horizons besides the Upper Cretaceous, abnormal, fistulose, pustulose, or hispid forms occur belonging to a variety of different genera and species. It soon becomes apparent from a study of the literature and samples from numerous horizons from Lower Jurassic to Recent, that at scattered levels these abnormal forms are produced haphazardly. They are often few in number compared with the root form. They occur in the genera *Polymorphina*, *Pyrulina*, *Pyrulinoides*, *Guttulina*, and *Globulina*. Forms ornamented with costae are extremely rare, and the majority of species are smooth or abnormally hispid, pustulose, or fistulose.

Terquem (1864), in his monograph on the Lias polymorphinids, figures two species, *Polymorphina breoni* Terquem and *P. cruciata* Terquem, and amongst the numerous figures given, a few forms occur showing hispid tests. The ornament covers all the test, and is not confined to the end-chambers only.

Amongst forms figured by Tappan (1940) from the Grayson Formation (Albian) is the species *Pyrulina longa* Tappan, an elongate form with a small but well-formed fistulose end. Tappan states (p. 114) 'aperture generally obscured by a fistulose growth which has openings at the ends of the tubes'. Apparently this species is non-hispid, non-pustulose, with well-marked sutures.

Certain Tertiary species are worthy of attention. *Globulina inaequalis* Reuss var. *spinata* Cushman and Ozawa from the Upper Oligocene bears strong spines or tubes over the whole surface, hence differing from the typical species. Terquem (1878, pl. 4, figs. 9–12) shows variation in *Globulina oviformis* Terquem, an Upper Pliocene species. Figs. 9, 10 show normal smooth forms, whereas figs. 11, 12 show numerous outgrowths which may be confined to the last chamber or distributed over the whole test. In the Tertiary of the Vienna basin d'Orbigny (1846) records *Globulina tubulosa* d'Orbigny (p. 228, pl. 13, figs. 15, 16), a smooth globular form with a stellate fistulose, but smooth outgrowth. Terquem (1878, p. 39, pl. 3, figs. 20, 21), in a monograph on the Upper Pliocene Foraminifera from Rhodes Island, shows one figure of *Polymorphina praelonga* Terquem to have a smooth fistulose outgrowth almost stellate in development.

A number of authors working on Recent forms have also recorded abnormalities. Williamson (1858, p. 72, pl. 6, fig. 150), when describing *Polymorphina lactea* (Walker) var. *fistulosa* Williamson, states '. . . develops numerous irregular expansion and tubular growths. Ends which frequently dichotomise are often open, but I believe this to be the result of accident, and that in their normal state they are mere cul-de-sacs.' This is contrary to the opinion of the present author, who has observed many open tubes in this group of fossils, some broken, but many well formed, and obviously serving as supplementary apertures.

Some species, for example *Polymorphina longicollis* Brady (1881, p. 64, pl. 73, figs. 18, 19), show later chambers only becoming hispid, coupled with the development of a long, single apertural neck, the latter often having a well-marked lip. Cushman (1923) shows

some specimens of *Polymorphina extensa* Cushman to have hispid ends with the apertures occurring on elongate narrow tubular necks.

Systematic descriptions of the various species from the Chalk are given below together with an account of the abnormalities in certain species. Specimens in the British Museum (Natural History) have the prefix BM.

SYSTEMATIC DESCRIPTIONS

Genus GLOBULINA d'Orbigny 1839

Genotype. Polymorphina (*Globulina*) *gibba* d'Orbigny.

The two genera *Apiopterina* and *Raphanulina* were proposed by Zborzewski 1834; both the figured specimens are fistulose forms. The former, with the monotypic species *Apiopterina d'Orbignyi*, appears to be a fistulose specimen of a species belonging to the genus *Pyrulina*, and the latter, *Raphanulina humboldtii*, belongs to the genus *Globulina*. However, the two genera *Apiopterina* and *Raphanulina* predate *Pyrulina* and *Globulina* respectively as pointed out by Galloway (1933), and it is possible that if the forms were accurately described (if the type specimens are still in existence), that they would replace the genera *Pyrulina* and *Globulina*.

On the grounds of common usage it is intended in the present paper to retain the genera *Pyrulina* and *Globulina*. Also, because the original descriptions take no account of the arrangement of the chambers it would be difficult to place these forms correctly.

The present author is of the opinion that the fistulose forms are abortive offshoots of more normal polymorphine species, and it is inadvisable to establish genera on this evidence.

