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FORAMINIFERA

Their Classification and Economic Use

BY

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TO

SUSAN MINNS

BY WHOSE SYMPATHETIC INTEREST

AND

GENEROUS HELP

THIS WORK HAS BEEN MADE POSSIBLE

ERRATA

Page 17. Line 16 from bottom—*For* cyclindrical *read* cylindrical
Page 40. Line 14 from top—*For* apparantly *read* apparently
Page 46. Line 12 from top—*For* Kerammosphaeridae *read* Keramosphaeridae
Page 82. Line 4 from top—*For* Reecnt *read* Recent
Page 83. Line 8 from bottom—*For Nuberculariella read Nubeculariella*
Page 84. Line 5 from bottom—*For tumanowicizii read tumanowiczii*
Page 94. Line 8 from bottom—*For* (Reuss) *read* Reuss
Page 100. Line 3 from bottom—*For* Doderlein *read* Döderlein
Page 104. Line 19 from bottom—*For* Parker and Jones *read* Jones and Parker
Page 122. Line 11 from top—*For subrotunda read subrotundata*
Page 124. Line 14 from bottom—*For subrotunda read subrotundata*
Page 124. Line 9 from bottom—*For* H. B. Brady *read* (H. B. Brady)
Page 132. Line 12 from top—*For* Fisher *read* Fischer
Page 138. Line 12 from bottom—*For* obscurbed *read* obscured
Page 140. Line 6 from top—*For agassizii read agassizi*
Page 140. Line 4 from bottom—*For* (Terquem) *read* Terquem
Page 140. Line 2 from bottom—*For delongschampsi read deslongchampsi*
Page 142. Line 3 from top—*For* W. B. Carpenter *read* H. B. Brady
Page 146. Line 13 from bottom—*For* (d'Orbigny) *read* d'Orbigny
Page 159. Page heading—*For* OPTHALMIDIIDAE *read* OPHTHALMIDIIDAE
Page 161. Page heading—*For* OPTHALMIDIIDAE *read* OPHTHALMIDIIDAE
Page 161. Line 9 from bottom—*For difformis read diffusa*
Page 165. Page heading—*For* OPTHALMIDIIDAE *read* OPHTHALMIDIIDAE
Page 166. Line 12 from bottom—*For* (Parker and Jones) *read* (Jones and Parker)
Page 169. Page heading—*For* OPTHALMIDIIDAE *read* OPHTHALMIDIIDAE
Page 190. Line 3 from bottom—*For* Jones and Parker *read* (Jones and Parker)
Page 193. Line 12 from bottom—*For* Deutschr. *read* Denkschr.
Page 204. Line 5 from top—*For pompiloides read pompilioides*
Page 250. Line 23 from bottom—*For* H. B. Brady *read* (H. B. Brady)
Page 250. Line 20 from bottom—*For* (d'Orbigny) *read* d'Orbigny
Page 300. Line 2 from bottom—*For* d'Orbigny *read* (d'Orbigny)
Page 306. Line 6 from bottom—*For* 1826 *read* 1839
Page 326. Line 2 from bottom—*For mediterraneansis read mediterranensis*
Page 332. Line 14 from bottom—*For* Schlumberger *read* Munier-Chalmas
Page 340. Line 11 from top—*For* PSEUDORBITOIDES. . .1922
read CLYPEORBIS. . .1915

CONTENTS

INTRODUCTION

The foraminifera have come to have a place of economic importance as well as of general scientific interest. Their use in geologic correlation especially as an aid in determining subsurface structures in connection with petroleum investigations has become wide spread.

At the present time there is no general account of the foraminifera in English since that published by Chapman in 1902 and that is now out of print. To fill this need in an outline form rather than in detail the present volume is offered. The preliminary paper entitled: "An Outline of a Reclassification of the Foraminifera" (Contrib. Cushman Lab. Foram. Res., vol. 3, pt. 1, 1927) published a year ago has met with such an unlooked for favorable reception that the edition is practically exhausted. The more complete volume here presented is a fulfillment of the statement made in the earlier paper. It has been necessary to see and study certain of the older collections containing type specimens. On these specimens depends the status of many of the earlier species and the genera based upon them. Fortunately these collections are for the most part splendidly preserved, and it has therefore been possible to settle many of the mooted points by an examination of the type specimens this last summer.

To those in charge of these collections in various European museums and universities, I am indebted for many courtesies extended to me in pursuing these studies. As a result I have seen actual types of nearly all those species which have become genotypes and in the others in almost all cases seen topotype material. As a result of these studies it is now possible to know very definitely what should be the characters in many of the genera where questions have arisen and which might have been easily settled by a glance at the type specimens.

The classification here used is practically that given in the preliminary outline. It is based upon the known geologic history of the genera, upon the phylogenetic characters through a study of much fossil material and finally by a study of the ontogeny in very many microspheric specimens which show the relationships much more definitely than do the megalospheric specimens of the same species.

There are so many institutions and individuals to whom I am indebted for the gift or loan of material for study that to mention them all would add pages to this volume. It may be sufficient to say that without their co-operation this work could hardly have been attempted. To my friends, Dr. Yoshiaki Ozawa and Dr. T. Wayland Vaughan, I am under deep obligation for taking care of the difficult families of the Fusulinidae and Orbitoididae, two families of great importance on which very intensive researches are now being carried on in many parts of the world.

To my daughter, Miss Alice E. Cushman, I am under great debt for taking excellent care of manuscripts and proofs, and to Miss Margaret S. Moore for painstaking work in making the drawings for the half-tone plates.

Under the various headings will be found many of the common facts in regard to the present day knowledge of foraminifera, their uses and their classification. Keys are given which it is hoped will prove useful to teachers, students, and those engaged in economic work. A bibliography of important works is also given for the sake of those who may wish to consult the literature on the subject. There are still a number of genera that are not sufficiently well known so that their position in the classification can be accurately determined and a number of them are left out until their genotypes can be studied in detail. To try to place them at present from our present inadequate descriptions or figures without studying the actual types would only lead to confusion and thus it has been thought wisest to leave these until some one may actually study the types.

FORAMINIFERA

CHAPTER I

THE LIVING ANIMAL

The foraminifera are almost entirely marine animals, a very few living in brackish or even fresh water. They are single celled animals belonging to the Protozoa. Except for a few of the simplest types, there is developed a test, either of agglutinated foreign material, or chitin, or of calcareous material secreted by the animal itself. These tests are preserved as fossils in many of the geologic formations since Cambrian time. In the existing oceans, foraminifera occur in enormous numbers, and in water from the continental shelf out to about 2,000 fathoms or more their tests form the thick *Globigerina*-ooze of the ocean floor. As fossils they are often very abundant, and in the Palaeozic as well as in the younger formations they have formed thick limestones. The great pyramids of Egypt are constructed from limestones made largely of fossil foraminifera. In the tropics, the sands of the beaches are often largely composed of the tests of foraminifera, and in shallow water their great numbers actually form obstructing shoals.

Most of the abundant living species are of small size except in the shallow waters of the tropics where numerous species of considerable size still exist. In the Eocene and Oligocene, species with large tests several inches across were developed. There is but a single living species, now found in the Indo-Pacific, which has as large a diameter as those of the earlier fossils, and this species has a very thin discoid form.

Species have definite geologic and geographic ranges, and when these are known in detail, they become of importance in determining the age of sediments and the conditions under which they were deposited.

In spite of the fact that so much has been written in regard to the foraminifera, a literature now including several thousand papers, very little has been written about the animal itself. This is surprising when they may be obtained on almost any seacoast and may live and develop for years in a balanced aquarium. Until only in very recent years has the complete life history been known. Much remains to be done on the habits and the physiologic characters of the animal in the different groups. Such studies will probably add materially to our knowledge of relationships in the group.

The animal in the foraminifera should be considered as living both inside and outside of its test. In other words the test in many groups at least is an internal one. Even in the imperforate groups the ornamentation of the exterior is added to after the test is completed, and in such forms even when disturbed, the protoplasm is not wholly withdrawn into the test.

The living animal consists of a mass of protoplasm with a nucleus, the latter inside the test while the thinner protoplasm streams out from the test in fine reticulate pseudopodia in all directions. In these streams, there are usually two currents, the central portion moving outward, and the periphery moving inward toward the test. This is not a steady movement but has definite rhythms. The form of the pseudopodia in the different families is not the same, and these should be further studied. The incoming currents bear food particles and debris of various sorts thus in attached specimens, the outer surface often becomes more or less covered with such debris. The pseudopodia in the moving or feeding individual often extend out very many times the diameter of the test. The whole animal in the free forms may move forward with its test over the surface at a slow pace.

It may be rather definitely stated that individuals of different species at least, are repellant to one another. Numerous examples of this were observed at the Tortugas laboratory. There is certainly no fusing of individuals of different species or genera to form tests of an intermediate character as has been sometimes advanced in theory.

Life History

An alternation of generations in the foraminifera has been known for some time. Two forms of the species are usually found together, one small in size but with a large proloculum or initial chamber, the other of larger size but starting with a much smaller proloculum. From the size of the proloculum, these two forms were named respectively *megalospheric* and *microspheric*. The megalospheric form is usually much more abundant. The two forms are to be looked for in all species, and it is important in descriptive work to distinguish these.

The microspheric form has a number of nuclei, often a larger number than there are chambers, scattered irregularly through the protoplasm of the body. There seems to be a rather definite relation between the size of the nuclei and the size of the chamber in which they occur, the larger nuclei being in the larger chambers, and the reverse. Apparently these nuclei simply divide in their reproduction during the growth of the test.

When the animal attains its adult stage there is a great increase in the number of nuclei, and the entire protoplasm either leaves the test and accumulates about the exterior or is drawn into the outer chambers. Finally, each nucleus gathers a mass of protoplasm about itself and secretes the proloculum of a new test. This newly formed proloculum is of the larger type and is the first chamber of the megalospheric form, instead of being of the same size as that of the microspheric parent from which it was derived. The megalospheric form differs from the microspheric form in having a single nucleus. This does not divide, but moves along as new chambers are added, keeping in about the middle chamber numerically. Nucleoli appear in increasing numbers as the growth continues, and finally the whole nucleus breaks down and a great number of minute nuclei appear. These draw about themselves portions of the protoplasmic mass and then divide by mitotic division. Finally, the mass leaves the test in the form of flagellated zoospores. These then conjugate and give rise to the small proloculum of the microspheric form, thus completing the life cycle. The empty tests thus left behind must form a large proportion of the dredged foraminifera, and account for the great number of adult forms always present in both recent and fossil collections.

The microspheric form is thus the result of a conjugation or a sexual process, while the megalospheric form is the result of simple division or an asexual process. As a rule the megalospheric form is by far the more common, and in many species the microspheric form is very rare, or even as yet unknown. The microspheric form, while it starts as a smaller individual, in most cases attains a much larger size than the megalospheric, as might be suspected from the nature of the reproductive processes by which it is formed. In species where there are definite stages in development, it is usually the microspheric form which repeats these more fully, these stages being reduced or entirely skipped in the megalospheric form of the species.

In some cases the megalospheric form may give rise to a group of megalospheric young instead of to zoospores. On the whole, the life cycle agrees well with the alternation of generations as seen in certain other groups of animals.

The relations of the microspheric and megalospheric forms to an understanding of the development of the group will be discussed later.

Habits

Most foraminifera are bottom-living forms, crawling slowly about on the surface of the ocean bottom muds and oozes, or attached to various objects on the ocean bottom. All foraminifera are free in their earliest stages. There are numerous fixed forms such as *Carpenteria, Rupertia, Homotrema* and others which become fixed in the early stages and thereafter do not again become free. There are many more forms which may attach themselves loosely to other objects for all or a part of their life history, but are never fixed. Hydroid stems are often encrusted with a mass of living foraminifera of the Rotaliidae and Miliolidae. The short eel grass, *Posidonia,* of tropical shallow waters is often covered with specimens of *Planorbulina, Sorites,* and other forms. These may later detach themselves and become free. A few species have become adapted to a pelagic existence and their modifications will be discussed on a later page.

The rate of movement in the foraminifera is very slow, yet when compared with their size, they may cover considerable distances. In order to pick up material for the test in those species which show selective habits, a considerable area must be covered. At the Tortugas laboratory I timed the movement of a number of individuals of different families. The most rapid movement was that of *Iridia diaphana* which moved at its fastest speed at the rate of almost a millimeter per minute with an average of about a centimeter per hour. A species of *Discorbis* had an average speed of six millimeters per hour but it is a much smaller form. *Archaias aduncus* moved for a short distance at the rate of about five millimeters per hour. This species has a relatively heavy thick test. *Sorites duplex* in a single observation moved for a time at the rate of about twelve millimeters per hour. From observations made, it would seem that the test is pulled along by the pseudopodia.

When a feeding or moving specimen is disturbed, the pseudopodia are drawn back to the test but soon are sent out again. At the Tortugas it was found that in all cases, if no actual injury to the animal was made, the pseudopodia were thrust out again within a period of five minutes from the time of contraction.

Individuals, particularly of different species or genera, have a decided repellant relation when their pseudopodia meet. It was noted in several instances that such specimens when their pseudopodia came in contact, changed their direction to avoid one another. On the other hand when portions of the same individual had been cut in two, pseudopodia were rapidly thrown out from each portion and in contact these fused and the two parts moved toward one another and finally coalesced.

At the Tortugas it was discovered that in specimens of *Iridia* the tests were often left entirely by the animal which moved about as a naked mass of protoplasm, with a free and comparatively rapid movement. That the animal may withdraw from the test and pass some time without one is very significant from the standpoint of the method of growth. Growth of the test in those species which have a single chamber has often been a subject of speculation. If the test can be abandoned at will and another secreted or made by collecting more material in the case of those which have agglutinated tests, this difficulty is solved, and we may also understand how various sedentary species are able to collect various materials which are not common and make them into tests. Given free movement and a power of discrimination, which certain species seem to possess, it is not difficult to ex-plain how such tests are made of one sort of building material, spicules, mica-flakes, ambulacral plates of brittle stars, etc. The occurrence of specimens of *Iridia* on the leaves of *Posidonia* some inches above the sea bottom, while its test is composed of material from the bottom, is also explained. The material could easily be carried up to this elevation while ingested in the moving mass of protoplasm, and then concentrated on the surface when the animal settled down to form its test.

Food

In general, so far as known, the usual food of the foraminifera consists of vegetable material, the diatoms and various other algae furnishing the greater part. In some of the pelagic forms it has been observed that copepods are captured and eaten as well as other protozoa.

