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These contributions will be issued quarterly. They will contain short papers with plates, describing new forms and other interesting notes on the general research work on the foraminifera being done on the group by the workers in this laboratory. New literature as it comes to hand will be briefly reviewed.

Subscription \$2.50 per year post paid.

Volume 1, parts 1-4, April 1925—January 1926, complete \$2.50

Volume 2, parts 1-4, April 1926—January 1927, complete \$2.50

Volume 3, Part 1, March 1927,.....\$1.50

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Owing to the fact that the Volume date in the previous Volumes did not correspond with the calendar year, a change has been made in the date of publication. Volume 3 will have its parts issued in March, June, September, and December 1927, so that all numbers of the Volume will be dated 1927.

Copies of Volume 3, Part 1 were first mailed FEB 28 1927

CONTRIBUTIONS  
FROM THE  
CUSHMAN LABORATORY  
FOR  
FORAMINIFERAL RESEARCH

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39. AN OUTLINE OF A RE-CLASSIFICATION OF THE  
FORAMINIFERA.

JOSEPH A. CUSHMAN

*Lecturer in Micropalaeontology, Harvard University*

AND

*Director, Cushman Laboratory for Foraminiferal Research.*

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VOLUME 3, PART 1

MARCH 1927

SHARON, MASSACHUSETTS, U. S. A.



# CONTRIBUTIONS FROM THE CUSHMAN LABORATORY FOR FORAMINIFERAL RESEARCH

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## 39. AN OUTLINE OF A RE-CLASSIFICATION OF THE FORAMINIFERA.

JOSEPH A. CUSHMAN

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Very much has been published in the last twenty years on different groups of the Foraminifera looking toward a more natural grouping. The necessity of presenting this to graduate students in Harvard University has made imperative the concentration of the results of this work in an outline form. With the already published work has been incorporated the results of my own notes accumulated during twenty-five years of active work on the foraminifera. Believing that the results of this work toward a natural grouping of the foraminifera would be useful, especially to those now teaching the subject and the many new workers in the field, they are here published in outline until they may later be incorporated in a larger and more nearly complete form. Some of the genera proposed are purposely left out in this outline as it is often difficult unless one can study actual specimens and especially sections of the young to place them accurately.

Too much stress can hardly be laid upon the necessity of studying specimens rather than figures and of sections showing the early stages as well as the external characters. In this way, relationships are often revealed that would be hardly suspected otherwise. Abundance of material is essential as the microspheric form is often comparatively rare and only in this form are the early stages preserved in their more detailed sequence. Megalospheric specimens skip many of these early stages so essential for the real understanding of the relationships. In general the



microspheric form is retrospective, going back and repeating in its young many of the stages in its ancestry while the megalospheric form is prophetic and although skipping certain of the early stages, arrives at the stages of adult development earlier and may take on later characters not developed in the microspheric form.

There are certain very definite characters which the group tends toward. In the early development, stages become more complex, the simple tubular form becomes divided into chambers, the arrangement of the chambers becomes more complex to a certain climax, then repeats the earlier stages of the young in reverse order. Coiled forms may become biserial, then triserial, back to biserial, and then to uniserial, but usually not coiled again. Through parallelism, many groups although starting along different lines have come to develop a test of chambers in a rectilinear group and then to single chambered forms. The group of *Lagena* for example contains many of these single-chambered end forms which have been derived from different groups and belong really in different families. The same is true of many other "generic" groups. Further study, especially of large suites of specimens and in particular of fossil species must be made before the final grouping of many of these will be determined.

The form of the adult test has been used as the basis of classification in most earlier groupings. This is not alone sufficient as may be easily demonstrated. It is only the earlier stages that will give the true relationships, and these in the microspheric form. The material of the test is an essential character and has been held for very long periods through the fossil sequence. For example in the Pennsylvanian, I have seen *Ammodiscus* with a *Tolypammima* attached to it, both showing a reddish color in the arenaceous wall as do the two genera in the present ocean in the same association.

H. Douvillé (Bull. Soc. Geol. France, ser. 4, vol. 6, 1906, p. 588 et seq.) has given some statements along the line of classification that are adopted here and can hardly be improved upon. "The foraminifera are all derived from a fundamental form which is spirally coiled and symmetric." This is true for most groups and the spiral forms of *Ammodiscus*, *Spirillina* and *Cornuspira* with their modifications into spirals of various types form early simple genera in most of the more primitive families in this outline. The exception to this is seen in the early and very primi-

tive families in the arenaceous group which have been derived directly from the Allogromiidae or simple related forms.

The stages in the development of the foraminiferal test as given by Douvillé are also logical and agree with the known facts. The earliest foraminifera were nude, next developed chitinous tests, later added foreign material to form the arenaceous test, and in the highest forms developing a calcareous test. These characters of the test are fundamental, and represent deep-seated physiologic expression. There is no actual evidence that I have ever seen that a form which has developed a secreted, perforated calcareous test ever returns to an arenaceous test with ferruginous cement. Many of the developmental characters will be enlarged upon elsewhere (See Amer. Journal Science).

The contribution of many workers who have added much new material in the way of developmental stages and new generic forms has made possible a more nearly complete understanding of the Foraminifera. Carpenter's researches on the inner structure of the larger forms opened the way. To Munier-Chalmas and Schlumberger must be given great credit for really making clear the essential value of the study of early stages from thin sections. Since their day, much has been accomplished. In England the work of Heron-Allen and Earland, Hickson, Lister, Nuttall and Sidebottom has contributed much. On the continent in later years, H. and R. Douvillé, Egger, Fornasini, Franke, Hofker, Lange, Liebus, Martinotti, Paalзов, Rhumbler, Schellwein, Schubert, A. Silvestri, Spandel, Toula, and many others have contributed greatly to our understanding of numerous genera. In Japan, Yabe with Hanzawa and Ozawa have added both to the recognized new genera and the stages of development of old ones. Chapman, with his work covering Australia and other regions as well, has given numerous new genera to fill gaps in the existing classification.

This is entirely exclusive of the very concentrated work done by a host of workers on the special groups of the Fusulinidae, the Nummulitidae and the Orbitoididae which, as a result, have a literature all their own.

The clearer understanding of the relationships expressed in this outline is therefore but in very small part my own but is rather a result of slow growth from many sources and much is still to be done before it is at all complete. The study of sections of many fossil species especially of microspheric forms will

be found to add greatly to our existing knowledge of relationships.

The nomenclature especially as it relates to genera is much confused, and I have here adopted older names only where it seems that it cannot be avoided. The study of early types especially those which are still extant in Europe should be undertaken, as the earlier figures are often inadequate. Some of the earlier genera such as *Discorbis*, *Rotalia*, *Eponides*, *Archais*, *Cibicides*, etc. are readily distinguishable if material from the type localities is studied. In other genera proposed by early authors, an evident mixture of genera makes the early name of too doubtful a character to be used unless actual type specimens are in existence. Such names as *Tinoporus*, *Pyrgo*, *Planularia*, etc. come under this group. No good purpose can be served by adopting such questionable names until type specimens can be studied if they actually exist.

Most of the genera in the present outline are illustrated on the plates. In a number of the families, the relationship of the various genera is indicated by arrows on the plates. A table is also given showing the apparent relationships of the various families. The number of families is much increased to more nearly represent those in other groups of animals. The increased number will be found not to represent a complexity but rather a simplicity over the older families which contained many remotely related forms. An earlier paper—An Introduction to the Morphology and Classification of the Foraminifera, (Smithsonian Misc. Coll., vol. 77, No. 4, 1925)—will serve to connect the present classification with that of the earlier literature. Numbers are given to the families for easy reference rather than to show their relationships, a thing obviously impossible in a single numerical sequence. To my daughter, Alice E. Cushman, I am indebted for help in getting into outline form the mass of accumulated data.

## ORDER FORAMINIFERA.

## FAMILY 1. ALLOGROMIIDAE.

The foraminifera included in this family are the simplest in the whole order. For the most part they are found in fresh or brackish water. The pseudopodia are relatively simple, the body is without a test, or has one of simple chitin which in some genera has foreign material attached to the surface. The family therefore illustrates well the early and primitive characters of the group. Due to the character of the test, they are not found as fossils. The grouping of the subfamilies and genera is practically that given by Rhumbler. Owing to their impermanent character of test and fresh water or brackish habitat, they are rarely seen or studied by workers on the foraminifera. The Myxothecinae are often not included as true foraminifera.

Subfamily 1—*Myxothecinae*.

Genus *Schultzella* Rhumbler.

“ *Myxotheca* Schaudinn.

“ *Boderia* Str. Wright.

“ *Plagiophrys* Claparede and Lachman.

“ *Dactylosaccus* Rhumbler.

Subfamily 2—*Allogromiinae*.

Genus *Allogromia* Rhumbler.

“ *Lieberkuhnia* Claparede and Lachman.

“ *Shepherdella* Siddall.

“ *Rhynchosaccus* Rhumbler.

“ *Rhynchogromia* Rhumbler.

“ *Diplogromia* Rhumbler.

“ *Echinogromia* Schrod.

“ *Amphitrema* Archer.

“ *Diaphoropodon* Archer.

## FAMILY 2. ASTRORHIZIDAE.

Test free consisting of a central chamber from which radiate tubular channels to the exterior, either simple or branching; wall with a chitinous lining, arenaceous or of foreign material.

Genus: ASTRORHIZA Sandahl, 1857 (Pl. 1, fig. 1).—Test stellate or subcylindrical, wall of loosely cemented mud or sand with little selection.—Jurassic to Recent.

Genus *MASONELLA* H. B. Brady, 1889 (Pl. 1, fig. 2).—Test stellate, much compressed, central chamber large, tubules fine, branching, with a very thin arenaceous layer between, in a single plane.—Recent.

Genus *RHABDAMMINA* W. B. Carpenter, 1869 (Pl. 1, fig. 4).—Test radiate, subcylindrical or branching, wall firmly cemented, showing some selection of materials.—Jurassic to Recent.

Genus *CRITHIONINA* Goës, 1894 (Pl. 1, fig. 3).—Test spherical or lenticular, usually with a central chamber from which branching tubes radiate to the surface, wall thick, soft, of sponge spicules and fine sand or mud.—Recent.

Genus *VANHOEFFENELLA* Rhumbler, 1905.—Test composed of an outer polygonal tubular chamber with openings at the angles, the inner portion very thin, chitinous, with a central mass of protoplasm with radial lines of protoplasm to the outer ring.—Recent.

The members of this family are very simple in structure; a single chamber with numerous connections with the exterior, either in one plane or spherical, wall of very slightly selected material. Such forms are primitive and represent little more than the chitinous members of the *Allogromiidae* with the material of their environment built up about the channels by which the protoplasm streams to the exterior. As they are usually rather loosely cemented and difficult of recognition in the fossil state most of the records are from recent material. *Rhabdammina* and *Astorhiza* which are the most firmly cemented have been recorded as far back as the Jurassic, and it will probably be found that their history is much older than this, owing to the difficulty of recognizing fossils of this character in the older rocks.

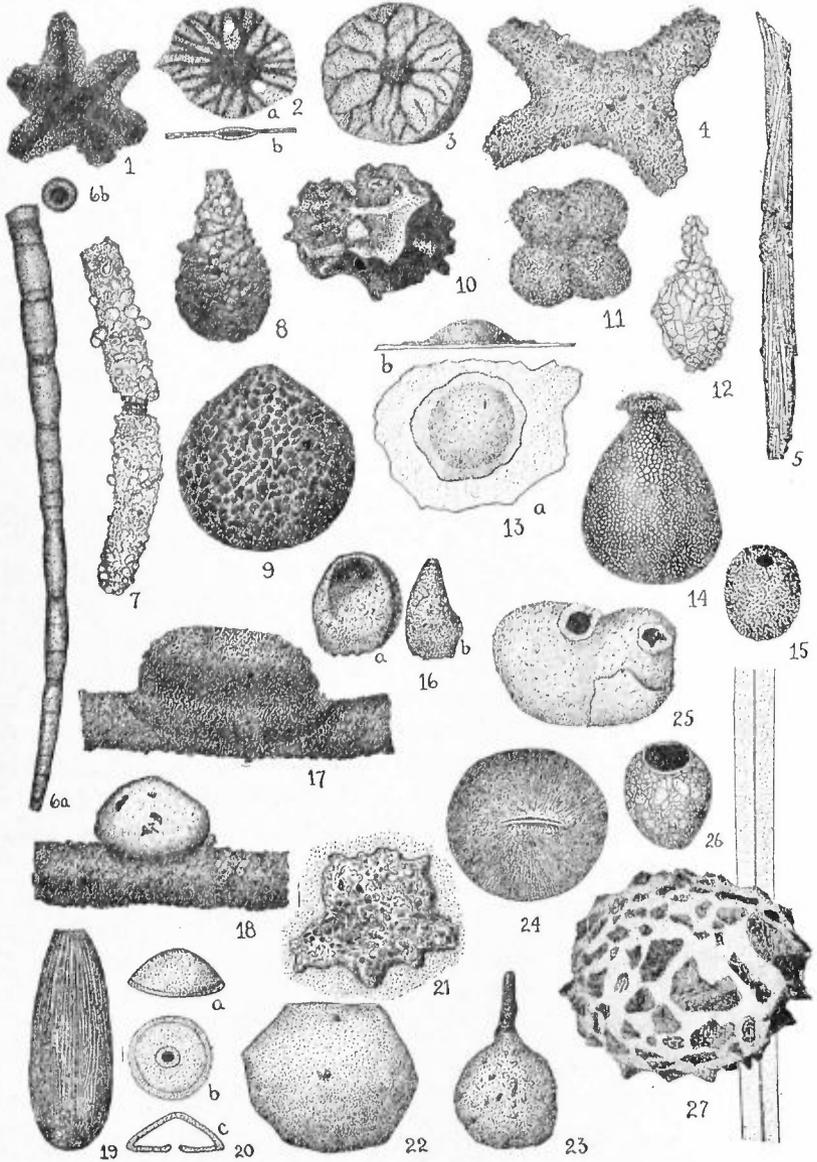
### FAMILY 3. RHIZAMMINIDAE.

Test consisting of a tubular chamber opening at both ends, with a chitinous lining, the exterior of foreign material.

Genus *MARSIPELLA* Norman, 1878 (Pl. 1, fig. 5).—Test generally cylindrical or fusiform, wall of sand grains with added sponge spicules especially near the open ends.—Jurassic to Recent.

Genus *BATHYSIPHON* M. Sars, 1871 (Pl. 1, fig. 6).—Test cylindrical or tapering, wall of spicules and fine arenaceous material with much cement.—Cretaceous to Recent.

Genus *RHIZAMMINA* H. B. Brady, 1879 (Pl. 1, fig. 7).—



Test a simple or dichotomously branching chitinous tube with the exterior covered with foreign materials.—Cretaceous to Recent.

Genus BRACHYSIPHON Chapman, 1906.—Test roughly cylindrical; wall with a chitinous lining covered with sand grains and tests of other foraminifera; apertures, the open ends of the short tube.—Recent.

Such forms as those included in this family having a chitinous wall and tubular chamber open at the ends may have been directly derived from such a simple form as *Shepherdella* in the Allogromiidae.

#### FAMILY 4. SACCAMMINIDAE.

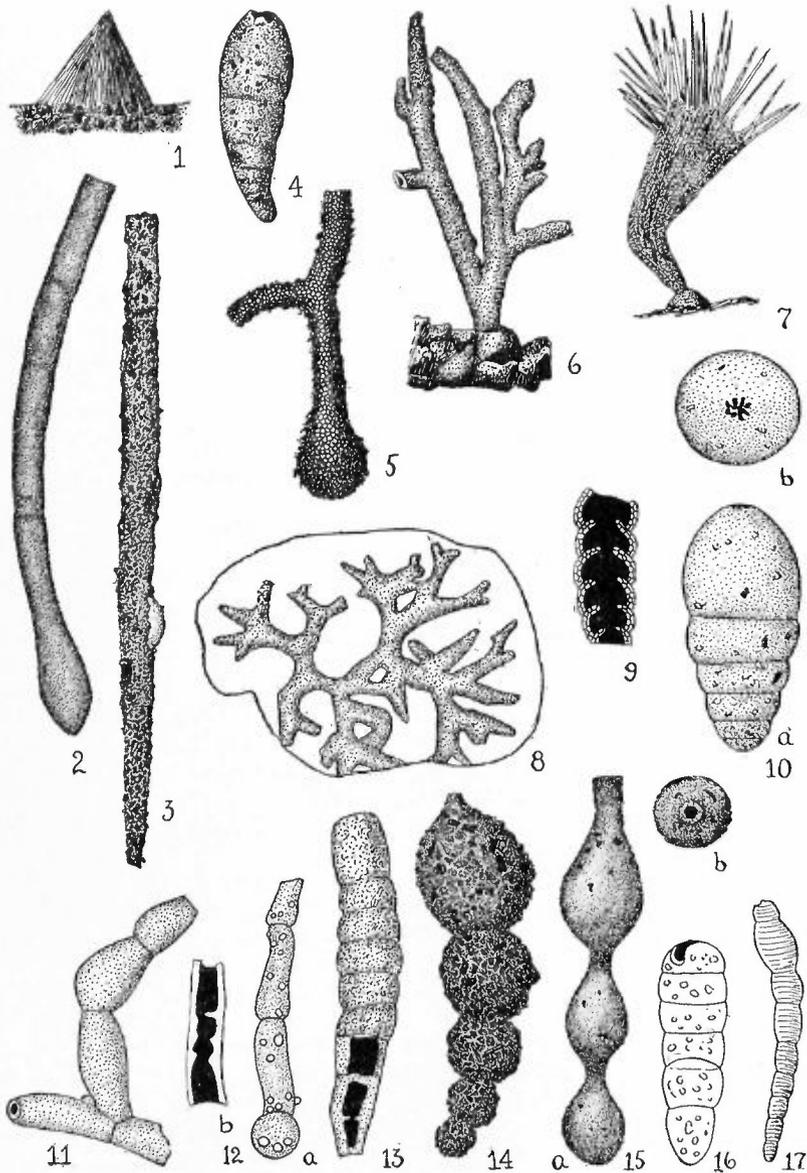
Test composed of a single chamber, wall lined with chitin, exterior of agglutinated material.

#### EXPLANATION OF PLATE 1.

##### ASTRORRHIZIDAE, RHIZAMMINIDAE, SACCAMMINIDAE.

#### FIG.

- 1—*Astrorhiza arenaria* Norman. (After H. B. Brady.)
- 2—*Masonella planulata* H. B. Brady. (After H. B. Brady.)
- 3—*Crithionina rotundata* Cushman.
- 4—*Rhabdammina abyssorum* W. B. Carpenter.
- 5—*Marsipella cylindrica* H. B. Brady.
- 6—*Bathysiphon rufus* de Folin.
- 7—*Rhizammina indivisa* H. B. Brady.
- 8—*Proteonina difflugiformis* (H. B. Brady).
- 9—*Saccamina sphaerica* G. O. Sars. (After H. B. Brady.)
- 10—*Storthosphaera albida* F. E. Schultze. (After H. B. Brady.)
- 11—*Sorosphaera confusa* H. B. Brady. (After H. B. Brady.)
- 12—*Lagenammina laguncula* Rhumbler. (After Rhumbler.)
- 13—*Webbinella hemisphaerica* (H. B. Brady).
- 14—*Lagunculina urnula* (Gruber). (After Gruber.)
- 15—*Marsupulina schultzei* Rhumbler. (After Schultze.)
- 16—*Millettella pleurostomelloides* (Millett). (After Millett.)
- 17—*Verrucina rudis* Goës.
- 18—*Tholosina bulla* (H. B. Brady).
- 19—*Technitella legumen* Norman.
- 20—*Pseudarcella rhumbleri* Spandel. (After Spandel.)
- 21—*Iridia diaphana* Heron-Allen and Earland. (After Heron-Allen and Earland.)
- 22—*Thurammina papillata* H. B. Brady. (After H. B. Brady.)
- 23—*Pelosina rotundata* H. B. Brady. (After H. B. Brady.)
- 24—*Pilulina jeffreysii* W. B. Carpenter. (After Carpenter.)
- 25—*Ammosphaeroides distoma* Cushman.
- 26—*Urnulina difflugiaeformis* Gruber. (After Gruber.)
- 27—*Psammosphaera parva* Flint.



## Subfamily 1. Psammosphaerinae.

Test without a definite aperture.

Genus PSAMMOSPHAERA F. E. Schulze, 1875 (Pl. 1, fig. 27).—Test free or attached, without a definite aperture; wall of sand grains, mica flakes, sponge spicules or other foraminiferal tests, firmly cemented.—Jurassic to Recent.

Genus SOROSPHERA H. B. Brady, 1879 (Pl. 1, fig. 11).—Test a colony of inflated chambers without definite apertures, wall arenaceous.—Recent.

Genus STORTHOSPHERA F. E. Schulze, 1875 (Pl. 1, fig. 10).—Test free, irregularly rounded, wall thick, of fine whitish sand very loosely cemented, no visible aperture.—Middle Oligocene to Recent.

## Subfamily 2. Saccammininae.

Test free, with a definite aperture, wall of firmly agglutinated sand or sponge spicules.

Genus SACCAMMINA W. B. Carpenter, 1869 (Pl. 1, fig. 9).—Test globular, of a single layer of sand grains firmly cemented, aperture circular often with a short neck.—Carboniferous to Recent.

Genus PROTEONINA Williamson, 1858 (Pl. 1, fig. 8).—Test fusiform or flask-shaped, wall of sand grains, mica flakes or other foreign material firmly cemented; aperture usually circular, typically with a neck.—Jurassic to Recent.

## EXPLANATION OF PLATE 2.

## SACCAMMINIDAE, HYPERAMMINIDAE, REOPHACIDAE.

## FIG.

- 1—*Rhaphidoscene conica* Vaughan-Jennings. (After Vaughan-Jennings.)
- 2—*Hyperammina laevigata* J. Wright.
- 3—*Jaculella obtusa* H. B. Brady.
- 4—*Hippocrepina indivisa* Parker. (After H. B. Brady.)
- 5—*Saccorhiza ramosa* (H. B. Brady). (After H. B. Brady.)
- 6—*Dendrophrya erecta* Strethill Wright. (After H. B. Brady.)
- 7—*Haliphysema tumanowiczii* Bowerbank. (Adapted from H. B. Brady.)
- 8—*Sagenina divaricans* H. B. Brady. (After H. B. Brady.)
- 9—*Ammofrondicularia angusta* Schubert. (After Schubert.)
- 10—*Haplostiche dubia* (d'Orbigny). *a*, front view, *b*, apertural view.
- 11—*Aschemonella catenata* Norman. (After H. B. Brady.)
- 12—*Kalamopsis vaillanti* Folin. (After Folin.) *a*, front view, *b*, section.
- 13—*Nodosinella cylindrica* H. B. Brady. (After H. B. Brady.)
- 14—*Reophax pilulifer* H. B. Brady.
- 15—*Hormosina ovicula* H. B. Brady. *a*, front view, *b*, apertural view.
- 16—*Turriclavula interjecta* Rhumbler. (After Rhumbler.)
- 17—*Nodellum membranaceum* (H. B. Brady). (After H. B. Brady.)

Genus *LAGENAMMINA* Rhumbler, 1911 (Pl. 1, fig. 12).—Test bottle-shaped, wall a layer of chitin with foreign bodies attached to the exterior; aperture rounded.—Recent.

Genus *LAGUNCULINA* Rhumbler, 1903 (Pl. 1, fig. 14).—Test flask-shaped, the wall of fine sand grains, aperture circular with a neck and flaring lip.—Recent.

Genus *MILLETTELLA* Rhumbler, 1903 (Pl. 1, fig. 16).—Test ovate, wall thick, finely arenaceous; aperture curved in a depression at one side of the test.—Recent.

Genus *MARSUPULINA* Rhumbler, 1903 (Pl. 1, fig. 15).—Test ovate, wall arenaceous, aperture rounded at one side near the end.—Recent.

Genus *URNULINA* Gruber, 1884 (Pl. 1, fig. 26).—Test obovate, initial end pointed, apertural end broad; wall arenaceous; aperture terminal, large, rounded.—Recent.

Genus *PSEUDARCELLA* Spandel, 1909 (Pl. 1, fig. 20).—Test planoconvex, base flat, dorsal side convex; wall chitinous; aperture circular in the middle of the ventral face.—Oligocene.

Genus *AMMOSPHAEROIDES* Cushman, 1910 (Pl. 1, fig. 25).—Test subglobular; wall finely arenaceous, with much cement; apertures two, each at the end of a short tube.—Recent.

Genus *THURAMMINA* H. B. Brady, 1879 (Pl. 1, fig. 22).—Test spherical or compressed; wall finely arenaceous with some chitin and much cement; apertures numerous at the end of small protuberances.—Carboniferous to Recent.

#### Subfamily 3. Pelosininae.

Test free, wall typically of matted spicules and fine amorphous material. Aperture usually single.

Genus *PELOSINA* H. B. Brady, 1879 (Pl. 1, fig. 23).—Test rounded or elongate; wall with a chitinous base covered with loosely agglutinated fine particles; aperture typically single and terminal, rounded.—Carboniferous (?) to Recent.

Genus *TECHNITELLA* Norman, 1878 (Pl. 1, fig. 19).—Test elongate, oval or fusiform; wall of sponge spicules and fine sand; aperture rounded, terminal.—Recent.

Genus *PILULINA* W. B. Carpenter, 1870 (Pl. 1, fig. 24).—Test globular or ovate; wall of felted spicules and very fine sand; aperture elongate, in a slightly depressed area.—Recent.

#### Subfamily 4. Webbinellinae.

Test attached, wall of agglutinated foreign material.

Genus *WEBBINELLA* Rhumbler, 1903 (Pl. 1, fig. 13).—Test circular in outline, central portion convex surrounded by a flat

border; wall of fine sand grains and much cement; no general aperture, pseudopodia thrust out along basal rim.—Carboniferous to Recent.

Genus IRIDIA Heron-Allen and Earland, 1914 (Pl. 1, fig. 21).—Test irregular, dorsal side convex; wall with a chitinous lining with the exterior of foreign material, aperture not apparent.—Recent.

Genus RHAPHIDOSCENE Vaughan Jennings, 1896 (Pl. 2, fig. 1).—Test conical, base broad, apex pointed; wall of sponge spicules placed lengthwise of the cone with a white cement and fine amorphous material; aperture indistinct, at the apex.—Recent.

Genus THOLOSINA Rhumbler, 1895 (Pl. 1, fig. 18).—Test hemispherical; wall finely arenaceous with much cement; aperture consisting of fine openings along the outer rim at the base. Recent.

Genus VERRUCINA Goës, 1896 (Pl. 1, fig. 17).—Test irregular, ovoid; interior somewhat labyrinthic; wall coarsely arenaceous; aperture usually double in a depressed area in the middle of the dorsal side.—Recent.

These single-chambered arenaceous forms are closely allied to *Allogromia* and others of the same family. They show a considerable degree of selective power in the materials of the test and in a few genera, show signs of being subdivided. *Thuramina* is a peculiar form which may be a specialized genus derived from some of the higher arenaceous forms as it sometimes contains a series of smaller chambers within.

## FAMILY 5. HYPERAMMINIDAE.

Test free or attached, consisting of a globular proloculum and a more or less elongated, but not close-coiled, sometimes branching, portion, not divided into chambers; wall of various agglutinated materials.

### Subfamily 1. Hyperammininae.

Test free, simple.

Genus HYPERAMMINA H. B. Brady, 1878 (Pl. 2, fig. 2).—Test cylindrical, simple; wall of cemented sand grains; aperture formed by the open end of the tube.—Cambrian (?) Silurian to Recent.

Genus JACULELLA H. B. Brady, 1879 (Pl. 2, fig. 3).—Test conical, widest at the apertural end, wall of cemented sand

grains; aperture circular, formed by the open end of the tube.—Tertiary and Recent.

Genus HIPPOCREPINA Parker, 1870 (Pl. 2, fig. 4).—Test elongate, tapering; wall thin, finely arenaceous with much cement; aperture curved or irregular, sometimes with a raised lip. Pliocene to Recent.

Subfamily 2. Dendrophryinae.

Test attached, usually branching.

Genus SACCORHIZA Eimer and Fickert, 1899 (Pl. 2, fig. 5).—Test cylindrical, branching, wall arenaceous, the exterior with projecting sponge spicules; apertures formed by the open ends of the tubes.—Jurassic to Recent.

Genus DENDROPHRYA Str. Wright, 1861 (Pl. 2, fig. 6).—Test tubular, simple or branching; wall arenaceous with a chitinous base; apertures at the ends of the arms.—Cretaceous to Recent.

Genus HALIPHYSEMA Bowerbank, 1862 (Pl. 2, fig. 7).—Test columnar, simple or branched, with a spreading base; wall arenaceous with many sponge spicules; apertures terminal, partially obscured by clustered sponge spicules.—Recent.

Genus SAGENINA Chapman, 1900 (Pl. 2, fig. 8).—Test dichotomously branching; wall arenaceous; apertures at the ends of the tubes.—Silurian (?), Jurassic to Recent.

Genus PSAMMATODENDRON Norman, 1881.—Test attached by the bulbous proloculum, rest of test free, erect, dichotomously branching; wall arenaceous; apertures at the ends of the tubes.—Recent.

Genus SYRINGAMMINA H. B. Brady, 1883.—Test with many branching arms or masses of anastomosing tubes; wall finely arenaceous; apertures at the ends of the tubes.—Recent.

Genus OPHIOTUBA Rhumbler, 1894.—Test irregularly winding; wall chitinous; aperture at the open end of the tube; attached to the interior of larger foraminiferal tests.—Recent.

Genus DENDROTUBA Rhumbler, 1894.—Test irregularly winding and anastomosing; wall chitinous; apertures, the open ends of the tubes. Attached to the interior of other foraminifera. Recent.