Globulina lacrima Reuss

Text-figs. 1*a*, *b*, *k*, *l*

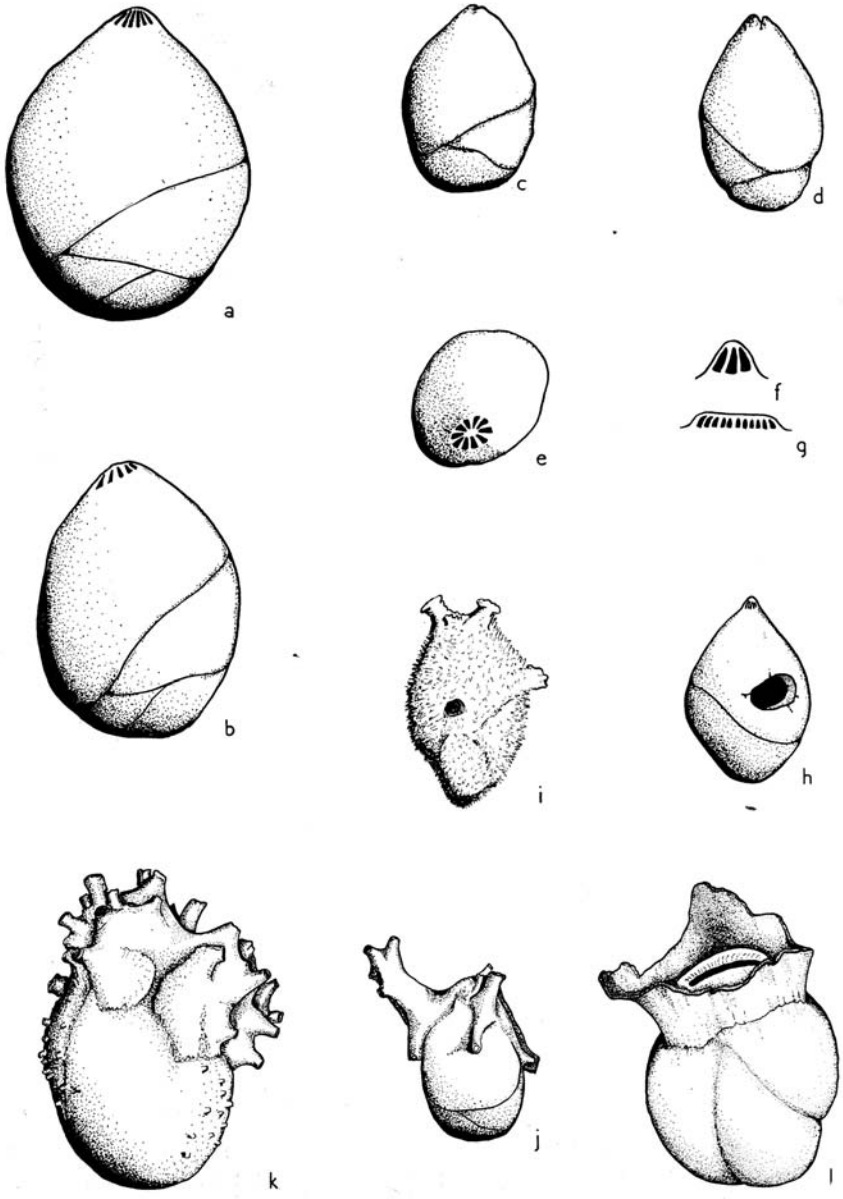
1845 *Polymorphina* (*Globulina*) *lacrima* Reuss, p. 40, pl. 12, fig. 6.
1891 *Polymorphina proteus* Beissel (pars), p. 59, pl. 11, figs. 1–6; pl. 13, fig. 83; pl. 12, figs. 9–16 (*non* 13).
1896 *Polymorphina gibba* d'Orbigny; Chapman, p. 9, pl. 2, fig. 5.
1930 *Polymorphina lacrima* Reuss; Cushman and Ozawa, p. 77, pl. 13, figs. 1, 2.
1930 *Polymorphina gibba* d'Orbigny; Hofker, p. 5, figs. 7–9.
1946 *Globulina lacrima* Reuss; Schijfsma, p. 66, pl. 7, fig. 2.
1951 *Globulina lacrima* Reuss; Visser, p. 241, pl. 4, fig. 7.
1957 *Globulina lacrima* Reuss; Hofker, p. 170, figs. 212, 213.