Color

Living specimens often are beautifully colored. From my own observations, it would seem that the protoplasm itself is differently colored in different groups. The Miliolidae often have a light pinkish color, while the Orbitolitidae are usually of a salmon color. Other groups have the protoplasm various shades of brown and in some it is wholly or in part colorless. This matter of color may be of greater significance than now appears if it is studied in connection with the relationships of the different groups.

The test itself is often colored, especially when fresh. The Homotremidae are brilliantly colored, pink, red or orange. Some of the Calcarinidae also show marked color when fresh. *Rotalia rubra*, a common species of the West Indian region, is a deep red or pink as is also *Globigerinoides rubra*. Many of the Rotaliidae have a brownish color especially in the young. Nearly all the arenaceous forms are reddish- or yellowish-brown.

CHAPTER II

THE TEST

The covering of the animal in the foraminifera is usually referred to as a test rather than a shell such as is secreted by special organs in the Mollusca, etc. In the very simplest forms of the Allogromiidae, the test is naked and without a distinct test. In other primitive forms there is a more definite cell wall but this may be broken through at any point.

Chitinous Tests. The most primitive sort of definite test that is developed is a chitinous one, often thin and transparent but with a definite shape and aperture. Such tests occur in the Allogromiidae but also occasionally in other groups such as *Pseudarcella,* etc.

Arenaceous Tests. In most of the earlier and more primitive groups of the foraminifera there is an arenaceous or agglutinated test made up of foreign material, sand grains, sponge spicules, mica flakes, etc., loosely or firmly cemented together over a thin chitinous inner layer representing the primitive chitinous test of the still simpler groups. This outer material of the arenaceous tests is of various sorts. In some of the most primitive forms as in *Astrorhiza* for example (Pl. 2, fig. 1) the mud and sand of the ocean bottom in which the animal lives is loosely cemented about channels leading to the central chamber. Foreign bodies of all sorts, sponge spicules, other foraminifera, etc., are included indiscriminately, and only the inner portion is at all firmly cemented. The only purpose seems to be to form a somewhat rigid protection about the softer protoplasmic body.

Other less primitive forms show some power of selection in that they take some general constituent of the bottom. *Rhabdammina* in its various species usually uses sand grains while *Marsipella* takes mostly sponge spicules. There does not seem to be any high degree of selection, but a certain general constituent of the bottom is chosen and others discarded.

In a few groups such as illustrated in the genus *Psammosphaera,* there is a high degree of selectivity. The North Atlantic species although they build a simple, more or less globular, single chambered test show the following selective characters: *Psammosphaera fusca* (Pl. 3, fig. 13) uses only sand grains of various sizes, those of one color sometimes being used to the exclusion of others; *P. parva* (Pl. 3, fig. 15) uses sand grains of more or less uniform size and usually adds a single large acerose sponge spicule which is built into the wall and projects on either side often to a distance greater than the diameter of the test itself. That this is accidental can not be held, for the specimens without the spicules are few and I have never seen one with a short or broken spicule, but always with a very long uninjured one; *Proteonina testacea* (Pl. 4, fig. 8) builds its test of other foraminiferal tests and lives as would be expected in *Globigerina*-ooze; the tests vary in size and shape but sand grains or spicules are not used even though in the same bottom sample may be other genera and species largely made up of spicules or sand grains; *Psammosphaera bowmanni* (Pl. 5, fig. 16) uses only mica flakes which cemented together by their edges make a weak and irregular test, and the selective power must be great for in most bottom samples the amount of mica flakes is not great; *P. rustica* (Pl. 5, fig. 15) uses acerose sponge spicules for the framework of the test, fitting smaller pieces of broken spicules into the polygonal areas in such a manner that they completely fill the openings. If the material is ingested in the protoplasmic body and then carried to the surface and cemented, it is not difficult to account for the apparent mechanical ability of the organism. That this selection occurs in single celled forms which are but a speck of protoplasmic material is the great wonder.

The cement of the test may be apparently chitinous in the most primitive forms and there is merely an agglutinating of the materials to the outside of the primitive chitinous test. In the majority of arenaceous forms from the Palaeozoic to the present oceans, the cement is ferruginous and has a yellowish- or reddish-brown color. This may be in a small amount as in *Rhabdammina* (Pl. 2, fig. 9) or in very large proportion as in such genera as *Ammolagena* (Pl. 9, fig. 17) where the arenaceous particles are very inconspicuous. Siliceous cement is used in a few groups, notably the Silicinidae although siliceous tests may be developed in the Miliolidae as will be noted later. Calcareous cement is used in some shallow water tropical forms.

Siliceous Tests. In a very few groups siliceous tests may be developed. In the Silicinidae such tests are the rule. In the more primitive Miliolidae under brackish water or deep sea conditions tests of nearly pure silica may be developed. This is an unusual form of test for the foraminifera.

Calcareous Tests. In the Miliolidae and Ophthalmidiidae there are developed entirely imperforate tests of calcareous material. In the more primitive Miliolidae there may be sand grains incorporated in the exterior but only as a secondary feature. In the Peneroplidae and related families an imperforate test is developed after a perforate young showing that in these families the imperforate character is a secondary and not a primitive one.

In the majority of species of the foraminifera, perforate calcareous tests are the rule. These may be thin and nearly transparent as in many species of *Lagena* or of very heavy character and large size as in the orbitoids. The perforations may be very small and fine or very large and coarse, with sometimes more than one kind in a single test, *Orbulina,* etc. In some tests the early stages may be very finely perforated and in successive chambers increase in size until the adult chambers are very coarsely perforate, and the reverse may be true in other species.

Forms of the Test. The simplest form of test is that of the Astrorhizidae where there is a central body and numerous channels out to the surface, representing the material collected about the pseudopodia. In the Rhizamminidae there are two open ends. In the Saccamminidae, the chamber becomes more definite, and a single aperture is developed. After the single chamber, the next stage in development is the formation of an elongate tubular chamber usually coiled about the proloculum or first chamber. This may then be broken up into irregular chambers and finally into the definitely chambered forms. Uncoiling as elsewhere in the animal kingdom is often a sign of gerontic or old age characters. In the foraminifera as in other groups this may finally result in specialized, almost or wholly uncoiled, forms. The primitive coiled forms may be planispiral or may develop conical or even cylindrical spirals. From the planispiral types by division into chambers are derived many forms in the different groups. From the conical spiral types have developed great groups such as the Rotaliidae and the families derived from it. Such forms are spoken of as trochoid tests, after the genus *Trochus* in the Mollusca. In such forms the chambers of all the whorls are visible from the dorsal side but usually only those of the last formed chamber from the ventral side (Fig. 1). There is usually an umbilical area in the central portion of the ventral side which may be either open or variously filled.

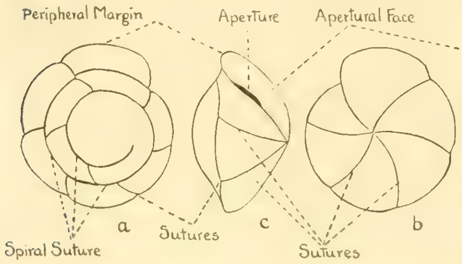


FIGURE 1

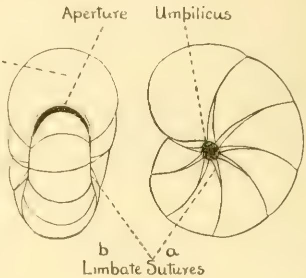


FIGURE 2

Chambers. The initial chamber in the foraminifera is known as the *proloculum* and may be either small and the result of the union of zoospores—the *microspheric* proloculum—or larger and the result of asexual division—the *megalospheric* proloculum. In primitive forms the second chamber is often elongate and tubular, either straight or variously coiled. Chambers may be closely coiled, loosely coiled, or uncoiled. In many coiled forms the chambers remain evolute, showing those of the earlier coils as in *Assilina* (Pl. 29, fig. 7) or closely involute, covering the earlier coils as in *Camerina* (Pl. 29, fig. 15). Many of the terms used in the description of chambers need no explanation as they are common terms and easily understood. The portions of the chamber are named similarly to those of the walls and are usually thought of in connection with the wall. Such terms as peripheral, proximal, dorsal, ventral, etc., will be readily understood. In trochoid forms (Fig. 1) the side which shows all the whorls of the spire is the dorsal side, and the one showing only the last-formed whorl is the ventral side. The dorsal side is usually more or less convex but may be flat or even slightly concave in forms which are attached by the dorsal side. That portion of the chamber which is adjacent to or contains the aperture is spoken of as the apertural face.

Chambers are usually simple (Pl. 29, fig. 6), that is undivided. In many of the higher forms they are divided into chamberlets (Pl. 32, fig. 5). In some forms, especially among the arenaceous group, there is a secondary filling of chambers resulting in "*labyrinthic*" chambers (Pl. 10, fig. 15). This is usually the sign of the approaching culmination of a group as are similar structures elsewhere.

In the orbitoid group and in some of the other large forms, the proloculum and immediately succeeding chambers are spoken of as the "nucleoconch".

In this group also there are two distinct sets of chambers developed, those of the central plane known as *equatorial chambers* and those of the two sides known as *lateral chambers.* The shape and position of these make important diagnostic characters in the orbitoids.

In different descriptions there is a great discrepancy in the use of the words height, breadth and thickness as applied to chambers. It may be convenient to think of an uncoiled form such as *Saracenaria* (Pl. 24, fig. 3) as a simple one. If the test is oriented with the aperture up, the height and breadth of the chamber will be as ordinarily understood and the thickness, the measurement generally at right angles to the breadth. If the straight forms are for the most part uncoiled forms then the coiled forms may be similarly treated. The height of the chamber will be the distance between the sutures generally in the axis of coiling, and the breadth the measurement at right angles to the coiling or between the periphery and the spiral suture. This terminology will allow of the same relative use in coiled and uncoiling chambers which often occur in the same species.

Specialized chambers are sometimes developed at certain stages of the individual, illustrations of which are the "float" and spherical chambers developed in the adult free-swimming stage of *Tretomphalus* (Pl. 43, fig. 10).

Sutures. The division between chambers and between whorls are spoken of as sutures. The line between the succeeding whorls or coils in a test is often spoken of by authors as the spiral suture in distinction from the ordinary sutures between chambers, Fig. 1. The suture ordinarily is the line of that portion of the wall between two adjacent chambers of the same whorl and inside the test may consist of the old enclosed wall of the chamber as seen in section. In many of the higher forms a complete wall is built with each chamber, that is, the new chamber builds a floor over the included portion of the preceding chamber. This results in a double wall in sections. Between these two walls there is developed in the Camerinidae for example a series of tubules which may be complex and lead to all parts of the interior of the test comparable in general appearance to a circulatory system in the higher animals.

Sutures may be flush with the surface, more commonly depressed, or in some cases raised above the general surface. They are often very much thickened and are then spoken of as "*limbate*", a character of importance in descriptive work.

Wall. The materials of which the wall of the test are made have already been discussed. In most foraminifera the wall is perforate. These openings either large or small allow the fine protoplasmic materials access to the exterior as well as through the larger aperture. Occasionally the perforations may be very definitely placed as in the higher forms such as the Globigerinidae (Pl. 47, figs. 16, 17) where each is in a polygonal area of the surface.

The wall may be locally thickened giving rise to a pattern as is seen in some species of *Lagena*, in *Epistomina* (Pl. 40, fig. 6 *b*) and elsewhere. The thickening gives whiter areas against a darker background of the thinner portions. In the Globigerinidae a much specialized character is found in the development of fine spines clothing the test. These are outgrowths of the wall and in these specialized pelagic forms may have a function in supporting the protoplasm which often becomes attenuated and many times the diameter of the test.

In some of the higher groups especially the orbitoids there are solid masses called "*pillars*" developed in the wall. These may start very early and be continued to the surface throughout further development. The presence or absence of these is of diagnostic importance in several groups.

Ornamentation. The calcareous foraminifera especially are often highly ornamented. This seems to be due in many cases to an excessive amount of calcareous material. The ornamentation may involve various parts of the test in varying degrees, such as the general surface of the chamber, the sutures, the periphery, the spiral suture, or the aperture.

Patterns in the chamber wall due to difference in thickness have already been noted. There may also be pits either irregularly distributed or making up more or less geometrical patterns in the wall. These depressions in the higher forms like the Globigerinidae (Pl. 47, fig. 2), the Rupertiidae, etc., may produce a definite cancellated appearance of the wall due to the greater thickening along the sides of polygonal areas with the perforations in the center.

The most common ornamentation of the general chamber wall is in the form of raised areas. These may take the form of raised costae, knobs, spines, or various types of raised meshwork. These raised forms of ornamentation may be generally scattered, form characteristic patterns, or be confined to certain definite portions of the chamber surface.

The sutures may be raised into definite ridges or costae (Pl. 40, fig. 1 *a*), and these costae may again be broken up into rows of bead-like knobs (Pl. 40, fig. 10 *a*) or may even develop spines. The sutures are often thick and limbate, or clear shell material appearing darker against the lighter areas between the sutures (Pl. 40, fig. 6). Where the sutures meet the periphery, spines are often developed or peripheral keels connecting with the sutures.

The periphery of the test in spiral forms is a place where ornamentation is often greatly developed. It may consist of a thickened keel or one that is thin and becomes a broad carina in several families (Pl. 24, fig. 2). Spines either in relation to the ends of the sutures, the keel or the general surface are often developed to large size (Pl. 35, figs. 1-5, 17). Costae of the general surface may be developed into spines at their outer edge.

The spiral suture is itself often thickened, standing above the general surface or broken into knobs. Its ornamentation is usually more closely related to that of the sutures and periphery than to that of the general chamber surface.

About the aperture, spinose or granular surfaces are often developed in several different families. Where a neck and lip are developed there are often spines about the outer surface. In forms like *Buliminoides* (Pl. 35, fig. 11) or some species of *Dis-*

corbis, etc., where there is a depressed umbilical area or apertural face, specialized costae running in toward the aperture are developed, often becoming highly ornate.

In the old age of individuals or in the later development of species the ornamentation is often lost as in other animals, and the test that was highly ornamented in the early stages becomes gradually less so and in the adult entirely smooth (Pl. 35, fig. 17). Such a disappearance of characters does not take place equally in all parts of the test. In coiled forms of the Lagenidae for example, the ornamentation on the general chamber surface becomes smooth first on the proximal side and the ornamentation is held longest on the peripheral part. In the same specimen the ornamentation of the suture lines disappears first in the peripheral part of the suture, and is retained longest on the proximal end, an exact reverse of the conditions on the chamber wall between the sutures.

In many species the ornamentation is closely identified with the individual chambers and sutures or patterns are broken at the edges of the chambers (Pl. 36, fig. 27). In others, the ornamentation belongs to the test as a whole and is continued unbroken from chamber to chamber (Pl. 35, fig. 11). The large spines may be added to as each chamber is built so that they have a laminated appearance in section.