The foraminifera included in this family have their beginnings well back in the Palaeozoic. The simple globular proloculum and elongated undivided second chamber is a primitive character. From forms such as *Hyperammia* by division of the tubular

chamber have come the Reophacidae which also developed very early in the geologic series.

#### FAMILY 6. REOPHACIDAE.

Tests consisting of a generally rectilinear series of chambers typically increasing in size as added; wall arenaceous with a chitinous lining.

##### Subfamily 1. Aschemonellinae.

Chambers irregular.

Genus ASCHEMONELLA H. B. Brady, 1879 (Pl. 2, fig. 11).—Test with several tubular or inflated chambers in a single or branching series; wall thin, arenaceous; apertures at the ends of the tubular necks.—Cretaceous to Recent.

Genus HOSPITELLA Rhumbler, 1913.—Test a series of connected chambers in the interior of larger tests; wall chitinous; aperture, the open end of the test.—Recent.

Genus KALAMOPSIS de Folin, 1882 (Pl. 2, fig. 12).—Test subcylindrical, a globular proloculum and an irregular series of linear chambers; wall of much cement with a very little arenaceous material; aperture rounded, at the end of the tube.

##### Subfamily 2. Reophacinae.

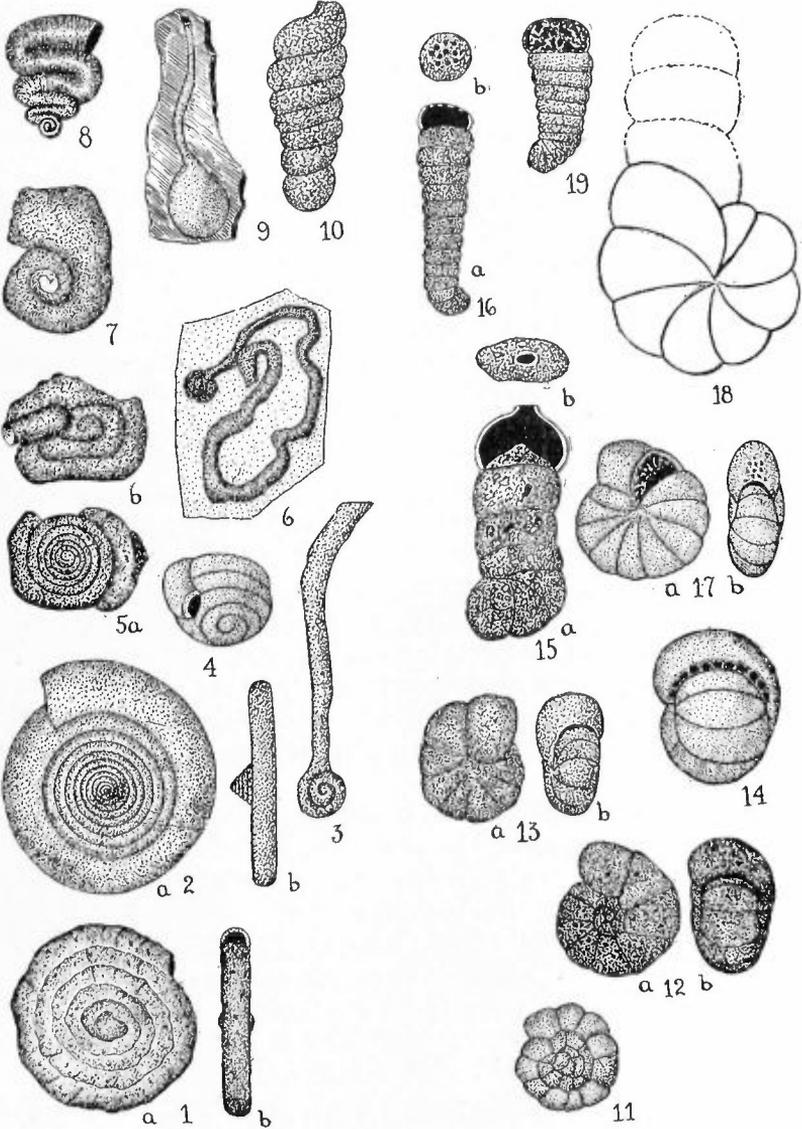
Chambers usually in a regular rectilinear series.

Genus REOPHAX Montfort, 1808 (Pl. 2, fig. 14).—Test elongate, of several undivided chambers ranging from overlapping to remotely separated ones connected by stolon-like necks; wall of agglutinated material, sand grains, mica scales, spicules, or other foraminifera; aperture simple, terminal.—Jurassic to Recent.

Genus NODOSINELLA H. B. Brady, 1876 (Pl. 2, fig. 13).—Test straight or arcuate, chambers usually distinct, sometimes labyrinthic; wall finely arenaceous, imperforate; aperture usually simple and terminal.—Carboniferous to Cretaceous.

Genus HORMOSINA H. B. Brady, 1879 (Pl. 2, fig. 15).—Test straight or irregular, chambers undivided more or less closely placed; wall usually thin, finely arenaceous, with an excess of cement; aperture circular, terminal or sometimes at one side, often with a neck.—Jurassic to Recent.

Genus HAPLOSTICHE Reuss, 1861 (Pl. 2, fig. 10).—Test with the interior of the chambers labyrinthic; walls thick, coarsely arenaceous, smoothly finished; aperture in the young simple, in the adult of several pores or dendritic, occasionally with a short neck.—Carboniferous (?), Jurassic to Recent.



Genus AMMOFRONDICULARIA Schubert, 1902 (Pl. 2 fig. 9).—Test compressed, the chambers overlapping; wall arenaceous; aperture elliptical, terminal.—Lower Oligocene.

Genus TURRICLAVULA Rhumbler, 1911 (Pl. 2, fig. 16).—Test chitinous, with some arenaceous material; chambers few; in a rectilinear series; aperture elongate, elliptical, terminal.—Recent.

Genus NODELLUM Rhumbler, 1913 (Pl. 2, fig. 17).—Test chitinous, of numerous slightly inflated chambers in a rectilinear series; aperture rounded, terminal.—Cretaceous, Recent.

The various forms included in this family have probably had their origin in such forms as *Hyperammia* by the division of the tubular chamber into many small chambers. There is a regular series from the simple *Reophax* to *Haplostiche* which is labyrinthic and with a cribrate aperture. The entirely chitinous *Nodellum membranaceum* (H. B. Brady) is found in deep water. In the largest megalospheric forms of *Hormosina*, a single-chambered form is developed hardly separable from some species of *Saccammia* except by the apertural characters.

## EXPLANATION OF PLATE 3.

## AMMODISCIDAE, LITUOLIDAE.

## FIG.

- 1—*Ammodiscus incertus* (d'Orbigny). *a*, side view, *b*, peripheral view.
- 2—*Ammodiscoides turbinatus* Cushman. *a*, side view, *b*, peripheral view.
- 3—*Lituotuba lituiformis* (H. B. Brady).
- 4—*Glomospira charoides* (Jones and Parker). (After H. B. Brady.)
- 5—*Hemidiscus carnicus* Schellwein. (After Schellwein.) *a*, *b*, from opposite sides.
- 6—*Tolypammia vagans* (H. B. Brady).
- 7—*Psammonyx vulcanicus* Doderlein. (After Rhumbler.)
- 8—*Psammophis inversus* Schellwein. (After Schellwein.)
- 9—*Ammolagena clavata* (Parker and Jones).
- 10—*Turritellella shoneana* (Siddall). (After Rhumbler.)
- 11—*Trochamminoides proteus* (Karrer).
- 12—*Haplophragmoides scitulum* (H. B. Brady). (After H. B. Brady). *a*, side view, *b*, apertural view.
- 13—*Endothyra bowmanni* Phillips. (After H. B. Brady.) *a*, side view, *b*, apertural view.
- 14—*Cribrostomoides bradyi* Cushman. (After H. B. Brady.)
- 15—*Ammobaculites calcareum* (H. B. Brady). *a*, side view, *b*, apertural view.
- 16—*Haplophragmium lituolinoideum* (Goës). *a*, side view, *b*, apertural view.
- 17—*Cyclammia pauciloculata* Cushman. *a*, side view, *b*, apertural view.
- 18—*Pseudocyclammia lituus* (Matajiro). (After Neumann and Neumayr.)
- 19—*Lituola mexicana* Cushman.

## FAMILY 7. AMMODISCIDAE.

Test composed of a globular proloculum and long undivided tubular second chamber, usually closely coiled, at least in the young, planospirally or in changing planes or to form a spiral test; wall of fine sand with much cement; usually a reddish or yellowish brown, aperture formed by the open end of the tubular chamber.

Genus *AMMODISCUS* Reuss, 1861 (Pl. 3, fig. 1).—Test free, planospiral, coiled regularly in one plane.—Silurian to Recent.

Genus *AMMOLAGENA* Eimer and Fickert, 1899 (Pl. 3, fig. 9).—Test attached, proloculum oval, tubular chamber variously winding.—Carboniferous (?) to Recent.

Genus *TOLYPAMMINA* Rhumbler, 1895 (Pl. 3, fig. 6).—Test attached, with the early portion coiled, later portion irregular.—Carboniferous to Recent.

Genus *AMMODISCOIDES* Cushman, 1909 (Pl. 3, fig. 2).—Test free, early portion forming a hollow cone, later portion flaring in a flattened coil.—Recent.

Genus *GLOMOSPIRA* Rzehak, 1888, (Pl. 3, fig. 4).—Test free, the tubular chamber winding about its earlier coils in various planes.—Carboniferous to Recent.

Genus *PSAMMOPHIS* Schellwein, 1897 (Pl. 3, fig. 8).—Test attached, early portion coiled, later and larger portion bending back and forth generally progressing forward in one general direction.—Carboniferous to Jurassic.

Genus *HEMIDISCUS* Schellwein, 1897 (Pl. 3, fig. 5).—Test in the young planospiral, later with the coils partially covering the flattened side.—Carboniferous.

Genus *LITUOTUBA* Rhumbler, 1895 (Pl. 3, fig. 3).—Test coiled in the young, later with an elongate uncoiled tubular portion, sometimes constricted but not into true chambers.—Carboniferous to Recent.

Genus *TURRITELLELLA* Rhumbler, 1903 (Pl. 3, fig. 10).—Test free, coiled in an elongate, close spiral.—Recent.

Genus *PSAMMONYX* Doderlein, 1892 (Pl. 3, fig. 7).—Test free, early portion loosely coiled, later uncoiled, compressed, flaring.—Recent.

The forms included under this family represent primitive tests similar to those from which many of the multilocular forms of the higher groups of the arenaceous foraminifera took their

origin. The simplest of them are among the oldest known of the foraminifera.

### FAMILY 8. LITUOLIDAE.

Test free, arenaceous, planospiral, at least in the young, later portion often uncoiled; divided into chambers, either simple or labyrinthic; aperture simple or compound; usually with a yellowish or reddish brown cement.

#### Subfamily 1. Haplophragmiinae.

Test composed of simple chambers, not labyrinthic.

Genus *TROCHAMMINOIDES* Cushman, 1910 (Pl. 3, fig. 11).—Test of several coils, not involute, aperture simple at the end of the last-formed chamber.—Carboniferous to Recent.

Genus *HAPLOPHRAGMOIDES* Cushman, 1910 (Pl. 3, fig. 12).—Test of several coils, usually not completely involute; aperture simple at the base or lower part of the apertural face.—Carboniferous to Recent.

Genus *ENDOTHYRA* Phillips, 1864 (Pl. 3, fig. 13).—Test close-coiled, often completely involute, chambers simple; wall arenaceous, often with a large proportion of cement; aperture simple usually at the base of the apertural face but occasionally above the base.—Carboniferous to Triassic.

Genus *CRIBROSTOMOIDES* Cushman, 1910 (Pl. 3, fig. 14).—Test similar to *Haplophragmoides* but the aperture consisting of a linear series of rounded openings at the base of the apertural face.—Recent.

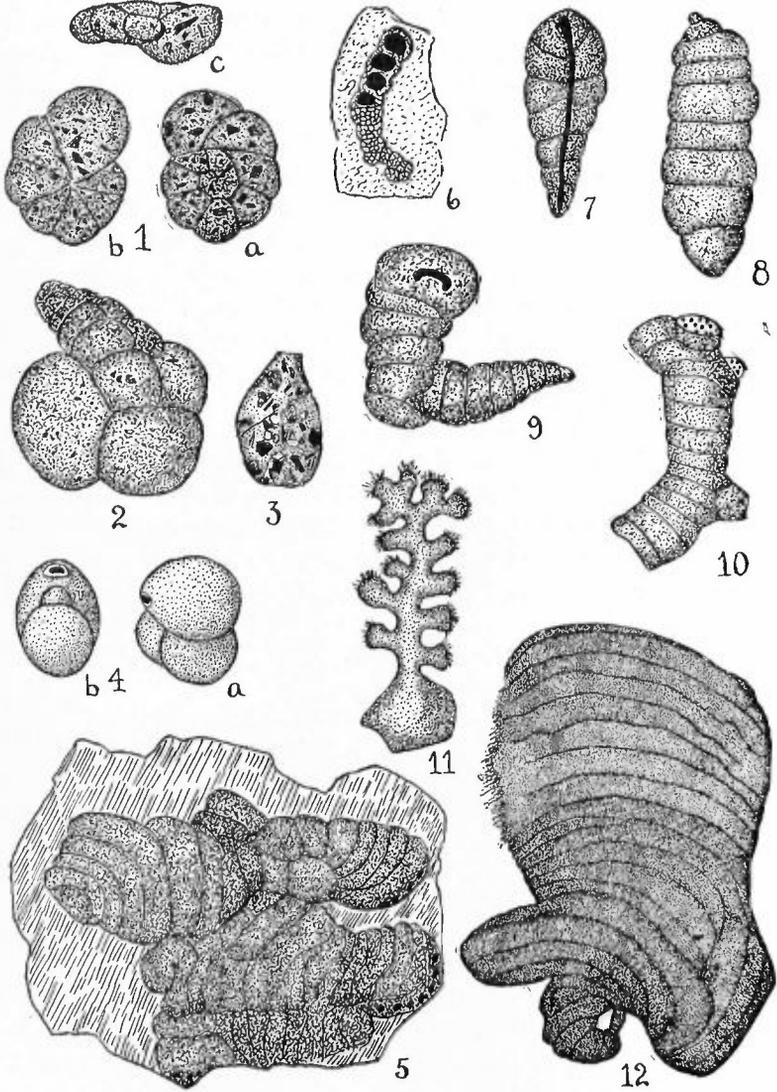
Genus *AMMOBACULITES* Cushman, 1910 (Pl. 3, fig. 15).—Test with the early portion planospiral, later portion uncoiled, with a linear series of chambers; aperture in the adult, uncoiled portion, a single, simple, terminal opening.—Carboniferous to Recent.

Genus *HAPLOPHRAGMIUM* Reuss, 1860 (Pl. 3, fig. 16).—Test similar to *Ammobaculites* but with the aperture consisting of a number of pores in the terminal face.—Cretaceous to Recent.

#### Subfamily 2. Lituolinae.

Test composed of labyrinthic chambers.

Genus *CYCLAMMINA* H. B. Brady, 1876 (Pl. 3, fig. 17).—Test with thick walls, closely coiled, more or less involute; chambers labyrinthic especially on the peripheral portion; aperture a simple curved slit at the base of the apertural face with a series of supplementary, rounded pores on the ventral face.—Cretaceous to Recent.



Genus *CHOFFATELLA* Schlumberger, 1904.—Test compressed, chambers narrow and elongate, nearly completely involute; chambers labyrinthic especially the peripheral portion; aperture consisting of numerous pores from the peripheral margin to the base of the chamber.—Cretaceous.

Genus *LITUOLA* Lamarck, 1804 (Pl. 3, fig. 19).—Test with the young close-coiled, later adult portion uncoiled and straight; chambers labyrinthic with radial vertical partitions and secondary septae; aperture typically of several pores.—Carboniferous to Recent.

Genus *PSEUDOCYCLAMMINA* Yabe and Hanzawa, 1926 (Pl. 3, fig. 18).—Test close-coiled except the last few chambers which are rectilinear; interior irregularly labyrinthic; aperture terminal, of several pores.—Cretaceous.

This family includes those arenaceous forms which are planospiral at least in their earlier stages. The test may be composed of simple or labyrinthic chambers. Under the name *Endothyra* have been included in the past many forms which it seems should be placed elsewhere.

#### FAMILY 9. TEXTULARIIDAE.

Test in the earliest stages of at least primitive forms, planospiral, later in all but the most accelerated forms developing either biserial or triserial forms, final development of various sorts; wall arenaceous.

Subfamily 1. Spiroplectammininae.

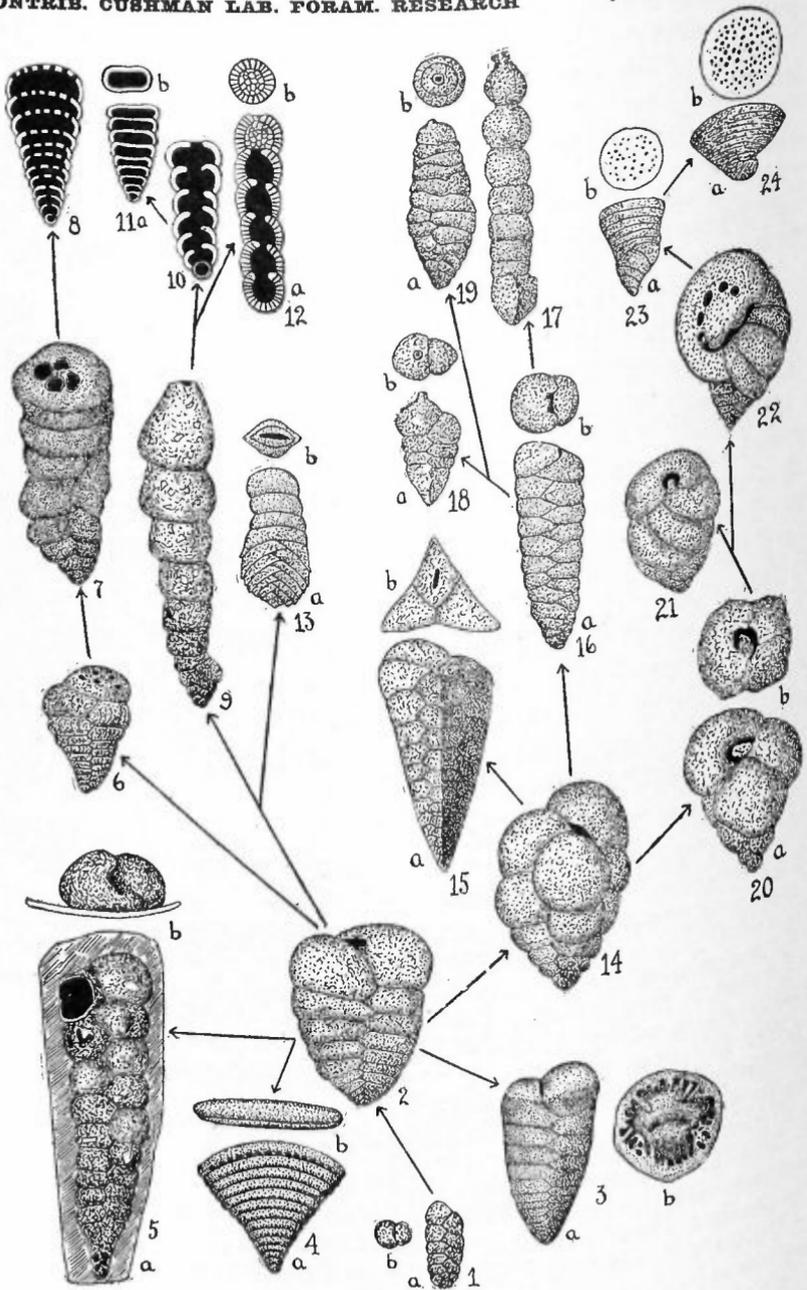
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#### EXPLANATION OF PLATE 4.

##### TROCHAMMINIDAE, PLACOPSILINIDAE, NEUSINIDAE.

FIG.

- 1—*Trochammina nana* (H. B. Brady). (After H. B. Brady.) *a*, dorsal view, *b*, ventral view, *c*, peripheral view.
- 2—*Globotextularia anceps* (H. B. Brady). (After H. B. Brady.)
- 3—*Nouria polymorphinoides* Heron-Allen and Earland. (After Heron-Allen and Earland.)
- 4—*Ammochilostoma galeata* (H. B. Brady). (After H. B. Brady.) *a*, side view, *b*, apertural view.
- 5—*Bdelloidina aggregata* Carter. (After H. B. Brady.)
- 6—*Placopsilina cenomana* d'Orbigny. (After H. B. Brady.)
- 7, 8—*Stacheia pupoides* H. B. Brady. 7, from below, 8, from above.
- 9—*Haddonina torresiensis* Chapman. (After Chapman.)
- 10—*Polyphragma cribrosa* Reuss. (After Perner.)
- 11—*Botellina pinnata* Pearcey. (After Pearcey.)
- 12—*Neusina agassizii* Goës.



Test with the early chambers distinctly planospiral in both microspheric and megalospheric forms; later chambers biserial; wall arenaceous.

Genus *SPIROPECTAMMINA* Cushman, new genus (Pl. 5, fig. 1). (Genotype *Spiropecta biformis* Parker and Jones).—Test with the characters of the subfamily.—Carboniferous (?), Cretaceous to Recent.

## EXPLANATION OF PLATE 5.

## TEXTULARIIDAE, VERNEULINIDAE, VALVULINIDAE.

FIG.

- 1—*Spiropectamina biformis* (Parker and Jones). (After H. B. Brady).  
a, front view, b, end view.
- 2—*Textularia gramen* d'Orbigny.
- 3—*Textulariella barrettii* (Jones and Parker). (After H. B. Brady).  
a, front view, b, interior.
- 4—*Cuneolina pavonia* d'Orbigny. (After d'Orbigny.) a, front view, b,  
end view.
- 5—*Textularioides inflata* Cushman. a, side view, b, end view.
- 6—*Cribrostomum textulariforme* Möller. (After Möller.)
- 7—*Climacammina antiqua* H. B. Brady. (After H. B. Brady.)
- 8—*Cribrogenerina*. (Idealized section.)
- 9—*Bigenerina nodosaria* d'Orbigny.
- 10—*Monogenerina atava* Spandel. (After Spandel.) Section.
- 11—*Geinitzella postcarbonica* Spandel. (After Spandel.) Sections. a, longi-  
tudinal, b, transverse.
- 12—*Nodosaroum lahusei* (Möller). (After Möller.) Sections. a, longi-  
tudinal, b, transverse.
- 13—*Vulvulina pennatula* (Batsch). (After H. B. Brady.) a, front view,  
b, end view.
- 14—*Verneulina bradyi* Cushman.
- 15—*Tritaxia pyramidata* Reuss. (After Reuss.) a, front view, b, end view.
- 16—*Gaudryina subrotunda* Schwager. (After H. B. Brady.) a, front view,  
b, end view.
- 17—*Clavulina humilis* H. B. Brady, var. *mexicana* Cushman.
- 18—*Heterostomella rugosa* (d'Orbigny). (After d'Orbigny.) a, front view,  
b, end view.
- 19—*Tritaxilina caperata* H. B. Brady. (After H. B. Brady.) a, front view,  
b, end view.
- 20—*Valvulina oviedoiana* d'Orbigny. a, front view, b, end view.
- 21—*Arenobulimina presli* (Reuss).
- 22—*Cribrobulimina mixta* (Parker and Jones).
- 23—*Lituonella liburnica* Schubert. (After Schubert.) a, front view, b, end  
view.
- 24—*Coskinolina liburnica* Stache. (After Schubert.) a, front view, b, end  
view.

## Subfamily 2. Textulariinae.

Test typically biserial or becoming uniserial, usually free; wall arenaceous, usually perforate, aperture simple or cribrate.

Genus TEXTULARIA DeFrance, 1824 (Pl. 5, fig. 2).—Test elongate, tapering, early stages in the microspheric form coiled, later ones in two linear series, alternating; wall arenaceous; aperture typically an arched slit at the inner margin of the last-formed chamber, occasionally in the apertural face.—Cambrian to Recent.

Genus TEXTULARIOIDES Cushman, 1911 (Pl. 5, fig. 5).—Test similar to *Textularia* but attached.—Recent.

Genus TEXTULARIELLA Cushman, new genus (Pl. 5, fig. 3) (Genotype *Textularia barrettii* Jones and Parker).—Test similar to *Textularia*, but with the test usually circular in section and the chambers labyrinthic.—Cretaceous to Recent.

Genus CUNEOLINA d'Orbigny, 1839 (Pl. 5, fig. 4).—Test similar to *Textularia* but compressed so that the alternating series form a zigzag line on the narrow sides of the test, chambers numerous, low and broad; labyrinthic; aperture very elongate or composed of a row of rounded pores.—Cretaceous to Recent.

Genus BIGENERINA d'Orbigny, 1826 (Pl. 5, fig. 9).—Test with the early stages textularian, later chambers in a simple rectilinear series; aperture single, rounded, terminal.—Carboniferous to Recent.

Genus VULVULVINA d'Orbigny, 1826 (Pl. 5, fig. 13).—Test much compressed throughout, early stages biserial, later chambers uniserial; wall finely arenaceous, with much cement; aperture elongate, simple, terminal.—Eocene to Recent.

Genus MONOGENERINA Spandel, 1901 (Pl. 5, fig. 10).—Test uniserial throughout, wall arenaceous; aperture circular, simple, terminal.—Carboniferous.

Genus GEINITZELLA Spandel, 1901 (Pl. 5, fig. 11).—Similar to *Monogenerina* but compressed.—Carboniferous.

Genus NODOSAROUM Rhumbler, 1913 (Pl. 5, fig. 12).—Test uniserial throughout, wall arenaceous and coarsely perforate; aperture rounded, simple, terminal.—Carboniferous.

Genus CRIBROSTOMUM Möller, 1879 (Pl. 5, fig. 6).—Test biserial, wall finely arenaceous and perforate; apertural face cribrate.—Carboniferous to Permian.

Genus CLIMACAMMINA H. B. Brady, 1876 (Pl. 5, fig. 7).—Test in the early stages, biserial, later uniserial; wall finely

arenaceous and perforate; apertural face cribrate.—Carboniferous to Permian.

Genus *CRIBROGENERINA* Schubert, 1907 (Pl. 5, fig. 8).—Test uniserial throughout, wall finely arenaceous, aperture in early chambers simple, in later ones cribrate.—Carboniferous and Permian.

This family is directly derived from a planospiral ancestry such as the Lituolidae by the addition of the biserial character. In the more primitive genera the early stages in the microspheric form show the coiled stage but this is lost in the higher ones. In a number of respects the family apparently reached its climax in the Carboniferous and Permian although further study may show these Palaeozoic forms to be possibly from a distinct ancestry.

#### FAMILY 10. VERNEUILINIDAE.

Test in the early stages triserial, later biserial or uniserial; wall arenaceous; aperture simple or multiple.

Genus *VERNEUILINA* d'Orbigny, 1840 (Pl. 5, fig. 14).—Test triserial, chambers simple; wall arenaceous; aperture a low opening at the inner margin of the last-formed chamber.—Lower Cretaceous to Recent.

Genus *TRITAXIA* Reuss, 1860 (Pl. 5, fig. 15).—Test triserial, triangular in section, chambers simple, wall arenaceous; aperture an elongate opening on the inner margin of the chamber.—Lower Cretaceous to Recent.

Genus *GAUDRYINA* d'Orbigny, 1839 (Pl. 5, fig. 16.).—Test in the early stages triserial, in the adult biserial; wall arenaceous; aperture either a low opening at the inner margin of the chamber or in the wall of the apertural face.—Lower Cretaceous to Recent.

Genus *HETEROSTOMELLA* Reuss, 1865 (Pl. 5, fig. 18).—Test bi— or triserial with the aperture having an elongate neck and straight lip; wall arenaceous.—Cretaceous to Recent.

Genus *TRITAXILINA* Cushman, 1911 (Pl. 5, fig. 19).—Test in its early stages triserial, later biserial and finally uniserial; wall arenaceous; chambers labyrinthic; aperture simple in the young, multiple in the adult.—Eocene to Recent.

Genus *CLAVULINA* d'Orbigny, 1826 (Pl. 5, fig. 17).—Test cylindrical or angled, early portion triserial, later sometimes biserial before the adult uniserial stage; wall arenaceous; cham-

bers simple; aperture rounded, terminal, sometimes with a neck and tooth.—Cretaceous to Recent.

This family is very closely related to and derived from the biserial Textulariidae. The triserial character is shoved back and is replaced by biserial and uniserial stages in the higher genera. The family apparently reached its climax in the Cretaceous.

#### FAMILY 11. VALVULINIDAE.

Test in the early stages triserial, later with a secondary spiral development, finally in some genera becoming angular; wall arenaceous; aperture simple or cribrate.

Genus VALVULINA d'Orbigny, 1826 (Pl. 5, fig. 20).—Test triserial, conical, umbilicate; wall arenaceous; aperture at the border of the inner margin of the chamber with a simple valvular tooth.—Carboniferous to Recent.

Genus ARENOBULIMINA Cushman, 1927 (Pl. 5, fig. 21).—Test in the early portion triserial, later with several chambers in a spiral whorl; wall finely arenaceous; aperture at the border of the inner margin of the chamber rounded with a rounded flat tooth.—Cretaceous.

Genus ATAXOPHRAGMIUM Reuss, 1861.—Test in the very early portion triserial, later with a spreading coil of several chambers, the wall arenaceous, aperture extending in from the edge in the young until in the adult it may become enclosed in the apertural face.—Cretaceous.

Genus CRIBROBULIMINA Cushman, 1927 (Pl. 5, fig. 22).—Test in the young triserial, later with whorls of numerous chambers; wall arenaceous; aperture in the young simple with a flat tooth, later becoming cribrate.—Recent.