Globulina lacrima subsphaerica (Berthelin)

Text-figs. 1*c–j*, 3

1880 *Polymorphina subsphaerica* Berthelin, p. 58, pl. 4, fig. 18.
1957 *Globulina lacrima* Reuss var. *subsphaerica* (Berthelin); Hofker, p. 171, figs. 214, 215.

Description. The globular thick-walled smooth test shows little or no tendency to vary in shape. Smaller forms and early stages of the test show a tendency to be slightly elongated vertically. The curved sutures are flush with the surface of the test and rarely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show constrictions, so that the arrangement of the chambers is almost impossible to interpret. Occasional decorticated specimens show that there are few chambers, about five, constituting the test, and they are arranged irregularly about a vertical axis. Not only is the end-chamber large, making up one-half of the volume of the test, but it overlaps the earlier chambers.

Generally the aperture is radiate and situated on a conical protuberance, but often the aperture becomes elliptical. Numerous peculiar forms occur as offshoots from the main stock and some of these are described below.

Horizon. Zone of *Belemnitella mucronata.*

Dimensions of hypotypes:
Globulina lacrima, *a*: BM P44758. Height 1·14 mm., breadth 0·95 mm. (text-fig. 1*a*).
b: BM P44759. Height 1·06 mm., breadth 0·76 mm. (text-fig. 1*b*).
c: BM P44764. Height 1·14 mm., breadth 0·72 mm. (text-fig. 1*k*).
G. lacrima subsphaerica, *d*: BM P44760. Height 0·76 mm., breadth 0·60 mm. (text-fig. 1*c*).
e: BM P44761. Height 0·80 mm., breadth 0·53 mm. (text-fig. 1*d*).
f: BM P44762. Height 0·76 mm., breadth 0·46 mm. (text-fig. 1*i*).
g: BM P44763. Height 0·64 mm., to extension 0·84 mm., breadth 0·38 mm. (text-fig. 1*j*).

Localities. *a*, *b*, *g*: H. Attock's Pit, New Catton, Norwich, Norfolk.
d, *e*, *f*: Council's Pit, Newmarket Road, Norwich, Norfolk.
c: Earlham Limekiln, Dereham Road, Norwich, Norfolk.

The development of the Globulina lacrima *Reuss group* (text-fig. 2)

The writer considers that the large form *G. lacrima* Reuss, described above, is not the central root-stock of the group. A somewhat smaller, more abundant form, *G. lacrima* Reuss var. *subsphaerica* Berthelin, is considered to be the persistent and central form. This form is slightly elongated, but has the same general characters as *G. lacrima* Reuss, and ranges through the Upper Chalk. At certain horizons, as well as the abundant smaller tests, there occur specimens of *G. lacrima* Reuss, showing a tendency to become

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TEXT-FIG. 1. All figs. ×90, except *l* (×150).

a, *b*, *Globulina lacrima* Reuss; H. Attock's Pit, Norwich, Norfolk; *Belemnitella mucronata* Zone; normal large globular forms; *a*, BM P44758; *b*, BM P44759.

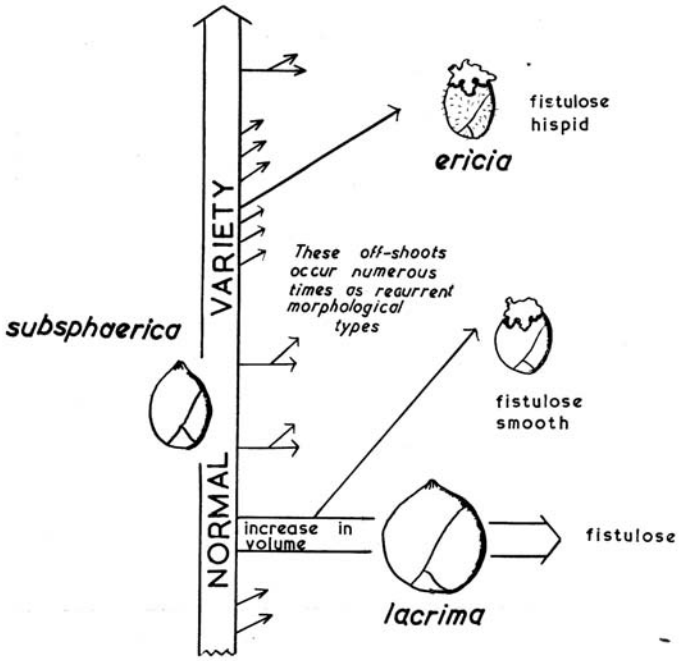
c–j, *Globulina lacrima* Reuss var. *subsphaerica* Berthelin; *Belemnitella mucronata* Zone. *c*, *d*, *i*, Council's Pit, Newmarket Road, Norwich, Norfolk; BM P44760, P44761, and P44762 respectively. *j*, H. Attock's Pit, Norwich, Norfolk; BM P44763.