Aperture. The aperture of the test is one of its most important parts from the standpoint of relationships and descriptive work. It is the opening through which the main body of protoplasm has its chief egress to the exterior. The aperture in the adult of a given species is rather constant when its development is known. The fact that the aperture changes as the test develops has been held to be a feature which would deprive the aperture of much consideration as a feature of systematic descriptive worth. The fact that its changes are usually in a logical sequence and that these very changes are capable of interpreting relationships has often been overlooked. The young of a complex form will have in its early stages the simple aperture that is characteristic of the genus related to that stage in its development. Thus in *Pyrgo*, the early quinqueloculine stage will have the simple tooth characteristic of *Quinqueloculina,* in its next or triloculine stage, the bifid tooth characteristic of

Triloculina, and in the adult the broad tooth characteristic of that species of *Pyrgo.*

In the more primitive forms the aperture is but a simple opening in the wall of the test (Pl. 5, fig. 3). In most coiled forms it is a simple opening between the base of the chamber wall and the preceding whorl (Pl. 10, fig. 6 *b*). In uncoiled forms, the aperture tends to become terminal and to appear in the apertural face itself finally becoming entirely terminal (Pl. 20, fig. 12 *a*). The same is true in the biserial forms such as the Textulariidae and the uniserial forms that have developed from them (See plate 11).

In forms that become much compressed so that the aperture tends to become a very long narrow opening, there are partitions built across the opening as in *Peneroplis* (Pl. 31, fig. 1) even though the chamber itself is not divided into chamberlets. In complex types in which the chambers are subdivided into chamberlets, the apertures are usually multiple. Toward the end of development in many different groups there is a decided tendency to have multiple apertures instead of a single one. This can be seen by referring to the various plates showing development (Pls. 13, 19, 37). Many species in their adult chamber have numerous large pores or supplementary apertures, especially those that have become pelagic in habit.

The forms which have become uniserial as a rule have terminal apertures. These typically develop a cyclindrical neck and often a phialine lip (Pl. 36, figs. 13, 23), characters more closely associated with mechanical form than with systematic relationships. Parallelisms of this general type are abundant in the foraminifera.

In many foraminifera there is developed a tooth of some sort in the aperture. This is usually an outgrowth of the side and many become very complex. In the Miliolidae (Pl. 18) and the Valvulinidae (Pl. 12) some of these forms will be found. In the Bulminidae and the Ellipsoidinidae there are frequently tooth-like structures in the aperture that are related to the tubular structures connecting the apertures within the chambers themselves.

The Lagenidae and Polymorphinidae have developed a peculiar radiate aperture that is very distinctive. The primitive aperture as seen in *Robulus* is simple. Above this simple aperture in many genera of these families is developed an *"apertural chamber"* or small cavity, the inner aperture into the main body of the chamber being simple and the outer one radiate.

In general the aperture is one of the features of the test most worthy of study both in its adult form and in the successive changes in the development of the earlier stages.

CHAPTER III

COLLECTING AND PREPARING MATERIAL

Recent Material may be collected in many localities along beaches. On coasts with shallow waters which have many algae or hydroids, the tests of foraminifera often come in on the beach in enormous numbers. As these are very light, each wave carries them up and deposits them at its highest point. When the wave recedes, a whitish line often largely composed of foraminifera will be found. This may be scraped up carefully, and later prepared for study. Such deposits at Rimini on the Adriatic furnished the earlier authors with many of their species, and the deposits there today when the waves are breaking are very rich. Where there are deposits of fossil foraminiferal material along the shore the fossil species may be mingled with the recent ones and make the study of such collections a difficult one.

In deeper water of a few feet or fathoms it is often possible to make good collections by means of a simple dredge. In Jamaica with a bright new tin pail which could be seen in several fathoms through a water glass I found it possible to get samples of the bottom even among coral reefs in ten fathoms or more. A much better means is by use of the "bull-dog" snapper which is so devised that it shuts on contact with the bottom and brings up a tea-cup full of the bottom material. By adding a weight to this apparatus, samples can be obtained even in two or three hundred fathoms.

Preserving. For studying the animal itself, nothing can take the place of living material. However, material collected in alcohol is of some use but formaldehyde should not be used as it frequently destroys the lime of the tests.

If only the tests are to be studied, it is by far the best to wash the material in fresh water and then dry it. It can be then packed in bottles or boxes and await future opportunity for its study without any deterioration.

Washing. For the examination of the foraminifera, clean tests are necessary. In order to get these, the dredged material which contains mud and fine sand, should be washed. This is best done by means of nested sieves, such as are obtainable at most laboratory supply houses. Brass sieves with meshes of 200, 120, 80, 40, etc., to the inch can be obtained. For more practical purposes sieves with 40-, 80-, and 200-mesh to the inch are sufficient. The mud is placed directly in the top sieve, and a stream of water with a fine spray played upon the material. If the sieves are shaken so that the material is kept in motion, the finer particles will be washed through readily. The resulting clean foraminifera can then be dried. It is sometimes more satisfactory to wash material through the coarsest sieve first into some sort of retainer, and then this again passed through the finer sieves. By this means the finer meshed sieves do not clog with the material. If sufficient water is used constantly, the tests will be in practical suspension and will not be damaged even with a rather strong current of water. With very delicate material, it is sometimes best to wash the material in muslin bags simply agitating the bag in a container of water until all fine mud is washed away. Material may be dried in the open air or if speed is necessary by artificial means, either a hot plate or on some sort of stove. With very delicate material, it is often best not to dry the sample too quickly or to have it get too hot in the process.

Sorting. After the material is washed it often helps in the examination if preliminary sorting can be done. There are different methods of doing this. One is that called "spinning". By this method, the material is put with clean water in a plate or watch glass or in any dish with water so that a circular motion can be set up. This is the old method by which gold was "panned" by the miners. The gold dust was heavier than the sand and came to the middle of the pan. In the case of the foraminifera, however, they being lighter material than the sand, accumulate on the outer edges. This can be washed off in the process into a larger receptacle below.

Another method by which rough sorting can be done is by "decanting". If the material is shaken up in a tall vessel of some sort, the lighter specimens will stay in suspension for a short period and can be poured off, leaving the heavier ones on the bottom. Successive stages will separate most of the calcareous tests from the sand and the heavier foraminifera.

One of the most useful methods is that of "floating". The washed material is taken after drying and slightly heated. Then if this heated material is thrown upon cold water those smaller tests, which are filled with air, will float on the surface and can be poured off. In this way beautiful material can be prepared which is very largely pure foraminiferal tests. This last method combined with "decanting" will give the best results.

By the use of heavy liquids such as bromoform, etc., it is possible to greatly concentrate the tests of foraminifera and separate them from the remainder of the material. It is often possible in this way to save hours of work that would be involved in looking over a sample and picking out the individual specimens. All such work should be done with the use of a ventilating hood.

Storage of Material. It is possible to store washed material in a variety of ways. Bottles or boxes of convenient size may be used. The various sizes of jars with snap covers make one of the very best and most convenient sorts of containers as they may be opened with a simple pressure on the center of the cap and closed tightly by a pressure at the sides. For small samples, the folded papers used by chemists are very convenient. They can have the data written on them before they are filled, and then can be easily filed in a very small space. They are also very light and if carefully packed will stand shipment well.

Fossil Material may be collected from many kinds of sediments. For the study of free forms, it is best to collect from the shaly or marly partings frequently found alternating with harder beds. Unconsolidated fossil material may be treated as already described for recent collections.

With harder material various methods may be used. By boiling with alkaline solutions, soda or potash, the specimens may frequently be gotten out in clean condition for study. The use of the autoclave has been described by Driver (1928). The use of the oxy-acetylene torch has been described by G. D. Hanna and by F. and H. Hodson. In the case of hard material, it has been found that the use of a grinding machine will often break down the sample in such a way that the individual specimens will crack out along the surface, and a considerable percentage of specimens with a well preserved surface for study may be obtained.

With very hard compact material such as limestones, the only resort is a study of sectioned specimens. This method is of use with the orbitoids, the Fusulinidae, and some others, but not as valuable for many of the Rotaliidae or other groups where the exterior is necessary for specific determinations. Weathered specimens will often show good exteriors and after their determination, it is possible to recognize the same species in sections from the same horizon.

CHAPTER IV

METHODS OF STUDY

The treatment of material will vary much according to the use to be made of it. If it has been collected and prepared purely for the purpose of making a determination of age for stratigraphic correlation, it may be of no further value to the worker. If the sample has been collected for scientific study, it will take a very different course. In the next chapter, the methods used in Economic work will be discussed and here the treatment for scientific study only.

Selecting and Mounting. If a fauna is to be worked up for a scientific collection or for publication, it will be necessary to pick out the specimens that are desired. In this work a binocular microscope with a large field and plenty of light is almost a necessity. As most recent foraminifera and many fossil ones are light colored the material should be loosely scattered over a darker surface. Black is the most commonly used although at least one of my students much prefers green. Blackened trays may be made by blacking a shallow pasteboard tray with waterproof ink. When this is scratched, another coat can be easily applied. An excellent tray may be made by placing a plate of glass over a piece of black velvet. This gives an intense black surface against which specimens stand out with great distinctness. It is best to have the specimens so scattered that individuals stand out clearly. If the material is put on thickly, it is difficult to distinguish forms clearly and the eye strain is much greater. Lines in white may be ruled so that the black surface is divided into squares if one wishes to search the whole area, and a mechanical stage is of still greater help. One of the simplest backgrounds may be made by exposing a photographic plate and developing it so that a uniform black surface results. This may be used for the bottom of a tray, or if corners are to be eliminated with their danger of retaining specimens, the plate alone may be used on the stage of the microscope.

The selected specimens may be mounted on slides directly or may be sorted to families and genera for further study. In picking out the specimens, the best method is to use a moistened brush. The finest brushes obtainable, 00 size, made of red sable bristles are by far the best. These make a very fine point indeed and, if moistened and touched to the specimen can be used to carry it to the slide. Needles are sometimes used but they are not elastic, do not retain moisture, and easily break delicate specimens. Camel's hair brushes are not sufficiently elastic to be of much service. The sable brushes if left moistened and the tip drawn to a point will last for a long time.

It is necessary to mount the selected material for safety for further study and for permanent preservation. Slides of various sorts are used. One of the simplest, cheapest, and most generally satisfactory types of slide is made of two pieces of pasteboard, the upper of good grade and thick, the bottom one of cheaper grade and thinner. The upper one is punched with holes of the desired size and number, and between the two a piece of black paper inserted. The two then are pasted with Map Mounter's Paste which is very strong. To avoid the black paper, the lower piece may be made of black surfaced heavy paper or be covered with various black waterproof substances.

For slides of individual species, it is best to have a slide with a single opening, preferably centered, and not over a half-inch in diameter. This then leaves plenty of room for labelling and for cover. A very simple method is to place an ordinary cover glass above the opening with a tiny drop of glue at three or four places near the edge. The point of a knife or needle will quickly snap off the cover if it is necessary to change the position of the specimens for further study. A neater method of cover is that provided by a sheath made of a glass slide and a base of a thin strip of cardboard, the two attached by strips of gummed paper at the sides. For the study of faunas, it is often useful to have slides with several rows of small openings into which may be put different species from the same sample. These may have the glass sheath. There are various types of pasteboard slides on the market which are very cheap but that is their chief recommendation. As a rule they are of too poor quality material to take ordinary ink well, especially in damp weather and the opening too large and too shallow to afford safety to specimens of any size. Manufactured slides with central opening and of considerable depth are now obtainable and meet the requirements much better than most of the commercial slides.

Dr. Zinndorf of Germany has produced a slide which is very excellent in many ways. It is made of black or dark blue celluloid with a central cavity and a square glass cover held in place by two clips cemented to the slide. These slides have the advantage of being very firmly closed yet easily opened, and specimens can be kept loose in the slides with a large margin of safety. The main objection to them is the danger of celluloid, and slides of other substances such as bakelite can be made as cheaply.

Another type of pasteboard slide that is used to good advantage is one with a large rectangular opening, the background made of double-thick photographic paper in black with white lines forming 10, 20, 50, or 100 squares, each with a white number. When these are covered with a glass sheath, they make excellent slides for the rapid study of faunas.

All the slides so far described are 3x1 inches. Dr. A. Franke of Arnstadt has advocated the use of a smaller slide which is much more compact. These are described in his papers. They are arranged in narrow trays which may be placed under the microscope and all the slides of a tray examined one by one without removing the slide from the tray. Dr. Franke showed me his collection mounted in these slides and they certainly have the advantage of taking up very little space.

Specimens may be kept loose in the openings of slides that are covered with the glass sheaths or in the Zinndorf type of slide. With most slides and for greater safety, specimens should be attached. For this purpose, gum of some sort is necessary. Ordinary glue will crack on drying and frequently break the specimen. It is difficult to soften glue when it is desired to change the position of a specimen. In this laboratory the gum that has been found most satisfactory is one made by dissolving ordinary gum arabic in warm water to form a consistency desirable for the size specimens to be mounted, then adding enough glycerin to prevent cracking. A drop or two of formaldehyde can be added to avoid moulding. This gum is transparent and a thin coating can be placed directly on the slide and allowed to dry. The moisture from the brush as the specimen is transferred will soften the gum sufficiently so that the specimen will become attached, and before drying, the specimen can be oriented to the desired position. A very little gum should be used so as not to cover important structures and for ease in removing the specimen if desired.

Some workers prefer to use glass slides with concave cells placing the specimens in these under an ordinary cover glass. These have the difficulty of the specimens getting lodged between the cover and the slide, and thus becoming broken. The slides themselves are easily broken and must have some sort of label attached whereas the cardboard slides can be written upon directly.

In studying and drawing specimens, it is often necessary to place them in different positions. Ordinary plasticene can be used, preferably dark colored sorts. This is sticky however, and it is often difficult to clean specimens. A better material is the black wax used in biological laboratories for making models from serial sections. It is easily softened with the warmth of the hand, and is not sticky. A hole may be made with the point of a needle and the specimen set in it, or often simply stood on end on the wax itself. Far better than either of the above in my own work is the Prism Rotator. With this simple device, it is possible to study the specimen without moving it, and to get views from above and below. The entire periphery may be viewed from every angle by rotating the prism. It is invaluable for full study of specimens especially if one wishes to view the aperture from all angles to see the different aspects. For drawing this may be used with the ordinary camera-lucida and all views made without touching the specimen. For measuring specimens this is also invaluable for with an ocular micrometer, the various dimensions may be obtained without disturbing the specimen.