Genus LITUONELLA Schlumberger and Douvillé, 1905 (Pl. 5, fig. 23).—Test conical, in the young a low coil of several chambers, later becoming conical with annular chambers; chambers labyrinthic extending clear across the test without surface modifications; aperture cribrate, on the flattened face.—Eocene.

Genus COSKINOLINA Stache, 1875 (Pl. 5, fig. 24).—Test conical, the early stages consisting of chambers in a low spiral, later with the chambers forming annuli, divided roughly into chamberlets; wall finely arenaceous; aperture cribrate on the flattened side of the chamber.—Eocene.

This family forms a distinct group which if it were not for the intermediate stages to be seen in the young of the various genera

would hardly be supposed to have been derived from the Textulariidae. The parallelism with the Orbitolinidae is marked but is only superficial as will be seen by the structure of the test as well as its development. The even more superficial resemblance to the Buliminidae has caused some of these genera to be placed with that group by earlier workers.

#### FAMILY 12. FUSULINIDAE.

Test bilaterally symmetrical; entirely involute; wall imperforate on the exterior, more or less arenaceous; aperture a single elongate slit, or row of rounded openings, at the basal margin of the apertural face; interior often with "mesh work" or labyrinthic.

The classification of this family as here given is taken entirely from the new grouping proposed by Ozawa (Journ. Coll. Sci. Imp. Univ. Tokyo, vol. 45, 1925, pp. 14-16).

##### Subfamily 1. Fusulininae.

Test lenticular to fusiform; wall and septa consisting essentially of the median lamella and mesh structure but in primitive forms often with deposition or supplementary layers on both sides of the walls as well as of the septa; mesh work often wanting; aperture single.

Genus *STAFFELLA* Ozawa, 1925.—Test lenticular or sphaeroidal, the axial length less than the diameter at right angles to it; wall composed of a median lamella, alveolar structure and deposition layers, the last often indistinct or wanting; septa almost plane; aperture a relatively large single aperture.—Carboniferous and Permian.

Genus *NEOFUSULINELLA* Deprat, 1912 (in part).—Test globular or fusiform, the axial length greater than the diameter at right angles to it; earlier volutions spheroidal and symmetrical, wall thin and mesh-structure often wanting; septa almost plane, aperture single, large; no septal perforation.—Carboniferous (?) to Permian.

Genus *FUSULINA* Fischer v. Waldheim, 1829.—Test globular, fusiform or cylindrical; earlier volutions almost symmetrical; wall composed essentially of thin lamella and alveolar structure; deposition layers present or wanting; septa strongly folded or almost plane; septal perforation often present.—Carboniferous to Permian.

Subgenus *FUSULINELLA* v. Möller, 1877.—Test fusiform, deposition layers well developed; mesh work wanting, septa

strongly folded or almost not at all, no septal perforation.

Subgenus SCHELLWIENIA v. Staff and Wedekind, 1912.—Test globular, fusiform or cylindrical; mesh work generally distinct, deposition layers often partly developed; septal perforation present or not.

Subgenus SCHWAGERINA Möller, 1877 (emended).—Test globular, fusiform or cylindrical; mesh work sometimes developed, early whorls low, those of the main portion of the test high, later ones often again becoming low; lower border of septa often strongly folded; aperture simple.

Subfamily 2. Verbeekinae.

Test sphaeroidal or fusiform, wall composed essentially of thin lamella and mesh work, the latter absent in specialized forms, septa not folded; aperture consisting of numerous openings, basal skeletons well developed; septal perforations wanting.

Genus DOLIOLINA Schellwein—with the following subgenera.

Subgenus DOLIOLINA Schellwein.—Test cylindrical; wall thin, composed of compact thin lamella only, no deposition layers; basal skeletons well developed, primary septa only.—Permian.

Subgenus VERBEEKINA Staff, 1910.—Test sphaeroidal to fusiform, earlier volutions like *Endothyra*, wall composed of thin lamella and mesh-structure; basal skeletons indistinct in earlier whorls.—Upper Carboniferous to Permian.

Genus NEOSCHWAGERINA Yabe, 1906.—Test globular or fusiform; volutions numerous, generally more than ten, earlier volutions sphaeroidal and closely resembling *Verbeekina*; transverse septa and lateral passages developed; false septa present or wanting, wall composed of thin lamella and mesh-work.—Permian.

Subgenus CANCELLINA Hayden.—Test with no false septa.

Subgenus NEOSCHWAGERINA Ozawa, 1925.—Test with three kinds of septa usually developed, viz., primary meridional auxiliary meridional and primary equatorial, auxiliary equatorial septa generally absent.

Subgenus YABEINA Deprat, 1919.—Test with four kinds of septa, adding auxiliary equatorial to those in the preceding, the septa more delicate than in the *Neoschwagerina*, the end usually swollen as in the next subgenus.

Subgenus SUMATRINA Volz.—Test with the four kinds of septa well developed, central chamber sphaeroidal, wall of

median lamella and alveolar structure.

This is a very specialized group and on which very much detailed work is being done. It was evidently derived from the general group represented by *Endothyra* and its allies. The structures involved are detailed but can be best studied from the excellent photomicrographs published in the more recent works of various authors.

#### FAMILY 13. LOFTUSIIDAE.

Test large, arenaceous, coiled about an elongate axis, fusiform or elliptical; wall arenaceous; interior labyrinthic.

Genus LOFTUSIA H. B. Brady, 1869 (Pl. 6, fig. 5).—Test with the characters of the family.—Eocene.

There is some question about the position of *Parkeria* which in some of its characters resembles the foraminifera but in others appears to be nearer certain groups of the Coelenterata. It has been included with *Loftusia* by some authors but seems best left out until its status is more clearly defined.

#### FAMILY 14. NEUSINIDAE.

Test arenaceous with some chitin, apparently attached, whole body of the test labyrinthic, flexible; apertures numerous, small.

Genus NEUSINA Goës, 1892 (Pl. 4, fig. 12).—Test expanded, much compressed, early chambers apparently planospiral, later ones broad and flat; wall of fine mud and sand with chitinous net work, flexible; apertures numerous, along the edge of the chamber.—Recent.

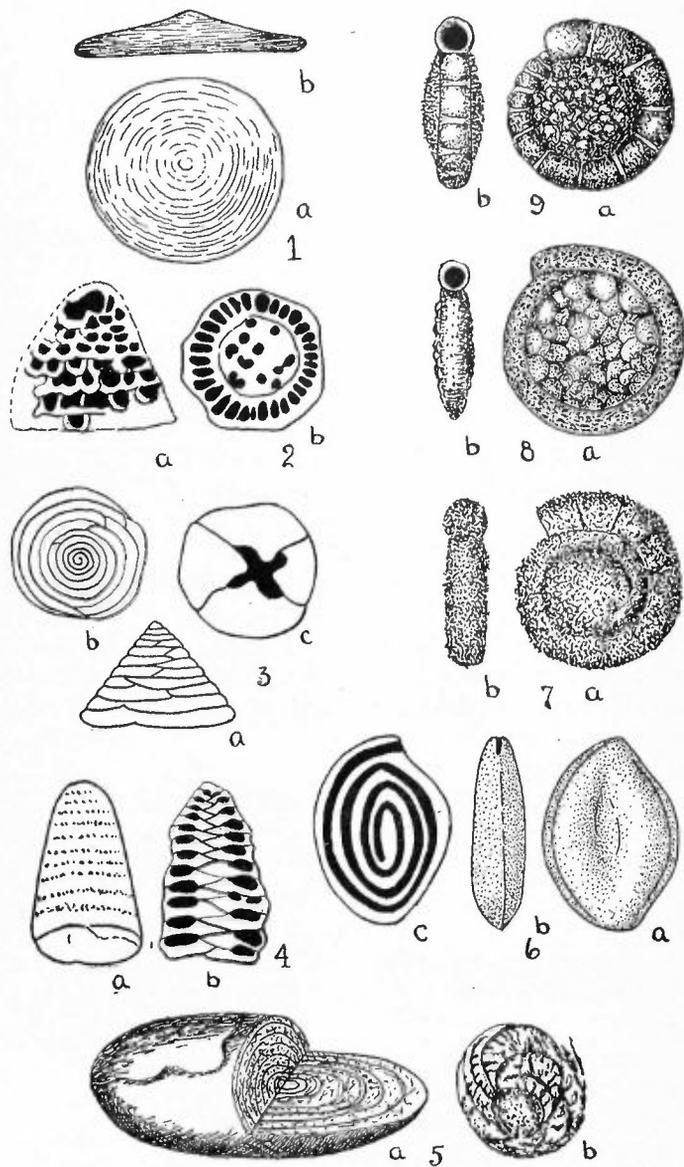
Genus BOTELLINA W. B. Carpenter, 1869 (Pl. 4, fig. 11).—Test generally cylindrical, sometimes branched, one end rounded and swollen; wall arenaceous, whole test labyrinthic with a common tubular chamber through the length of the test.—Recent.

The forms assigned to this family are uniserial ones and very limited in their distribution, found only in the present ocean.

#### FAMILY 15. SILICINIDAE.

Test usually planospiral; simply undivided or divided into chambers, the sides building up masses of secondary shell material; arenaceous, siliceous or calcareous; aperture at the end of the tube on last-formed chamber.

Genus SILICINA Bornemann, 1874 (Pl. 6, fig. 7).—Test arenaceous, usually siliceous and imperforate, an open close-



coiled tubular chamber or slightly divided; aperture at end of the tube.—Lias.

Genus RZEHAKINA Cushman, new genus (Pl. 6, fig. 6).—Test finely arenaceous, usually siliceous; wall thin; planospiral, compressed, but the chambers forming a half coil, the test longer than broad, median portion depressed; aperture somewhat narrow, constricted.—Upper Cretaceous and lowest Eocene.

Genotype, *Rzehakina epigona* (Rzehak) (Annal. K. K. Naturhist. Hofmuseums, vol. 10, 1895, p. 214, pl. 6, fig. 1). This peculiar siliceous form is recorded by Rzehak from the oldest Tertiary of Austria. A very similar species occurs in the Velasco shales of Mexico.

Genus INVOLUTINA Terquem, 1862 (Pl. 6, fig. 8).—Test planospiral, or sometimes conical, calcareous, with an arenaceous surface, tubular chamber partially divided by incomplete walls; sides of the test built up with secondary additions; aperture circular at the end of the tubular chamber.—Jurassic.

Genus PROBLEMATINA Bornemann, 1874 (Pl. 6, fig. 9).—Test planospiral, arenaceous, with much cement, the tubular chamber partially divided; the sides strongly built up with secondary shell material; aperture circular in the end of the chamber.—Lias.

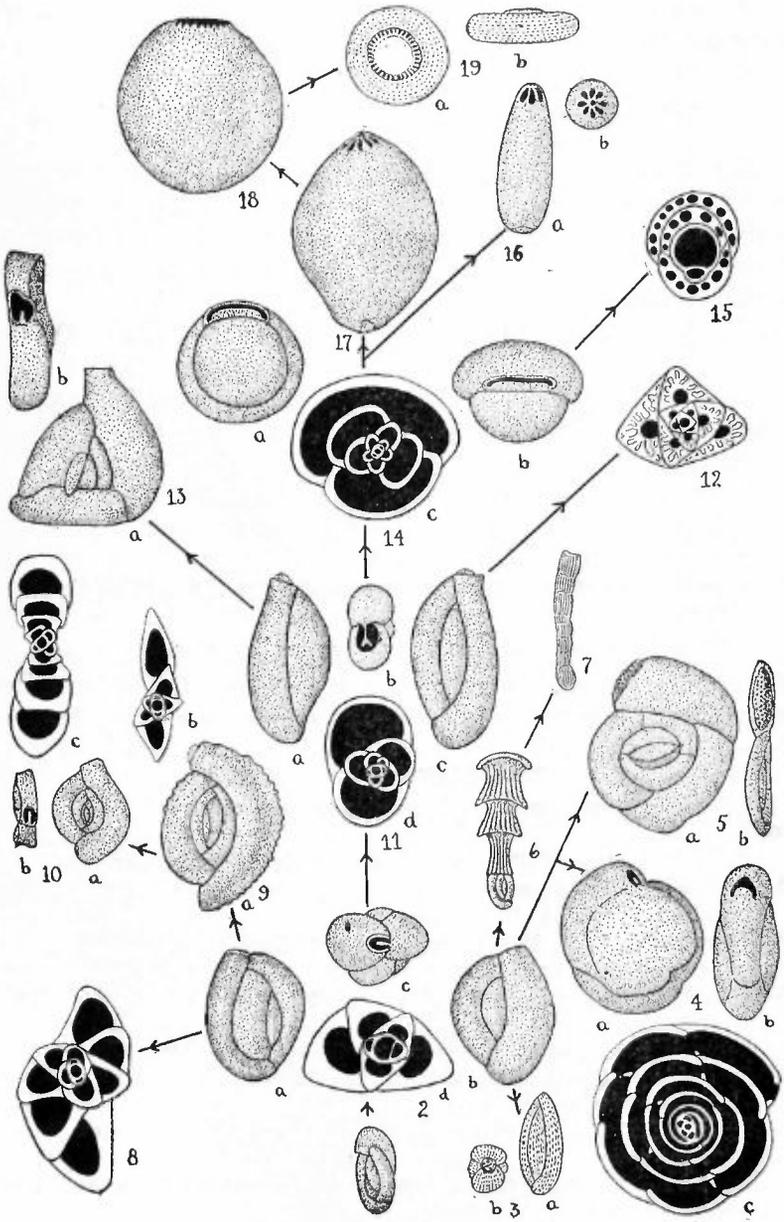
This is an especially interesting family as it foreshadows very strongly the development of the Miliolidae. Coincidentally such imperforate calcareous planospiral forms may have developed

#### EXPLANATION OF PLATE 6.

##### ORBITOLINIDAE, LOFTUSIDAE, SILICINIDAE.

##### FIG.

- 1—*Orbitolina concava* d'Orbigny. *a*, dorsal view, *b*, side view.
- 2—*Chapmania gassinensis* A. Silvestri. (After A. Silvestri.) Sections. *a*, longitudinal, *b*, transverse.
- 3—*Tetrataxis conica* Ehrenberg. (After Möller). *a*, side view, *b*, dorsal view, *c*, ventral view.
- 4—*Howchinia bradyana* (Howchin). (After Howchin.) *a*, side view, *b*, section.
- 5—*Loftusia persica* (H. B. Brady and Carpenter). (After Chapman.)
- 6—*Rzehakina epigona* (Rzehak). (After Rzehak). *a*, side view, *b*, peripheral view, *c*, section.
- 7—*Silicina limitata* (Terquem). (After Terquem). *a*, side view, *b*, peripheral view.
- 8—*Involutina klassica* (Jones). (After Terquem). *a*, side view, *b*, peripheral view.
- 9—*Problematina deslongschampsii* (Terquem). (After Terquem). *a*, side view, *b*, peripheral view.



*Cornuspira*. *Rzehakina* also shows the relation to the Miliolidae not only in form but in its siliceous test as the Miliolidae are one of the few groups of the foraminifera capable of developing an entirely siliceous test under acidic conditions of brackish or very deep water.

#### FAMILY 16. MILIOLIDAE.

Test typically coiled about an elongate axis in various planes, at least in the young; chambers normally a half coil in length; wall calcareous, imperforate, occasionally with included sand grains on the exterior; aperture terminal simple or cribrate, usually with a tooth.

#### EXPLANATION OF PLATE 7.

##### MILIOLIDAE.

##### FIG.

- 1—*Agathammina pusilla* (Geinitz). (After H. B. Brady.)
- 2—*Quinqueloculina vulgaris* d'Orbigny. *a*, *b*, opposite sides, *c*, apertural view, *d*, section (After Schlumberger).
- 3—*Miliola saxorum* Lamarck. (After Terquem). *a*, side view, *b*, apertural view.
- 4—*Nummuloculina contraria* (d'Orbigny). *a*, side view, *b*, apertural view (After H. B. Brady). *c*, section (After Steinmann).
- 5—*Hauerina bradyi* Cushman. (After H. B. Brady.) *a*, side view, *b*, apertural view.
- 6—*Articulina sagra* d'Orbigny. (After H. B. Brady.)
- 7—*Tubinella funalis* (H. B. Brady). (After H. B. Brady.)
- 8—*Sigmoilina herzensteini* Schlumberger. (Section after Schlumberger.)
- 9—*Massilina secans* (d'Orbigny). (After Schlumberger.) *a*, side view, *b*, section.
- 10—*Spiroloculina depressa* d'Orbigny. (After Martinotti.) *a*, side view, *b*, apertural view, *c*, section.
- 11—*Triloculina laevigata* d'Orbigny. (After Schlumberger.) *a*, *c*, opposite sides, *b*, end view, *d*, section.
- 12—*Trillina howchini* Schlumberger. (Section after Schlumberger.)
- 13—*Flintina triquetra* Cushman, *a*, side view, *b*, apertural view.
- 14—*Biloculina bradyi* Schlumberger. *a*, front view, *b*, apertural view, *c*, section.
- 15—*Fabularia discolithes* DeFrance. (Section after Schlumberger.)
- 16—*Nevillina coronata* (Millet). (After Sidebottom.) *a*, front view, *b*, end view.
- 17—*Idalina antiqua* (d'Orbigny). (After Munier-Chalmas and Schlumberger.)
- 18—*Periloculina zitteli* Munier-Chalmas and Schlumberger. (After Munier-Chalmas and Schlumberger.)
- 19—*Lacazina compressa* (d'Orbigny). (After Munier-Chalmas and Schlumberger.) *a*, apertural view, *b*, side view.

Genus AGATHAMMINA Neumayr, 1887 (Pl. 7, fig. 1).—Test tubular, undivided, winding about an elongate axis; wall imperforate, calcareous, with arenaceous material at the surface; aperture formed by the open end of the tubes.—Carboniferous to Jurassic.

Genus QUINQUELOCULINA d'Orbigny, 1826 (Pl. 7, fig. 2).—Test with the coiling in five planes, the chambers added successively in planes  $144^\circ$  apart, five chambers completing a circle, each chamber  $72^\circ$  from its adjacent one, but  $144^\circ$  from the immediately preceding one; aperture usually with a simple tooth.—Carboniferous? to Recent.

Genus MILIOLA Lamarck, 1804 (Pl. 7, fig. 3).—(*Pentellina* Schlumberger, 1905).—Test similar to *Quinqueloculina* but very elongate and with a cribrate aperture.—Eocene.

Genus MASSILINA Schlumberger, 1893 (Pl. 7, fig. 9).—Test with the early chambers quinqueloculine, later ones added on opposite sides in a single plane, the quinqueloculine stage present in both megalospheric and microspheric forms.—Cretaceous to Recent—(probably older).

Genus SPIROLOCULINA d'Orbigny, 1826 (Pl. 7, fig. 10).—Test with the early chambers in the microspheric young quinqueloculine, later ones in a single plane; all in the megalospheric form planospiral, chambers a half coil in length; apertural end usually with a neck and lip, with a simple or bifid tooth.—Permian ? to Recent.

Genus NUMMOLOCULINA Steinmann, 1881 (Pl. 7, fig. 4).—Test with the earliest chambers quinqueloculine, later ones in a single plane, several making up a coil; aperture rounded with a flat circular tooth.—Jurassic to Recent.

Genus HAUERINA d'Orbigny, 1848 (Pl. 7, fig. 5).—Test with the early chambers quinqueloculine, later ones more or less in one plane, gradually shortening so that more than two make up one coil; aperture cribrate.—Tertiary and Recent.

Genus SIGMOILINA Schlumberger, 1887 (Pl. 7, fig. 8).—Test with the early chambers quinqueloculine, later ones in planes slightly more than  $180^\circ$  from one another making a continuously revolving spiral and in section producing a sigmoid appearance; aperture with a simple tooth; exterior often with superficial arenaceous material.—Tertiary and Recent.

Genus ARTICULINA d'Orbigny, 1826 (Pl. 7, fig. 6).—Test with the early chambers quinqueloculine, later ones in a rectili-

near series; aperture with a neck and lip.—Lower Eocene to Recent.

Genus TUBINELLA Rhumbler, 1906 (Pl. 7, fig. 7).—Test with an ovoid early portion, the remainder of the test nearly straight, cylindrical; partially divided; aperture the open end of the last chamber.—Recent. From many of its characters this is probably a somewhat degenerate form derived from *Articulina*.

Genus NUBECULINA Cushman, 1924.—Test in the adult in a rectilinear series, exterior thickly coated with sand grains, interior calcareous, imperforate, aperture usually with a tooth.—Recent.

Genus TRILOCULINA d'Orbigny, 1826 (Pl. 7, fig. 11).—Test with the early chambers quinqueloculine, later ones added in planes  $120^\circ$  from one another, the third of each series added in the plane of the third preceding and covering it so that the surface is composed of but three visible chambers; aperture typically with a bifid tooth.—Triassic to Recent.

Genus TRILLINA Munier-Chalmas and Schlumberger, 1893 (Pl. 7, fig. 12).—Test like *Triloculina* but with the chambers labyrinthic and the aperture cribrate.—Eocene.

Genus FLINTINA Cushman, 1921 (Pl. 7, fig. 13).—Test with the early chambers quinqueloculine, then triloculine, and in the adult planospiral, three chambers to a coil; aperture with a large complex tooth.—Recent.

Genus BILOCULINA d'Orbigny, 1826 (Pl. 7, fig. 14).—Test with the early chambers at least in the microspheric form quinqueloculine, then triloculine, and in the adult added in planes  $180^\circ$  apart and involute, the exterior being composed of but two chambers; aperture typically with a broad bifid tooth.—Lias to Recent.

Genus FABULARIA Defrance, 1820 (Pl. 7, fig. 15).—Test like *Biloculina* but the chambers labyrinthic and the aperture cribrate.—Eocene to Miocene.

Genus NEVILLINA Sidebottom, 1905 (Pl. 7, fig. 16).—Test like *Biloculina* but in the final stage the last chamber almost completely embracing the earlier ones; aperture circular, complex, formed by numerous incurved lamellae meeting centrally; chambers not labyrinthic.—Recent.

Genus IDALINA Schlumberger and Munier-Chalmas, 1884 (Pl. 7, fig. 17).—Test in the microspheric form quinqueloculine, then triloculine, then biloculine, in the adult with the penultimate chamber showing as a narrow strip at one side near the base;

aperture cribrate but the chambers not labyrinthic.—Upper Cretaceous.

Genus PERILOCULINA Munier-Chalmas and Schlumberger, 1885 (Pl. 7, fig. 18).—Test similar to *Idalina* but the last-formed chamber completely involute, the chambers labyrinthic.—Upper Cretaceous.

Genus LACAZINA Munier-Chalmas, 1882 (Pl. 7, fig. 19).—Test like *Periloculina* in the young but later compressed into a flattened spheroid, the apertures appearing as a ring of pores near the periphery on the dorsal side.—Upper Cretaceous.

The Miliolidae form a very complete series from the undivided *Agathammina* of the Carboniferous to the very complex *Lacazina* of the Upper Cretaceous. The microspheric form in section shows the various developmental stages whereas they are often skipped in the acceleration of the megalospheric form. The climax of the family was reached in the Upper Cretaceous where in various parts of the world as well as in the Eocene "Milioline-limestones" were formed. In the present oceans the Miliolidae are abundant in warm shallow waters but are represented by simpler forms than those developed in the Upper Cretaceous. The most complex types now living are found in the Indo-Pacific. In deep sea conditions or in brackish water siliceous and chitinous tests may be formed showing the relation to the Silicinidae and the earlier chitinous groups.

#### FAMILY 17. OPTHALMIDIIDAE.

Test calcareous, imperforate, usually without an arenaceous coating; early chambers at least, planospiral, except in degenerate forms; either a single chamber or multilocular; aperture typically open, without a tooth.

##### Subfamily 1. Cornuspirinae.

Test made up of a single planospiral tubular chamber.

Genus CORNUSPIRA Schultze, 1854 (Pl. 8, fig. 1).—Test consisting of a proloculum and elongate planospiral second chamber the open end serving as the aperture.—Carboniferous (?) Jurassic to Recent.

Genus VIDALINA Schlumberger, 1899 (Pl. 8, fig. 2).—Test similar to *Cornuspira* but involute, the umbonal region thickened.—Cretaceous.

##### Subfamily 2. Nodobaculariinae.

Early portion as in *Cornuspira*, later with the chambers in a rectilinear series.

Genus *NODOBACULARIA* Rhumbler, 1895 (Pl. 8, fig. 3).—Test with a globular proloculum followed by a planospiral tubular chamber, the adult chambers in a rectilinear series; aperture with a lip.—Lias to Recent.

Subfamily 3. *Ophthalmidiinae*.

Test planospiral, in the later stages two or more chambers making up a coil, later chambers variously arranged.

Genus *OPHTHALMIDIUM* Zwingli and Kübler, 1870 (Pl. 8, fig. 4).—Test planospiral, compressed, not involute; a globular proloculum followed by a tubular chamber usually two or more coils, following chambers decreasing in relative length, loose coiled, the intermediate area filled with a thin, shelly plate; aperture at the end of the chamber, rounded, without lip or tooth.—Lias to Recent.

Genus *SPIROPTHALMIDIUM* Cushman, new genus (Pl. 8, fig. 5).—Test similar to *Ophthalmidium* but accelerated, the stage of two chambers in a coil quickly reached; plate between the chambers usually present; aperture open without teeth.—Lias to Recent.—(Genotype *Spiroptthalmidium acutimargo* H. B. Brady, Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, pl. 10, fig. 13).

Genus *DISCOSPIRINIA* Munier-Chalmas, 1902 (Pl. 8, fig. 6).—Test similar to *Ophthalmidium* in the young, later chambers annular with divisions into chamberlets, apertures at the periphery of the very thin test.—Tertiary and Recent.

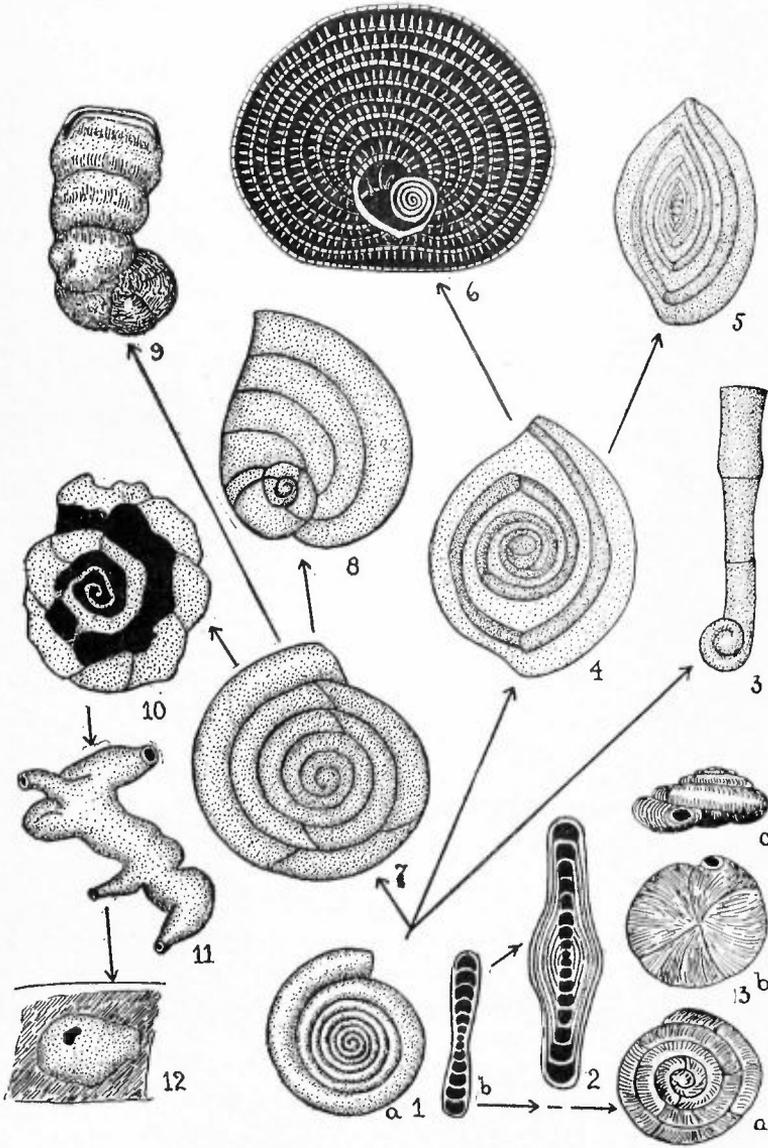
Genus *PLANISPIRINA* Seguenza, 1880 (Pl. 8, fig. 7).—Test in the early stages like *Cornuspira*, later divided into chambers, several to a coil; aperture open, without a tooth.—Cretaceous to Recent.

Genus *RENULINA* Lamarck, 1804 (Pl. 8, fig. 8).—Test in the young, planospiral, in the adult, the chambers becoming relatively shorter and broader, until in the completed test they even become annular; not divided; aperture narrow slit-like.—Eocene.

Genus *VERTEBRALINA* d'Orbigny, 1826 (Pl. 8, fig. 9).—Test with the early chambers planospiral, later ones in a rectilinear series; aperture a narrow slit; aperture without teeth.—Eocene to Recent.

Subfamily 4. *Nubeculariinae*.

Genus *NUBECULARIA* DeFrance, 1825 (Pl. 8, fig. 10).—Test typically coiled, planospiral, free or attached, an oval proloculum with a second *Cornuspira*-like chamber followed by irregular chambers varying with the attached surface.—Lias to Recent.



Genus *CALCITUBA* Roboz, 1883. (Pl. 8, fig. 11).—Test adherent, branched, of irregular chambers, more or less cylindrical, wall imperforate; apertures at the ends of the branches.—Recent.

Genus *SQUAMULINA* Schultze, 1854 (Pl. 8, fig. 12).—Test adherent, a single inflated chamber with the wall calcareous and imperforate, attached, aperture simple, on the convex surface.—Recent.