c, *d*, common small variety;
e–g, showing variation of aperture;
h, broken wall to show thickness;
i, fistulose hispid variety;
j, smooth form with stellate fistulose chambers.

k, *Globulina lacrima* Reuss; Earlham Limekiln, Dereham Road, Norwich, Norfolk; *Belemnitella mucronata* Zone; BM P44764. Large form showing extremely complicated fistulose end-chamber with numerous apertures, also a tendency for pustules to develop along parts of the test wall.

l, *Globulina lacrima* Reuss, ×150. Quarry at Curfs (near Houthem), near Maastricht, Holland; Beds *Md.*, Upper Maestrichtian; BM P44771. The specimen shows an early globular stage, followed by an irregular end-chamber. This later chamber has been broken to enable the earlier apertures to be seen. The final aperture of the globular portion shows distinct signs of resorption, changing from the normal radiate aperture to a long regular slit, following the general surface of the test.

almost spherical and to increase in size. This form rarely gives rise to fistulose forms. One of these (text-fig. 1*k*) shows the large globular test of *G. lacrima* Reuss, with an irregular pustulose ornament over the initial chambers. Later a large irregular stellate outgrowth occurs, spreading down the test. This fistulose last portion of the test has numerous tube-like prolongations, at the ends of which are circular apertures which often have small but thick lips. These tube-like extensions may be arranged irregularly



TEXT-FIG. 2. A diagrammatic representation of the variation and evolution of the *Globulina lacrima* Reuss var. *subsphaerica* Berthelin group.

over the surface, or placed along the stellate outgrowths. In both cases a wide coverage of the surface area is obtained.

Many authors have stated that these fistulose outgrowths are only the last chamber; however, specimens have been obtained where several chambers are involved and the irregular portion is not just an outgrowth from the last chamber. Also in some forms the fistulose portion stretches down almost to the initial chamber, and there are connexions through the wall of the test to earlier chambers. In these forms there is often a resorption of the internal septa or chamber walls, so that the test is almost 'unilocular', except for small but regular parts of the original walls. The regularity of these 'fragments' suggests resorption rather than subsequent alteration. The fistulose globular forms occur as sporadic offshoots from the large *Globulina lacrima* Reuss stock, and occur at disconnected levels.

Throughout the longer history of *Globulina lacrima subsphaerica*, offshoots arise with several variations. For convenience these are divided into three groups:

1. *Smooth test, with fistulose outgrowths* with:
   (*a*) an irregular arrangement of a few apertures;
   (*b*) a regular arrangement of the apertures;
   (*c*) a tendency for portions of the end-chambers to become tubular with bunched tubular apertures (text-fig. 3*a*);
   (*d*) sometimes a tendency for the tubular apertures to lie along the surface of the test (text-fig. 1*j*).

2. *Pustulose test*:

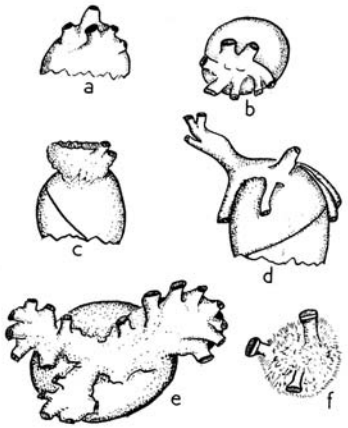
All the above types occur, but often with an irregular pustulose ornament; however, all the variants are rare.

3. *Hispid test*:

The test becomes increasingly hispid until the whole test is covered by a thick covering of small spines (text-fig. 1*i*). In this case the apertures are few in number, separated, and often raised well above the surface of the test and have well-developed lips.

The various arrangements and types of apertures are shown in text-fig. 3*a–f*. The evolution of this group of species is illustrated diagrammatically in text-fig. 2, which shows how the various morphological types fit into the pattern of development of the gens.