In the study of dry specimens, it will often be found that moistening the exterior will bring out the structure very distinctly. This may be done with water or if a long study is needed in drawing, glycerin will dry less rapidly.

Photography is very useful in the study of specimens and making permanent records. The methods in use in this laboratory were described (Contrib. Cushman Lab. Foram. Res., vol. 2, pt. 1, 1926, pp. 1-3), and are repeated here.

Various methods have been tried out for a number of years, but always difficulty was encountered in getting sufficient depth of focus with the desired magnification. Several years ago a method was worked out by the writer, and later put into definite form. It has continued to give excellent results. The main idea has been to obtain a negative of the greatest possible depth of focus regardless of magnification, and then the enlargement from this negative to the desired size. In this way the details are kept with the deep focus.

For the actual photographing a vertical camera is used. The particular camera used in the laboratory is a type "H", Bausch and Lomb, with the camera parts to take 5x7 plates. Kits are used in the plate holders for smaller sizes. Any good compound microscope may be used. For objective the Micro-Tessars of Bausch and Lomb are used. The 32-millimeter equivalent focus has been found to be of the greatest value although those of greater focal length are excellent for large specimens. For focusing, the diaphragm should be wide open or nearly so, but for the actual exposure the stop should be cut down at least to 11 of the scale, or even to 22 to get the greatest possible sharpness and depth. An ocular may be used if desired, but much the best results are obtained without it. With the type "H" camera with the bellows extended to full length, there is a magnification of the image on the plate to about 18 to 20 diameters. This will give an excellent depth. By all means a focusing glass of some form should be used, and every change of specimens very carefully refocused. The entire result depends on this point of very exact focus. With the combination of a 32-millimeter, no ocular, and bellows full length all the specimens in a circle of about 5 millimeters may be photographed at once.

For the lighting, one of the regular Bausch and Lomb illuminating outfits with a 6-volt, 108-watt lamp is used. This is placed in the most advantageous position, and then screwed to the table to form a permanent fixture with a table switch. With the microscope and camera fixed, the only thing needed is to get the slide in position. The light from this unit will be found very intense and the shadows it casts very dark. In the laboratory here a counter-light is used. This a 250-watt, 115-

volt "floodlight" bulb in an ordinary pliable gooseneck which can be quickly bent to any desired position.

In actual operation a table was built in across the end of the "exposure room" of the laboratory, the centre of the top removable with a second solid shelf below. In this lower part the camera and microscope are placed, also the counter-light. On the top at the left is the strong light as already noted. This arrangement brings the top of the camera when extended low enough so that focusing can be done from the floor. A medium position is thus obtained obviating stooping to place the slides in position and change the diaphragm, and also standing on a higher level for focusing.

When these factors already mentioned have become fixed, a table of variant factors should be worked out. The intensity of the strong light may be varied by focusing, and this will greatly change the time of exposure. The greatest speed can be obtained with the filament just out of focus on the slide. Each new bulb will be found to vary, sometimes as much as fifty per cent, and the intensity is apt to decrease with use. This factor must be constantly checked. Specimens will require very different exposures. White foraminifera of tropical reefs containing chalk-white Miliolidae will need much less exposure than the gray, dull material of much of the American Cretaceous, for example. Length of exposure should be increased rather than opening the iris diaphragm.

The best results will be obtained from fairly slow plates, and any good plate will give excellent results. The normal development time for the plate should be taken as the base, and length of exposure, intensity of light, etc., varied until the desired sharpness of the developed plate results. Tank development is used entirely.

When good negatives are obtained, the next step is to get the size best adapted to the purpose desired. In this work an Eastman auto-focus enlarging camera is used. With this camera working in a vertical position no focusing is necessary, with the enlarging paper placed directly on the table in the red light, with a smaller auto-focus enlarger a magnification of 3½ times may be obtained, making the final print 60 to 75 diameters, a size sufficient for all practical purposes. Where records are desired for filing in the laboratory, printing is done on double thick, 4x6 paper, which can then be used as 4x6 file card with any notes that may be necessary.

By the methods outlined here, we have photographed 2,500 specimens of foraminifera in an afternoon on less than a hundred slides, and had the negatives ready for printing in the evening if necessary.

The longest time is spent in mounting the slides for photographing, but if flat slides are used with a black background gummed ready for use, one quickly becomes very expert in placing the specimen in position and arranging a number in the 5-millimeter circle. Specimens of fairly uniform size should of course be mounted together to insure uniform focus.

This method proved by several years of constant usage here in the laboratory will be found a very valuable one wherever numbers of foraminifera are handled, and where permanent records are desired.

The only changes that have been made in the apparatus described is to increase the length of the bellows to gain a greater magnification and therefore obviating so much secondary enlargement. As a consequence the camera is used in a horizontal position.

Sections in many specimens are very necessary for the study of the structure of the wall and of the early stages. They may be made by infiltrating the specimen with balsam and when hard, grinding it down upon an ordinary hone until the desired plane is reached. It may be left in this condition, or softened, turned over and ground down to a thin section according to the particular need. Larger specimens in matrix may be treated the same as in the making of ordinary rock sections.

In describing foraminifera the following outline is offered as that which the writer has long used; general appearance, chambers, sutures, wall, aperture, and color. These five or six distinctive groups of descriptive characters are set off from one another by semicolons for clearness.

1. General appearance will include: relative size, proportions, characters of the periphery, changes in plan of development, condition of attachment, and such other general points as are not included in the following more detailed characters:

2. Chambers, including number, relative size and shape, and arrangement.

3. Sutures, including amount of depression or elevation; clearness; amount of limbation, if any; changes in various parts or sides of the test; direction; straight or, if curved, the relative amount; relations to the ornamentation.

4. Wall, including relative thickness; materials of which composed; kind and relative amount of cement; finish of the exterior; relative size of perforations, if a perforate form; ornamentation, especially changes in different stages of development or in different parts of the wall.

5. Aperture, including changes of position at different stages of development, relation to peculiar structures or modifications of the chamber, development of neck or lip or ornamentation directly connected with the aperture itself.

6. Color, usually not evident in fossil forms although occasionally of decided importance.

CHAPTER V

ECONOMIC USE

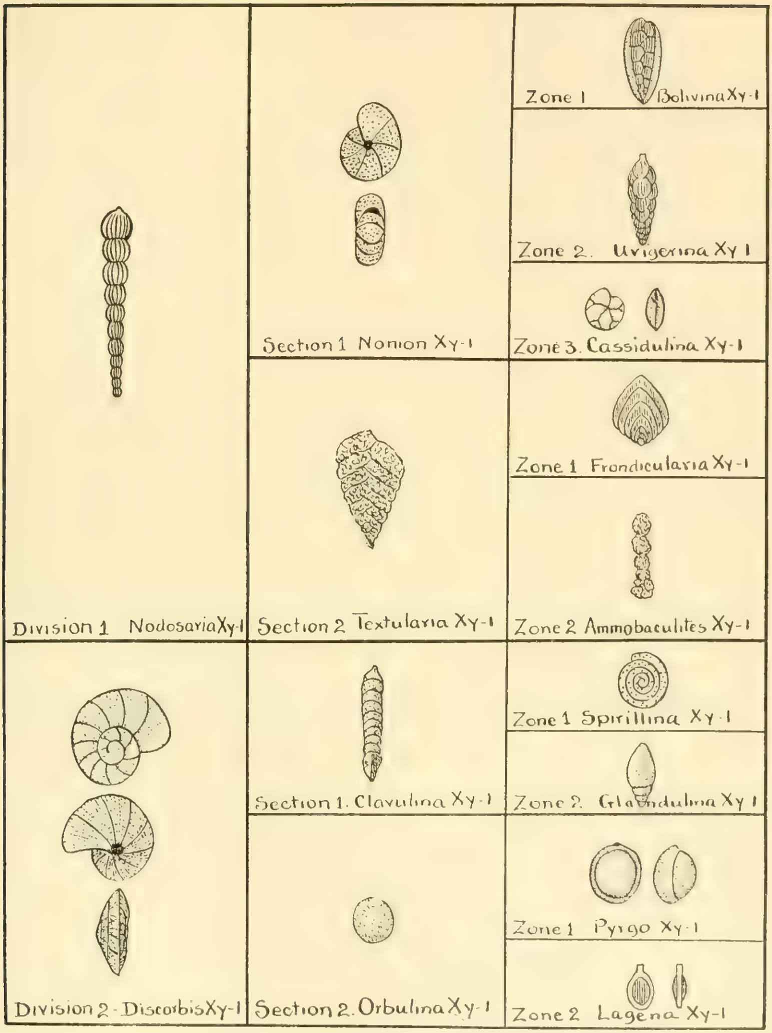
For the use of foraminifera in determining geologic correlation, especially in checking well drillings, methods different from those used for purely scientific study are necessary. Speed in handling material is often one of the most important factors. Anything that will allow of the greatest speed and at the same time the greatest accuracy is essential, and other things may be sacrificed to these.

Avoidance of scientific names other than that of the genus has been used by the writer in all his economic work. It has been found sufficient to place a specimen in its proper genus, then to give it a number with the formation character. Thus *Nodosaria* Tm-1 will stand in the work as a definite species of *Nodosaria* from the Tertiary and the Miocene Monterey shale; *Nodosaria* Cv-1 a particular species from the Cretaceous, Velasco shale of Mexico. A "type specimen" is selected and mounted as a permanent reference slide for each "species" or number. A short description on a card catalog card is made and filed for reference under its number and camera-lucida drawings in different views made and filed. As *Nodosaria* Tm-2 is found, it finds its proper place and is likewise permanently recorded. For ease in reference, plates are built up of the figures so that all numbered Nodosarias for instance are quickly seen on one plate. No occasion arises for consulting published figures or the general literature which, unless time and a large library are available, would probably result in a wrong specific name being given to the specimen. The abbreviated form of letter and number makes recording simple, makes columns in charts less difficult to handle, and is a great time saver. It also places the species in its general geologic position for future work. A worker can mount, draw, and briefly describe many numbered forms while he might be trying to run down the form to a satisfactory name even if plenty of literature were at hand.

Vertical Ranges. As material is studied from a section, from a well core, or even from carefully collected samples from a standard tool well, the vertical distribution becomes known. With the quick reference to the figures as the samples are studied changes are easily seen and new numbered "species" are added to the growing list. Occurrences are noted with records as to relative abundance.

From this data a chart may be constructed showing the vertical distribution of the numbered "species" in the particular section or well. It will be found in any section that there are species which are so rare that they are of little use in determining the position of samples. Even if their ranges are short and accurate, the time consumed in finding them in a sample and the possibility of missing them make their value very slight. On the other hand, there will be found species whose ranges are long and which may be present through too much of the section to be of use in detailed work. In every section however there are species whose ranges are relatively short and which are abundant enough to be quickly found in a sample if they are present at all. Such species are ideal for correlation purposes. If, then, these key species are selected, a chart may be built up from them that will make the placing of unknown samples in the section a matter of comparison. The "tops" and "bottoms" of ranges may be used. If two species of different but overlapping ranges are both present, it is at once apparent that the sample that contains them came from the zone of their overlapping. By using many species, the zone of overlap becomes narrowed until with rich faunas carefully worked out, the accuracy of placing samples becomes one of close discrimination of specific characters. Even if the zone of overlap may be of considerable amount in a case where but a few species are available, the relative abundance of species may serve as an additional check and narrow down the limits. Even in similar sediments the relative abundance of species at different horizons is often widely different.

Charts may be made and duplicated to give a series of workers the data that has been worked out by the persons specializing in different parts of a section. One of the best of these is



Idealized Chart of Section Zoned by Foraminifera.

a visual chart which is really a key to the particular section. See figure. For the first division two very different forms each of which is common yet limited to its own part of the section should be chosen. The left side of the chart may thus be divided into Divisions 1 and 2, those of *Nodosaria* Xy-1 and *Discorbis* Xy-1. The upper portion, Division 1, may be further divided by *Nonion* Xy-1 and *Textularia* Xy-1. The zone of *Nonion* Xy-1 may be subdivided into three horizons represented by *Bolivina* Xy-1, *Unigerina* Xy-1, and *Cassidulina* Xy-1 and so on with the other main divisions. The figures of each of these key species for the different divisions may be placed in the proper position on the charts and it becomes entirely a matter of discrimination of characters to find the particular horizon where an unknown sample should be placed. Endless variations in making charts of this sort will suggest themselves to workers engaged in such problems.

With drilling wells where ranges are known, it is very simple to keep up with the horizons if charts of the sections from nearby wells or sections are worked out. Various horizons will be recognized so that they may be picked up even in rotary drillings when material from such horizons comes to the surface. The main use is in the case of core samples or bit samples where the exact position in the well is known but the problem becomes one of placing the samples exactly in the section. It is a simple matter with good samples to tell when passage is made from one clear formation to another if the section has been worked out, but to place random core or bit samples accurately means a greater refinement of detailed ranges. Such work can be done accurately however with sufficiently detailed material to start with by a worker who can recognize valid distinctions and has keen powers of discrimination.

For the building up of sections continuous core samples are by far the best. With overlapping cores it becomes possible to build up continuous sections for long vertical distances. Next to cores, samples carefully taken from cable tool drilled wells are useful in working up sections. If the first sample out of the bailer is taken, and samples are taken at frequent and regular intervals, very good working sections may be built up. Rotary well samples are often not worth the time spent on them as far as gaining information for detailed work is concerned. After the section has been built up, it becomes possible to use rotary samples, but only to use the "tops" of ranges, and thus to tell when a horizon may have been reached.

In examination of samples the "wet method" advocated by Driver may be found useful. Many species show their characters much better when wet than when dry, and this method is useful from this point of view as well as being a time saver over that which requires the material to be dried before examination. The appearance of specimens is very different in liquid from what it is when dry, and a change of samples from one method to the other is not advocated.

In speeding up the handling of specimens, the procedure adopted in this laboratory by Earl A. Trager will be found useful. Where many samples are to be handled, the containers are of the same size and shape so as to pack to take up as little space as possible. Each container has its own number. This "pan number" becomes the key to the sample. The data from each sample is written on a sheet and each sample given its "pan number." The specimen is then put to soak in its pan, samples washed as they are ready, and transferred to a filter paper on which the "pan number" is again written. When dry, the "pan number" is inserted in the container and comparison with the original sheets gives the person making the examination the full data to substitute for the "pan number" which is then ready for the next lot. It has been found possible by this method to have a great many samples under preparation at one time without fear of loss of data or of trouble in keeping labels dry or with their proper sample. It saves much clerical labor and makes for speed in handling material.