In this family all the forms are planospiral at the beginning except the degenerate ones such as *Squamulina*. There is a direct line to the rectilinear series in *Nodobacularia*. From *Cornuspira* to *Planispirina* by a division into chambers is but a simple step and from these to the other members of the subfamily the developmental stages are well shown in the microspheric forms of the several genera. That no tooth develops in the aperture makes this family at once distinguished from the Miliolidae where a toothed aperture is the rule. There are parallelisms between the two groups but the development shows the distinct character of such genera as *Spirothalmidium* and *Spiroloculina*, or of *Nodobacularia* and *Articulina*. As no toothed apertures are developed so also no cribrate forms occur nor are labyrinthic forms found, the whole family consisting of relatively simple forms. The character of incorporating arenaceous material in the surface of the test is not taken up by this family as it is in the simpler Miliolidae.

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#### EXPLANATION OF PLATE 8.

##### OPHTHALMIDIDAE, FISCHERINIDAE.

###### FIG.

- 1—*Cornuspira involvens* Reuss. *a*, side view, *b*, section.
- 2—*Vidalina hispanica* Schlumberger. (Adapted from Schlumberger).
- 3—*Nodobacularia tibia* (Parker and Jones). (After Rhumbler.)
- 4—*Ophthalmidium inconstans* H. B. Brady.
- 5—*Spirothalmidium acutimargo* (H. B. Brady). (After H. B. Brady.)
- 6—*Discospirina tenuissima* (Carpenter). (Adapted from H. B. Brady.)
- 7—*Planispirina exigua* H. B. Brady. (Adapted from H. B. Brady.)
- 8—*Renulina opercularia* Lamarck.
- 9—*Vertebralina striata* d'Orbigny. (After Williamson.)
- 10—*Nubecularia lucifuga* DeFrance. (After H. B. Brady.)
- 11—*Calcituba polymorpha* Roboz (After Roboz.)
- 12—*Squamulina laevis* Schultze (Adapted from Schultze.)
- 13—*Fischerina helix* Heron-Allen and Earland. (Adapted from Heron-Allen and Earland). *a*, dorsal view, *b*, ventral view, *c*, side view.

## FAMILY 18. FISCHERINIDAE.

Test coiled, imperforate, early coils planospiral or nearly so, later ones becoming trochoid, chambers all visible from the dorsal side, four or five making the last-formed coil and visible on the ventral side; aperture rounded, formed by the open end of the tube.

Genus FISCHERINA Terquem, 1878 (Pl. 8, fig. 13).—Test with the characters of the subfamily.—Pliocene to Recent.

This family represented by the single genus *Fischerina* represents the attempt in fairly recent times of the assuming of a trochoid form. It is surprising that this trochoid form taken on by many groups has never been successfully tried out by the vitreous or porcellaneous groups.

## FAMILY 19. TROCHAMMINIDAE.

Test in general trochoid, of numerous chambers or irregular; wall arenaceous with much cement, usually of a yellowish or reddish brown color.

Subfamily 1. Trochammininae.

Test trochoid, chambers in spiral whorls, aperture ventral.

Genus TROCHAMMINA Parker and Jones, 1860 (Pl. 4, fig. 1).—Test free or adherent, spiral, trochoid, all chambers visible from the dorsal side, only those of the last-formed coil from the ventral; aperture an arched slit on the ventral side of the chamber where it meets the preceding whorl.—Carboniferous to Recent.

Genus CARTERINA H. B. Brady, 1884.—Test trochoid, usually attached, the later chambers irregularly spreading, the wall made of cement in which are peculiar, thin, translucent, fusiform bodies irregularly scattered; aperture on the ventral side near the umbilicus.—Recent.

Genus ROTALIAMMINA Cushman, 1924.—Test attached by the ventral side, dorsal side showing numerous trochoid chambers; dorsal wall of matted spicules, ventral side of thin chitin; aperture ventral, along the edge of the chamber.—Recent.

Subfamily 2. Globotextularinae.

Test irregularly spiral, the chambers globose, aperture in the open umbilical area.

Genus GLOBOTEXTULARIA Eimer and Fickert, 1899 (Pl. 4, fig. 2).—Test as above.—Recent.

Subfamily 3. Ammosphaeroidininae.

Test with the early portion trochoid, later chambers few, embracing; aperture arched, on the umbilical border of the chamber or in the apertural face.

Genus *AMMOSPHEROIDINA* Cushman, 1910.—Test globose, adult with but three chambers exposed; wall coarsely arenaceous, aperture arched, at the umbilical border of the chamber.—Recent.

Genus *AMMOCHILOSTOMA* Eimer and Fickert, 1899 (Pl. 4, fig. 4).—Test subglobose, adult with but two or three chambers exposed; wall very finely arenaceous with much cement, aperture at the base or in the apertural face of the last-formed chamber.—Recent.

Genus *NOURIA* Heron-Allen and Earland, 1914 (in part) (Pl. 4, fig. 3).—Test free, of several chambers, irregularly arranged; wall arenaceous; aperture terminal.—Recent.

#### FAMILY 20. PLACOPSILINIDAE.

Test attached; wall arenaceous; chambers numerous and distinct, early ones often coiled or trochoid; interior simple or labyrinthic.

##### Subfamily 1. Placopsilinae.

Chambers simple, not labyrinthic.

Genus *PLACOPSILINA* d'Orbigny, 1850 (Pl. 4, fig. 6).—Test composed of numerous chambers, earlier ones often close-coiled, later uncoiling and spreading out in a generally linear series, last chambers sometimes free above the attachment; wall coarsely arenaceous; aperture rounded, at the end of the last-formed chamber.—Silurian to Recent.

Genus *BDELLOIDINA* Carter, 1877 (Pl. 4, fig. 5).—Test of irregular chambers, broad and low; wall arenaceous with sponge spicules; apertures, numerous pores on the outer face of the chamber.—Jurassic to Recent.

##### Subfamily 2. Polyphragminae.

Chambers labyrinthic.

Genus *HADDONIA* Chapman, 1898 (Pl. 4, fig. 9).—Test with the early chambers often coiled, later ones broad and low; wall arenaceous with coarse pores; aperture a crescent-shaped slit on the upper face of the last-formed chamber.—Recent.

Genus *POLYPHRAGMA* Reuss, 1871 (Pl. 4, fig. 10).—Test attached, later portion cylindrical, with short cylindrical chambers, the interior labyrinthic; wall double, the outer arenaceous

and imperforate, inner hyaline and perforate; aperture cribrate.—Cretaceous.

Genus *STYLOLINA* Karrer, 1877.—Test with the early chambers spiral, later ones forming a cylindrical test; wall arenaceous; aperture formed by a ring of pores near the periphery of the outer face.—Miocene.

Genus *STACHEIA* H. B. Brady, 1876 (Pl. 4, figs. 7, 8).—Test attached, early chambers suggesting a spiral arrangement, later ones irregular labyrinthic; wall arenaceous, imperforate; aperture simple, circular, often with a neck.—Carboniferous to Lias.

The forms included in this family are all attached, at least in their early stages. It may be that some of these are more or less degenerate forms and do not have the same ancestral source but all have certain characters in common. Heron-Allen and Earland have figured specimens which they refer to *Haddononia* in which the early stages are Textularian. If these are really the same, *Haddononia* should be transferred to the Textulariidae. As Chapman's figure and description indicate that the originals had a coiled young, the genus is left here until these points are more clearly defined.

#### FAMILY 21. ORBITOLINIDAE.

Test usually conical, early chambers spiral, later ones annular, subdivided into chamberlets, the central portion of the test with irregular chambers; apertures on the basal side of the test; wall finely arenaceous, siliceous or calcareous.

Genus *HOWCHINIA* Cushman, new genus (Pl. 6, fig. 4) Genotype *Howchinia bradyana* (Howchin) Journ. Roy. Micr. Soc. Soc., 1888, p. 544, pl. 9, figs. 22-25).—Test free, conical, trochoid, consisting of an undivided compressed spiral chamber; sutures limbate, externally with a row of pits; umbilicus depressed.—Carboniferous.

Genus *TETRATAXIS* Ehrenberg, 1843 (Pl. 6, fig. 3).—Test conical, early chamber like a conical *Ammodiscus*, later broken up into elongate crescentic chambers which may be divided into chamberlets in some species; aperture elongate in the umbilical region.—Carboniferous and Permian.

Genus *ORBITOLINA*, 1847 (Pl. 6, fig. 1).—Test of agglutinated siliceous particles, depressed conical, lower side usually concave; outer portion of each chamber subdivided by secondary partitions; base with numerous rounded apertures.—Cretaceous.

Genus *DICTYOCONUS* Blanckenhorn, 1900.—Test conical, finely arenaceous, calcareous, with a fine exterior layer below which is a sub-epidermic, finely reticulate structure, exposed in worn specimens; chambers annular and divided into chamberlets; central portion a mass of chambers in layers parallel to the base of the test, without pillars; apertures at the base.—Eocene.

Genus *CUSHMANIA* Silvestri, 1925.—Test similar to *Dictyoconus* but the small tubular chambers uniform over the test connecting directly with the large interior labyrinthic chambers.—Eocene.

Genus *CHAPMANIA* Prever and Silvestri, 1905 (Pl. 6, fig. 2).—Test conical, finely arenaceous, calcareous, chambers annular, divided into chamberlets, but without the finely reticulate sub-epidermic layer of *Dictyoconus*, partitions between the chamberlets double throughout except in the very earliest chambers; medium chambers in horizontal layers; apertures basal, circular or crescentic.—Eocene.

Genus *DICTYOCONOIDES* Nuttall, 1925.—Test similar to *Chapmania* but the whole test calcareous, and the addition of pillars of clear shell material in the central portion.—Eocene.

This family contains species which although very similar in their general characters may not have been derived from the same ancestral source. Most of them evidently arose from a Palaeozoic conical form comparable to the young of *Ammodiscoides* and with the division into chambers, later into chamberlets. *Tetrataxis* evidently represents an early stage in this development before annular chambers were taken on but with the division into chamberlets already accomplished. *Dictyoconoides* is a very peculiar form and may possibly have its affinities elsewhere. *Cyclolina* probably belongs here also.

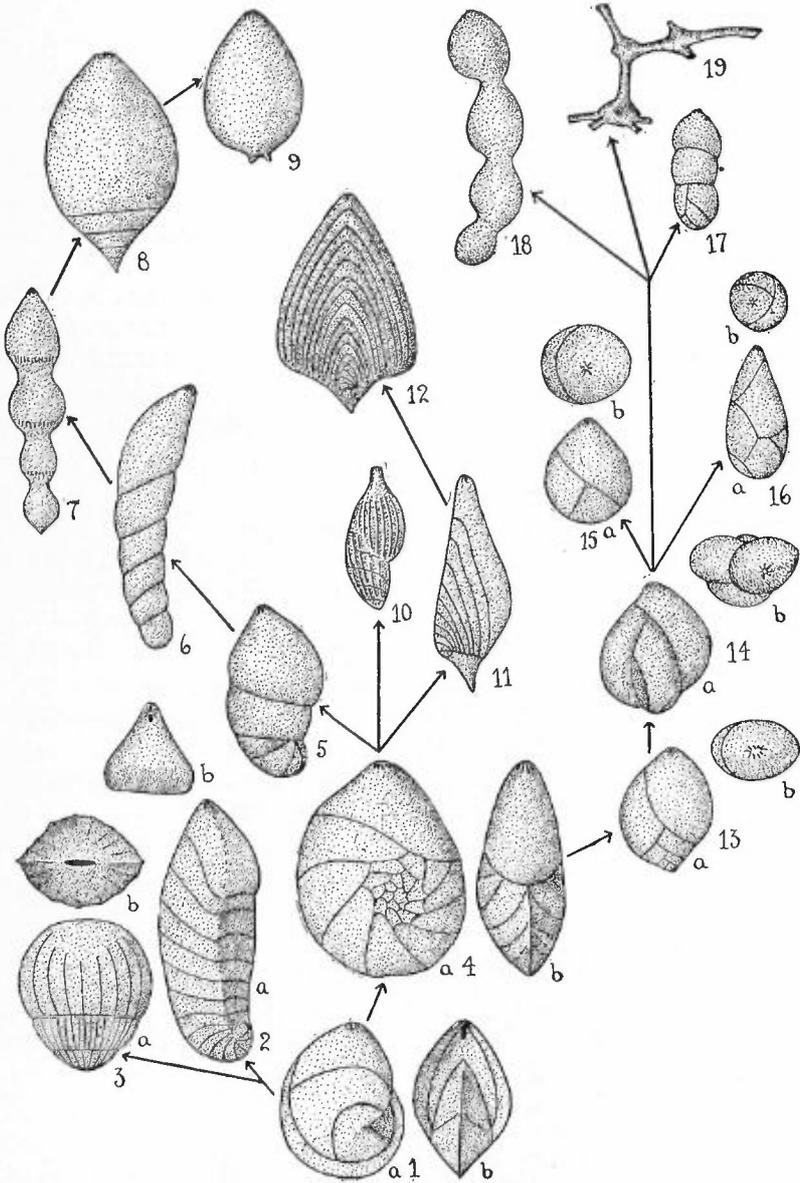
#### FAMILY 22. LAGENIDAE.

Test vitreous, with a glassy lustre, perforations very fine; chambers simple not biserial or irregularly spiral; wall calcareous; aperture typically radiate.

Subfamily 1. Nodosariinae.

Test multilocular.

Genus *CRISTELLARIA* Lamarck, 1812 (Pl. 9, fig. 4).—Test planospiral, bilaterally symmetrical, typically close-coiled; chambers numerous; wall hyaline, variously ornamented; aperture radiate, at the peripheral angle of the apertural face.—Upper



Cambrian to Recent. [The name *Cristellaria* is preoccupied by numerous names given by Montfort in 1808, but I have not adopted them here as *Cristellaria* is one of the most used names in the foraminiferal literature and should be saved if possible. The genus *Planularia* DeFrance, 1824, occasionally used for compressed forms was probably based on the free valve of a barnacle. *Hemicristellaria* Stache, 1864, was proposed for uncoiling forms but no sharp lines can be drawn in the Lagenidae and there are many stages between *Cristellaria* and *Marginulina*.]

Genus MARGINULINA d'Orbigny, 1826 (Pl. 9, fig. 5).—Test subcylindrical, very early portion close-coiled, later uncoiled, final chambers often inflated; aperture in the early coiled portion as in *Cristellaria*, in the uncoiled portion becoming central and terminal.—Cambrian to Recent.

Genus DENTALINA d'Orbigny, 1826 (Pl. 9, fig. 6).—Test arcuate, the chambers with the sutures oblique, the aperture at

## EXPLANATION OF PLATE 9.

## LAGENIDAE, POLYMORPHINIDAE.

## FIG.

- 1—*Robulus crassa* d'Orbigny. (After H. B. Brady). *a*, side view, *b*, front view.
- 2—*Saracenaria italica* DeFrance. (After H. B. Brady.) *a*, side view, *b*, end view.
- 3—*Lingulina carinata* d'Orbigny. *a*, front view, *b*, end view.
- 4—*Cristellaria convergens* Bornemann. *a*, side view, *b*, apertural view.
- 5—*Marginulina glabra* d'Orbigny. (After H. B. Brady.)
- 6—*Dentalina roemeri* Neugeboren.
- 7—*Nodosaria soluta* Reuss.
- 8—*Glandulina laevigata* d'Orbigny.
- 9—*Lagena apiculata* (Reuss).
- 10—*Amphicoryne falx* Jonès and Parker. (After H. B. Brady.)
- 11—*Vaginulina patens* H. B. Brady. (After H. B. Brady.)
- 12—*Fronidicularia alata* d'Orbigny. (After H. B. Brady.)
- 13—*Polymorphina ovata* d'Orbigny. (After H. B. Brady.) *a*, front view, *b*, end view.
- 14—*Guttulina problema* d'Orbigny. (After d'Orbigny.) *a*, front view, *b*, end view.
- 15—*Globulina gibba* d'Orbigny. (After d'Orbigny.) *a*, front view, *b*, end view.
- 16—*Pyrulina gutta* d'Orbigny. (After d'Orbigny.) *a*, front view, *b*, end view.
- 17—*Dimorphina tuberosa* d'Orbigny. (After d'Orbigny model.)
- 18—*Vitrewebbina sollasi* Chapman. (After Chapman.)
- 19—*Ramulina globulifera* H. B. Brady. (After H. B. Brady.)

least in the early portion toward the convex side of the test.—Jurassic to Recent.

Genus NODOSARIA Lamarck, 1812 (Pl. 9, fig. 7).—Test with the chambers in a straight linear series, the chambers distinct, not strongly embracing, the sutures normally at right angles to the axis; the aperture central and terminal, radiate.—Cambrian to Recent.

Genus GLANDULINA d'Orbigny, 1826 (Pl. 9, fig. 8).—Test similar to *Nodosaria* but the chambers embracing, the last-formed one making up a large proportion of the surface of the test.—Jurassic to Recent.

Genus AMPHICORYNE Schlumberger, 1881 (Pl. 9, fig. 10).—Test in the young like a compressed *Cristellaria* loosely coiled, the last-formed chambers like *Nodosaria*. [Such forms are usually megalospheric and may not represent a true generic character.]

Genus ROBULUS Montfort, 1808 (Pl. 9, fig. 1).—Test similar to *Cristellaria* but the proximal radial slit of the normal radiate aperture enlarging and extending into the usually triangular face of the test, in some species becoming separated.—Jurassic to Recent.

Genus SARACENARIA Defrance, 1824 (Pl. 9, fig. 2). (*Hemirobulina* Stache, 1864).—Test with the earliest chambers close-coiled, later uncoiling, aperture as in *Robulus*, the test usually triangular in transverse section.—Jurassic to Recent.

Genus RIMULINA d'Orbigny, 1826.—Test arcuate, of few chambers, aperture narrow, elongate extending from the apex well along the median line of the convex side.—Recent. [A study of the original model of d'Orbigny's makes one strongly suspect that this genus was founded upon an Ostracod. None of the very few forms referred to it since are like the original and no such species as *R. glabra* d'Orbigny has been found by later workers although d'Orbigny's original reference and figure have been copied by later authors.]

Genus LINGULINA d'Orbigny, 1826 (Pl. 9, fig. 3).—Test in the early stages, at least of the microspheric forms planospiral, later ones in a rectilinear series, compressed, aperture becoming elongate, elliptical.—Permian to Recent. (The forms which show traces of the coiling in the early chambers were called *Lingulinopsis* by Reuss).

Genus VAGINULINA d'Orbigny, 1826 (Pl. 9, fig. 11).—Test compressed, arcuate, one side of the test straight representing

the periphery, the other convex, sutures oblique, highest on the straight side of the test, aperture at the peripheral angle.—Jurassic to Recent.

Genus FRONDICULARIA DeFrance, 1824 (Pl. 9, fig. 12).—Test in the early stages planospiral, at least in the microspheric form, later chambers extending back on the two sides of the test forming inverted V-shaped chambers, aperture in the young peripheral, gradually becoming terminal.—Permian to Recent. (*Flabellina* d'Orbigny, 1839 was applied to the forms which showed the coiled early stages. *Flabellinella* Schubert, 1900 was applied to a form in which the young was like *Vaginulina* and later development like *Frondicularia*. It was megalospheric.)

Subfamily 2. Lageninae.

Test consisting of a single chamber; aperture typically radiate.

Genus LAGENA Walker and Jacob, 1798 (Pl. 9, fig. 9).—Test unilocular, aperture typically radiate, or at least rounded, terminal, central; wall vitreous, very finely perforate, variously ornamented, chambers without an internal tube.—Silurian to Recent.

The Lagenidae represent one of the most variable of all the groups of the Foraminifera. If the early Palaeozoic records are really *Nodosaria*, etc., the family record is one of the oldest in the group. In many ways the entire group appears protean. The genera are not clearly defined as are those of most other families. It is possible in the same species from a single fossil sample or recent dredge haul to find megalospheric forms referable to *Nodosaria*, specimens with a small proloculum and curved test referable to *Dentalina*, and one with a still smaller proloculum coiling at the base and referable to *Marginulina*. While *Robulus* and *Cristellaria* may be separated in many forms nevertheless there are species in which more compressed specimens gradually lose the distinctive character of the elongated specialized slit and the aperture reverts to the equally radiate.

So also in the Nodosarian forms there may be a very gradual series from those with remote chambers and stoloniferous connections back to ones in which the chambers are closely set, or even overlapped.

The subfamily Lageninae contains those single-chambered forms which have arisen through the megalospheric form of embracing species of *Glandulina*. Those species with Entosolenian tubes and narrow curved apertures do not belong here but are

end forms of the Ellipsoidinidae. Others of the group also are end forms derived in a similar manner from the Buliminidae and other families but need careful research on abundant material to be placed with accuracy. It is a complex group which shows its position at the end of a line of development by the excessive ornamentation that has been developed. This is not true of the more recently acquired single-chambered condition in the Ellipsoidinidae which are still smooth like most of the other members of the family.

It is possible that *Robulus* with its larger aperture represents the primitive stage and the original aperture of the early coiled, single-chambered ancestor. The family was abundant in the Jurassic and Triassic and has developed few new characters since that time. *Frondicularia* and allied forms reached their climax in the Cretaceous.

#### FAMILY 25. POLYMORPHINIDAE.

Test calcareous, vitreous, very finely perforate; chambers simple, biserial, or in an irregular spiral, becoming uniserial or finally single-chambered; aperture radiate, terminal.

Subfamily 1. Polymorphininae.

Chambers biserial or irregularly spiral at least in the young, chambers in a close mass.

Genus POLYMORPHINA d'Orbigny, 1926 (Pl. 9, fig. 13).—Test biserial.—Triassic to Recent.

Genus GUTTULINA d'Orbigny, 1826 (Pl. 9, fig. 14).—Test becoming triserial or irregular, the chambers inflated.—Jurassic to Recent.

Genus GLOBULINA d'Orbigny, 1826 (Pl. 9, fig. 15).—Test generally triserial, much embracing, the last three chambers usually forming the entire surface of the test.—Triassic to Recent.

Genus PYRULINA d'Orbigny, 1826 (Pl. 9, fig. 16).—Test irregularly biserial, chambers partially embracing, not greatly inflated.—Triassic to Recent.

Genus DIMORPHINA d'Orbigny, 1826 (Pl. 9, fig. 17).—Early chambers polymorphine, later ones in a rectilinear series.—Cretaceous to Recent.

Subfamily 2. Ramulininae.

Test free or attached, chambers widely separated by stoloniferous connections.

Genus RAMULINA Rupert Jones, 1875 (Pl. 9, fig. 19).—Test

free, branching, consisting of more or less rounded chambers connected by long stoloniferous tubes; wall thin, hyaline.—Jurassic to Recent.

Genus VITREWEBBINA Chapman, 1892 (Pl. 9, fig. 18).—Test attached, consisting of a series of rounded chambers with tubular connections; wall very finely perforate; early chambers sometimes polymorphine.—Cretaceous.

The Polymorphinidae were probably derived from a planospiral *Cristellaria*-like ancestor as are many of the biserial forms in other groups of the foraminifera. Specimens showing this early coiled stage are occasionally found. From the simple biserial forms came *Guttulina* and *Globulina*, the latter probably giving rise to certain of the forms referred to *Lagena globosa*. In *Dimorphina* there is a tendency toward a uniserial condition. In many species of this group there are developed peculiar "wild growths", thin walled, hyaline, and branching which may have given rise to the peculiar forms grouped under the genus *Ramulina* and attached forms such as *Vitrewebbina*.

#### FAMILY 24. NONIONIDAE.

Test typically planospiral, more or less involute, aperture simple or cribrate; at the base of the apertural face if simple, wall calcareous, perforate.

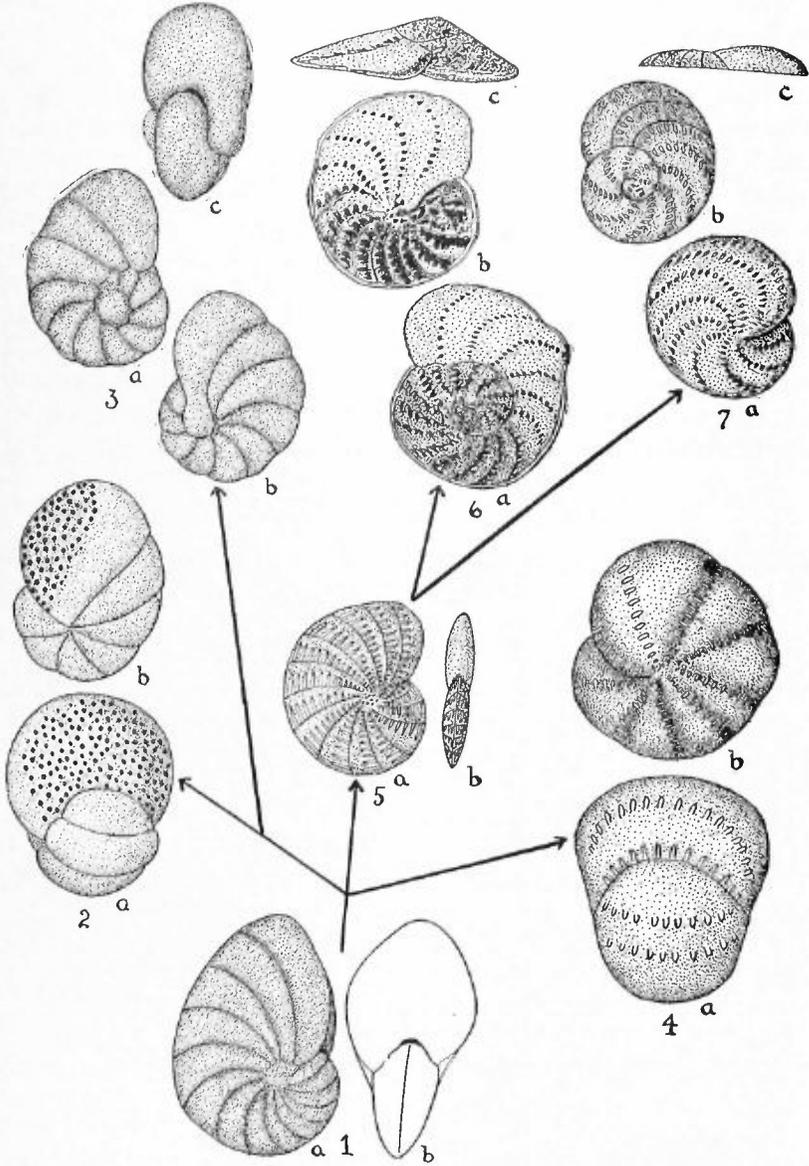
Genus NONION Montfort, 1808 (Pl. 10, fig. 1).—Test usually involute, sometimes with the earlier coils not entirely covered, bilaterally symmetrical, aperture an arched, usually narrow opening at the base of the last-formed chamber.—Carboniferous to Recent.

Genus CRIBROSPIRA Möller, 1878 (Pl. 10, fig. 2).—Test mostly involute, bilaterally symmetrical, aperture cribrate, the numerous rounded openings in a more or less concentric grouping on the apertural face.—Carboniferous to Cretaceous?

Genus NONIONELLA Cushman, 1926 (Pl. 10, fig. 3).—Test tending to become trochoid, the last-formed chambers on one side extending toward the umbilicus.—Cretaceous to Recent.

Genus BRADYINA Möller, 1878 (Pl. 10, fig. 4).—Test mostly involute, the sutural regions with depressions, early chambers apparently not entirely bilaterally symmetrical.—Carboniferous.

Genus ELPHIDIUM Montfort, 1808 (Pl. 10, fig. 5). (*Polystomella* Lamarck, 1816).—Test mostly involute, bilaterally symmetrical, sutural regions with septal bridges and depres-



sions, apertures numerous, at the base of the apertural face.—Jurassic to Recent.

Genus POLYSTOMELLINA Yabe and Hanzawa, 1923 (Pl. 10, fig. 6).—Test similar to *Elphidium* but trochoid, planoconvex, ventral side flattened, dorsal convex.—Tertiary and Recent.

Genus FAUJASINA d'Orbigny, 1839 (Pl. 10, fig. 7).—Test similar to *Elphidium* but trochoid, planoconvex, dorsal side flattened, ventral convex.—Cretaceous to Recent.

This small family includes *Bradyina* and *Cribrospira*, two Carboniferous genera which seem allied to *Nonion* and *Elphidium* but the fuller study of their complete development may change this view. There is little difference in the type species of *Nonion* and *Pullenia* but both may be kept especially on the basis of the difference in the apertures and their different relationships.

#### FAMILY 25. NUMMULITIDAE

Test generally planospiral, bilaterally symmetrical, in the early stages involute, later often evolute; wall calcareous, perforate, in the higher forms with a secondary skeleton and complicated canal system.

Genus ARCHAEDISCUS H. B. Brady, 1873 (Pl. 11, fig. 1).—Test lenticular, consisting of a proloculum and long undivided second chamber, close-coiled with a thick wall of finely perforate shell-material built up on the upper and lower surfaces; aperture at the open end of the chamber.—Carboniferous.

Genus NUMMULOSTEGINA Schubert, 1907 (Pl. 11, fig. 2).—Test lenticular, divided into chambers, bilaterally symmetrical, without complex secondary skeleton or canal system.—Carboniferous.