The dominant form or root-stock, *Globulina lacrima subsphaerica*, persists throughout the whole of the Chalk (Cenomanian to Maestrichtian). Its relative abundance varies considerably from horizon to horizon. This form gives rise repeatedly to large variants of the *G. lacrima* type, which show an increase in volume and a tendency, rarely developed, to produce fistulose, pustulose spherical forms. *G. lacrima subsphaerica* also produces smaller fistulose variants as recurrent morphological types. At scattered horizons, the smaller *G. lacrima subsphaerica* develops fistulose variants which have a hispid test ornamented by numerous short, fine spines, resembling *G. ericia* Cushman and Ozawa. A similar development has been observed by the author in specimens belonging to the gens from the Chalks of Germany, France, Holland, and Denmark.



TEXT-FIG. 3. Various apertures and fistulose outgrowths in *Globulina lacrima* Reuss var. *subsphaerica* Berthelin. *a*, *b*, Stellate arrangement of the fistulose portion. *c*, A small isolated outgrowth of the last chamber with only two apertures. *d*, The tubular apertures are either isolated and lie along the surface of the test, or are separated from it, but bunched together on a long tubular extension of the chamber. *e*, Stellate arrangement of numerous bunched apertural tubes. *f*, Hispid variety with single isolated lipped apertures.

Genus GUTTULINA d'Orbigny 1839

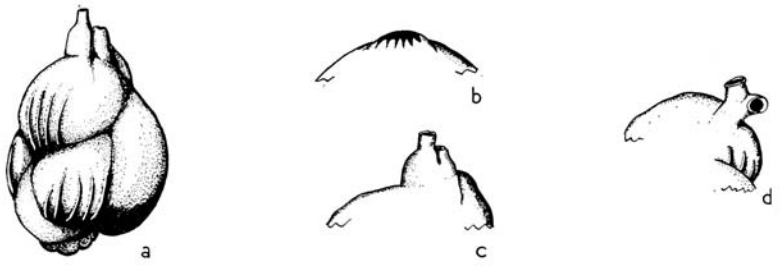
Genotype. *Polymorphina* (*Guttulina*) *communis* d'Orbigny.

Guttulina semicostata (Marsson)

Text-figs. 4*a–d*

1878 *Polymorphina semicostata* Marsson, p. 150, pl. 2, fig. 19*a–c*.
1925 *Polymorphina semicostata* Marsson; Franke, p. 78, pl. 6, fig. 21.
1930 *Guttulina semicostata* (Marsson); Cushman and Ozawa, p. 48, pl. 15, fig. 8.
1948 *Guttulina spicaeformis* Roemer; Brotzen, p. 49, figs. 10, 11.
1957 *Guttulina semicostata* (Marsson); Hofker, p. 167, fig. 206.

Description. The globular test is often slightly elongate with the broadest part more than half-way up the test. The initial end varies from broad obtuse to the more usual pointed end, a factor having a direct bearing on the ornament of the test. The chambers are rounded, inflated with well-marked, depressed sutures forming constrictions in the test.



TEXT-FIG. 4. *a*, *Guttulina semicostata* (Marsson); Earlham Limekiln, Dereham Road, Norwich, Norfolk; *Belemnitella mucronata* Zone; BM P44765, ×90. Fine costae developed on the lower portions of the chambers only. *b–d*, *Guttulina semicostata* (Marsson), showing variation in the aperture; *b*, radiate in the normal form; *c*, two tube-like apertures on an apertural chamberlet; *d*, bifurcating tube with circular apertures in the fistulose form, ×90.

Usually the chambers do not embrace the earlier ones, and form a quinqueloculine series, as each successive chamber is added farther from the base. Often the initial end is triangular in plan view. The ornament varies considerably. In some forms the chambers are angular, with coarse, broad ribs running longitudinally along the angles, which are slightly removed from the sutures.

Occasionally a similarly shaped rib runs parallel to the main costae, so that there is an almost flattened part to the chamber between the two ribs. The flat valley may either be shallow or deep. In some specimens the ribs join at the base of the first chamber and, from the node thus formed, a small point extends. Often in these forms the ribs become less pronounced and even disappear towards the distal end. In other specimens with coarse costae, the ribs along the angles of the chambers bifurcate and sometimes a third rib is interposed. The costae on the chambers usually follow the shape of the chamber and then disappear towards the distal end of each chamber. Rarer forms with twelve fine ribs to each chamber occur, and these may belong to a different species, but one specimen was found in which the development of the ribs appears to be intermediate between the two forms above. The development of fistulose forms appears to be in its early stages in the specimens at the author's disposal, for only small 'chambers' occur on the final chamber. These influence the shape of the aperture, which is normally radiate, but becomes circular and lipped in fistulose forms and may even be multiple (text-fig. 4*b–d*).