CHAPTER VI

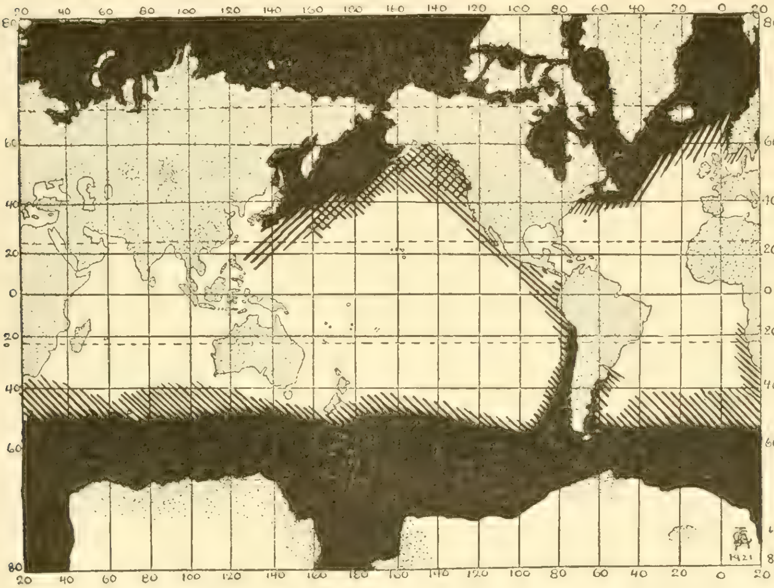
GEOGRAPHIC DISTRIBUTION

There are many papers on the Recent foraminifera but nearly all of these are faunal papers taking up limited areas. In the case of the *Challenger* Report which covered all the seas, Brady had such a wide latitude in his conception of species that faunal limits were not distinguished except in a general way. It has been possible in the studies of all the living species of certain genera as well as a study of faunas from various parts of the world to arrive at a fairly comprehensive idea of the living foraminiferal fauna. That there are very definite faunas is apparent and many of them may be subdivided. These faunas are of interest to the worker on fossil foraminifera as well as to one working on the living faunas, for the later Tertiary and Recent faunas have been established for a considerable period. The Pliocene faunas of Florida and California are very dissimilar but each is very close to the Recent fauna now living off the coast of the respective regions.

The migrations of faunas in Tertiary times have been marked. For example the Eocene (Lutetian) fauna of southern England and the Paris Basin migrated gradually through the Mediterranean region to Australia. Many of these species of the European Eocene are found but little changed in the Miocene of Australia and some of them are found with but little modification in the recent material from the Australian coast. The Miocene warm water faunas of the Austrian and Hungarian regions also migrated to the Indo-Pacific, and many of the species are still living in that area. So in the Lower Oligocene of the Southeastern United States, the species became extinct at the end of the Lower Oligocene in that region but had migrated to the Pacific, and now some of them or closely allied species still persist. Many of the large forms now living only in the Indo-Pacific, *Operculina, Siderolites, Baculogypsina, Cal-*

carina, etc., were very widely distributed in the Tertiary, but have now become extinct except in these restricted areas.

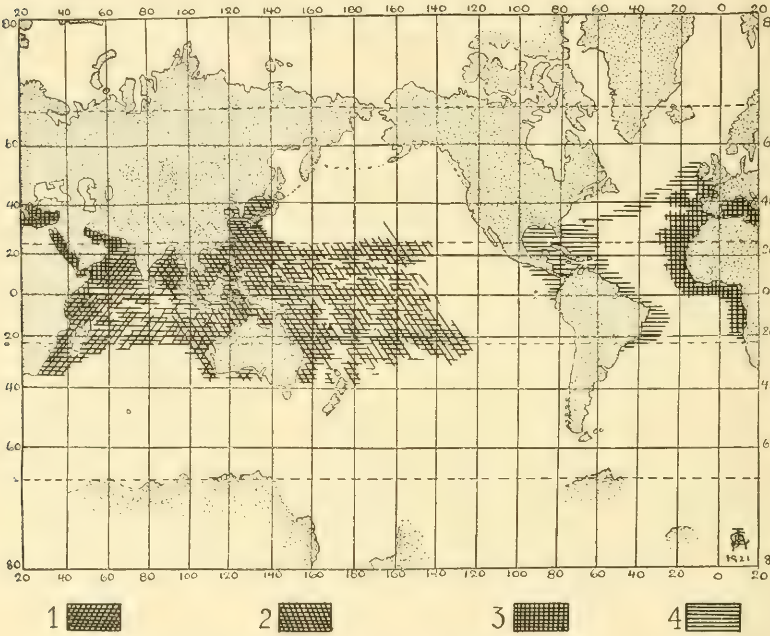
These migrations of the Tertiary account in a large measure for some of the peculiar distributions that are found today. The living fauna of the Caribbean and West Indian region is much more like that of the Australian region than any other. The cold water fauna of the west coast of South America is more like that of northern Europe than it is like that of the islands of the Oceanic groups a comparatively short distance away.



Distribution of Cold Water Faunas.

In general the bottom living recent foraminifera may be divided into cold water and warm water faunas. These are shown crudely on the two accompanying maps. The cold water faunas are also found to some extent in the deeper colder waters of the oceans. The Arctic fauna covers the cold waters of the Arctic region and comes southward along both sides of the Atlantic, much farther to the south on the western side. Likewise, it works southward into the Pacific especially on the western side, but some species work southward along the eastern side.

The Antarctic fauna is very similar in many of its groups to the Arctic one, but has many characteristic species. It covers the general Antarctic regions and works northward especially on the eastern side of the Pacific and also along the coast of Africa to some extent.



Distribution of Warm Water Faunas.

1. East African. 2. Indo-Pacific. 3. Mediterranean. 4. West Indian.

The warm water faunas are more easily subdivided and may have many more subdivisions than shown on the accompanying map. What may be termed the Mediterranean fauna works out into the eastern Atlantic and also into the Red Sea and Indian Ocean. The West Indian fauna extends from the coast of Florida to southern Brazil northward to Bermuda in lesser degree and in a still less characteristic form across the ridges of the Atlantic to the coast of Ireland. In the Pacific there is a general fauna covering the region from Africa to the Polynesian Islands. Many things are lacking in the western portion which may be separated as an East African fauna and the other kept as an East Indian fauna including Polynesia, running northward to southern Japan and including Hawaii where many of the characteristic things are again lacking. It is possible to draw lines more closely and find a number of smaller faunas in this general area.

With the foraminifera, it may be said that temperature is the great controlling force, and depth except as controlled by temperature a much smaller factor.

The most abundant single deposit of foraminiferal origin today is *Globigenina*-ooze. It is made up of the tests of the pelagic foraminifera of the Globigerinidae and Globorotaliidae and is formed in the ocean basins from 500 to 2500 fathoms in depth. There are many other groups represented especially from 1000 fathoms up, but these two families greatly predominate.

In abyssal depths where it is difficult for carbonate of lime to accumulate, many arenaceous forms are found. This is not due as seems to be a current opinion because they are found only in such habitats, but that they are the only ones that can persist under the particular conditions. If an equal amount of *Globigerina*-ooze were treated with weak acid, it would probably be found that the residue would be richer in arenaceous forms than the red clay areas of greater depth. Arenaceous forms are abundant often in rather warm shallow waters although certain forms become very abundant in shallow cold waters. It is the rule in cold waters in other groups as well as in the foraminifera that the number of species is few but the individuals occur in enormous numbers.

The Lagenidae as a rule are characteristic of the continental shelf and from 50 to 500 fathoms are very abundant. The Miliolidae are most abundant in shallow warm water of coral reef regions, but *Pyrgo* has become adapted in a number of species to deeper colder waters. The larger foraminifera of the families Camerinidae, Peneroplidae, Alveolinellidae, Calcarinidae, etc. are almost exclusively tropical in waters under 30 fathoms. The approximate depth of many Tertiary sediments may be rather definitely determined from what is known of the distribution of their contained genera in the present oceans.

Pelagic foraminifera. The deposits of *Globigerina*-ooze as has already been mentioned are composed very largely of pelagic foraminifera. These are distributed by warm ocean currents and their tests fall to the bottom in great numbers gradually building up a sticky calcareous mud. Fossil oozes of this type are found especially in tropical islands that have apparently been raised during the Tertiary. The following 26 species have been recorded as pelagic. All but one of these, *Tretomphalus bulloides,* belong to the two families Globigerinidae and Globorotaliidae. *Tretomphalus* becomes pelagic only in the adult phase and is mainly found in tow net collecting about coral islands. The early stages are apparently bottom living and the species are not therefore to be grouped with the oceanic pelagic group. The following species are noted as pelagic:

Globigerina bulloides d'Orbigny.
Globigerina dubia Egger.
Globigerina inflata d'Orbigny.
Globigerina cretacea d'Orbigny (?).
Globigerina pachyderma Ehrenberg.
Globigerina dutertrei d'Orbigny.
Globigerinoides rubra (d'Orbigny).
Globigerinoides sacculifera (H. B. Brady).
Globigerinoides conglobata (H. B. Brady).
Globigerinoides helicina (d'Orbigny).
Globigerinella aequilateralis (H. B. Brady).
Globigerinella digitata (H. B. Brady).
Orbulina universa d'Orbigny.
Hastigerina pelagica H. B. Brady.
Pulleniatina obliquiloculata (Parker and Jones).
Candeina nitida d'Orbigny.
Sphaeroidinella dehiscens (Parker and Jones).
Globorotalia menardii (d'Orbigny).
Globorotalia tumida (H. B. Brady).
Globorotalia patagonica (d'Orbigny).
Globorotalia canariensis (d'Orbigny).
Globorotalia crassa (d'Orbigny).
Globorotalia truncatulinoides (d'Orbigny).

Globotruncana linneiana (d'Orbigny).
Globotruncana marginata (Reuss).

To these may be added *Tretomphalus bulloides* (d'Orbigny) and *Hastigerinella digitata* (Rhumbler) both so far as known not of oceanic types.

The two families of the Globigerinidae and Globorotaliidae have developed either very large or multiple apertures, a generally globular or tumid form and a rugose or spinose surface often the surface clothed with long slender spines. Of these, *Orbulina* has the most perfect adaptation with its entirely spherical chamber.

CHAPTER VII

GEOLOGIC DISTRIBUTION

It is not possible in a short chapter to take up the detailed geologic distribution of any but the larger groups of the foraminifera. The nude types must be very old and of course have left no traces in the rocks. Likewise those forms which have developed chitin alone are almost without hope of being preserved in recognizable form unless they might somewhere have developed in such numbers as to have made a recognizable mass. At least they are not known from the earlier rocks. The arenaceous group, especially those which have very definite tests, are capable of good preservation if conditions are favorable. The chitinous base and more or less elastic cementing materials make them much less capable of holding their form under pressure than is the case with the calcareous forms. In Cretaceous and even Tertiary sediments which although unconsolidated have been subjected to stresses and shearing the calcareous foraminifera will be found to have held their shape well while the arenaceous forms with them will often be greatly twisted out of shape. The more firmly cemented forms such as the Textulariidae have been found in the early formations and a careful study of such sediments for arenaceous forms will undoubtedly bring many more to our knowledge. The calcareous forms are well preserved as a rule unless there has been leaching or the material turned to greensand before it was fully fossilized.

In the very early rocks microscopic objects have been found which have been assigned to the foraminifera, usually to the genus *Orbulina* which really is a specialized end form and in no sense a primitive one and whose geologic history is not long. In the pre-Cambrian quartzites of France, Cayeux has recorded microscopic objects which he has referred to the foraminifera although noting that the structure is obliterated and that some of them may be equally well referred to the radiolaria. The size of the chambers, .01 mm. in diameter, is much smaller than the microspheric proloculum of known forms and there is nothing about the specimens as figured to suggest foraminifera as much as yeast cells or many other microscopic objects. Dawson figures very similar objects which occur in great numbers in association with *Eozoon,* often apparently occurring in the chambers of that form. These he designates as Archaeosphaerinae. His figures and description certainly indicate a very close relationship to *Eozoon,* a form which has long since lost its claim to be considered as belonging to the foraminifera. The very close similarity of Dawson's and Cayeux's figures would seem to indicate a similar source for the two sets of objects and that neither can have any valid claim as foraminifera.

Matthew records from the Cambrian of New Brunswick both *Orbulina* and *Globigerina,* giving several specific names under both genera. I have examined specimens of both genera as named by Matthew in his collections but have been unable to make out anything of true foraminiferal nature in either. They very strongly resemble minute concretions. The so-called Orbulinas are merely small globular bodies and the so-called Globigerinas aggregates of these in various groupings. That they are in any sense related to the highly specialized and much later appearing genera to which they are assigned is hardly tenable or in my own mind, from the material I have studied, that they are foraminifera at all is equally questionable.

There are however in the Cambrian other evidences which are much more convincing. Chapman has recorded from the Cambrian of the Malverns in England well distinguished foraminifera which he refers to the genera *Lagena, Nodosaria, Marginulina, Cristellaria,* and *Spirillina.* These are rather abundant especially the *Spirillina* and so well preserved that they show the tubules of the wall of the test. There may possibly be some question as to the generic names to be used but no question as to the foraminiferal nature of the tests. From the Cambrian of Russia, Ehrenberg records numerous casts which are referred to *Verneuilina, Bolivina, Nodosaria, Pulvinulina,* and *Rotalia.* These might equally well be casts of *Verneuilina, Textularia, Nodosinella* or *Reophax,* and *Trochammina.* The originals show very little. Brady records *Lagena* from the Silurian which, however, may be *Archaelagena.* Terquem describes four species referred to *Placopsilina,* on crinoids from the Upper Silurian, three of which at first glance would appear to be Nodosarias and in section might easily be mistaken for this genus. According to Terquem, however, they were attached forms. He also refers specimens questionably to *Orbulina, Lagenulina, Cristellaria, Fusulina,* and *Globigerina.* Keeping refers material from the Silurian of Central Wales to *Dentalina, Rotalia* (?), and *Textularia.* The figures of the last-mentioned genus at least seem to be correctly identified. There are other scattered records from the pre-Carboniferous but these are enough perhaps to indicate that the foraminifera, except from the material from the Malverns in the Cambrian, are not at all abundant. The first abundant species which can be unquestionably referred to the foraminifera is *Spirillina* or at least a planispiral form with a proloculum and long undivided second chamber. The other records indicate that the Lagenidae and Textulariidae were also already developed.