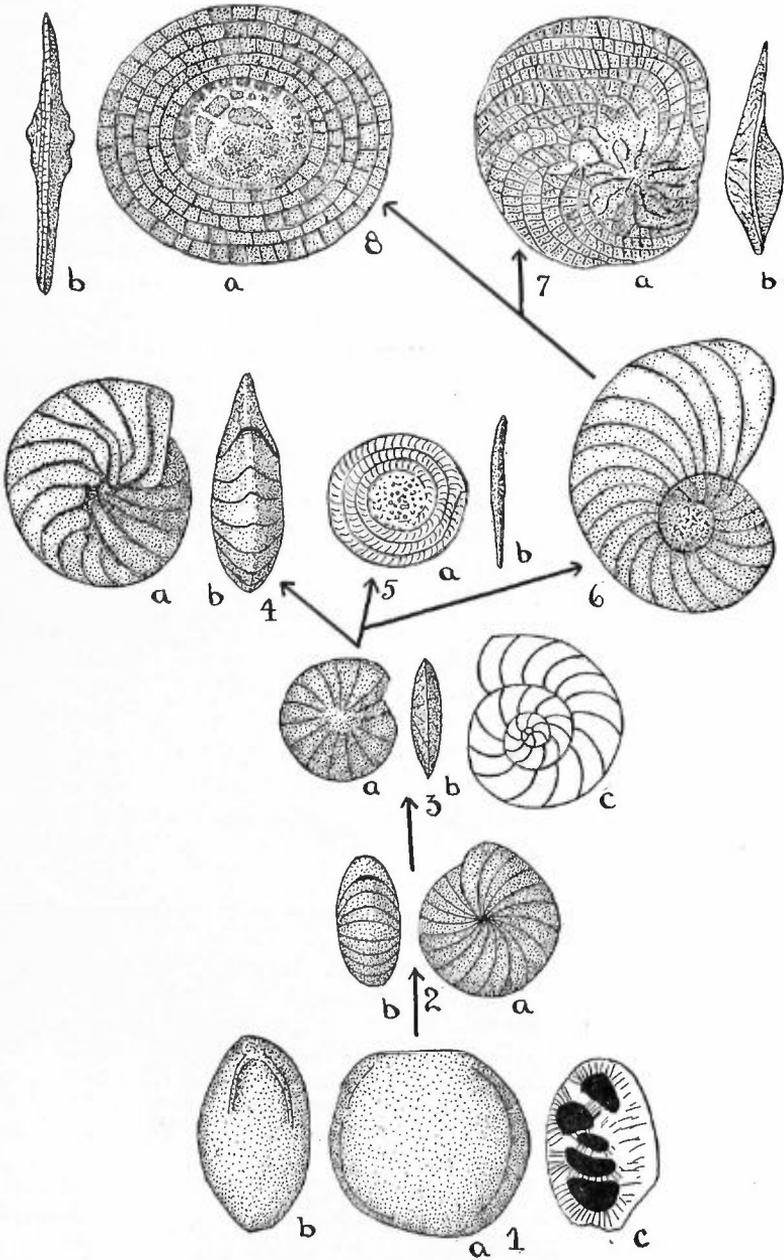
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#### EXPLANATION OF PLATE 10.

##### NONIONIDAE.

##### FIG.

- 1—*Nonion incisa* Cushman, *a*, side view, *b*, apertural view.
- 2—*Cribrospira panderi* Möller. (Adapted from Möller.) *a*, apertural view, *b*, side view.
- 3—*Nonionella auris* (d'Orbigny). *a*, *b*, opposite sides, *c*, apertural view.
- 4—*Bradyina nautiliformis* Möller. (Adapted from Möller.) *a*, apertural view, *b*, side view.
- 5—*Elphidium macella* (Fichtel and Moll). *a*, side view, *b*, apertural view.
- 6—*Polystomellina discorbinooides* Yabe and Hanzawa. (After Yabe and Hanzawa.) *a*, dorsal view, *b*, ventral view, *c*, peripheral view.
- 7—*Faujasina carinata* d'Orbigny. (After d'Orbigny.) *a*, ventral view, *b*, dorsal view, *c*, peripheral view.



Genus CAMERINA Brugiere, 1792 (Pl. 11, fig. 3).—Test lenticular, planospiral, involute, a secondary skeleton and complicated canal system developed, aperture simple at the base of the apertural face, median.—Carboniferous to Oligocene.

Genus ASSILINA d'Orbigny, 1826 (Pl. 11, fig. 5).—Test similar to *Camerina* but the test flattened, the chambers either not completely involute or so thin-walled that the earlier coils are visible from the exterior.—Eocene.

Genus OPERCULINELLA Yabe, 1918 (Pl. 11, fig. 4).—Test lenticular and involute in the young, in the adult with a broadly flaring complanate border, chambers simple.—Late Tertiary and Recent.

Genus ARNAUDIELLA H. Douvillé, 1907.—Test lenticular early chambers involute, later ones somewhat more compressed and somewhat evolute, exterior granular.—Eocene.

Genus OPERCULINA d'Orbigny (Pl. 11, fig. 6).—Test typically complanate, all the coils visible from the exterior, earlier coils more nearly involute; wall smooth or ornamented with bosses; aperture single at the base of the apertural face, median.—Lower Cretaceous to Recent.

Genus HETEROSTEGINA d'Orbigny, 1826 (Pl. 11, fig. 7).—Test similar to *Operculina*, the early chambers simple, later ones divided into chamberlets, aperture consisting of a row of rounded openings on the narrow apertural face.—Eocene to Recent.

Genus SPIROCLYPEUS H. Douvillé, 1905.—Test similar to

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#### EXPLANATION OF PLATE 11.

##### NUMMULITIDAE.

##### FIG.

- 1—*Archaeodiscus karreri* H. B. Brady. (After H. B. Brady.) *a*, side view, *b*, edge view, *c*, section.
- 2—*Nummulostegina velibitana* Schubert. (After Schubert.) *a*, side view, *b*, edge view.
- 3—*Camerina budensis* (Hantken). (After Hantken.) *a*, side view, *b*, edge view, *c*, section.
- 4—*Operculinella cumingii* (Carpenter). (After H. B. Brady.) *a*, side view, *b*, edge view.
- 5—*Assilina undata* d'Orbigny. (After d'Orbigny.) *a*, side view, *b*, edge view.
- 6—*Operculina bartschi* Cushman.
- 7—*Heterostegina depressa* d'Orbigny. (After H. B. Brady.) *a*, side view, *b*, edge view.
- 8—*Cycloclypeus guemelianus* H. B. Brady. (After H. B. Brady.) *a*, side view, *b*, edge view.

*Heterostegina*, but the test very complanate, the outer whorls not involute.—Miocene.

Genus *HETEROCLYPEUS* Schubert, 1906.—Test similar to *Heterostegina* in the young but the chambers becoming annular in the later development.—Tertiary.

Genus *CYCLOCLYPEUS* W. B. Carpenter, 1856 (Pl. 11, fig. 8).—Test in the microspheric form like *Heterostegina*, in later development discoidal, much compressed, the chambers annular and divided into rectangular chamberlets.—Miocene to Recent.

This family has some very complex forms in the development of the secondary skeleton and canal system. There is no evidence however that anywhere in the series there is a true trochoid development and it seems to have kept its generally bilateral symmetry since the Carboniferous. It is one of the few families that seem to have developed strongly in the Tertiary and in the present ocean is developing large and complex species, especially in the warm shallow waters of the Indo-Pacific.

#### FAMILY 26. PENEROPLIDAE.

Test imperforate except the proloculum and second chamber which are distinctly perforate, calcareous, in general planospiral in the young then becoming annular or uncoiling, chambers typically divided into chamberlets; aperture in simple forms slit-like, becoming multiple in the complex forms or rounded and terminal in uncoiled forms.

##### Subfamily 1. Spirolininae.

Test close-coiled in the young, becoming uncoiled in the adult.

Genus *PENEROPLIS* Montfort, 1808 (Pl. 12, fig. 1).—Test planospiral, close-coiled in the young, usually involute; chambers undivided, in the adult becoming variously shaped, close coiled, flaring, annular or commencing to uncoil.—Cretaceous? Tertiary and Recent. The Cretaceous forms referred to this genus as not typical but are more like the uniserial portion of *Spirolina*.

Genus *DENDRITINA* d'Orbigny, 1826 (Pl. 12, fig. 3).—Test with the aperture dentritic, the test usually showing a tendency to uncoil.—Eocene to Recent.

Genus *SPIROLINA* Lamarck, 1804 (Pl. 12, fig. 2).—Test with the early chambers close coiled usually not completely involute, the later ones uncoiled; aperture rounded, terminal.—Cretaceous? to Recent.

Genus *MONALYSIDIUM* Chapman, 1900 (Pl. 12, fig. 4).—Test with very thin porcellanous walls, surface smooth or with minute tubercles in vertical rows; early chambers coiled, later ones rectilinear, aperture circular, terminal, or with a short neck and lip.—Recent.

Subfamily 2. Archaisinae.

Test discoid, the early chambers spiral and simple, later ones divided into chamberlets, later stages variously involute.

Genus *FALLOTIA* H. Douvillé, 1902.—Test nummulitoid throughout the growth, the growing edge always peripheral; chambers involute, V-shaped.—Upper Cretaceous.

Genus *MEANDROPSINA* Munier-Chalmas, 1899. Test with the growing edge of the flattened faces of the test, variously meandering, the apertures rounded in a single row along this edge.—Upper Cretaceous.

Genus *ARCHAIS* Montfort, 1808 (Pl. 12, fig. 5) (*Orbiculina* Lamarck, 1816)—Test in the early stages planospiral and lenticular, in later stages becoming flaring, even annular; apertures in several rows on the apertural face.—Miocene to Recent.

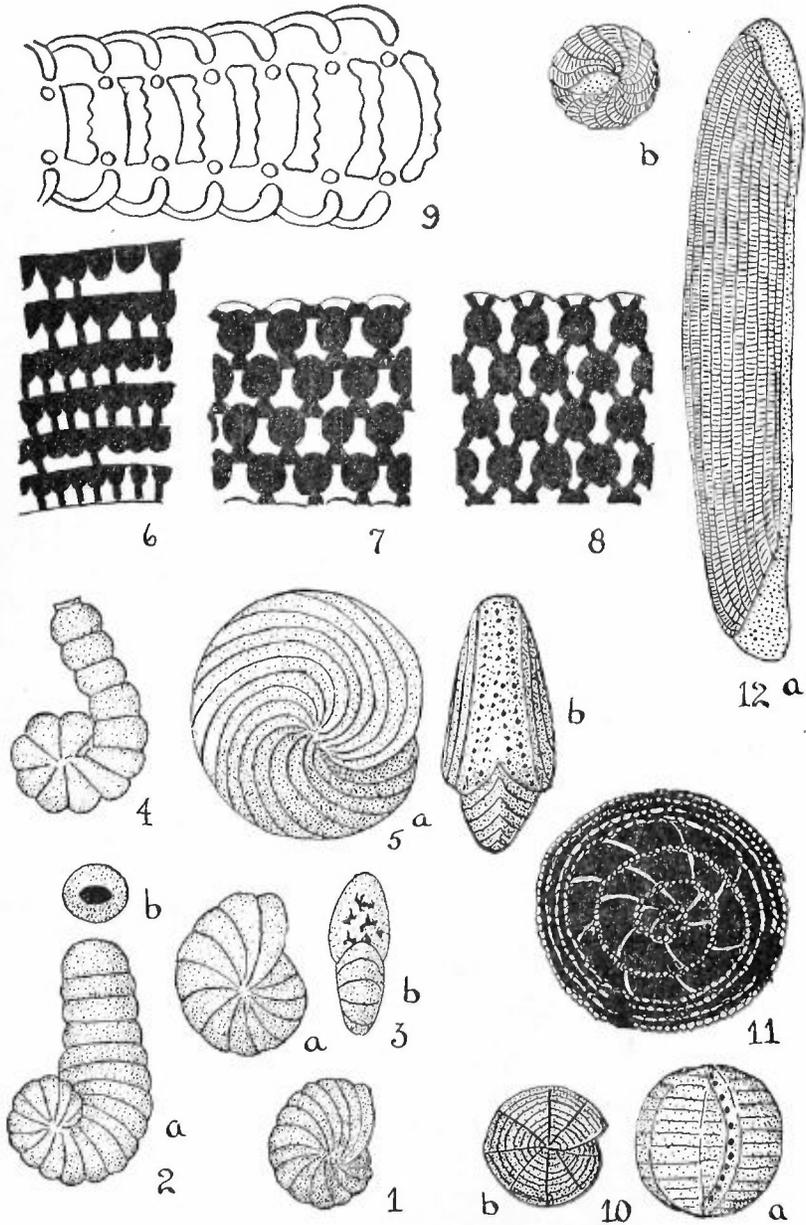
Subfamily 3. Orbitolitinae.

Test in the early stages planospiral, at least in the microspheric form, later annular, in the simplest forms the chambers only partially divided, in the more complex forms completely so; apertures on the peripheral face.

Genus *PRAESORITES* H. Douvillé, 1902 (Pl. 12, fig. 6).—Test with the chambers in a single plane, apertures numerous, the chambers nearly but not completely divided.—Cretaceous. (This should not be confused with *Discospirinia* Munier-Chalmas which it resembles but which is a very thin test derived from *Ophthalmidium*).

Genus *SORITES* Ehrenberg, 1838 (Pl. 12, fig. 7).—Test with one or two layers of chamberlets, the apertures in one or two lines along the periphery, the chamberlets of each annular chamber communicating with the adjacent ones as well as those of the preceding and succeeding annular chambers.—Miocene to Recent.

Genus *MARGINOPORA* Quoy and Gaymard, 1834 (Pl. 12, fig. 9).—Test in the young stages like *Sorites*, with one or two rows of apertures, later with the two original planes of chambers forced apart and filled with a high series of chamberlets those adjacent in each annular chamber connecting, the outer wall projecting beyond the peripheral plane of the lateral chambers,



the apertures in more or less vertical rows on the periphery with a horizontal row above and below.—Recent to Indo-Pacific.

Genus ORBITOLITES Lamarck, 1801 (Pl. 12, fig. 8).—Test differing from the preceding in having no communication between chamberlets of the same annular chamber but communicating with those of the adjacent preceding and succeeding annuli.—Eocene.

Genus OPERTORBITOLITES Nuttall, 1925.—Test similar to *Orbitolites* but with the flat sides of the test covered with a thick imperforate layer.—Eocene.

The Peneroplidae present a fairly regular series from simple to complex in their structure. In the present oceans they are limited to shallow warm waters, a habitat they seem to have preferred through their geologic history. The early perforate chambers form a very puzzling problem in the classification of the group showing that they were derived from a perforate ancestry. Just what that ancestry may be is not easily seen at present and must be solved by a study of Cretaceous material where there are forms referred to *Peneroplis* that seem to hold the clue to this problem. They have kept to the planospiral form and in many ways show a close resemblance to the Nummulitidae.

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#### EXPLANATION OF PLATE 12.

##### PENEROPLIDAE, ALVEOLINELLIDAE.

##### FIG.

- 1—*Peneroplis proteus* d'Orbigny. (After d'Orbigny.)
- 2—*Spirolina depressa* Lamarck. (After Defrance.) *a*, side view, *b*, apertural view.
- 3—*Dendritina antillarum* d'Orbigny. (After d'Orbigny.) *a*, side view, *b*, apertural view.
- 4—*Monalysidium sollasi* Chapman. (After Chapman.)
- 5—*Archais aduncus* (Fichtel and Moll). (After H. B. Brady.) *a*, side view, *b*, apertural view.
- 6—*Presorites*, showing central chambers in section. (After H. Douville.)
- 7—*Sorites*, showing central chambers in section. (After H. Douville.)
- 8—*Orbitolites*, showing central chambers in section. (After H. Douville.)
- 9—*Marginopora*, axial section. (Adapted from Carpenter.)
- 10—*Borelis melo* (Fichtel and Moll). (After H. B. Brady.) *a*, apertural view, *b*, end view.
- 11—*Flosculina globosa* Leymerie. (Section after Nuttall.)
- 12—*Alveolinella boscii* (Defrance). (After H. B. Brady.) *a*, apertural view, *b*, end view.

## FAMILY 27. ALVEOLINELLIDAE.

Test imperforate except the proloculum and second chamber; general shape of the test fusiform, coiled about an axis, chambers completely involute, divided into chamberlets; apertures numerous in one or more rows on the face of the last-formed chamber.

Genus FLOSCULINA Stache, 1880 (Pl. 12, fig. 11).—Test with the early coils high and of few chambers, later ones low, apertures in a single row.—Eocene.

Genus BORELIS Montfort, 1808 (Pl. 2, fig. 10). (*Alveolina* d'Orbigny, 1826).—Test globular or fusiform, early coils as well as later ones low; apertures in a single row.—Eocene to Recent.

Genus ALVEOLINELLA H. Douvillé, 1907 (Pl. 12, fig. 12).—Test fusiform, all coils low; apertures in several rows.—Recent.

This group has parallelisms in the group of *Fusulina* and its allies in the Palaeozoic and in the arenaceous group with *Loftusia*. The form is easily derived from such a genus as *Peneroplis* by the division of the close-coiled forms into chamberlets and an elongation of the axis. Some species which may be referred to *Borelis* are very much flattened in the line of the axis and are very close to *Peneroplis* except that the chambers are divided. Such forms are widely distributed in the Eocene.

## FAMILY 28. KERAMOSPHAERIDAE.

Test globular, the wall imperforate, of generally concentric chambers divided into chamberlets, generally flattened, parallel to the surface in concentric layers, communicating with adjacent chambers both in the same layers and in the layers above and below; apertures rounded, all at the margin of each chamberlet.

Genus KERAMOSPHAERA H. B. Brady, 1882.—Test with the characters of the family.—Very rare, Recent.

The position of this peculiar form must be close to *Orbitolites* and its associated genera. The globular form is superficially like that of the globular Miliolidae, *Periloculina* and *Lacazina*, but neither the apertures nor the known developments of the two have anything in common. It does not show any but superficial resemblance to the globular Alveolinellidae. The apertures, one to each chamberlet, together with the means of communication between chamberlets are those of the *Orbitolites* group.

Genus CRATERITES Heron-Allen and Earland, 1924.—This

very peculiar genus lately described which may have been attached shows some relationships to Orbitolites but its real position must be left to the future until further material is available for study and comparison.

## FAMILY 29. HETEROHELICIDAE.

Test in the more primitive forms planospiral in the young, later becoming biserial, in the more specialized genera the spiral stage and even the biserial stage may be wanting and the relationships shown by other characters; well calcareous, perforate, ornamentation in higher genera bilaterally symmetrical; aperture when simple, usually large for the size of the test, without teeth, in some forms with apertural neck and phialine lip.

### Subfamily 1. Heterohelicinae.

Test in early stages distinctly planospiral, later chambers biserial, aperture large at the inner margin of the character.

Genus HETEROHELIX Ehrenberg, 1843 (Pl. 13, fig. 1).—Test with the planospiral stage forming a considerable part of the whole, the few adult chambers biserial; aperture large on the inner margin of the last-formed chamber.—Cretaceous.

### Subfamily 2. Pavonininae.

Test with the planospiral stage much reduced, the biserial stage of short duration and the adult with single chambers extending clear across the face of the test or even becoming completely annular.

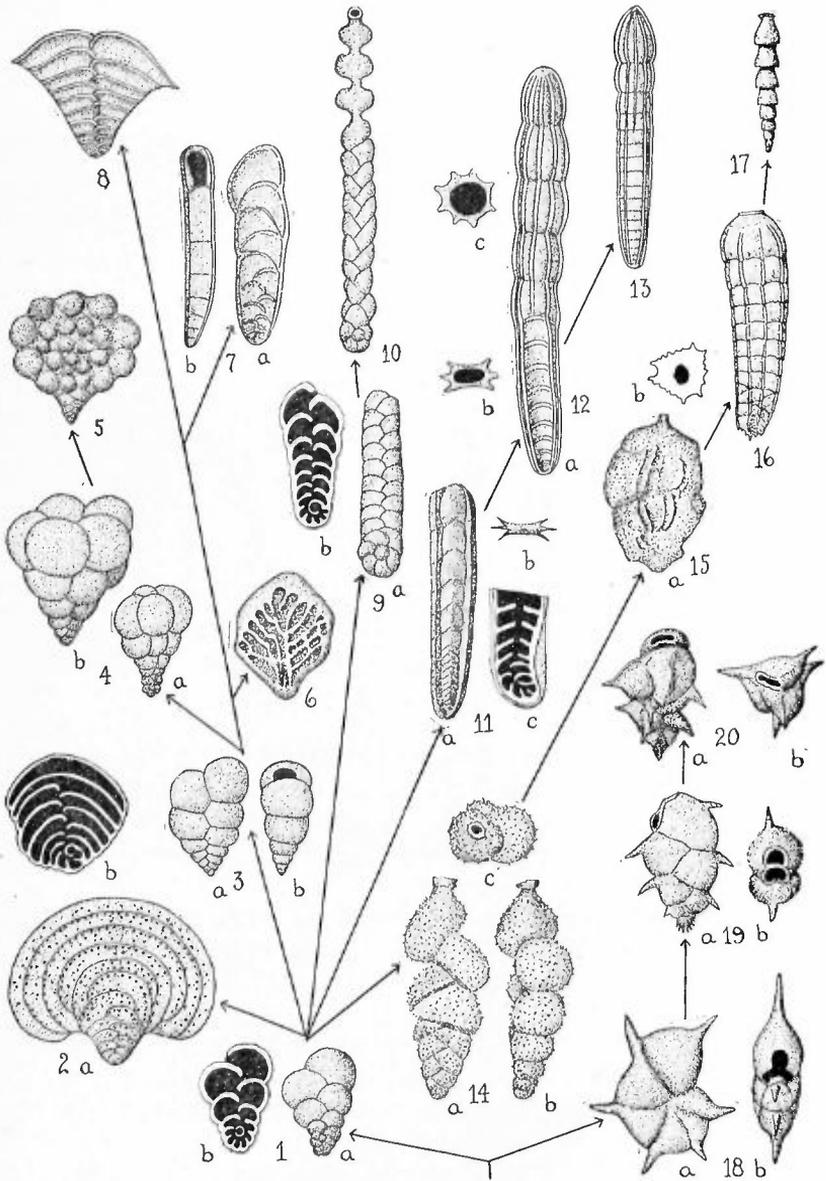
Genus PAVONINA d'Orbigny, 1826 (Pl. 13, fig. 2).—Test with the characters of the subgenus, apertures in the adult numerous, made up of rounded pores on the apertural face.—Upper Cretaceous? Eocene to Recent.

### Subfamily 3. Guembelininae.

Test in the microspheric young planospiral, often skipped in the megalospheric form, followed by a biserial condition which may be continued or give rise to globular chambers variously arranged.

Genus GUEMBELINA Egger, 1899 (Pl. 13, fig. 3).—Test with the early chambers planospiral at least in the microspheric form, later chambers biserial; wall finely perforate, variously ornamented; aperture at the base of the inner margin of the last-formed chamber, usually large, arched, without teeth.—Upper Cretaceous.

Genus PSEUDOTEXTULARIA Rzehak, 1886 (Pl. 13, fig. 4).—Test with the early chambers as in *Guembelina* but in the adult



having a series of globular chambers arranged in a more or less spiral manner about the upper portion of the test.—Upper Cretaceous.

Genus PLANOGLOBULINA Cushman, 1927 (Pl. 13, fig. 5).—Test with the earliest chambers in the microspheric form planospiral, followed by a series arranged biserially and in the adult by a series of globular chambers spread out fan-shaped or even partially extending back toward the earlier chambers on either side, the later chambers in a single plane; wall calcareous, perforate.—Upper Cretaceous.

Subfamily 4. Bolivinitinae.

Test in the adult biserial, compressed, aperture in the median line.

Genus BOLIVINOIDES Cushman, 1927 (Pl. 13, fig. 6).—

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EXPLANATION OF PLATE 13.

HETEROHELICIDAE, HANTKENINIDAE.

FIG.

- 1—*Heterohelix americana* Ehrenberg. (Adapted from Ehrenberg.) *a*, exterior, *b*, section.
- 2—*Pavonina flabelliformis* d'Orbigny. *a*, side view. (After Heron-Allen and Earland). *b*, section of *P. mexicana* Cushman.
- 3—*Guembelina globosa* (Ehrenberg).
- 4—*Pseudotextularia varians* Rzehak. *a*, microspheric, *b*, megalospheric.
- 5—*Planoglobulina acervulinoides* (Egger).
- 6—*Bolivinoides rhomboidalis* (Cushman).
- 7—*Bolivinita eleyi* Cushman. *a*, front view, *b*, side view.
- 8—*Bolivinella folium* Parker and Jones.
- 9—*Spiroplectoides rosula* (Ehrenberg). (Adapted from Ehrenberg.) *a*, exterior, *b*, section of another specimen.
- 10—*Spiroplectinata unnectens* (Parker and Jones). (After Parker and Jones.)
- 11—*Plectofrondicularia mexicana* Cushman. *a*, front view, *b*, apertural view, *c*, section.
- 12—*Amphimorphina hauerina* Neugeboren. (After Neugeboren.) *a*, front view, *b*, section of compressed portion, *c*, section of inflated portion.
- 13—*Nodomorphina compressiuscula* (Neugeboren). (After Neugeboren.)
- 14—*Eouvigerina gracilis* Cushman. *a*, front view, *b*, side view, *c*, apertural view.
- 15—*Pseudouvigerina cristata* (Marsson). *a*, front view, *b*, section.
- 16—*Siphogenerinoides plummeri* (Cushman).
- 17—*Nodogenerina bradyi* Cushman.
- 18—*Hantkenina alabamensis* Cushman. *a*, side view, *b*, apertural view.
- 19—*Mimosina hystrix* Millett. (Adapted from Millett.) *a*, side view, *b*, apertural view.
- 20—*Trimosina milletti* Cushman. (After Millett.) *a*, front view, *b*, apertural view.

Test compressed, rhomboid, the thickest portion near the aperture, this end usually appearing like a thickened lip without ornamentation, ornamentation in general at right angles to the sutures.—Upper Cretaceous.

Genus *BOLIVINITA* Cushman, 1927 (Pl. 13, fig. 7).—Test with the chambers biserial, the periphery concave with strongly developed angles, end view quadrate, aperture broad and high.—Upper Cretaceous to Recent.

Genus *BOLIVINELLA* Cushman, 1927 (Pl. 13, fig. 8).—Test much compressed, the proloculum in the megalospheric form rectangular, in the microspheric form the young apparently planospiral, later biserial; chambers long and recurved, not overlapping; wall calcareous, perforate; aperture transverse to the compression of the test, without teeth, but with numerous papillae on the wall near the opening.—Eocene to Recent.

Subfamily 5. Spiroplectininae.

Test elongate, early portion clearly planospiral, later biserial or uniserial, wall calcareous, perforate.

Genus *SPIROPLECTOIDES* Cushman, 1927 (Pl. 13, fig. 9).—Test with the early chambers planospiral, later ones biserial, elongate sides nearly parallel with biserial chambers very numerous; aperture elliptical, terminal or nearly so in the adult.—Cretaceous.

Genus *SPIROPLECTINATA* Cushman, new name (Pl. 13, fig. 10).—Test with the early chambers planospiral, later ones biserial, sides of the test straight and nearly parallel, the last group of chambers uniserial with distinctly constricted necks and a rounded terminal aperture.—Cretaceous. (The name *Spiroplectina* has already been used by Schubert although without species and *Spiroplectinata* is proposed for this form instead of *Spiroplectina* Cushman, not Shubert.)

Subfamily 6. Plectofrondicularinae.

Test in the microspheric form planospiral in the initial stages, later biserial and then uniserial or in the higher forms starting as uniserial tests; ornamentation bilaterally symmetrical; aperture rounded or elliptical, terminal.

Genus *PLECTOFRONDICULARIA* Liebus, 1903 (Pl. 13, fig. 11).—Test in the microspheric form with the early chambers planospiral, then biserial, the adult with chambers in a rectilinear series, much compressed, aperture terminal, elliptical.—Cretaceous to Recent.

Genus *AMPHIMORPHINA* Neugeboren, 1850 (Pl. 13, fig.

12).—Test uniserial except in the microspheric form which may show traces of the biserial stage, the earlier portion of the test flattened as in *Plectofrondicularia*, later portion with the chambers inflated, aperture in the young elliptical later circular.

—Miocene.

Genus NODOMORPHINA Cushman, 1927 (Pl. 13, fig. 13).

—Test in the early stages compressed but soon inflated and the test *Nodosaria*-like, the aperture terminal, circular or broadly elliptical, without teeth or radiate fissures; ornamentation bilaterally symmetrical.—Miocene.

Subfamily 7. Eouvigerinae.

Test in the early stages biserial, occasionally planospiral, later stages triserial or uniserial in some genera.

Genus EOUVIGERINA Cushman, 1926 (Pl. 13, fig. 14).—

Test occasionally planospiral in the young of the microspheric form, later biserial, the adult with the chambers tending to become triserial; aperture rounded, with a neck and phialine lip.

—Upper Cretaceous.

Genus PSEUDOUVIGERINA Cushman, 1927 (Pl. 13, fig.

15).—Test in the early stages biserial, later triserial; wall calcareous, coarsely perforate; chambers triangular in section with the outer angle usually truncated; aperture usually with a tubular neck and phialine lip.—Upper Cretaceous and perhaps Tertiary to Recent.

Genus SIPHOGENERINOIDES Cushman, new genus (Pl. 13,

fig. 16). (Genotype *Siphogenerinoides plummeri* (Cushman)).—Test in the early stages biserial, later uniserial, aperture with a neck and phialine lip; without siphons between the chambers.—Cretaceous.

Genus NODOGENERINA Cushman, 1927 (Pl. 13, fig. 17).

—Test uniserial, straight, chambers increasing in size as added, distinct, inflated, constricted at the connection between the chambers; wall calcareous, finely perforate; aperture terminal, central, rounded, with a cylindrical neck and phialine lip.—Cretaceous to Recent.