Locality. Earlham Limekiln, Dereham Road, Norwich, Norfolk.

Horizon. Zone of *Belemnitella mucronata.*

Dimensions. Height 0·84 mm., breadth 0·46 mm.

Hypotype. BM P44765 (text-fig. 4*a*).

Guttulina trigonula (Reuss)

Text-fig. 5

1845 *Polymorphina trigonula* Reuss, p. 40, pl. 13, fig. 84.
1845 *Polymorphina damaecornis* Reuss, p. 40, pl. 13, fig. 85.
1891 *Polymorphina glommerata* Roemer; Beissel (pars), p. 62, pl. 12, figs. 21–29.
1951 *Guttulina trigonula* (Reuss); Visser, p. 239, pl. 4, fig. 5.
1957 *Guttulina trigonula* (Reuss); Hofker, p. 165, fig. 203.

Description. The small test consists of a few globular or slightly elongated chambers, with deep constrictions, so that each chamber is clearly seen. The initial end is rounded, and the proloculum does not have a spine attached. The test is smooth and no fistulose forms occurred in the specimens available to the author. The terminal aperture is radiate with triangular clefts opening into a central hole.

TEXT-FIG. 5. *Guttulina trigonula* (Reuss); H. Attock's Pit, New Catton, Norwich, Norfolk; *Belemnitella mucronata* Zone; BM P44766, ×90.

Locality. H. Attock's Pit, New Catton, Norwich, Norfolk.

Horizon. Zone of *Belemnitella mucronata.*

Dimensions. Height 0·76 mm., breadth 0·57 mm.

Hypotype. BM P44766 (text-fig. 5).

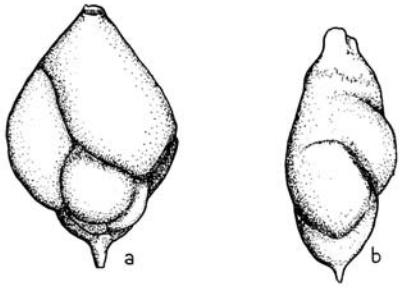
Remarks. Although Cushman and Ozawa (1930, p. 28, pl. 4, fig. 2) figure a form assigned to Reuss's species, the specimens are different and, moreover, come from the Gault Clay of Barnwell Pit near Cambridge. This is similar to the Cenomanian species described below.

Guttulina sororia (Reuss)

Text-fig. 6*a*, *b*

1862 *Polymorphina* (*Guttulina*) *sororia* Reuss, p. 121, pl. 2, figs. 25–29.
1896 *Polymorphina sororia* Reuss; Chapman, p. 12, pl. 2, fig. 11.

Description. The test is large, slightly compressed and elongated. The chambers, about seven in number, are easily visible because the sutures are deeply constricted. Earlier chambers tend to overlap. The initial chamber bears a characteristic strong conical spine. Usually the aperture is central, terminal and radiate, but occasionally there is a tendency for it to become multiple. This tendency shows the early stages of fistulose trend.



TEXT-FIG. 6*a*, *b*. *Guttulina sororia* (Reuss); Sundon Lime Quarry, near Dunstable; *Schloenbachia varians* Zone, Cenomanian; showing the apiculate early chamber; BM P44767, ×90.

Locality. Sundon Lime Quarry, near Dunstable.

Horizon. Zone of *Schloenbachia varians*.

Dimensions. *a*, Height 0·99 mm., breadth 0·65 mm. *b*, Height 1·03 mm., breadth 0·38 mm.

Hypotype. BM P44767 (text-fig. 6*a*, *b*).