Beginning with the Carboniferous, foraminifera are often abundant. In the Pennsylvanian of America there are rich faunas with abundant specimens. Arenaceous forms almost completely predominate. The Saccamminidae, Hyperamminidae, Reophacidae, Ammodiscidae, Lituolidae, Textulariidae, Verneuilinidae, Fusulinidae, Trochamminidae, Orbitolinidae, and Placopsilinidae, a majority of the arenaceous group, are present and some of them well developed in the Pennsylvanian. Some of the Lagenidae are possibly present, and the beginnings of the Miliolidae and Camerinidae. There are a few other groups recorded but they should be carefully checked as they rest upon single specimens in some cases. Altogether the Palaeozic foraminifera are predominantly or almost exclusively arenaceous and this condition continues on into the Permian where some of the lines of development reach their climax and become extinct.

Triassic foraminifera are extremely rare. Those that seem to be well enough preserved for generic identification are almost entirely genera which have already appeared in the Palaeozoic.

The Jurassic is characterized by the dominance of the Lagenidae. These become very abundant and develop very many species. Arenaceous groups persist and at some horizons are abundant and the first records of most of the other arenaceous families like the Astrorhizidae and Rhizamminidae appear. This is probably due to lack of earlier records rather than that these represent the first records of the group. The Silicinidae appear in the Lias, more of the Miliolidae and Ophthalmidiidae are developed. The earliest unmistakable primitive genera of the Buliminidae and Rotaliidae also appear, but not the more specialized families derived from the Rotaliidae.

There are very few large species of foraminifera in the Jurassic, but the faunas have many smaller ones. For the first time the calcareous types, as represented by the Lagenidae particularly, predominate over the arenaceous forms although in some horizons the latter are abundant.

With the Lower Cretaceous there is a great development of new forms. Arenaceous forms continue as they do to the Recent oceans, but they are largely overshadowed by the calcareous forms. More of the genera of the Buliminidae appear such as *Virgulina* and *Bolivina*. In the Rotaliidae a few more of the primitive genera appear. The Globigerinidae make their first appearance with undoubted species, and the Heterohelicidae appear although better developed in the Upper Cretaceous. The simpler forms of the Anomalinidae appear. Of the large forms, *Orbitolina* becomes very abundant.

The Upper Cretaceous greatly increases the number of genera that are developed. Many of them such as *Pseudotextularia*, *Planoglobulina*, *Eouvigerina*, etc., became extinct in America with the Cretaceous although in Europe they apparantly persisted into the Lower Eocene. With the Upper Cretaceous there are new families appearing, especially the more specialized ones derived from the Rotaliidae such as the Calcarinidae, Chilostomellidae, Globorotaliidae, Peneroplidae, and theOrbitoididae. Some of these may be found to have had their real beginnings in the Lower Cretaceous. Pelagic foraminifera appear to have been first definitely developed in the Cretaceous. The Globigerinidae and Globorotaliidae were well developed and abundant, and the Guembelinas seem to have been pelagic at this time although none of their group are pelagic today. In general, the Upper Cretaceous takes on many modern aspects in the foraminifera although in many respects it is primitive. The specialized groups of this period have mainly disappeared.

With the Eocene, modern forms are more abundant. Large species are developed in the warm seas of this time. The genera

Orbitolites, Opertorbitolites, Alveolinella, Flosculina, Borelis, Operculina, Heterostegina, Camerina, Asterigerina, Amphistegina, Lepidocyclina, Discocyclina, and others develop large species. The higher groups of the Rotaliidae and derived families appear. While many of these had specialized species the general character of the fauna has persisted and many of the genera are now found living in the shallow waters of the Indo-Pacific. As the Tertiary progresses, species are replaced by more modern ones, and gradually the fauna comes to that of the present oceans. Outside of the Allogromiidae which naturally would not be found in the fossil state, none of the families except the Neusinidae and Kerammosphaeridae are wholly represented by recent species. These two are very specialized families with very few genera and species, and very limited in their distribution at the present time. The accompanying chart shows the distribution of the families in geologic time, the dotted portion the probable range where not yet definitely known.

CHAPTER VIII

CLASSIFICATION

Numerous attempts at classification of the foraminifera have been made from the time of the appearance of d'Orbigny's classic Tableau Méthodique published in 1826. Nearly all the classifications since d'Orbigny's time have been based upon the resemblance in form of the adult test. The classification adopted in Brady's *Challenger* Report of 1884 with its ten families has been the one in most general use since that date. It however places together forms which are now known to have very different beginnings, although their adult forms may have certain points in common. The classification adopted here is that given in outline about a year ago, Cushman, An Outline of a Reclassification of the Foraminifera, (Contrib. Cushman Lab. Foram. Res., vol. 3, pt. 1, 1927, pp. 1-105, pls. 1-21.) In that outline an attempt was made to bring together the best thought developed on the relationships of the foraminifera since the publication of Brady's Monograph in 1884. Since that date, much has been learned in regard to the development of foraminifera, and many new genera have been erected.

An ideal classification should be based upon the known phylogeny of a group as shown by the fossil record, and coupled with the ontogeny of the individual as shown in its complete development together with what may be learned of the morphology and physiology of the group.

In the foraminifera as has been mentioned, there are at least two distinct forms, one the result of the fusion of gametes after mitotic division, the microspheric form, the other the result of simple division, the megalospheric form. In the firstof theseforms the early stages are more nearly complete while in the second and early stages may be skipped and the adult characters taken on almost at once. It is very evident that any classification must be based upon the relationships shown in this microspheric form of the species. Unfortunately the microspheric form is often rare and the megalospheric form the common one. Acceleration of development takes place in various groups so that there are species which hold to ancestral characters and show several developmental stages, whereas others are much more specialized and skip or greatly reduce these stages. Also parallelisms, or the development of similar structural forms in the adult, are very common in the foraminifera.

The simplest foraminifera are the Allogromiidae where the test is either wanting or consists of a thin chitinous wall. This latter may be more or less globular or elongate and open at both ends. With the advent of the arenaceous or agglutinated test on the outside of the thin chitinous layer, a structure of more or less permanency is established, and in the strongly cemented tests is capable of preservation in the fossil series. One of the simplest of this form of test is that seen in the Astrorhizidae (Pl. 2) where there is a central chamber and irregular arms, the whole test rather loosely cemented. Another simple form is the agglutinated test open at both ends in the Rhizamminidae (Pl. 3), a form easily derived from such primitive forms as *Shepheardella* in the Allogromiidae (Pl. 1, fig. 9). The simple single chambered forms of the Saccamminidae (Pl. 4) may be directly derived from such primitive forms as *Allogromia* (Pl. 1, figs. 6, 7).

As the next simplest stage in development, there is the initial chamber of proloculum followed by a long undivided tubular chamber. This may be straight as in *Hyperammina* (Pl. 6, figs. 1, 2) or become coiled in various types of spirals as in *Ammodiscus* and its allies (Pl. 9). The planispiral form is the simplest of these and occurs in the different types, the arenaceous in *Ammodiscus* (Pl. 9, figs. 2-4), in *Cornuspira* in the imperforate calcareous group (Pl. 20, figs. 1, 2), and in *Spirillina* in the perforate calcareous group (Pl. 39, fig. 1). The long chamber next becomes divided into divisions or chambers. and the various families gradually make their appearance in the fossil series.

In the Textulariidae (Pl. 11), the early stages are planispiral, but the later ones become twisted and elongate finally settling down to a test with the chambers making a half turn of 180°, the aperture toward the central axis. From this type are derived many diverse forms (Pl. 13). These developed early in the Palaeozoic and many of the complex ones developed there did not persist to later times. Some of the arenaceous groups developed complex forms such as seen in the Fusulinidae, the Orbitolinidae, and the Loftusiidae, but all have become extinct.

The Miliolidae started their development in the Palaeozoic, but did not reach their height until the Upper Cretaceous. They had the power of adding arenaceous material to the outside of the calcareous test in the earlier, more primitive forms, but lost it in the more specialized ones. The calcareous test is imperforate. There are characters such as in the pseudopodia and color of the protoplasm which may help to show the distinctions in this group even more plainly than at present.

In the Lagenidae which have kept to a planispiral form of coiling and then straightening out there is a primitive group which reached its height in the Jurassic but still continues as a plastic group showing practically no new developments in later times.

A general group of families in which the test is planispiral or modifications from it, is seen in the lines leading to the Peneroplidae which became imperforate and the Camerinidae which continued the perforate character. Both of these specialized families reached the climax of their development in the Eocene.

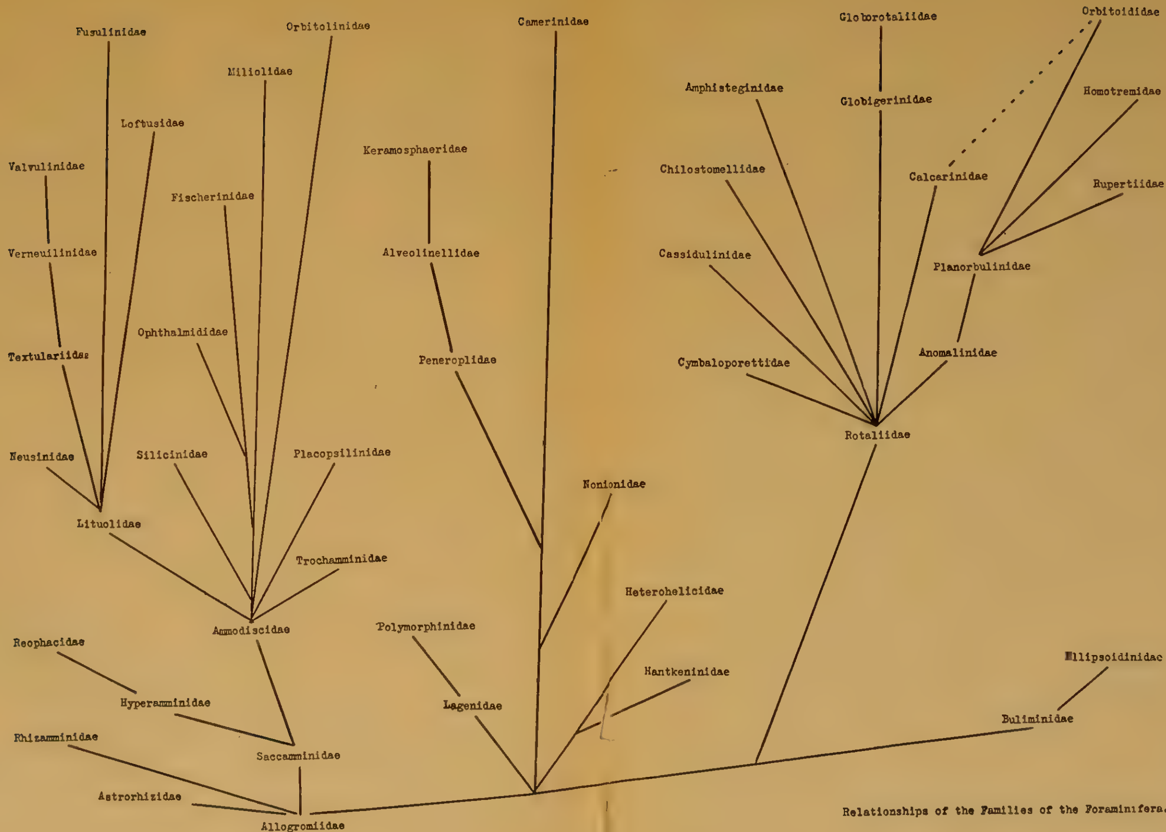
The other two great groups developed from elongate spires, more or less cylindrical in the Buliminidae and a flaring conical type in the Rotaliidae. The Buliminidae have their beginnings as far back as the Jurassic and have developed along many different lines usually terminating in a rectilinear uniserial test. These are abundant in the Tertiary and have many varied forms in the present ocean.

The Rotaliidae and the families derived from it are all perforate and calcareous. The simpliest forms perhaps go back to the Palaeozoic although the early records are very doubtful. In the Jurassic they have a few primitive forms, reaching their real development in the Cretaceous and Tertiary. From the Rotaliidae have developed several families, some very interesting in their adaptions. The Globigerinidae and Globorotaliidae have become specially adapted to a pelagic life with many modifications. The young of the highly globose, very spinose

Globigerinidae in the microspheric form is a trochoid, smooth, more or less flattened *Discorbis*-like form, showing the early ancestry of this group.

Some groups become attached and like the Homotremidae and Rupertiidae have developed peculiar forms which except that their early stages are trochoid forms like others of the Rotaliidae would hardly be classed with the rest of the foraminifera. Finally in the Orbitoididae there are complex large forms developed, which in the late Cretaceous and early Tertiary become very much specialized. These form excellent guide fossils for various formations during this particular time.

By taking into consideration the various stages in development, especially in the microspheric forms and the known geologic history of each group the following classification of the foraminifera has been developed. That it is perfect is not for a moment claimed, but that it is based upon known truth in regard to the past and present history of the group and on developmental stages makes it at least nearer the truth than the more artificial ones that have preceded it.



Relationships of the Families of the Foraminifera.

CHAPTER IX

SYSTEMATIC ARRANGEMENT OF THE FORAMINIFERA

In the following pages the families, subfamilies and genera are taken up in systematic order. Descriptions are short and simple, as to give fully all the details of the genera would make this work more than a single volume. Figures are given of practically all the genera treated here. The type figure is often copied, or where it is not adequate for the full understanding of the genus a later figure of the species is usually given. Other species are given in many genera for comparison, and many more figures could have been used to advantage but there are limits to the illustrations that can be used. A very careful selection of figures has been made to have those which would give the clearest idea of the necessary structural points. Sections are used throughout for a fuller understanding of the structure.

A few of the plates show the relationships of the genera in the families and the lines of development. The other plates give various views of typical specimens. A key is given to the families but it is not complete in its details. Many of the genera in various families assume so many forms that it is difficult to get the full details into a simple statement of a line or so. As the student will gain much more from working with actual specimens than with the best of books, he will soon learn in which families various forms belong. In those families where there are numerous genera, simple keys are given. The student should not depend upon them except as aids, and then should carefully check the fuller generic characters in the text.

The genotypes are given under each genus. Wherever the genus in monotypic, and whether the actual genoholotype species was designated as such or not, the type species has been here called a genoholotype. Designation of genotypes has been made if other authors have not already done so in genera where several species were known at the time of its naming, but the particular genotype neither then nor since designated. Synonyms have been introduced where it would seem to be a help in the understanding of the earlier literature. Many generic names used in the foraminifera will not be found here as it is necessary to see the actual types before they can be placed with full confidence. The author undertook this past year to see as many genotypes as possible, and in all but about six percent of the genera here used, the type species, either the actual type specimen or authentic material, was seen. In the case of the others, they are very rare forms usually based on a single specimen, and not readily available. For generous help in the loan of material and opening collections for his study, the author is greatly indebted to many individuals and to those in charge of the numerous European type collections.