This family although there is a great variety of form in the adult stages, especially of the more specialized forms, shows a compact grouping. The diverse forms are connected by stages showing the relationships. They were all derived from a planospiral coiled ancestry of calcareous perforate type such as *Spirulina*. In *Heterohelix* the biserial portion is becoming the adult character as it is in a few of the other genera which are primi-

tive ones in the family. On this biserial stage are built the adult characters, broad low chambers becoming annular in *Pavonia*, globular chambers, spiral in *Pseudotextularia* or in a plane, in *Planoglobulina*, or triserial in *Eowigerina* and *Pseudowigerina* or finally uniserial in several of the genera representing terminal forms on various lines of development. There is no tooth in the aperture and apparently internal siphons are lacking, two characters which in addition to the planospiral beginning will distinguish these from the Buliminidae and the perforate calcareous test will separate them from the Textulariidae which are arenaceous.

### FAMILY 30. HANTKENINIDAE.

Test planospiral, at least in the young, involute, wall calcareous, perforate, each chamber with a long acicular spine; aperture a high arched opening often with basal lobes, or divided.

Genus HANTKENINA Cushman, 1924 (Pl. 13, fig. 18).—Test planospiral throughout, wall thin, calcareous perforate; chambers distinct, involute, each with an acicular spine at the anterior angle or becoming obsolete in the adult, aperture typically arched with a basal lobe at either side.—Upper Eocene.

Genus MIMOSINA Millett, 1900 (Pl. 13, fig. 19).—Test in the microspheric young at least apparently planospiral, later chambers biserial, chambers with single acicular spines; wall calcareous, vesicular, somewhat spongy; aperture compound, consisting of two parts, one rounded and nearly terminal, the other below near the rim of the chamber, more elongate, arched.—Recent.

Genus TRIMOSINA Cushman, new genus (Pl. 13, fig. 20). (Genotype *Trimosina milletti* Cushman, n. sp.—*Mimosina spinulosa* Millett, var., Millett, Journ. Roy. Micr. Soc., 1900, p. 548, pl. 4, fig. 13).—Test in the early stages biserial, later triserial, chambers with single acicular spines, or these obsolete, the wall calcareous, vesicular, aperture elongate, removed from the edge, sometimes with a series of rounded pores in addition along the basal rim.—Recent.

The relationships of the Recent Indo-Pacific genera with *Hantkenina* of the Upper Eocene is seen not only in the spinose character of the large acicular spine in each chamber, and the planospiral early development, but also in the apertural characters that of the specimen *Mimosina* shown being very much like

that of *Hantkenina* with the two parts separated. The family is related to the Heterohelicidae.

### FAMILY 31. BULIMINIDAE.

Test typically an elongate spiral, broken up into chambers, in the specialized genera biserial or uniserial or even monothalamous; wall calcareous, perforate; aperture loop-like or rounded and terminal.

#### Subfamily 1. Terebralinae.

Test an elongate close spiral; not divided into chambers; aperture rounded, terminal.

Genus *TEREBRALINA* Terquem, 1866 (Pl. 14, fig. 1).—Test with the characters of the subgenus.—Jurassic.

#### Subfamily 2. Turrilinae.

Test an elongate close spiral, divided into chambers, usually more than three in a coil, the lines of the spiral very distinct.

Genus *TURRILINA* Andreae, 1884 (Pl. 14, fig. 2).—Emend.—Test an elongate close spiral, the chambers three or more in a coil, the spiral suture marked and even, aperture with a broad base at the basal margin of the chamber, little if at all twisted, walls single.—Jurassic to Recent.

Genus *BULIMINELLA* Cushman, 1911 (Pl. 14, fig. 3).—Test an elongate close spiral, the spiral suture marked, chambers three or usually more in a coil; aperture very slightly twisted.—Cretaceous ? to Recent.

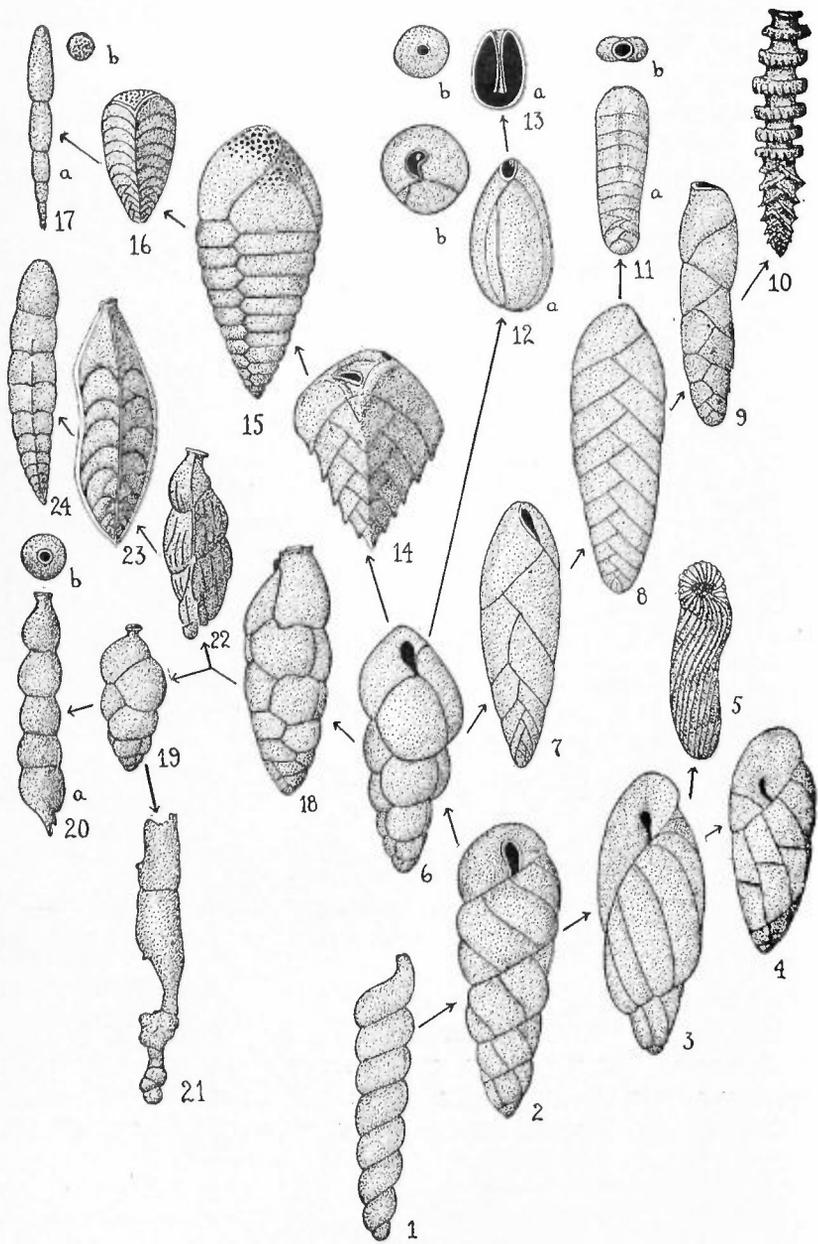
Genus *BULIMINOIDES* Cushman, 1911 (Pl. 14, fig. 5).—Test an elongate close spiral, spiral suture marked, aperture circular, terminal.—Recent.

Genus *ROBERTINA* d'Orbigny, 1846 (Pl. 14, fig. 4).—Test an elongate close spiral, the spiral suture marked, the chambers in each coil several, forming a double series; aperture elongate, curved.—Recent.

#### Subfamily 3. Bulimininae.

Test spiral, usually triserial, becoming involute and finally in *Entosolenia* monothalamous; aperture loop-shaped, the larger end away from the inner rim (or in *Entosolenia*, rounded) with a distinct tooth and internal tube connecting the chambers, free in *Entosolenia* at the base.

Genus *BULIMINA* d'Orbigny, 1826 (Pl. 14, fig. 6).—Test an elongate spiral generally triserial, the chambers inflated, spiral suture more or less obsolete; aperture loop-shaped with a tooth or plate at one side and an internal spiral tube con-



necting the chambers between the apertures, wall usually thin, finely perforate.—Jurassic to Recent.

Genus *GLOBOBULIMINA* Cushman, new genus (Genotype *Globobulimina pacifica* Cushman, new species).—Test spiral, early chambers tending to elongate, later ones extending backward and finally each chamber extends further back and encloses the preceding ones in its series, the last three chambers making the entire exterior; wall thin, finely perforate; aperture loop-shaped with a tooth or plate and internal tube.—Tertiary and Recent.

*Globobulimina pacifica* Cushman, new species (Pl. 14, fig. 12).—Test subglobular in the adult with three chambers making the exterior by enclosing the preceding ones; wall very thin, finely perforate; aperture loop-shaped with a slight border, a broad tooth or plate, and internal spiral tube.—(Holotype from East-

## EXPLANATION OF PLATE 14.

## BULIMINIDAE.

## FIG.

- 1—*Terebralina regularis* Terquem. (After Terquem.)
- 2—*Turrilina acicula* (Andreae). (After Andreae.)
- 3—*Buliminella elegantissima* (d'Orbigny). (After d'Orbigny.)
- 4—*Robertina arctica* d'Orbigny. (After d'Orbigny.)
- 5—*Buliminoides williamsoniana* H. B. Brady. (After H. B. Brady.)
- 6—*Bulimina elegans* d'Orbigny.
- 7—*Virgulina subsquamosa* Egger.
- 8—*Bolivina incrassata* Reuss.
- 9—*Proroporus plaita* (Carsey).
- 10—*Bifarina fimbriata* (Millett).
- 11—*Rectobolivina bifrons* (H. B. Brady). *a*, front view, *b*, apertural view.
- 12—*Globobulimina pacifica* Cushman. *a*, front view, *b*, apertural view.
- 13—*Entosolenia globosa* Williamson. (After Williamson.) *a*, section, *b*, end view.
- 14—*Reussia spinulosa* (Reuss).
- 15—*Chrysalidina gradata* d'Orbigny. (After d'Orbigny.)
- 16—*Chrysalidinella dimorpha* (H. B. Brady). (After H. B. Brady.)
- 17—*Chrysalogonium polystoma* (Schwager). (After Schwager.) *a*, front view, *b*, apertural view.
- 18—*Uvigerinella californica* (Cushman).
- 19—*Uvigerina canariensis* d'Orbigny.
- 20—*Siphonodosaria abyssorum* (H. B. Brady). (After H. B. Brady.) *a*, front view, *b*, apertural view.
- 21—*Sporadogenerina flintii* Cushman.
- 22—*Angulogerina angulosa* (Williamson).
- 23—*Trifarina bradyi* Cushman.
- 24—*Dentalinopsis subtriquetra* Reuss.

ern Pacific, Lat. 17°18'N, Long. 102°22'W, depth 1197 fath., U. S. N. M. No. 20285).

Genus *ENTOSOLENIA* Ehrenberg, 1848 (Pl. 14, fig. 13).—Test monothalamous, the single chamber with an internal tube free at the inner end, wall usually thin, finely perforate.—Tertiary and Recent.

Subfamily 4. *Virgulininae*.

Test usually showing traces of its spiral origin in the twisted young, later biserial and in the end forms uniserial.

Genus *VIRGULINA* d'Orbigny, 1826 (Pl. 14, fig. 7).—Test with the early chambers spiral, triserial, later ones becoming biserial, whole test usually twisted; wall finely perforate; aperture elongate loop-shaped usually with a tooth or plate and internal spiral tube.—Lower Cretaceous to Recent.

Genus *BOLIVINA* d'Orbigny, 1839 (Pl. 14, fig. 8).—Test typically biserial, the initial end often twisted, wall calcareous, finely perforate; aperture elongate, often with a plate-like tooth and internal spiral tube.—Lower Cretaceous to Recent.

Genus *RECTOBOLIVINA* Cushman, new genus (Pl. 14, fig. 11).—(Genotype *Siphogenerina bifrons* H. B. Brady).—Test in the young biserial, in the adult uniserial, usually compressed, wall thin, finely perforate, aperture rounded, with a slight lip and internal tube.—Tertiary and Recent.

Genus *PROROPORUS* Ehrenberg, 1844 (Pl. 14, fig. 9).—Test similar to *Bolivina* but in the last chambers the sutures extending clear across the test, the apertures becoming terminal and elliptical.—Cretaceous to Recent.

Genus *BIFARINA* Parker and Jones, 1872 (Pl. 14, fig. 10).—Test with the earlier chambers biserial like *Bolivina*, later ones uniserial, the aperture becoming terminal and rounded.—Tertiary and Recent.

Subfamily 5. *Reussiinae*.

Test distinctly triserial in the young at least, in specialized forms becoming uniserial, wall finely perforate, aperture in the simpler forms and young elongate, in the uniserial forms especially, cribrate.

Genus *REUSSIA* Schwager, 1877 (Pl. 14, fig. 14).—Test triserial, usually triangular, wall finely perforate, calcareous; aperture oblique, elongate.—Cretaceous to Recent.

Genus *CHRYSALIDINA* d'Orbigny, 1846 (Pl. 14, fig. 15).—Test triserial, the aperture cribrate.—Cretaceous to Recent.

Genus *CHRYSALIDINELLA* Schubert, 1907 (Pl. 14, fig. 16).

—Test in the early stages triserial, in the adult uniserial; aperture cribrate.—Miocene to Recent.

Genus *CHRYSALOGONIUM* Schubert, 1907 (Pl. 14, fig. 17).

—Test uniserial throughout, aperture cribrate.—Pliocene.

Subfamily 6. *Uvigerininae*.

Test generally triserial at least in the young, later uniserial or irregular, aperture typically terminal with a neck and phialine lip and in some genera a spiral tooth with an internal twisted tube.

Genus *UVIGERINELLA* Cushman, 1926 (Pl. 14, fig. 18).—Test generally triserial, chambers distinct and inflated, aperture connected with the border of the chamber, elongate, with a raised collar and a tooth, internal tube often present.—Miocene to Recent and probably earlier.

Genus *UVIGERINA* d'Orbigny, 1826 (Pl. 14, fig. 19).—Test generally triserial, rounded in transverse section, chambers distinct and inflated, aperture terminal, rounded, with a neck and phialine lip, often with a spiral tooth and an internal twisted tube.—Cretaceous to Recent.

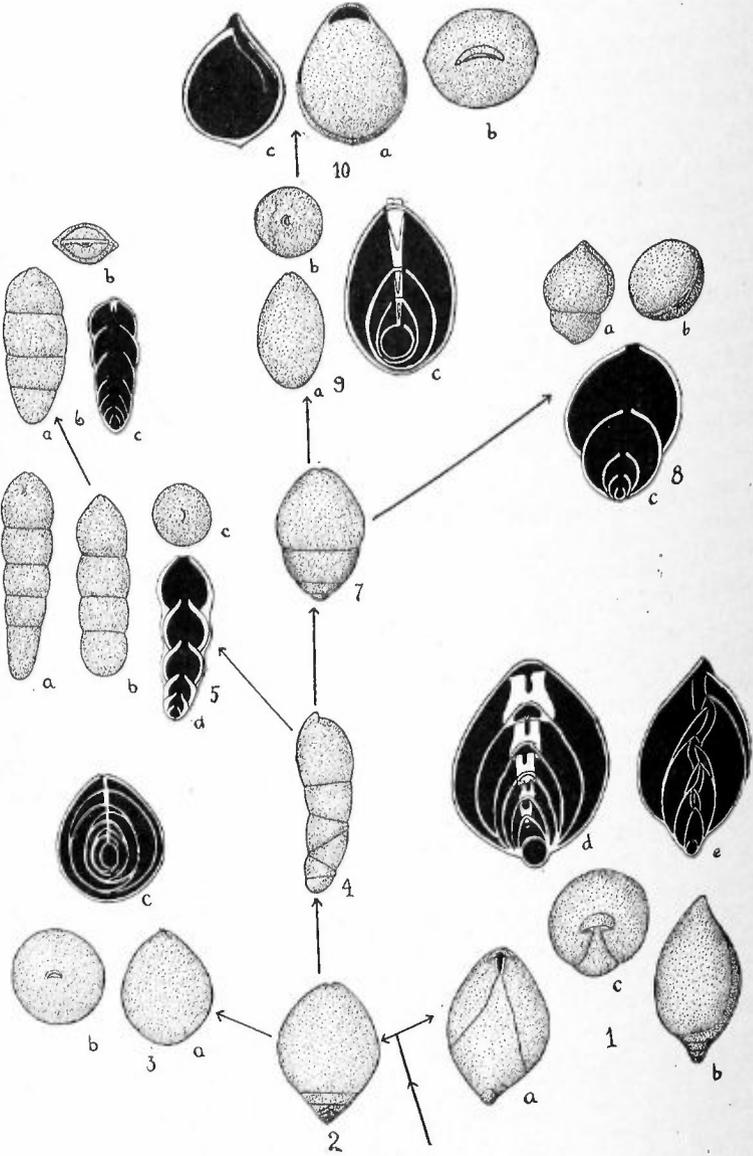
Genus *SIPHOGENERINA* Schlumberger, 1883. (*Sagrina* of authors, not d'Orbigny).—Test with the early stages typically triserial, rounded in section, later uniserial; aperture with a distinct neck and phialine lip and internal tube.—Cretaceous ? Eocene to Recent.

Genus *SIPHONODOSARIA* Silvestri, 1924 (Pl. 14, fig. 20).—Test uniserial, chambers generally globular, with a neck and phialine lip and large rounded aperture.—Tertiary and Recent.

Genus *ANGULGERINA* Cushman, new genus (Pl. 14, fig. 22). (Genotype *Uvigerina angulosa* Williamson, Rec. Foram. Great Britain, 1848, p. 67, pl. 5, fig. 140).—Test similar to *Uvigerina* but the whole test angled, with three flat sides and distinct angles, triangular in section.—Cretaceous ? Eocene to Recent.

Genus *TRIFARINA* Cushman, 1923 (Pl. 14, fig. 23).—(*Rhabdogonium* H. B. Brady, not Reuss).—Test triangular in transverse section, early chambers triserial, later ones uniserial; aperture rounded, terminal, with a short neck and phialine lip, and internal tube.—Cretaceous ? Eocene to Recent.

Genus *DENTALINOPSIS* Reuss, 1860 (Pl. 14, fig. 24).—Test uniserial, early chambers angled and triangular in section, later ones rounded, aperture terminal, rounded, not radiate.—Cretaceous.



Genus SPORADOGENERINA Cushman, 1927 (Pl. 14, fig. 21).—Test with the early chambers Uvigerine, especially in the microspheric form, later ones irregularly uniserial and elongate, aperture changing from a regular terminal position to one or more indefinite openings at the side of the chamber.—Recent.

The Buliminidae form a very closely-linked group, the intermediate stages of which are known so that the whole is well connected in all its parts. There is a tendency toward a complete uniserial development. The various lines herein have attained them to some degree and in the Bulimininae the single chambered form has been attained. The ancestral spiral form is maintained in most of the genera at least in the young. The aperture of the ancestral *Terebralina* which was in the middle of the face of the chamber breaks through to the periphery but is kept as a loop-shaped broader end in most of the forms. The tubular siphon-like internal structure is kept in all but the most specialized forms and will serve to separate these from their similarly shaped forms in other families. Species referred to *Siphogenerina* are derived from several sources. *Rectobolivina* has intermediate stages very clearly connecting it with species of *Bolivina* now living in the same ocean. It is possible that some of the triangular forms referred to *Lagena* as *Trigonulina*, etc. may be end forms from such genera as

## EXPLANATION OF PLATE 15.

## ELLIPSOIDINIDAE.

## FIG.

- 1—*Pleurostomella pleurostomella* (A. Silvestri). (After A. Silvestri.) *a*, front view, *b*, side view, *c*, apertural view, *d*, *e*, sections.
- 2—*Ellipsopleurostomella schlichti* A. Silvestri. (After A. Silvestri.)
- 3—*Ellipsobulimina seguenzai* A. Silvestri. (After A. Silvestri.) *a*, side view, *b*, apertural view, *c*, section.
- 4—*Nodosarella salmojrighii* Martinotti. (After A. Silvestri.)
- 5—*Ellipsonodosaria rotundata* d'Orbigny. (After A. Silvestri.) *a*, microspheric, *b*, megalospheric; *E. chapmani* A. Silvestri, *c*, end view, *d*, section. (After A. Silvestri.)
- 6—*Ellipsolingulina impressa* (Terquem). (After A. Silvestri.) *a*, front view, *b*, apertural view, *c*, section.
- 7—*Ellipsoglandulina labiata* (Schwager). (After A. Silvestri.)
- 8—*Gonatosphaera prolata* Guppy. (After Guppy.) *a*, front view, *b*, apertural view, *c*, section.
- 9—*Ellipsoidina ellipsoides* (Seguenza). (After A. Silvestri.) *a*, front view, *b*, apertural view, *c*, section.
- 10—*Ellipsolagena ventricosa* (A. Silvestri). (After A. Silvestri.) *a*, front view, *b*, apertural view, *c*, section.

*Trifarina*. The relationships in this family will be later enlarged upon as time and space permit.

### FAMILY 32. ELLIPSOIDINIDAE.

Test with the wall calcareous, finely perforate, variously formed, the aperture usually narrow, elongate, curved in the outline of a semi-ellipse; a hollow tube or rod-like structure, sometimes in the form of a curved plate connecting the various chambers, similar in general to that found in the Buliminidae.

Genus PLEUROSOTOMELLA Reuss, 1860 (Pl. 15, fig. 1).—Test usually elongate, biserial; aperture an arched opening, partially closed by two broad teeth at either side at the base with a narrow slit between.—Cretaceous to Recent.

Genus ELLIPSOPLEUROSOTOMELLA A. Silvestri, 1903 (Pl. 15, fig. 2).—Test with the early chambers biserial, later ones uniserial, aperture narrow, semicircular.—Cretaceous, Tertiary.

Genus ELLIPSOBULIMINA A. Silvestri, 1900 (Pl. 15, fig. 3).—Test with the early chambers somewhat biserial but entirely involute, the last-formed chamber making up nearly the entire test, aperture narrow, semicircular.—Miocene.

Genus NODOSARELLA Rzehak, 1895 (Pl. 15, fig. 4).—Test with the early chambers showing traces of the biserial ancestry but the later ones in a rectilinear series, very slightly involute; aperture narrow, semicircular.—Cretaceous and Tertiary.

Genus ELLIPSONODOSARIA A. Silvestri, 1900 (Pl. 15, fig. 5).—Test with all the chambers in a rectilinear series, rounded, aperture narrow, semielliptical.—Cretaceous, Tertiary.

Genus ELLIPSOLINGULINA A. Silvestri, 1907 (Pl. 15, fig. 6).—Test with all the chambers in a rectilinear series, compressed; aperture narrow, elliptical.—Tertiary.

Genus ELLIPSOGLANDULINA A. Silvestri, 1900 (Pl. 15, fig. 7).—Test with the chambers in a rectilinear series becoming involute, aperture semielliptical.—Cretaceous, Tertiary.

Genus GONATOSPHERA Guppy, 1904 (Pl. 15, fig. 8).—Test similar to *Ellipsoglandulina* but compressed, aperture elliptical.—Tertiary.

Genus ELLIPSOIDINA Seguenza, 1859 (Pl. 15, fig. 9).—Test with the chambers in a rectilinear series, but completely involute, a hollow tubular structure between the apertures and successive chambers, aperture semicircular, narrow.—Cretaceous and Tertiary.

Genus ELLIPSOLAGENA A. Silvestri, 1924 (Pl. 15, fig. 10).

—Test monothalamous, with an internal tube at one side of the chamber, the aperture elongate, curved with one side raised.—Tertiary and Recent.

This family for which a number of other generic names have been proposed is peculiar in the peculiar hooded form of the aperture which in end view is usually semicircular. The internal connecting tubular structure is closely similar to that of the Buliminidae from which this family is derived, probably through *Virgulina*. It developed in the Upper Cretaceous and is still represented in the present oceans. The relationships to the genera of the Lagenidae is not so close as the similarity of the generic names would indicate. From the early biserial forms which are near to *Virgulina* the series of chambers becomes either entirely involute as in *Ellipsobulimina* or continues on into uniserial forms becoming entirely involute in *Ellipsoidina* and finally in *Ellipsolagena* single-chambered as an end form.

### FAMILY 33. ROTALIIDAE.

Test perforate, calcareous, generally trochoid except in *Spirillina*, the aperture typically on the ventral side, all the chambers visible on the dorsal side except in a very few, somewhat involute forms, only those of the last-formed coil on the ventral side.

#### Subfamily 1. Spirillininae.

Test simple, consisting of a proloculum and planospiral undivided tubular second chamber, open end of the tubular chamber serving as the aperture.

Genus SPIRILLINA Ehrenberg, 1841.—Test with the characters of the subfamily.—Cambrian to Recent.

This genus as the ancestral form of the perforate, calcareous group is really a primitive form but it is included here for convenience rather than making a special family for it.

#### Subfamily 2. Turrispirillininae.

Test simple, consisting of a proloculum and spirally coiled second chamber the test making a cone.

Genus TURRISPIRILLINA Cushman, new genus (Pl. 16, fig. 1). (Genotype.—*Spirillina conoidea* Paalzow, Abhandl. Nat. Ges. Nürnberg, vol. 19, 1917, p. 17, pl. 41, figs. 8 a, b.)—Test making a hollow cone, the coils not appreciably involute, aperture a semicircular opening at the periphery.—Jurassic to Recent.

Genus CONICOSPIRILLINA Cushman, new genus (Pl. 16,

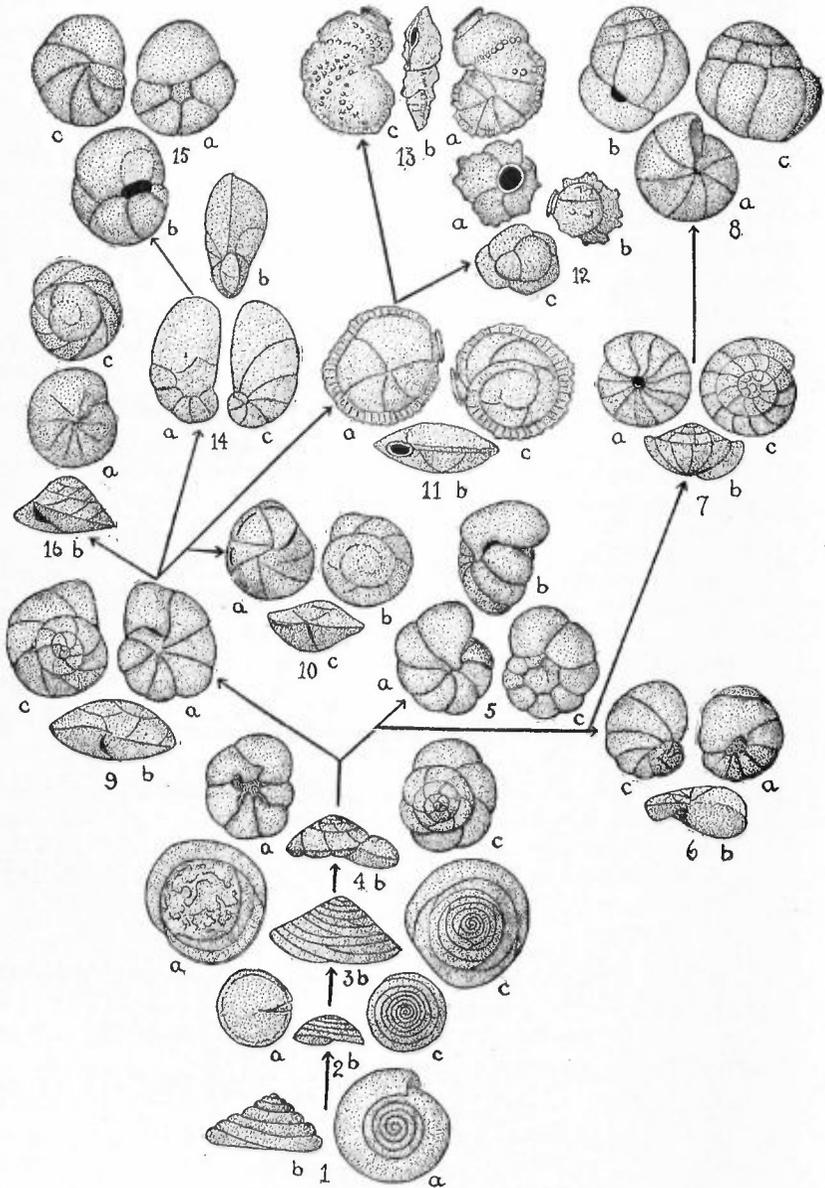


fig. 2). (Genotype.—*Spirillina trochoides* Berthelin, Revue et Mag. Zool., 1879, p. 37, pl. 1, figs. 20-22).—Test with the chambers completely involute on the ventral side, the aperture a narrow slit on the face of the revolving chamber from the periphery toward the umbilicus.—Jurassic.

Subfamily 3. Discorbisinae.

Test chambered, trochoid, umbilical region generally open, dorsal side with all chambers visible, only those of the last-formed coil visible on the ventral side; aperture ventral, not extending out to the periphery.

Genus PATELLINA Williamson, 1858 (Pl. 16, fig. 3).—Test

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EXPLANATION OF PLATE 16.

ROTALIIDAE.

FIG.