Genus PYRULINOIDES Marie

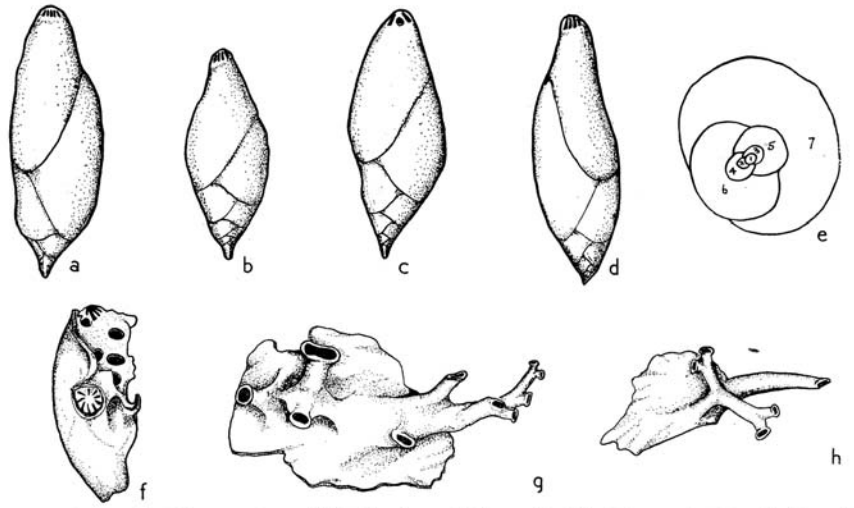
Genotype. *Pyrulina acuminata* d'Orbigny, 1840.

Pyrulinoides acuminata (d'Orbigny)

Text-figs. 7*a–h*

1840 *Pyrulina acuminata* d'Orbigny, p. 43, pl. 4, figs. 18, 19.
1941 *Pyrulinoides acuminata* (d'Orbigny); Marie, p. 170, pl. 24, figs. 243–50.
1957 *Pyrulinoides acuminata* (d'Orbigny); Hofker, p. 169, figs. 210, 211.

Description. The test is almost fusiform, long and narrow, the greatest breadth being at the centre. One side is slightly more bulbous than the other, making the test irregularly



TEXT-FIG. 7. *Pyrulinoides acuminata* (d'Orbigny). *a–d*, Council's Pit, Newmarket Road, Norwich, Norfolk; *Belemnitella mucronata* Zone; BM P44768, ×90. *e*, Showing the development of the test, and chamber arrangement. *f*, Quarry at Curfs (near Houthem), near Maastricht, Holland; Beds *Md*, uppermost Maestrichtian; BM P44772, ×90; broken to show part of the peculiar end-chamber, which has a small circular radiate aperture on a tube. The last chamber of the non-fistulose portion of the test shows part of the radiate aperture preserved, but over the remainder of the upper surface of the chamber a number of regular holes appear. It was originally thought that these may have been caused by an organism boring into the surface of the test. The holes, however, are confined to part only of the test, under the fistulose portion, and are not spread over the remainder of the surface. *g*, *h*, *?Pyrulinoides acuminata* (d'Orbigny); Quarry at Curfs (near Houthem), near Maastricht, Holland; Beds *Md*, uppermost Maestrichtian; *g*, BM P44773, *h*, BM P44774; broken specimens to show the long extension and bifurcation of the apertural tubes and the presence of lips around the apertures, ×150.

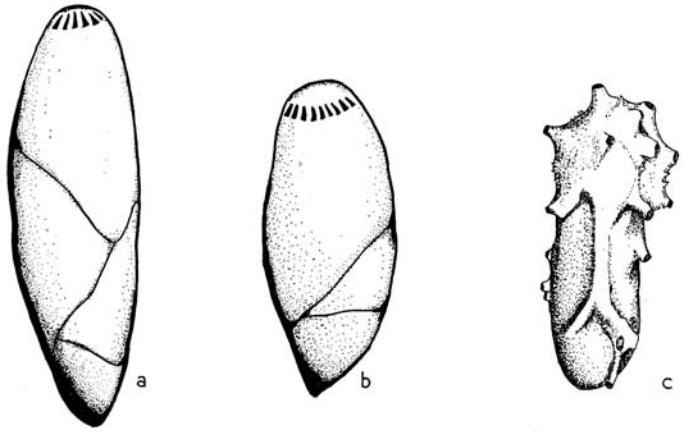
fusiform. Both the initial and apertural ends are pointed. The initial point is seen to contain several small chambers when the test is placed in aniseed oil. The end-chamber is large, elongate, and overlaps a considerable part of earlier chambers. The sutures are almost invisible, flush with the surface of the test, and show little or no constriction. The aperture is radiate, pointed, and sometimes occurs on a small prolongation of the end-chamber. No tendency towards a fistulose form was seen amongst numerous specimens.

Locality. Council's Pit, Newmarket Road, Norwich, Norfolk.

Horizon. Zone of *Belemnitella mucronata*.

Dimensions. *a*, Height 0·99 mm., breadth 0·38 mm. *b*, Height 0·91 mm., breadth 0·42 mm. *c*, Height 0·80 mm., breadth 0·38 mm. *d*, Height 0·99 mm., breadth 0·38 mm.