The ranges given for the genera are made from the author's own experience together with a consultation of the literature. Some of the earlier records, especially those from the Palaeozoic, should be confirmed before it can definitely be determined whether or not the genus as recorded is the same as the present day record for it. This is however a base upon which to build rather than a finished work, and is offered as such.

SYSTEMATIC TREATMENT

ORDER FORAMINIFERA

Animals with a single cell, a protoplasmic body usually developing some sort of test, of chitin, agglutinated material, or of calcareous or rarely siliceous material secreted by the animal, typically with one or more definite apertures and the test usually perforate, in some families imperforate, pseudopodia of fine threads freely anastomosing to form a net work.

A KEY TO THE FAMILIES OF THE FORAMINIFERA

I. Test wanting or of thin chitinous material, living forms in fresh or brackish water or in the ocean. ....Family 1. Allogromiidae.

II. Test wholly or in part arenaceous.

A. Test single chambered or rarely an irregular group of similar chambers loosely attached.

1. Test with a central chamber and two or more arms.
Family 2. Astrorhizidae.

2. Test without a central chamber, elongate, open at both ends.
Family 3. Rhizamminidae.

3. Test a chamber or rarely series of similar chambers loosely attached, with normally a single opening.
Family 4. Saccamminidae.

B. Test two chambered, a proloculum and long undivided tubular second chamber.

1. Test with the second chamber simple or branching, not coiled.
Family 5. Hyperamminidae.

2. Test with the second tubular chamber usually coiled at least in the young.

a. Test of arenaceous material with much cement, usually yellowish- or reddish-brown. Family 7. Ammodiscidae.

b. Test of siliceous material, second chamber partially divided. ....Family 15. Silicinidae.

C. Test typically many chambered.

1. Test with all the chambers in a rectilinear series.
Family 6. Reophacidae.

2. Test planispirally coiled at least in the young.

a. Axis of coiling short, many uncoiled forms.
Family 8. Lituolidae.

b. Axis of coiling usually long, all close coiled.

(1). Interior not labyrinthic, Palaeozoic.
Family 12. Fusulinidae.

(2). Interior labyrinthic, Eocene.
Family 13. Loftusiidae.

3. Test typically biserial at least in the young of the microspheric form. ....Family 9. Textulariidae.

4. Test typically triserial at least in the young of the microspheric form.

a. Aperture usually without a tooth, the test becoming simpler in higher forms...Family 10. Verneuilinidae.

b. Aperture typically with a tooth, the test becoming conical in higher forms............Family 11. Valvulinidae.

5. Test with whole body labyrinthic, large, flattened or cylindrical.
Family 14. Neusinidae.

6. Test trochoid at least in the young.
    a. Mostly free and typically trochoid throughout.
    Family 19. Trochamminidae.
    b. Attached, young trochoid, later stages variously formed.
    Family 20. Placopsilinidae.
    c. Free, conical, mostly of large size.
    Family 21. Orbitolinidae.
7. Test coiled in varying planes, wall imperforate, with arenaceous portion only on the exterior.
    Family 16. Miliolidae (in part).

III. Test calcareous, imperforate, porcellanous.
- A. Test with the chambers coiled in varying planes, at least in the young, aperture large, toothed. Family 16. Miliolidae (in part).
- B. Test trochoid. ....Family 18. Fischerinidae.
- C. Test planispiral, at least in the early stages.
    1. The axis very short, chambers usually simple.
    Family 17. Ophthalmidiidae.
    2. The axis short, test typically compressed and often discoid, chambers mostly with many chamberlets.
    Family 26. Peneroplidae.
    3. The axis typically elongate, chamberlets developed.
    Family 27. Alveolinellidae.
- D. Test globular, apertures small, not toothed.
    Family 28. Keramosphaeridae.

IV. Test calcareous, perforate.
- A. Test vitreous with a glassy lustre, aperture typically radiate, not trochoid.
    1. Test planispirally coiled or becoming straight, or single chambered. ....Family 22. Lagenidae.
    2. Test biserial or elongate spiral. Family 23. Polymorphinidae.
- B. Test not vitreous, aperture not radiate.
    1. Test planispiral, occasionally trochoid, then usually with retral processes along the suture lines, septa single, no canal system. ....Family 24. Nonionidae.
    2. Test planispiral, at least in the young, generally lenticular, septa double, canal system in higher forms.
    Family 25. Camerinidae.
    3. Test at least in the microspheric form of most genera biserial, aperture usually large, without teeth.
    Family 29. Heterohelicidae.
    4. Test planispiral, bi- or triserial with elongate spines and lobed aperture. ....Family 30. Hantkeninidae.
    5. Test typically with an internal tube, elongate.
        a. Aperture generally loop-shaped or cribrate.
        Family 31. Buliminidae.
        b. Aperture narrow, curved, with an overhanging portion.
        Family 32. Ellipsoidinidae.

6. Test trochoid, at least in the young of the microspheric form, usually coarsely perforate, when lenticular, with equatorial and lateral chambers.
   - a. Test trochoid throughout, simple, aperture ventral.
     - (1). No alternating supplementary chambers on the ventral side. ....Family 33. Rotaliidae.
     - (2). Alternating supplementary chambers on the ventral side. ....Family 34. Amphisteginidae.
   - b. Test trochoid and aperture ventral at least in the early stages.
     - (1). With supplementary material and large spines independent of the chambers. Family 35. Calcarinidae.
     - (2). With later chambers in annular series or globose with multiple apertures but not covering the earlier ones. ....Family 36. Cymbaloporettidae.
     - (3). With later chambers mostly somewhat biserial, aperture elongate, in the axis of coiling. Family 37. Cassidulinidae.
     - (4). With later chambers becoming involute, very few making up the exterior in the adult, aperture typically elongate, semicircular, in a few species circular. ....Family 38. Chilostomellidae.
     - (5). With chambers mostly finely spinose and wall cancellated, adapted for pelagic life, globular forms with the last chamber completely involute, apertures umbilicate or along the sutures. Family 39. Globigerinidae.
     - (6). Early chambers globigerine, later ones spreading and compressed. ....Family 40. Globorotaliidae.
   - c. Test trochoid at least in the young, aperture peripheral or becoming dorsal.
     - (1). Mostly attached, dorsal side usually flattened. Family 41. Anomalinidae.
     - (2). Later chambers in annular series. Family 42. Planorbulinidae.
   - d. Test trochoid in the very young, later growing upward.
     - (1). Later chambers in a loose spiral. Family 43. Rupertiidae.
     - (2). Later chambers in masses or branching, highly colored. ....Family 44. Homotremidae.
   - e. Test trochoid in the very young of the microspheric form, chambers becoming annular later, with definite equatorial and lateral chambers, often with pillars. Family 45. Orbitoididae.

FAMILY 1. ALLOGROMIIDAE

Test either wanting or of chitin, not porous; aperture either single or at each end of the test, the surface of the test sometimes with attached foreign materials; fresh and brackish water, sometimes marine, not known as fossils.

Subfamily 1. Myxothecinae.

Test when present of thin chitin, not rigid, the aperture not definite but the pseudopodia capable of being pushed out through any part of the exterior; mostly marine.

Genus SCHULTZELLA Rhumbler, 1903

Plate 1, figure 1

Genoholotype, *Schultzia diffluens* Gruber

Schultzella RHUMBLER, Arch. Prot., vol. 3, 1903, p. 197.

Lieberkühnia (part) GRUBER, Nova Acta Acad. Leop., vol. 46, 1884, p. 484.

Schultzia GRUBER, Ber. Ges. Freiberg, vol. 4, 1889, p. 36 (not of GRIMM, 1877).

Test hardly distinguishable, of thin chitin which may be broken at any point for emission of the pseudopodia, generally spherical, without foreign material on the surface.

Recent. Mediterranean.

Genus MYXOTHECA Schaudinn, 1893

Plate 1, figure 2

Genoholotype, *Myxotheca arenilega* Schaudinn

Myxotheca SCHAUDINN, Zeitschr. Wiss. Zool., vol. 57, 1893, p. 18.

Pleurophrys GRUBER, Nova Acta Acad. Leop., vol. 46, 1884, p. 486 (not of CLAPARÈDE and LACHMANN, 1859).

Test consisting of a thin chitinous layer, the body of the animal generally spherical or flattened on the base, somewhat changeable in shape, surface with occasional attached foreign material.

Recent. Mediterranean and Atlantic.

Genus BODERIA Str. Wright, 1867

Plate 1, figure 3

Genoholotype, *Boderia turneri* Str. Wright

Boderia STR. WRIGHT, Journ. Anat. and Physiol., vol. 1, 1867, p. 335.

Test extremely thin and delicate, colorless body of changeable form, flattened, more or less angular, from the angles are long, fine, somewhat branching pseudopodia.

Recent. Shallow water of North Sea.

Genus PLAGIOPHRYS Claparède and Lachmann, 1858

Plate 1, figure 4

Genoholotype, *Plagiophrys cylindrica* Claparède and Lachmann

Plagiophrys Claparède and Lachmann, Mém. Inst. Geneva, vol. 6, 1858, p. 453.

No definite test apparent, body short, cylindrical, pseudopodia from one end, the opposite end rounded.

Recent. Fresh water.

Genus DACTYLOSACCUS Rhumbler, 1894

Plate 1, figure 5

Genoholotype, *Dactylosaccus vermiformis* Rhumbler

Dactylosaccus Rhumbler, Zeitschr. Wiss. Zool., vol. 57, 1894, p. 601.

Test thin, chitinous body tubular and variously twisted, pseudopodia thrust out from irregular finger-like processes.

Recent. Marine, off Scandinavia.

Subfamily 2. Allogromiinae

Test chitinous, sometimes strengthened by attached foreign bodies scattered over the surface; apertures definitely placed, one or two, and the pseudopodia sent out only through these openings.

Marine and fresh water forms.

Genus ALLOGROMIA Rhumbler, 1903

Plate 1, figures 6, 7

Genoholotype, *Craterina mollis* Gruber

Allogromia Rhumbler, Arch. Prot., vol. 3, 1903, p. 203.

Gromia Dujardin, Ann. Sci. Nat., ser. 2, vol. 8, 1837, p. 312 (not *Gromia* 1835).

Craterina Gruber, Nova Acta Acad. Leop., vol. 46, 1884, p. 488 (not of St. Vincent, 1824).

Test spherical to ovoid, somewhat flexible, thin, chitinous, of variable thickness; aperture terminal, single.

Recent. Marine.

Genus LIEBERKÜHNIA Claparède and Lachmann, 1859

Plate 1, figure 8

Genoholotype, *Lieberkühnia wagneri* Claparède and Lachmann

Lieberkühnia CLAPARÈDE and LACHMANN, Mém. Inst. Geneva, vol. 6, 1859, p. 464.

Test ovoid, chitinous, thin, aperture toward the end but at one side, the pseudopodia thrust out through a sort of tubular portion.

Recent. Both marine and fresh water species.

Genus SHEPHEARDELLA Siddall, 1880

Plate 1, figure 9

Genoholotype, *Shepheardella taeniformis* Siddall

Shepheardella SIDDALL, Quart. Journ. Micr. Sci., vol. 20, 1880, p. 131.

Test elongate, cylindrical, pointed at the ends; wall thin, chitinous, colorless; pseudopodia mostly from the apertures at either end of the test.

Recent. Marine.

EXPLANATION OF PLATE 1

ALLOGROMIIDAE

FIG.

1. *Schultzella diffluens* (Gruber). (From Rhumbler, after type figure).
2. *Myxotheca arenilega* Schaudinn. (From Rhumbler, after type figure).
3. *Boderia turneri* Str. Wright. (From Rhumbler, after type figure).
4. *Plagiophrys cylindrica* Claparède and Lachmann. × 110. (From Rhumbler, after type figure).
5. *Dactylosaccus vermiformis* Rhumbler. × 15. (From Rhumbler, after type figure).
6. *Allogromia mollis* (Gruber). (From Rhumbler, after type figure).
7. *Allogromia lagenoides* (Gruber). (From Rhumbler, after type figure).
8. *Lieberkühnia wagneri* Claparède and Lachmann. × 35. (From Rhumbler, after Verworn).
9. *Shepheardella taeniformis* Siddall. × 8. (From Rhumbler, after type figure).
10. *Rhynchosaccus immigrans* Rhumbler. × 20. (After type figure).
11. *Rhynchogromia variabilis* Rhumbler. × 75. (After type figure).
12. *Diplogromia brunneri* (Blanc). × 75. (From Rhumbler, after type figure).
13. *Amphitrema wrightianum* Archer. × 200. (After Chapman).
14. *Diaphoropodon mobile* Archer. × 65. (After Chapman).

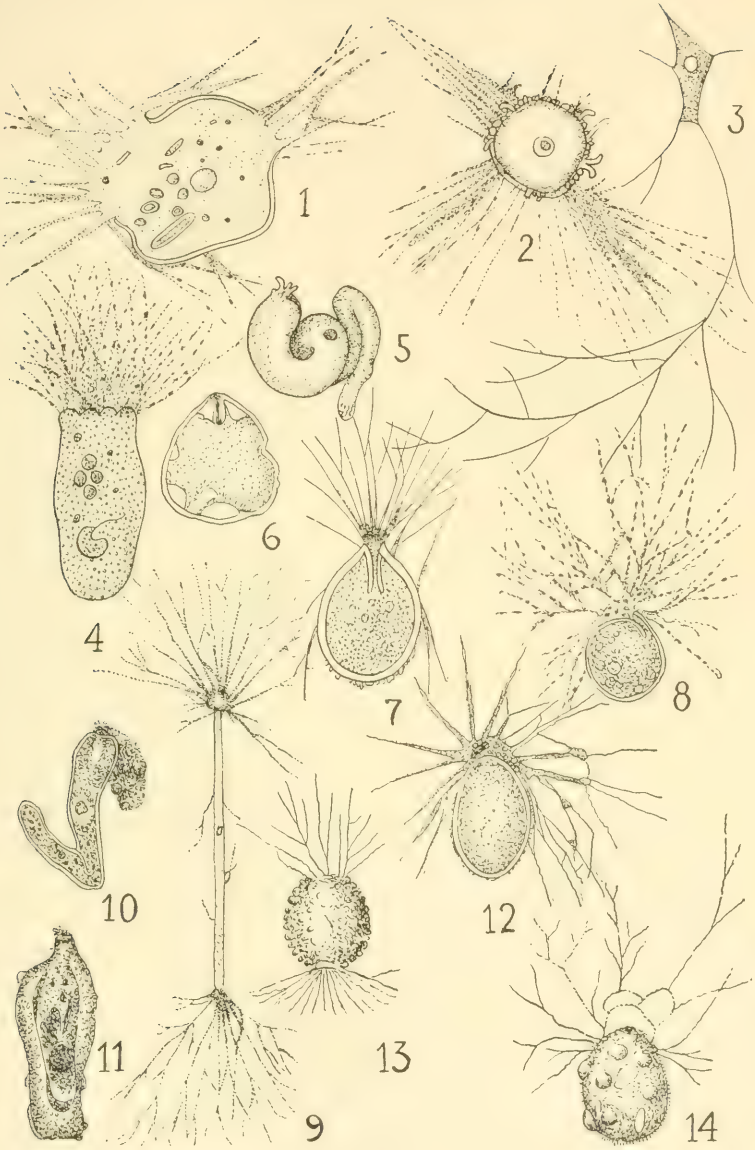


PLATE 1

Genus RHYNCHOSACCUS Rhumbler, 1894

Plate 1, figure 10

Genoholotype, *Rhynchosaccus immigrans* Rhumbler

Rhynchosaccus RHUMBLER, Zeitschr. Wiss. Zool., vol. 57, 1894, p. 595.