- 1—*Turrispirillina conoidea* (Paalzow). (After Paalzow.) *a*, ventral view, *b*, edge view.
- 2—*Conicospirillina trochoides* (Berthelin). (After Berthelin.) *a*, ventral view, *b*, edge view, *c*, dorsal view.
- 3—*Patellina corrugata* (Williamson). (After Williamson.) *a*, ventral view, *b*, edge view, *c*, dorsal view.
- 4—*Discorbis rosacea* d'Orbigny. (After H. B. Brady.) *a*, ventral view, *b*, edge view, *c*, dorsal view.
- 5—*Valvulineria californica* Cushman. *a*, ventral view, *b*, edge view, *c*, dorsal view.
- 6—*Lamarckina glabrata* (Cushman). *a*, ventral view, *b*, edge view, *c*, dorsal view.
- 7—*Gyroïdina soldani* d'Orbigny. (After d'Orbigny.) *a*, ventral view, *b*, edge view, *c*, dorsal view.
- 8—*Rotaliatina mexicana* Cushman. *a*, ventral view, *b*, edge view, *c*, opposite side.
- 9—*Eponides repandus* (Fichtel and Moll). (After H. B. Brady.) *a*, ventral view, *b*, edge view, *c*, dorsal view.
- 10—*Epistomina elegans* (d'Orbigny). (After H. B. Brady.) *a*, ventral view, *b*, edge view, *c*, dorsal view.
- 11—*Siphonina reticulata* (Czjzek). (After H. B. Brady.) *a*, ventral view, *b*, edge view, *c*, dorsal view.
- 12—*Siphoninoides echinata* (H. B. Brady). (After H. B. Brady.) *a*, ventral view, *b*, edge view, *c*, dorsal view.
- 13—*Siphoninella soluta* (H. B. Brady). (After H. B. Brady.) *a*, ventral view, *b*, edge view, *c*, dorsal view.
- 14—*Cancris auricula* (Fichtel and Moll). (After H. B. Brady.) *a*, ventral view, *b*, edge view, *c*, dorsal view.
- 15—*Baggina californica* Cushman. *a*, ventral view, *b*, edge view, *c*, dorsal view.
- 16—*Rotalia trochidiformis* Lamarck. (After Terquem.) *a*, ventral view, *b*, edge view, *c*, dorsal view.

conical or planoconvex, early whorls undivided, later ones divided into long chambers; aperture elongate at the inner border of the chamber; chambers often with internal sinuous septa.—Lower Cretaceous to Recent.

Genus DISCORBIS Lamarek, 1804 (*Discorbina* of authors) (Pl. 16, fig. 4).—Test typically planoconvex, the ventral side flattened, early portion sometimes showing a long *Spirillina*-like chamber before division; chambers often produced to partially cover the umbilical area; aperture a slit on the umbilical margin of the ventral side of the chamber.—Lower Cretaceous to Recent—possibly Carboniferous.

Genus LAMARCKINA Berthelin, 1880 (Pl. 16, fig. 6).—Test unequally biconvex or planospiral, ventral side less convex than the dorsal; chambers often with an umbilical projection; umbilical region open; aperture a low slit on the umbilical portion of the ventral margin; ventral side of the test usually polished.—Cretaceous? Tertiary and Recent.

Genus VALVULINERIA Cushman, 1926 (Pl. 16, fig. 5).—Test biconvex, umbilicus open, chambers with a projecting area over the umbilical region; aperture elongate, on the umbilical portion of the ventral margin.—Miocene to Recent, probably older.

Genus GYROIDINA d'Orbigny, 1826 (Pl. 16, fig. 7).—Test with the ventral side convex, the umbilicus small and deep, chambers in the central region usually higher than the peripheral ones and separated by a depressed channel; aperture a low arched opening on the ventral side toward the umbilical area.—Lower Cretaceous to Recent.

Genus ROTALIATINA Cushman, 1925 (Pl. 16, fig. 8).—Test with the ventral side very convex, the umbilicus small and deep, test with a high spire; aperture an arched opening on the ventral side midway between the umbilicus and periphery.—Eocene.

#### Subfamily 4. Rotaliinae.

Test trochoid, umbilical region typically closed, sometimes replaced with a definite conical plug of clear shell material; wall of the test often double; aperture ventral, along the margin of the chamber between the periphery and umbilical area.

Genus EPONIDES Montfort, 1808 (Pl. 16, fig. 9). (*Pulvinulina* of authors, in part.)—Test usually biconvex, trochoid, umbilical area closed; aperture a low opening between the periphery and umbilical area usually well away from the peripheral

margin; test often with thickened sutures and walls.—Carboniferous? Jurassic to Recent.

Genus *ROTALIA* Lamarck, 1804 (Pl. 16, fig. 16).—Test usually biconvex, the umbilical area closed and usually having a conical plug of clear shell material, sutures on the ventral side usually deeply depressed and often ornamented along the sides; wall often double; aperture an arched opening at the border of the ventral face midway between the periphery and the umbilical area, interseptal canals sometimes present.—Cretaceous to Recent.

#### Subfamily 5. Siphonininae.

Test trochoid at least in the young, umbilical area filled, supplementary apertures near the periphery on the ventral side, sometimes lipped.

Genus *EPISTOMINA* Terquem, 1883 (Pl. 16, fig. 10).—Test biconvex, trochoid, umbilical area filled, aperture at the ventral margin of the chamber with a supplementary elongate narrow opening parallel with the periphery and just below it on the ventral side.—Jurassic to Recent.

Genus *SIPHONINA* Reuss, 1849 (Pl. 16, fig. 11).—Test biconvex, trochoid, aperture just below the periphery, elliptical, with the long axis parallel to the periphery, in fully developed species with a short neck and phialine lip.—Cretaceous to Recent.

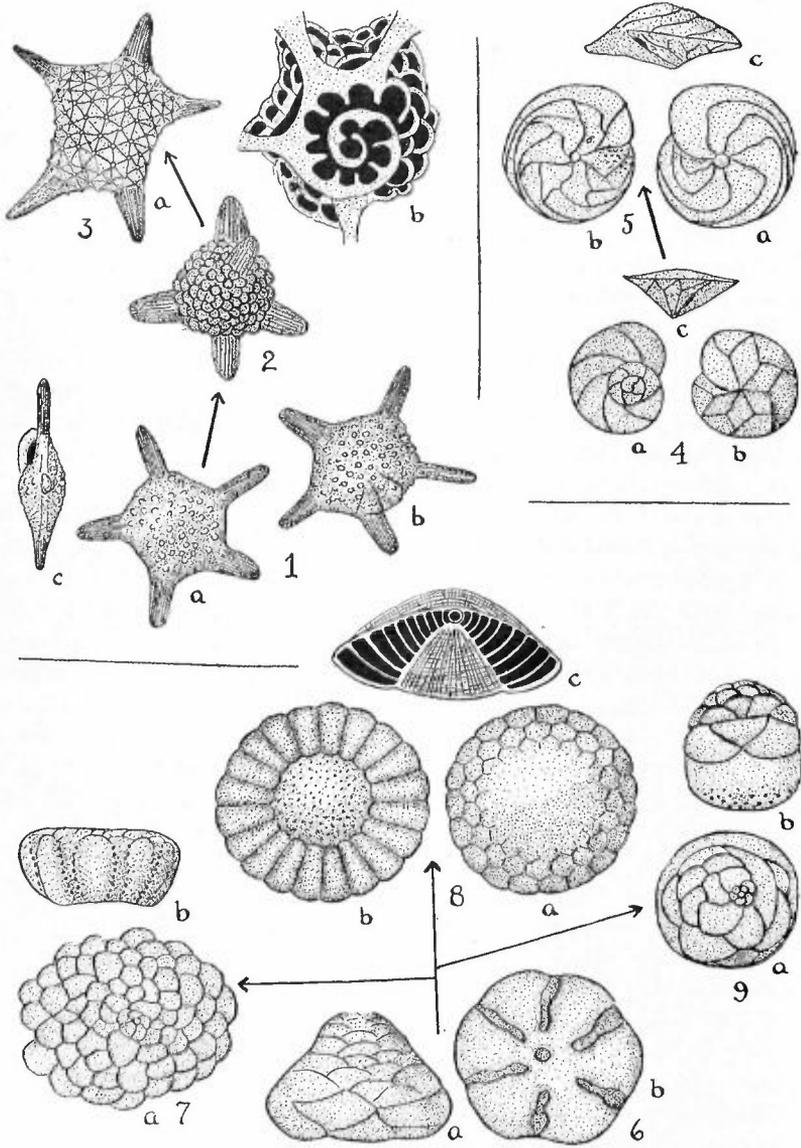
Genus *SIPHONINOIDES* Cushman, new genus (Pl. 16, fig. 12). Genotype, *Truncatulina echinata* H. B. Brady, Rep. Voy. Challenger, Zoology, vol. 9, 1884, p. 670, pl. 96, figs. 9-14).—Test globular, irregularly trochoid; aperture circular, with a very short neck and flaring lip.—Tertiary and Recent.

Genus *SIPHONINELLA* Cushman, new genus (Pl. 16, fig. 13). (Genotype, *Truncatulina soluta* H. B. Brady, Rep. Voy. Challenger, Zoology, vol. 9, 1884, p. 670, pl. 96, figs. 4 a.-c.)—Test in the early stages similar to *Siphonina*, in the later chambers becoming uncoiled, the aperture terminal with a neck and lip.—Eocene to Recent.

#### Subfamily 6. Baggininae.

Test generally biconvex, the umbilical area closed, the area adjacent to it on each chamber with a thinner rounded area clear, usually without perforations; aperture at the base of the ventral margin of the chamber.

Genus *CANCRIS* Montfort, 1808 (Pl. 16, fig. 14). (*Pulvinulina* of authors in part.)—Test nearly equally biconvex, compressed, the chambers few and rapidly becoming somewhat flar-



ing; umbilical area with a clear plate of rather large dimensions for the size of the test, aperture narrow.—Tertiary and Recent.

Genus BAGGINA Cushman, 1926 (Pl. 16, fig. 15).—Test trochoid, often slightly involute on the dorsal side, not compressed, chambers subglobular, umbilical area with a clear plate of small size, aperture arched.—Miocene to Recent.

As restricted here the Rotaliidae will include those forms which are trochoid, with definite dorsal and ventral sides, and the aperture wholly ventral. Such forms make a natural grouping closely related to one another and the steps between the genera often well filled by related forms. The group may be derived through the conical forms of *Spirillina* and the simple and more primitive forms of *Patellina* and *Discorbis*. The simpler forms are more or less umbilicate but this is filled in the higher forms. The earlier forms have simple walls, the higher ones double walls and canals. There is a gradual progression from very simple conditions to those foreshadowing the complex families which are derived from the Rotaliidae.

#### FAMILY 34. AMPHISTEGINIDAE.

Test rotaliform, trochoid, all chambers visible from the dorsal side except in involute forms of *Amphistegina*, those of the last-formed coil only visible on the ventral side, ventral side with angular supplementary chambers coming in between the regular series roughly rhomboid in shape from the surface; aperture

#### EXPLANATION OF PLATE 17.

##### CALCARINIDAE, AMPHISTEGINIDAE, CYMBALOPORIDAE.

##### FIG.

- 1—*Calcarina spengleri* (Linné). (After Carpenter). *a*, dorsal view, *b*, ventral view, *c*, edge view.
- 2—*Siderolites tetraedra* (Gumbel). (After Carpenter.)
- 3—*Baculogypsina sphaerulatus* (Parker and Jones). (After Carpenter.) *a*, exterior, *b*, section showing developmental stages.
- 4—*Asterigerina carinata* d'Orbigny. (After d'Orbigny.) *a*, dorsal view, *b*, ventral view, *c*, edge view.
- 5—*Amphistegina lessonii* d'Orbigny. *a*, dorsal view, *b*, ventral view, *c*, edge view.
- 6—*Cymbalopora squamosa* d'Orbigny. *a*, side view, *b*, ventral view.
- 7—*Cymbaloporella tabellaeformis* (H. B. Brady). (After H. B. Brady.) *a*, dorsal view, *b*, side view.
- 8—*Halkyardia minima* (Liebus). (After Heron-Allen and Earland.) *a*, dorsal view, *b*, ventral view, *c*, section.
- 9—*Tretomphalus bulloides* (d'Orbigny). (After H. B. Brady.) *a*, dorsal view, *b*, side view.

typically ventral, a slightly arched opening, the area adjacent to the aperture papillate.

Genus *ASTERIGERINA* d'Orbigny, 1839 (Pl. 17, fig. 4).—Test with all the chambers visible on the dorsal side, supplementary chambers large and regularly rhomboid, sutures a simple curve.—Eocene to Recent.

Genus *AMPHISTEGINA* d'Orbigny, 1826 (Pl. 17, fig. 5).—Test usually lenticular, often involute on the dorsal side in the adult; supplementary chambers more or less irregularly rhomboid, sutures and chambers with a pronounced angle, no true secondary canal system developed.—Tertiary to Recent. Carboniferous?

These two genera with their supplementary chambers on the ventral side are derived along a line from *Eponides*. The aperture is typically that of the *Rotaliidae* and it is evident from a study of the structure that *Asterigerina* is very closely allied to *Amphistegina* and that the two should be grouped together. *Amphistegina* has little in common with the *Nummulitidae* where it has usually been placed. There are records for *Amphistegina* from the Palaeozoic but they are not wholly satisfactory and probably represent some other genus.

#### FAMILY 35. CALCARINIDAE.

Test with the young, trochoid, aperture on the ventral side in general similar to *Rotalia*, soon adding a supplementary mass of shell material over which the new chambers are added, in the higher genera the chambers extending to the dorsal side and finally covering the whole test in a globular series, test developing bosses of shell material and large spines independent of the individual chambers; wall calcareous, perforate; aperture in the young like *Rotalia*, later consisting of numerous smaller openings, supplementary canal system well developed.

Genus *CALCARINA* d'Orbigny, 1826 (Pl. 17, fig. 1).—Test biconvex, with radial spines, independent of the individual chamber, usually in the plane of coiling, chambers usually confined to the ventral side; aperture typically a row of small openings along the inner ventral margin of the chamber.—Cretaceous to Recent.

Genus *SIDEROLITES* Lamarck, 1801 (Pl. 17, fig. 2).—Test in early stages similar to *Calcarina*, spines later added at right angles to the peripheral ones, chambers soon covering the dorsal side; aperture in the adult at the basal edge of each chamber,

finally represented by the circular openings of the chamber wall.  
—Cretaceous to Recent.

Genus BACULOGYPSINA Sacco, 1893 (Pl. 17, fig. 3). (*Tinoporus* of authors.)—Test in the early stages like *Calcarina*, very early developing four or more large spines which increase in size independently of the chambers, chambers quickly covering the whole surface, supplementary skeleton well developed, consisting of pillars at the angles of the chambers ending in rounded bosses at the surface and connected with surrounding ones by radial connecting rods giving a reticulate appearance to the test.—Tertiary and Recent.

This family which developed from the spinose forms of *Rotalia* shows a progressive complexity of structure from the simpler *Calcarina* to the complex *Baculogypsina*. The large spines are developed early and are one of the striking characters of the family. The species of the various genera are characteristic of warm shallow waters, at the present time in the Indo-Pacific.

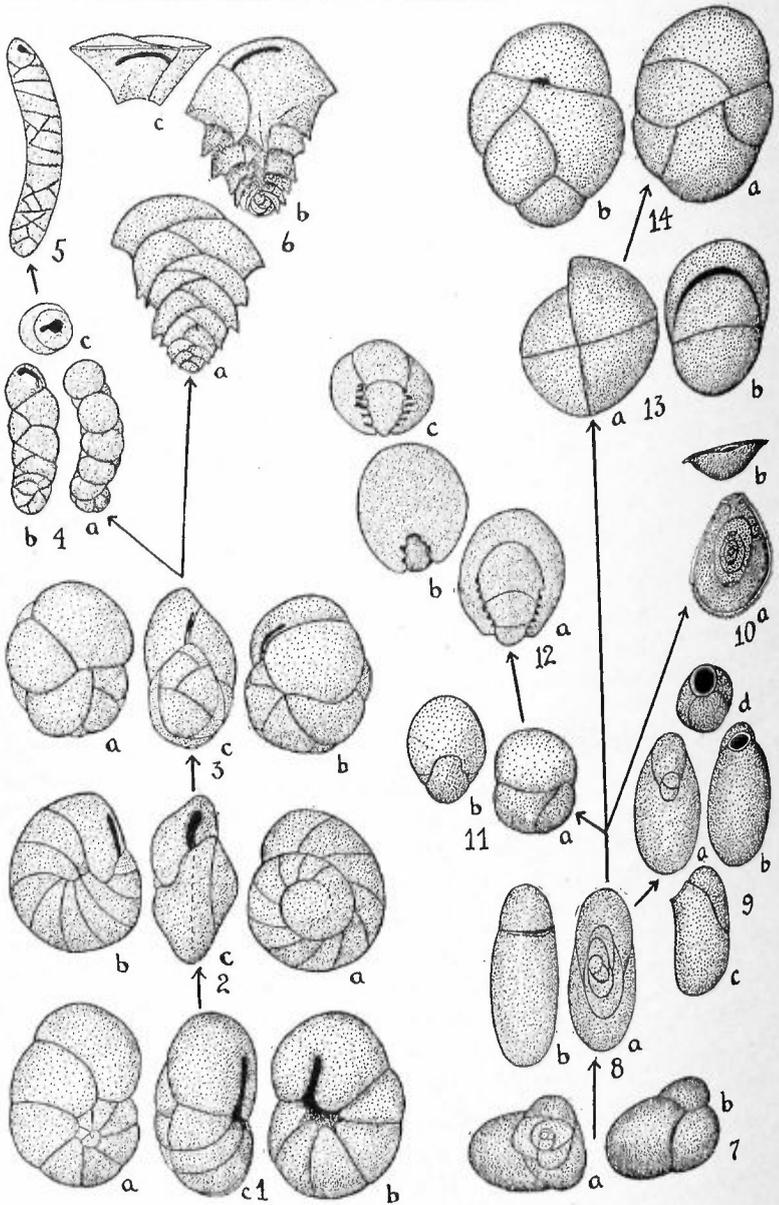
#### FAMILY 36. CYMBALOPORIDAE.

Test calcareous, perforate, in the young trochoid, close to *Discorbis*, in later development the chambers are in generally annular series about the periphery, apertures numerous, fine circular pores variously arranged, in *Tretomphalus* becoming pelagic.

Genus CYMBALOPORA Hagenow, 1850 (Pl. 17, fig. 6).—Test conical, with the early chambers trochoid, later ones in annular series separated somewhat from one another along the periphery, ventral side with depressions radiating from the central umbilicus; aperture consisting of fine circular pores along the ventral sides of the chamber.—Cretaceous ? to Recent.

Genus CYMBALOPORELLA Cushman, new genus (Pl. 17, fig. 7). (Genotype *Cymbalopora tabellaeformis* H. B. Brady, Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 637, pl. 102, figs. 15-18.)—Test compressed, the early chambers spiral, later ones in annular series, somewhat alternating in each series, apertures on the sides of the chamber on the peripheral face in generally vertical lines.—Late Tertiary and Recent.

Genus HALKYARDIA Heron-Allen and Earland, 1919 (Pl. 17, fig. 8).—Test in general conical, the dorsal side covered by a thickening of shell material, the ventral side with the umbilical area filled and with a series of pores.—Eocene.



Genus TRETOMPHALUS Moebius, 1880 (Pl. 17, fig. 9).—Test in the young somewhat similar to *Cymbalopora*, in the adult developing a large semiglobular "float chamber," an interior entire globular chamber and an outer one with many rounded apertures, the test at this stage becoming pelagic.—Recent.

This family evidently developed from a form close to *Discorbis* and has adopted the multiple-chambered arrangement of the chambers around the periphery in alternating annular series with numerous apertures in some respects resembling the structure developed in *Sorites*.

### FAMILY 37. CASSIDULINIDAE.

Test, at least in the young, trochoid, later in some genera with the chambers alternating on the ventral and dorsal surfaces of the test, or even uncoiling, wall calcareous, perforate; the aperture in the young of the simpler genera like the *Rotaliidae*

#### EXPLANATION OF PLATE 18.

##### CASSIDULINIDAE, CHILOSTOMELLIDAE.

FIG.

- 1—*Ceratobulimina contraria* (Reuss). (After H. B. Brady). *a*, dorsal view, *b*, ventral view, *c*, edge view.
- 2—*Pulvinulinella subperuviana* Cushman. *a*, dorsal view, *b*, ventral view, *c*, edge view.
- 3—*Cassidulina californica* Cushman and Hughes. *a*, dorsal view, *b*, ventral view, *c*, edge view.
- 4—*Cassidulinoides parkeriana* (H. B. Brady). (After H. B. Brady). *a*, dorsal view, *b*, ventral view, *c*, end view.
- 5—*Orthoplecta clavata* (H. B. Brady). (After H. B. Brady).
- 6—*Ehrenbergina pacifica* Cushman. (After H. B. Brady). *a*, dorsal view, *b*, ventral view, *c*, end view.
- 7—*Allomorphina trigona* Reuss. (After H. B. Brady). *a*, dorsal view, *b*, ventral view.
- 8—*Chilostomella oolina* Schwager. (After H. B. Brady). *a*, dorsal view, *b*, ventral view.
- 9—*Chilostomelloides oviformis* (Sherborn and Chapman). *a*, dorsal view, *b*, ventral view, *c*, side view, *d*, end view.
- 10—*Seabrookia pellucida* H. B. Brady. (After H. B. Brady). *a*, dorsal view, *b*, end view.
- 11—*Allomorphinella contraria* (Reuss). (After Reuss). *a*, side view, *b*, edge view.
- 12—*Chilostomellina fimbriata* Cushman. *a*, dorsal view, *b*, ventral view, *c*, end view.
- 13—*Pullenia sphaeroides* d'Orbigny. *a*, side view, *b*, apertural view.
- 14—*Sphaeroidina bulloides* d'Orbigny. *a*, dorsal view, *b*, ventral view.

but projecting into the apertural face in a direction becoming parallel to the periphery, elongate.

Subfamily 1. Ceratobulimininae.

Test rotaliform throughout.

Genus CERATOBULIMINA Toulou, 1920 (Pl. 18, fig. 1).—Test rotaliform, somewhat like *Valvulineria*, but the aperture elongate, pushing well into the ventral side of the chamber generally parallel to the axis of coiling in peripheral view, but well on the ventral side and extending in from the umbilical region.—Eocene to Recent.

Genus PULVINULINELLA Cushman, 1926 (Pl. 18, fig. 2).—Test rotaliform, compressed, umbilical area closed, the last few chambers alternating in relative length, every other one slightly longer; aperture elongate, extending into the apertural face on the ventral side near the periphery and parallel to it.—Tertiary and Recent.

Subfamily 2. Cassidulininae.

Test with the chambers alternating on the two sides of the axis.

Genus CASSIDULINA d'Orbigny, 1826 (Pl. 18, fig. 3).—Test with the chambers alternating on the two sides of the periphery, the aperture elongate, close to the peripheral plane, close-coiled.—Tertiary and Recent.

Genus CASSIDULINOIDES Cushman, new genus (Pl. 18, fig. 4). (Genotype, *Cassidulina parkeriana* H. B. Brady, Rep. Voy. Challenger, Zoology, vol. 9, 1884, p. 432, pl. 54, figs. 11-16.)—Test in the early stages like *Cassidulina* but in the adult becoming uncoiled in a series of alternating chambers, aperture terminal.—Miocene to Recent.

Genus ORTHOPLECTA H. B. Brady, 1884 (Pl. 18, fig. 5).—Test very elongate, chambers in an irregular biserial arrangement in the adult, those of the young appearing more as in *Cassidulina*, aperture nearly terminal. Recent.

Subfamily 3. Ehrenbergininae.

Test in the young as in *Cassidulina* but soon the chambers become compressed in a plane at right angles to that of the early coiling and becoming uncoiled, aperture elongate on the ventral side near the periphery.

Genus EHRENBURGINA Reuss, 1850 (Pl. 18, fig. 6).—Test with the characters of the subgenus, developing a dorsal side which is flattened or slightly convex and a ventral which is thickest near the median line.—Eocene to Recent.

This family is very closely related to the Rotaliidae, through such genera as *Valvulineria*, the test in *Ceratobulimina* being umbilicate with a change in the aperture clearly foreshadowing the conditions typical of *Cassidulina*. The uncoiled forms follow in their natural sequence. *Ehrenbergina* becoming compressed in a plane at right angles to the early coiling and with the adult chambers uncoiled, gives a new structural modification. On the basis of the biserial form, several of these genera have often been grouped with the Textulariidae. The Cassidulinidae are calcareous, perforate and have their close relationships to the Rotaliidae very clearly marked.

### FAMILY 38. CHILOSTOMELLIDAE.

Test in the early stages, typically trochoid, the chambers all visible on the dorsal side, only those of the last-formed coil visible on the ventral side, in later development variously arranged, the chambers inflated and becoming embracing, often covering the earlier stages; wall calcareous, perforate, aperture typically on the ventral side, at least in the young; most of the species pelagic.

#### Subfamily 1. Allomorphininae.

Test in the adult with usually three chambers to a coil, the chambers inflated and enlarging rapidly as added; aperture an elongate, curved slit at the border of the last-formed chamber on the ventral side.

Genus ALLOMORPHINA Reuss, 1850 (Pl. 18, fig. 7).—Test with the characters of the subfamily.—Upper Cretaceous to Recent.

#### Subfamily 2. Chilostomellinae.

Test in the adult with two chambers making up a coil, the chambers inflated and enlarging rapidly as added; aperture variously modified.

Genus CHILOSTOMELLA Reuss, 1850 (Pl. 18, fig. 8).—Test in the early stages, especially of the microspheric form, with the chambers as in *Allomorphina* but in the adult two chambers completing a coil, test ovoid or fusiform; aperture a narrow curved opening at the ventral margin of the last-formed chamber.—Upper Cretaceous.

Genus CHILOSTOMELLOIDES Cushman, 1926 (Pl. 18, fig. 9).—Test similar to *Chilostomella* but the aperture rounded and somewhat offset from the general contour of the test, with a neck in some species and slightly developed lip.—Upper Creta-

ceous and Lower Eocene.

Subfamily 3. *Seabrookiinae*.

Test with two chambers forming a coil but entirely embracing on the ventral side, the aperture elliptical and at the end of the chamber.

Genus *SEABROOKIA* H. B. Brady, 1890 (Pl. 18, fig. 10).—Test with the characters of the subfamily.—Recent.

It is probable that the genus *Cerviciferina* Goddard and Jensen, belongs here if it is found to be distinct from *Seabrookia*.

Subfamily 4. *Allomorphinellinae*.

Test with the early chambers indefinite, later ones in a planospiral coil, chambers rapidly increasing in size as added and embracing, aperture various.

Genus *ALLOMORPHINELLA* Cushman, new genus (Pl. 18, fig. 11). (Genotype, *Allomorphina contraria* Reuss, Haidinger's Nat., Abh., 4, pt. 1, 1851, p. 43, pl. 5, fig. 7.)—Test with the aperture elongate, narrow, at the periphery of the chamber at the median line.—Upper Cretaceous.

Genus *CHILOSTOMELLINA* Cushman, 1926 (Pl. 18, fig. 12).—Test with the aperture curved, along the periphery of the last-formed chamber, with short projecting tubes of the periphery of the chamber dividing the aperture into a series of rounded pores.—Recent.

Genus *PULLENIA* Parker and Jones, 1862 (Pl. 18, fig. 13).—Test planospiral, chambers completely involute, few; aperture an elongate opening at the inner margin of the last-formed chamber.—Cretaceous to Recent.

Subfamily 5. *Sphaeroidininae*.

Test in the earliest stages generally planospiral, later chambers irregularly embracing; aperture in the young, a crescent-shaped slit, in the adult, rounded, with a flat, rounded tooth-like projection.

Genus *SPHAEROIDINA* d'Orbigny, 1826 (Pl. 18, fig. 14).—Test with the characters of the subfamily.—Cretaceous.

The family shows a regular progression from the more primitive *Allomorphina* allied to the Rotaliidae such as *Baggina* to the specialized *Seabrookia*. The subfamily *Allomorphinellinae* apparently have the young as in *Allomorphina* but microspheric specimens are very rare and have not been fully studied. The early stages of *Sphaeroidina* connect this genus with *Allomorphinella* through *Pullenia*. It has no trace of the coarse wall or the spines characteristic of the Globigerinidae.

## FAMILY 39. GLOBIGERINIDAE.

Test, at least in the early stages, trochoid, umbilicate, wall calcareous, rather coarsely perforate, usually with a cancellated surface, in well preserved specimens of the simpler genera with fine spines; aperture typically large but in the higher genera consisting of numerous small openings variously placed.

## Subfamily 1. Globigerininae.

Wall clothed with fine spines, typically trochoid, but in some genera becoming planospiral, wall often cancellated, coarsely perforate.

Genus GLOBIGERINA d'Orbigny, 1826 (Pl. 19, fig. 1).—Test trochoid throughout, umbilicate, aperture a single opening into the umbilical area, usually large, wall coarsely perforate, fine spines covering the test in well preserved specimens.—Cretaceous to Recent.