Hypotype. BM P44768 (text-figs. 7*a–d*).



TEXT-FIG. 8. *Pyrulina cylindroides* (Roemer). *a*, *b*, Council's Pit, Newmarket Road, Norwich, Norfolk; *Belemnitella mucronata* Zone; BM P44769, ×90. *c*, Earlham Limekiln, Dereham Road, Norwich, Norfolk; *Belemnitella mucronata* Zone; BM P44770, ×90; fistulose variety, with tubes extending back to the initial end of the test.

Genus PYRULINA d'Orbigny 1839

Genotype. *Polymorphina* (*Pyrulina*) *gutta* d'Orbigny.

Pyrulina cylindroides (Roemer)

Text-figs. 8*a–c*

1838 *Polymorphina cylindroides* Roemer, p. 385, pl. 3, fig. 26.
1930 *Pyrulina cylindroides* (Roemer); Cushman and Ozawa, p. 56, pl. 14, figs. 1–5.
1930 *Pyrulinella cylindroides* (Roemer); Hofker, p. 13, figs. 26–28.
1951 *Sigmomorphina sp*. Visser, p. 248, pl. 3, fig. 2.
1951 *Pyrulina cylindroides* (Roemer); Visser, p. 244, pl. 3, fig. 5.
1957 *Pyrulina cylindroides* (Roemer); Hofker, p. 168, figs. 207–9.

Description. The elongate test is often almost fusiform or cylindrical in shape, but this depends largely upon the shape of the last chamber. The smooth test sometimes has

fistulose outgrowths on the end-chambers, and these may be either smooth, rough, or hispid. There are about five chambers with sutures either slightly constricted, or more usually flush with the surface of the test, and difficult to see except when immersed in oil. Later chambers do not overlap, but tend to be asymmetrical with one side sagging down towards the proloculum. Later sutures are almost parallel and the test becomes nearly uniserial. The terminal aperture is large and radiate, but often the radial triangular-shaped clefts composing the aperture are placed well down from the apex of the shell so that there is a solid calcite area in the centre of the aperture. The fistulose offshoots are described below.

Horizon. Zone of *Belemnitella mucronata.*

Dimensions and hypotypes:

a, *b*, BM P44769. Height: *a*, 1·56 mm.; *b*, 1·22 mm. Breadth: *a*, 0·49 mm.; *b*, 0·49 mm. (text-figs. 8*a*, *b*).

c, BM P44770. Height 1·22 mm., breadth 0·38 mm. (text-fig. 8*c*).

Localities. *a*, *b*, Council's Pit, Newmarket Road, Norwich, Norfolk.

c, Earlham Limekiln, Dereham Road, Norwich, Norfolk.

Remarks. Cushman and Ozawa (1930, p. 56) show forms with a wide variation in shape, from cylindrical Upper Senonian specimens to fusiform types from the Albian. Most forms are cylindrical to fusiform, but not as pointed as in *Pyrulina acuminata* (d'Orbigny). Hofker's (1957) specimens are much more rounded at the initial end than Cushman's, and less cylindrical. However, a fairly wide variation does occur in shape, but more particularly in size.

The development of the Pyrulina cylindroides *(Roemer) group*

This group appears to range from the Albian to the top of the Senonian. From this long-ranged group, short-ranged forms with fistulose outgrowths arise at numerous horizons. These outgrowths seem to be less irregular than in *Globulina lacrima* (Reuss), and often show a regular connexion with earlier chambers. Forms with fistulose outgrowths often have the main part of the outgrowth with apertures concentrated on a globular end-chamber. This may be rough, or hispid with tubular apertures.

On some of these forms rib-like prolongations often extend down almost to the proloculum. These ribs have short tubular portions. When the shells possess these rib-like prolongations, the apertures along them penetrate earlier chambers. The main part of the test is smooth. Some varieties have a small, smooth, almost cylindrical early test with a blunt initial end. These have a hispid fistulose part of the test fitting on the end-chamber, and bearing tubular apertures having a stellate arrangement when viewed from the top.

Many specimens show resorption of early chambers suggesting that there is some connexion between this character and the unrestricted tubular apertures by the replacing of the constricted radiate aperture. This long-range stock shows fistulose outgrowths at numerous horizons, for example the Chalk Marl, Zone of *Schloenbachia varians*, from Dunstable (Bedfordshire); Zone of *Micraster cor-testudinarium* from Seaford Head (Sussex); and Zone of *Micraster cor-anguinum* from Northfleet (Kent).

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