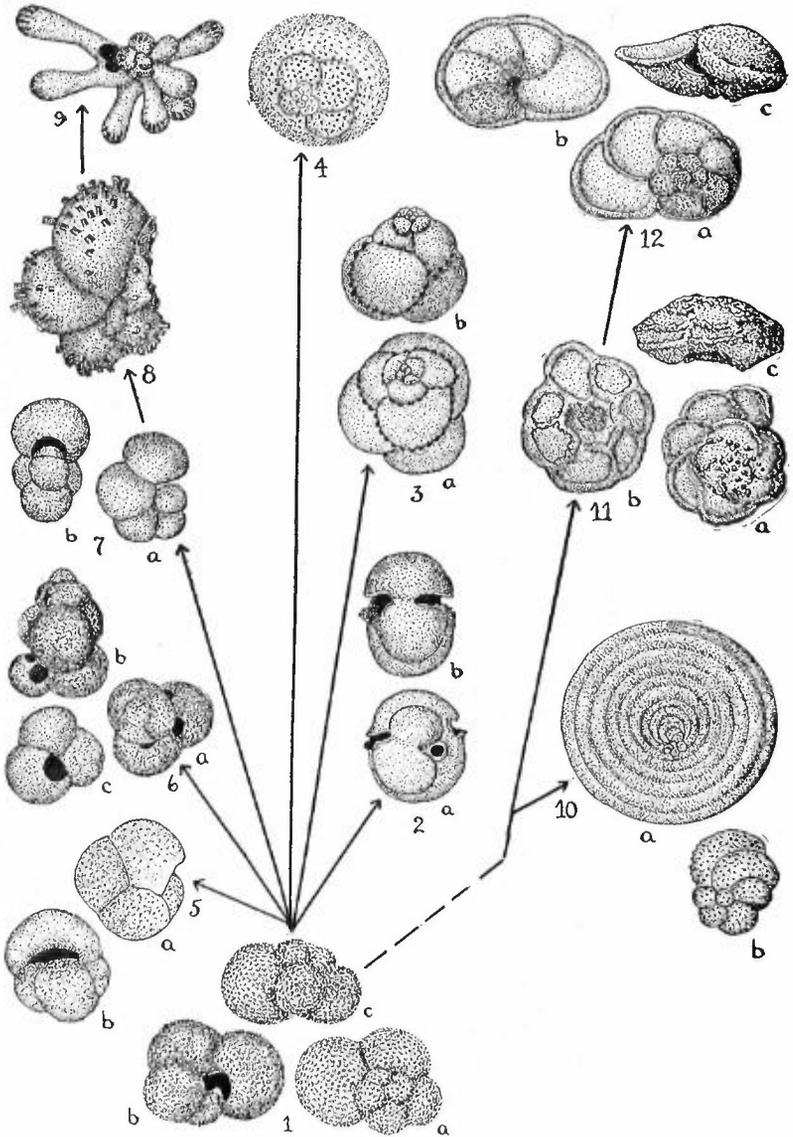
Genus GLOBIGERINOIDES Cushman, new genus (Pl. 19, fig. 6). (Genotype, *Globigerina rubra* d'Orbigny, in de la Sagra, Hist. Fis. Pol. Nat. Cuba, Foraminiferes, 1839, p. 82, pl. 4, figs. 12-14.)—Test usually trochoid throughout, aperture as in *Globigerina* with numerous large, supplementary apertures around the margin of the chamber, opening into the umbilical area, fine spines covering the test in well preserved specimens.—Tertiary and Recent.

## Recent.

Genus GLOBIGERINELLA Cushman, new genus (Pl. 19, fig. 7). (Genotype, *Globigerina aequilateralis* H. B. Brady, Rep. Voy. Challenger, Zoology, vol. 9, 1884, p. 605, pl. 80, figs. 18-21.)—Test trochoid in the young, at least in the microspheric form later becoming planospiral, aperture single, large, opening on the umbilicus in the young, in the adult median, fine spines covering the test in well preserved specimens.—Cretaceous to Recent.

Genus HASTIGERINA Wyville Thomson, 1876 (Pl. 19, fig. 8).—Test with the early chambers trochoid, later ones planospiral; surface with comparatively coarse spines, flattened, the edges parallel and toothed, each spine on a base projecting from the surface; aperture large, at the umbilical margin of the chamber.—Late Tertiary and Recent.

Genus HASTIGERINELLA Cushman, new genus (Pl. 19, fig. 9). (Genotype, *Hasterigerina digitata* Rhumbler, Foram. Plankton Exped., Part. 1, 1911, pl. 37, fig. 9 a, b).—Test similar to *Hastigerina* in the young, in the adult, the chambers elongate,



club-shaped, the spines limited to the outer end of the chambers.  
—Late Tertiary and Recent.

Subfamily 2. Orbulininae.

Test in the young like *Globigerina*, later developing a globular chamber entirely enclosing the earlier ones, which may be later resorbed, wall often of several layers, with perforations of various sizes, the large openings probably accidental, exterior with fine spines.

Genus ORBULINA d'Orbigny, 1826 (Pl. 19, fig. 4).—Test with the characters of the subfamily.—Tertiary and Recent.

Although there are references to "*Orbulina*" in the literature which would indicate its presence early in the fossil series, those from the Cambrian are certainly erroneous and it is to be suspected that those from the formations before the Tertiary are not truly *Orbulina*. I am inclined to agree with Earland that the so-called larger aperture of *Orbulina* is an accidental opening and not a true aperture. *Orbulina* is an end form and represents probably the complete attainment of a spherical test adapted for pelagic life.

Subfamily 3. Pulleniatininae.

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EXPLANATION OF PLATE 19.

GLOBIGERINIDAE, GLOBOROTALIIDAE.

FIG.

- 1—*Globigerina bulloides* d'Orbigny. (After H. B. Brady.) *a*, dorsal view, *b*, ventral view, *c*, side view.
- 2—*Sphaeroidinella dehiscens* (Parker and Jones). (After Parker and Jones.) *a*, dorsal view, *b*, ventral view.
- 3—*Candeina nitida* d'Orbigny. (After H. B. Brady.) *a*, dorsal view, *b*, side view.
- 4—*Orbulina universa* d'Orbigny. (After H. B. Brady.)
- 5—*Pulleniatina obliqueloculata* (Parker and Jones). (After H. B. Brady.) *a*, side view, *b*, apertural view.
- 6—*Globigerinoides rubra* (d'Orbigny). (After H. B. Brady.) *a*, dorsal view, *b*, side view, *c*, ventral view.
- 7—*Globigerinella aequilateralis* (H. B. Brady). (After H. B. Brady.) *a*, side view, *b*, apertural view.
- 8—*Hastigerina pelagica* Wyville Thompson. (After H. B. Brady.)
- 9—*Hastigerinella digitata* (Rhumler). (After Rhumler—but spines not complete.)
- 10—*Cycloloculina annulata* Heron-Allen and Earland. (After Heron-Allen and Earland.) *a*, adult, *b*, young.
- 11—*Globotruncana arca* (Cushman). *a*, dorsal view, *b*, ventral view, *c*, edge view.
- 12—*Globorotalia tumida* (H. B. Brady). (After H. B. Brady.) *a*, dorsal view, *b*, ventral view, *c*, edge view.

Test in the early stages, like *Globigerina*, later becoming involute and the later chambers covering the earlier ones, test without spines in the adult, coarsely porous.

Genus PULLENIATINA Cushman, new genus (Pl. 19, fig. 5). (Genotype, *Pullenia obliqueloculata* Parker and Jones, Philos. Trans., vol. 155, 1865, p. 368, pl. 19, figs. 4 a, b).—Test with the early chambers as in *Globigerina*, with the wall cancellated and apparently with spines, later with the chambers coarsely perforate, but smooth, except about the aperture, and the chambers involute, the last three or four forming the outer surface of the test, without spines in the adult, aperture elongate, arched.—Late Tertiary and Recent.

Genus SPHAEROIDINELLA Cushman, new genus (Pl. 19, fig. 2). (Genotype, *Sphaeroidina dehiscens* Parker and Jones, Philos. Trans., vol. 155, 1865, p. 369, pl. 19, figs. 5 a-c).—Test in the early stages, trochoid and like *Globigerina*, with coarse cancellated surface and probably with spines; in the adult with the chambers embracing, two or three forming the exterior, the chambers slightly separated, the edges with somewhat crenulated carinae, without spines. Pliocene to Recent.

#### Subfamily 4. Candeininae.

Test trochoid, in the young with the chambers roughened and spinose and the aperture as in *Globigerina*, in the adult the chambers smooth, without spines and the apertures formed by rows of circular openings along the sutures.

Genus CANDEINA d'Orbigny, 1839 (Pl. 19, fig. 3).—Test with the characters of the subfamily.—Late Tertiary (Indo-Pacific), and Recent.

The Globigerinidae represent the most successful adaptation of the foraminifera to pelagic life. The family developed strongly in the Cretaceous where it dominated certain of the environmental conditions at that time with the Globorotaliidae. This relationship still prevails and the two groups today form the great mass of the pelagic foraminifera and are the main constituents of *Globigerina*-ooze which covers immense areas of the ocean bottom. In the late Tertiary the more specialized forms of *Orbulina*, *Candeina*, *Hastigerina*, *Pulleniatina* and *Sphaeroidinella* developed. In *Orbulina* there is the perfect adaptation to pelagic life.

This family has developed from the umbilicate Rotaliidae such as *Discorbis* and the young of all the species of *Globigerina* in the microspheric form are smooth, flattened forms very similar

to *Discorbis*. The globular form of the chambers is attained later. The reversion to this condition seen in the development of their own young takes place in the next family. The development of a thick surface clothing of fine spines is unique in this family and is developed with their adaptation to pelagic life. The peculiar plate-like structure that develops over the umbilical area in fossil forms and which is occasionally seen in recent ones is foreshadowed in the similar structure developed in *Discorbis*. In many respects the Globigerinidae represent one of the highest and most specialized families in the whole group of the foraminifera.

#### FAMILY 40. GLOBOROTALIIDAE.

Test in the early stages trochoid, the chambers with rough cancellated exterior and often spinose, in the adult, resuming the ancestral rotalid form, but often retaining the rough spinose surface, aperture typically opening into the umbilical area, the older species often retaining the projecting covering above the umbilical area and traces of it appear in the living forms; largely pelagic.

Genus GLOBOTRUNCANA Cushman, new genus (Pl. 19, fig. 11). (Genotype *Pulvinulina arca* Cushman, Contrib. Cushman Lab. Foram. Research, vol. 2, 1926, p. 23, pl. 3, figs. 1 a-c.)—Test trochoid, the adult usually much compressed, the dorsal and ventral sides either flat or convex, ventral side sometimes slightly concave, the periphery truncate, usually with a double keel on the dorsal and ventral sides; aperture on the ventral side; apparently pelagic in part.—Upper Cretaceous to Recent.

Genus GLOBOROTALIA Cushman, new genus (Pl. 19, fig. 12). (Genotype *Pulvinulina tumida* H. B. Brady, Rep. Voy. Challenger, Zoology, vol. 9, 1884, p. 692, pl. 103, figs D-F.)—Test trochoid, early chambers often like *Globigerina*, dorsal side often flat, the ventral side broadly convex, aperture usually umbilicate, wall frequently roughened throughout, mostly pelagic.—Upper Cretaceous to Recent.

Genus CYCLOLOCULINA Heron-Allen and Earland, 1908 (Pl. 19, fig. 10).—Test in the early stages resembling *Globigerina*, wall coarsely perforate and somewhat spinose, later chambers elongating and in the adult becoming annular, aperture formed as in *Orbulina* by the perforations of the test, no special aperture developed.—Eocene.

Genus SHERBORNINA Chapman, 1922.—“Test discoidal,

moderately thin, median arch concave. Shell built up of a median annular series of chamberlets with a discorbine commencement; the loculi of the annuli widely spaced. External layer formed of small overlapping spatulate chamberlets. The primordial series of about 7 globular to reniform segments, lying in the median system, is discorbine—that is, depressed rotaline. Shell wall perforated with coarse tubulae.”—Miocene. (The above description is the original from Chapman.)

This family evidently represents a return to the rotalid ancestry of *Globigerina*, that of a *Discorbis*-like test.

The compressed forms seen in many of the species of this family have been included in the Globigerinidae and some of those which have been referred to *Pulvinulina* in the literature do not fit at all the forms now included under *Eponides*. The pelagic habit of many of these species and their association with the Globigerinidae in both recent and fossil *Globigerina*-marls and oozes shows their close relationship. By reversion to the ancestral form this group helps to make clear the fact that the Globigerinidae have developed from the Rotaliidae as a specialized group adapting themselves to a pelagic condition. In *Cycloloculina* there is developed the annular form which in its apertural characters allies it more or less closely to *Orbulina* and by its spinose condition to the others of the Globorotaliidae. *Sherbornina* is apparently close to *Cycloloculina*.

#### FAMILY 41. ANOMALINIDAE.

Test calcareous, perforate, free or attached by the dorsal surface which is typically flattened or concave, chambers arranged in a trochoid manner, at least in the young, aperture either at the periphery or shifting to the dorsal side.

Subfamily 1. Anomaliniinae.

Test compressed, nearly symmetrical on the two sides in the adult, aperture peripheral.

Genus ANOMALINA d'Orbigny, 1826 (Pl. 20, fig. 1).—Test, in the young, trochoid, in the adult, often nearly involute, with the chambers added nearly in a planospiral manner, aperture at the base of the chamber at the median line, usually with a ventral boss of clear material over the umbilical region.—Lower Cretaceous to Recent.

Genus PLANULINA d'Orbigny, 1826 (Pl. 20, fig. 2).—Test, in the young, trochoid, in the adult, very much compressed,

evolute, the earlier chambers visible from both sides of the test; aperture at the base of the chamber at the median line.—Cretaceous to Recent.

Genus PELLATISPIRA Boussac, 1906 (Pl. 20, fig. 3).—Test, in the young, trochoid, in the adult, much compressed, with a wide flange of clear material about the periphery and separating the later coils; aperture a low slit close to the periphery.—Eocene to Recent.

Genus ANOMALINELLA Cushman, new genus. (Genotype, *Truncatulina rostrata* H. B. Brady, Rep. Voy. Challenger, Zoology, vol. 9, 1884, p. 668, pl. 94, figs. 6 a-c.)—Test very similar to *Planulina* but with an added elongate aperture on the peripheral margin of the chamber.—Miocene (?) Recent.

#### Subfamily 2. Cibicidinae.

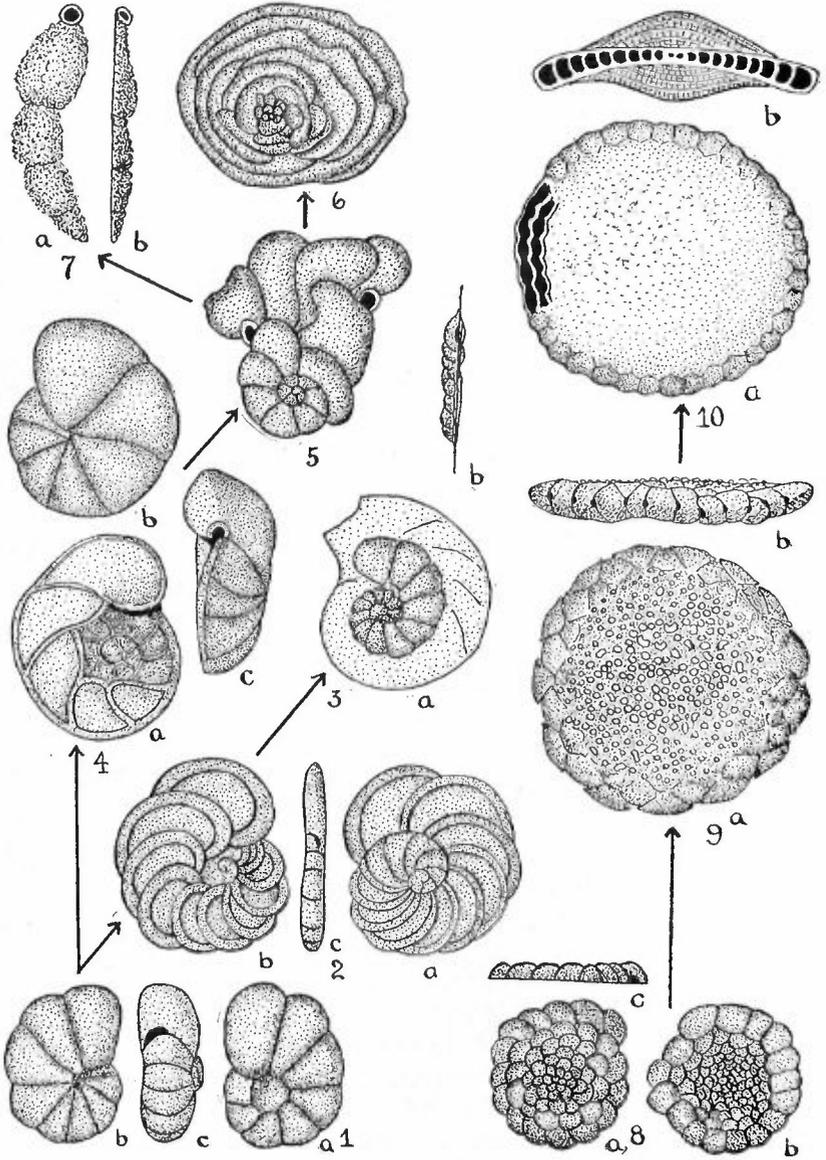
Test with the dorsal side flattened or concave, the aperture extending over onto the dorsal side along the inner margin of the chamber or entirely on the dorsal side, test typically attached by the dorsal side.

Genus CIBICIDES Montfort, 1808 (Pl. 20, fig. 4). (*Truncatulina* of d'Orbigny.)—Test close-coiled, trochoid, attached by the flattened dorsal side, aperture extending over onto the dorsal side from the periphery and forming an elongate slit along the inner margin of the chamber.—Carboniferous? Cretaceous to Recent.

Genus CYCLOCIBICIDES Cushman, new genus (Pl. 20, fig. 6). (Genotype *Planorbulina vermiculata* d'Orbigny, Ann. Sci. Nat. vol. 7, 1826, p. 280, No. 3; *Pulvinulina vermiculata* H. B. Brady, Rep. Voy. Challenger, Zoology, vol. 9, 1884, p. 687, pl. 115, figs. 2 a, b.)—Test, in the early stages, like *Cibicides*, then the chambers elongating and becoming nearly or completely annular, aperture in the young stages as in *Cibicides*, in the adult formed by the large pores of the surface.—Recent.

Genus CIBICIDELLA Cushman, new genus (Pl. 20, fig. 5). (Genotype *Truncatulina variabilis* d'Orbigny, Ann. Sci. Nat., vol. 7, 1826, p. 279; in Barker, Webb, and Bethelot, Hist. Nat. Iles Canaries, 1839, Foraminiferes, p. 135, pl. 2, fig. 29.)—Test attached by the flattened dorsal side, in the young similar to *Cibicides*, later chambers irregularly disposed, coarsely perforate; aperture, in the young, as in *Cibicides*, in the adult, rounded, on the dorsal side with a short neck and distinct lip.—Recent.

Genus WEBBINA d'Orbigny, 1839 (Pl. 20, fig. 7).—Test attached, consisting of a few chambers with a neck and circular



aperture with a slight lip, the wall calcareous and perforate.—Tertiary and Recent.

In this family which has been derived from the Rotaliidae, the aperture appears first in the median line with the bilateral test of *Anomalina*, then as the test becomes planoconvex and attached by the dorsal surface the aperture swings over to the dorsal side. In *Cyclocibicides* and *Cibicidella*, genera of the Mediterranean especially, there is an added structure, annular in one and irregular with flask-shaped chambers in the other. *Webbina* is probably a degenerate genus belonging here. From this family came the attached forms placed in the families Homotremidae and Rupertiidae by the development at right angles to the area of the attachment.

#### FAMILY 42. PLANORBULINIDAE.

Test, in the young, coiled, attached by the dorsal surface, chambers in a spiral arrangement, apertures single, later with the chambers added in annular series, the apertures multiple and the test free and becoming bilaterally symmetrical, not developing pillars.

Genus PLANORBULINA d'Orbigny, 1826 (Pl. 20, fig. 8).—Test attached by the dorsal side, the chambers in the young spirally coiled, later in irregular series about the periphery,

#### EXPLANATION OF PLATE 20.

##### ANOMALINIDAE, PLANORBULINIDAE.

##### FIG.

- 1—*Anomalina punctulata* d'Orbigny. (After d'Orbigny.) *a*, dorsal view, *b*, ventral view, *c*, edge view.
- 2—*Planulina ariminensis* d'Orbigny. (After d'Orbigny.) *a*, dorsal view, *b*, ventral view, *c*, edge view.
- 3—*Pellatispira pauperata* (Parker and Jones). (After H. B. Brady.) *a*, dorsal view, *b*, edge view.
- 4—*Cibicides lobatulus* (Walker and Jacob). (After H. B. Brady.) *a*, dorsal view, *b*, ventral view, *c*, edge view.
- 5—*Cibicidella variabilis* (d'Orbigny). (After H. B. Brady.)
- 6—*Cyclocibicides vermiculatus* d'Orbigny. (After H. B. Brady.)
- 7—*Webbina rugosa* d'Orbigny. (After d'Orbigny.) *a*, from unattached side, *b*, from edge.
- 8—*Planorbulina mediterraneanensis* d'Orbigny. (After d'Orbigny.) *a*, dorsal view, *b*, ventral view, *c*, edge view.
- 9—*Planorbulinella larvata* (Parker and Jones). (After H. B. Brady.) *a*, side view, *b*, edge view.
- 10—*Linderina brugesi* Schlumberger. (Adapted from Schlumberger.) *a*, from side, *b*, section.

aperture single or in the irregular forms multiple.—Tertiary and Recent.

Genus *PLANORBULINELLA* Cushman, new genus (Pl. 20, fig. 9). Genotype *Planorbulina larvata* Parker and Jones, Philos. Trans. vol. 155, 1865, p. 380, pl. 19, figs. 3 *a, b*).—Test in the young attached and like *Planorbulina*, soon having the chambers developed about the periphery in annular series those of each series alternating with those of the adjacent ones, apertures two, one at each side of the chamber in the median line, test bilaterally symmetrical.—Tertiary and Recent.

Genus *LINDERINA* Schlumberger, 1893 (Pl. 20, fig. 10).—Test similar to *Planorbulinella* but developing a thick layer of clear shell material over the central portion of the test on the two sides.—Upper Eocene.

Genus *GYPSINA* Carter, 1877.—Test a mass of small chambers not unlike those of *Planorbulina*, attached to a supporting surface, typically spreading outward and building up in layers; apertures at the border of the chambers or consisting of the coarse pores of the test.—Cretaceous to Recent.

Genus *CERIOPORA* Reuss, 1847.—Test consisting of a globular mass of flattened chambers, more or less regularly arranged, but with no supplemental skeleton, apertures made by the pores of the outer wall of each chamber.—Tertiary and Recent.

This family is closely related to the Anomalinidae but the relationship in the free forms is seen only by a study of the early chambers. Carter has described a genus *Aphrosina* which is an attached spreading form but the figures are so meagre that without seeing specimens, it is impossible to say where it should be placed.

#### FAMILY 43. RUPERTIIDAE.

Test, in the young, trochoid, attached by the dorsal side as in *Cibicides*, later extending upward from the base of attachment still keeping a loose spiral, wall calcareous, coarsely perforate, aperture either at the inner margin of the chamber or becoming terminal and rounded, often with a neck and lip.

Genus *RUPERTIA* Wallich, 1877 (Pl. 21, fig. 5).—Test with the chambers in a close coil throughout, the aperture narrow, at the base of the inner margin of the chamber.—Recent.

Genus *CARPENTERIA* Gray, 1858 (Pl. 21, fig. 4).—Test with the chambers becoming loosely coiled, even almost in a

rectilinear series; aperture rounded and terminal, with a neck and lip.—Cretaceous to Recent.

Genus ACERVULINA Schultze, 1854 (Pl. 21, fig. 6).—Test attached, consisting of an irregular group of hemispherical chambers, wall coarsely perforate.—Recent.

The genus *Uhligina* is probably distinct and if recognized should belong in this family which is directly derived from an attached form similar to *Cibicides*. *Acervulina* in one of its species at least shows traces of coiling and its coarsely perforate test seems allied to *Carpenteria*. It is evidently a degenerate form. *Eorupertia* of Yabe and Hanzawa with the genotype *E. boninensis* (Yabe and Hanzawa) also belongs in this family.

#### FAMILY 44. HOMOTREMIDAE.

Test, in the young, trochoid, attached by the dorsal surface, later becoming irregular and growing upward from the area of attachment, all trace of the early arrangement being lost, the chambers in a more or less confused mass, apertures large, open or covered by a perforated plate, reddish or orange color strongly developed.

Genus HOMOTREMA Hickson, 1911 (Pl. 21, fig. 3).—Test dark red in color, broad, not truly branching, surface solid with scattered foramina covered by a finely perforated plate.—Recent.

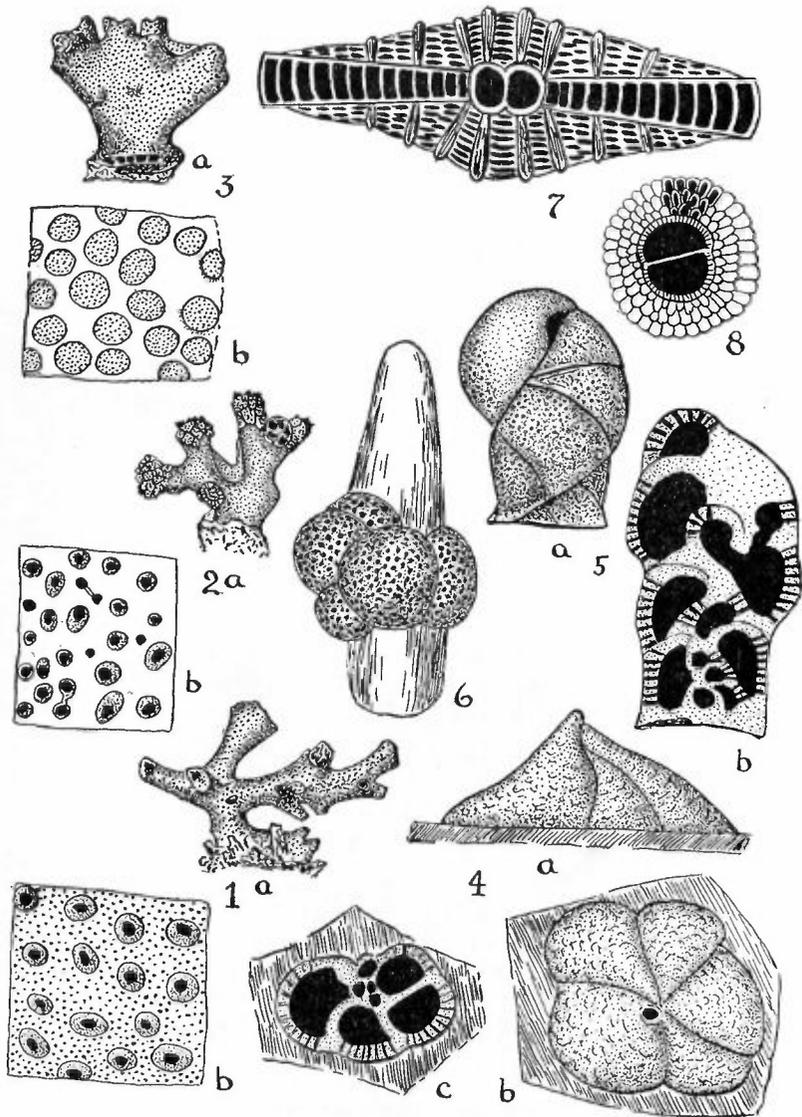
Genus SPORADOTREMA Hickson, 1911 (Pl. 21, fig. 2).—Test orange or red in color, sometimes branching, numerous chambers apparent at the outer end, surface solid with scattered foramina, not covered by a plate.—Recent.

Genus POLYTREMA Risso, 1826 (Pl. 21, fig. 1).—Test red, branching, in slender projections, surface finely perforate, with larger open foramina.—Late Tertiary and Recent.

This family has been derived from the attached trochoid forms such as *Cibicides*, and has become highly specialized. A very striking color is developed in the different genera, more pronounced than seen elsewhere except in a few scattered species of other families. For details of structure of the various genera the reader is referred to the excellent paper of Hickson—On *Polytrema* and Some Allied Genera (Trans. Linn. Soc. London, Zoology, vol. 14, No. 20, 1911).

#### FAMILY 45. ORBITOIDIDAE.

Test generally lenticular, consisting, in vertical section, of a median layer of equatorial chambers, with layers of lateral



chambers on either side, often with pillars of clear shell material radiating out to the surface, apertures at the periphery of the test. In the microspheric form the early chambers are very small and coiled but soon give way to an arrangement in which the chambers are in annular series about the periphery. In the megalospheric form there is a nucleoconch consisting of the proloculum and early chambers present at the time of breaking away from the parent test and the arrangement of these chambers has been made the basis of division of many of the genera. Four main genera may be distinguished.

Genus *ORBITOIDES* d'Orbigny, 1847.—Test discoidal, the equatorial chambers generally diamond-shaped.—Cretaceous.

Genus *DISCOCYCLINA* Gümbel, 1868.—Test discoidal, or rarely stellate, equatorial chambers rectangular.—Eocene.

Genus *LEPIDOCYCLINA* Gümbel, 1868.—Test discoidal, or rarely stellate, equatorial chambers hexagonal or modification of it.—Upper Eocene and Oligocene (Miocene of the Indo-Pacific).

Genus *MIOGYPSINA* Sacco, 1893.—Test irregularly discoidal, chambers generally rhomboid.—Miocene.

Owing to the intensive study that has been given to the Orbitoid group in recent years a very considerable literature has developed of a specialized nature. Many genera and subgenera have been recognized which it is out of the province of this preliminary outline to deal with. For many of the new genera and their relationships the reader is referred to recent papers, especially those of H. Douvillé, particularly his "Revision des

#### EXPLANATION OF PLATE 21.

##### HOMOTREMIDAE, RUPERTIIDAE, ORBITOIDIDAE.

###### FIG.

- 1—*Polytrema minaceum* (Pallas). (After Hickson). *a*, side view, *b*, enlarged portion of surface.
- 2—*Sporadotrema cylindricum* (Carter). (After Hickson). *a*, side view, *b*, enlarged portion of surface.
- 3—*Homotrema rubrum* (Lamarck). (After Hickson.) *a*, side view, *b*, enlarged portion of surface.
- 4—*Carpenteria monticularis* Carter. (Adapted from Carpenter.) *a*, side view, *b*, from above, *c*, section of young.
- 5—*Rupertia stabilis* Wallich. (After H. B. Brady). *a*, exterior, *b*, section.
- 6—*Acervulina inhaerens* Schultze. (After Schultze.)
- 7, 8—Idealized sections of *Lepidocyclus* (*Isolepidina*). 7, in vertical section, 8, early chambers in horizontal section.

Orbitoides." (Bull. Soc. Geol. France, ser. 4, vol. 20, pp. 209-232, and ser. 4, vol. 22, 1922, pp. 55-100.)

The family represents one of the most highly specialized groups to be found in the foraminifera, reaching its climax in the late Cretaceous and early Tertiary and now entirely extinct.

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