Test tubular, arcuate or with a sharp bend, both ends rounded, the apertural end with a projecting snout, wall thin, chitinous.

Recent. Marine.

Genus RHYNCHOGROMIA Rhumbler, 1894

Plate 1, figure 11

Genoholotype, *Rhynchogromia variabilis* Rhumbler

Rhynchogromia RHUMBLER, Zeitschr. Wiss. Zool., vol. 57, 1894, p. 590.

Test usually elongate, of a single chitinous layer, the protoplasmic contents usually not completely filling the interior which contains also more or less foreign material; aperture terminal.

Recent. Fresh water and marine.

Genus DIPLOGROMIA Rhumbler, 1903

Plate 1, figure 12

Holotype, by designation, *Gromia brunneri* Blanc

Diplogromia RHUMBLER, Arch. Prot., vol. 3, 1903, p. 214.
Gromia (part) BLANC, C. R. Soc. Helvet., ser. 3, vol. 16, 1886, p. 362 (not of DUJARDIN, 1835).

Test ovoid, with a double wall, the outer layer of flinty grains and other foreign material, the inner layer chitinous, clear; aperture terminal.

Recent. Fresh water, Switzerland.

Genus DIAPHOROPODON Archer, 1869

Plate 1, figure 14

Genoholotype, *Diaphoropodon mobile* Archer

Diaphoropodon ARCHER, Quart. Journ. Micr. Sci., vol. 9, 1869, p. 394.

Test ovate, of chitin with the exterior of foreign material; aperture terminal.

Recent. Fresh water, Ireland.

Genus AMPHITREMA Archer, 1870

Plate 1, figure 13

Genoholotype, *Amphitrema wrightianum* Archer

Amphitrema Archer, Quart. Journ. Micr. Sci., vol. 10, 1870, p. 122.

Test short fusiform, the ends truncate and open, exterior with foreign material.

Recent. Fresh water, Ireland.

For the most of the students who will use this book, the Allogromiidae are of only slight interest. They are important from the point of view of simple primitive types in the foraminifera however, and figures are given of the important genera. No fossil records exist as it is obvious that such tests as they possess would not leave their records in fossilization.

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 thin chitinous inner layer on all or part of which is agglutinated arenaceous material; apertures formed by the peripheral ends of the arms or by openings in the peripheral wall.

KEY TO THE GENERA

I. Test with distinct arms or projections beyond the general periphery.
   - A. Arms usually short, the central chamber large, wall loosely cemented. . . . . *Astrorhiza.*
   - B. Arms usually long, the central chambers small, wall firmly cemented. . . . . *Rhabdammina.*

II. Test without distinct arms.
   - A. Test generally spherical, thick walled, of fine arenaceous material. *Crithionina.*
   - B. Test generally flat and thin.
     1. Test entirely arenaceous, radiating arms distinct. *Masonella.*
     2. Test with only the periphery arenaceous, center thin and chitinous. . . . . *Vanhoeffenella.*

Genus ASTRORHIZA Sandahl, 1857

Plate 2, figures 1-6

Genoholotype, *Astrorhiza limicola* Sandahl

Astrorhiza SANDAHL, Öfv. Svensk. Vet. Akad. Förh., vol. 14, no. 7, 1857, p. 299.

Ammodiscus CARPENTER and JEFFREYS, Proc. Roy. Soc. London, 1870, p. 159 (not *Ammodiscus* REUSS, 1871).

Arenistella FISCHER and DE FOLIN, Les Fonds de la Mer, vol. 2, 1872, p. 26 (genoholotype, *A. agglutinans* FISCHER).

Astrodiscus F. E. SCHULTZE, II Jahr. Comm. wis. Unt. deutsch. Meer in Kiel, vol. 1, 1875, p. 113 (genoholotype, *A. arenaceus* F. E. SCHULTZE).

Haeckelina BESSELS, Jen. Zeitschr., vol. 9, 1875, p. 265 (genoholotype *H. gigantea* BESSELS).

Test free, flattened or tubular, stellate or subcylindrical, composed of a central chamber with communicating tubular portions

EXPLANATION OF PLATE 2

ASTRORHIZIDAE

FIG.

1, 2. *Astrorhiza limicola* Sandahl. × 5. (After H. B. Brady). Fig. 1, Exterior Fig. 2, Test partially laid open to show interior.

3, 4. *Astrorhiza arenaria* Norman. (After H. B. Brady). Fig. 3, Exterior. × 5. Fig. 4, Portion of surface enlarged to show structure of wall. × 65.

5, 6. *Astrorhiza granulosa* H. B. Brady. × 5. (After H. B. Brady). Fig. 5, Exterior. Fig. 6, Test laid open to show interior.

7–9. *Rhabdammina abyssorum* M. Sars. (After H. B. Brady). Fig. 7, Test laid open to show interior. × 7. Fig. 8, Exterior. × 7. Fig. 9, Portion of surface enlarged to show structure of wall. × 40.

10–12. *Rhabdammina linearis* H. B. Brady. (After H. B. Brady). Fig. 10, Exterior. × 7. Fig. 11, Test laid open to show the interior. × 7. Fig. 12, Portion of surface enlarged to show structure of wall. × 40.

13. *Rhabdammina irregularis* Carpenter. × 10. (After H. B. Brady).

14. *Crithionina rotundata* Cushman. × 7. Test laid open to show central chamber and tubes of the wall.

15, 16. *Crithionina mamilla* Goës. × 10. (After Goës). Fig. 15, Exterior. Fig. 16, Test laid open to show interior and structure of wall.

17, 18. *Vanhoeffenella gaussi* Rhumbler. Fig. 17 (After Heron-Allen and Earland), showing protoplasmic body. × 50. Fig. 18, (After type figure). × 28.

19. *Masonella planulata* H. B. Brady. × 3. (After type figure). *a*, Exterior showing central chamber and arms; *b*, section.

PLATE 2

to the exterior in the compressed stellate species or of an irregular tubular chamber in the subcylindrical ones; wall of loosely cemented mud or sand showing little selection, the interior with a thin chitinous lining; aperture at the outer ends of the tubular portions.

Jurassic to Recent, perhaps earlier.

Most of the species are characteristic of cool water conditions, and temperature is more of a control than depth.

The proportion of cement is small, and it is not surprising that recognizable specimens are not common in a fossil condition.

Genus MASONELLA H. B. Brady, 1889

Plate 2, figure 19

Genotype, by designation, *Masonella planulata* H. B. Brady

Masonella H. B. Brady, Ann. Mag. Nat. Hist., ser. 6, vol. 3, 1889, p. 295.

Test stellate or circular, much compressed, with a large central chamber with fine branching tubules, to the periphery; wall finely arenaceous, thin, especially between the tubules; apertures at the open ends of the tubules.

Recent.

There are two species known, both from the Indian Ocean.

Genus RHABDAMMINA M. Sars, 1869

Plate 2, figures 7-13

Genoholotype, *Rhabdammina abyssorum* M. Sars

Rhabdammina M. Sars, Forh. Selsk. Christiania, 1868, p. 248 *(nomen nudum)*; in W. B. Carpenter, Ann. Mag. Nat. Hist., ser. 4, vol. 4, 1869, p. 288.

Test free, either radiate, subcylindrical, or branching; wall firmly cemented, usually of sand grains but occasionally with sponge spicules and other foreign bodies, showing some selection, interior with a thin chitinous lining, cement usually yellowish-brown; open ends of the tubes serving as apertures.

Jurassic to Recent.

Most of the species are characteristic of cool water conditions and temperature is more of a control than depth. Some of the species occur in tropical waters but usually at considerable depths.

Genus CRITHIONINA Goës, 1894

Plate 2, figures 14-16

Genotype, by designation, *Crithionina mamilla* Goës

Crithionina Goës, Köngl. Svensk. Vet. Akad. Handl., vol. 25, no. 9, 1894, p. 14.

Test free, spherical, lenticular or variously shaped, interior either with a large chamber and thin wall, usually perforated, or with a small chamber and thick wall with the communication to the surface by means of numerous branching tubes; wall of sponge spicules and very fine sand, often chalky in appearance, soft, with little cement; color white or grayish.

Recent.

The species are most abundant in cold waters where specimens often occur in immense numbers.

Genus VANHOEFFENELLA Rhumbler, 1905

Plate 2, figures 17, 18

Genoholotype, *Vanhoeffenella gaussi* Rhumbler

Vanhoeffenella Rhumbler, Verhandl. Deutsch. Zool. Gesell., 1905, p. 105.

Test free, composed of a compressed chamber in the central portion with a chitinous wall, the exterior a polygonal tubular chamber with apertures at the angles, made of sand grains and other agglutinated materials.

Recent, at a depth of 400 meters.

This genus may best be understood in its relationships by imagining the central portion of a short-armed radiate *Astrorhiza* to have the arenaceous material removed from about the central portion leaving the thin chitinous wall and the resulting ring of arenaceous material cemented into a tube with the arms reduced.

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 *Astrorhiza* 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 open at both ends; wall with a chitinous lining and exterior of agglutinated foreign material, arenaceous grains, sponge spicules or other foraminifera; apertures formed by the open ends of the tubes.

KEY TO THE GENERA

I. Test cylindrical, not branching.
- A. Wall of sand grains and sponge spicules.
  - 1. Exterior showing the spicules .... *Marsipella.*
  - 2. Exterior smooth, spicules mostly on the interior; wall thick. .... *Bathysiphon.*
- B. Wall mostly of foraminiferal tests, test short .... *Brachysiphon.*

II. Test usually branching, wall of foraminiferal tests and chitin. *Rhizammina.*

Genus MARSIPELLA Norman, 1878

Plate 3, figures 1-3

Genoholotype, *Marsipella elongata* Norman

Marsipella NORMAN, Ann. Mag. Nat. Hist., ser. 5, vol. 1, 1878, p. 281.
Proteonina W. B. CARPENTER, Proc. Roy. Soc. London, vol. 18, 1869, p. 60 (not *Proteonina* WILLIAMSON, 1858).

Test free, tubular, cylindrical or fusiform, sometimes recurved at the ends; wall thin, firmly cemented, composed wholly or in part of sponge spicules, or the middle part of sand grains; aperture formed by the open ends of the tube or sometimes closed at one end by a loosely aggregated knob of spicules.

Jurassic to Recent.

The species are mostly found in cold water, but one species at least is abundant in rather warm water in less than a hundred fathoms off the coast of Florida. None of the many specimens of this warm water form show the peculiar head of loosely aggregated sponge spicules as found in the North Sea specimens and recorded by Heron-Allen and Earland.

Genus BATHYSIPHON M. Sars, 1872

Plate 3, figures 4-6

Genoholotype, *Bathysiphon filiformis* M. Sars

Bathysiphon M. SARS, in G. O. SARS, Forh. Vidensk.-Selsk. Christiania, 1871 (1872), p. 251.

Test free, cylindrical, often tapering slightly, straight or more often somewhat curved, in some species externally constricted but not internally divided; wall composed of a base of broken sponge spicules cemented and overlaid with a fine grained amorphous material, either soft or firmly cemented, often with a very thin surface coating; apertures at the ends of the tube.

Cretaceous to Recent.

The species are most abundant in cool water at rather shallow depths in high latitudes and at corresponding temperatures and greater depths in the tropics.

Genus RHIZAMMINA H. B. Brady, 1879

Plate 3, figures 7-10

Genoholotype, *Rhizammina algaeformis* H. B. Brady

Rhizammina H. B. BRADY, Quart. Journ. Micr. Sci., vol. 19, 1879, p. 39.
Marsipella (part) EIMER and FICKERT, Zeitschr. Wiss. Zool., vol. 65, 1899, p. 668.

Test a simple or dichotomously branching tube; wall flexible, chitinous, with various foreign bodies, usually other foraminiferal tests attached to the exterior; apertures formed by the open ends of the tubes.

Cretaceous to Recent.

There is a possibility that the species of this genus have been broken in dredging, and that when perfect they may be attached and not open at the base.

Genus BRACHYSIPHON Chapman, 1906

Plate 3, figures 11, 12

Genoholotype, *Brachysiphon corbuliformis* Chapman

Brachysiphon CHAPMAN, Trans. New Zealand Instit., vol. 38, 1905 (1906), p. 83.

Test free, a roughly cylindrical short tube; wall with an inner chitinous layer and an outer layer of sand grains and other foraminiferal tests; apertures at the ends of the tube, bordered by the thickened chitinous lining of the interior.

Recent, off New Zealand, 110 fathoms.

The wall of this species is like that of some species of *Rhizammina*, but the tubular chamber is very short.

The foraminifera belonging to this family are of very simple structure. The elongate cylindrical test with a chitinous inner layer and the apertures at the ends may be directly derived from such a simple form as *Shepheardella* in the Allogromiidae. The fossil record goes back to the Jurassic, but they are probably older and are to be looked for in the Palaeozoic

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EXPLANATION OF PLATE 3

Rhizamminidae, Saccamminidae

Fig.

1–3. *Marsipella elongata* Norman. Fig. 1, Exterior (After type figure). × 65. Figs. 2, 3, (After H. B. Brady). × 40. Fig. 2, Portion of surface of middle of test showing structure. Fig. 3, Portion of surface at end showing massed fragments of sponge spicules.

4–6. *Bathysiphon filiformis* M. Sars. (After H. B. Brady). Fig. 4, Transverse section of test by transmitted light showing base of sponge spicules covered with light colored amorphous material. × 40. Fig. 5, Longitudinal section by transmitted light. × 135. Fig. 6, Exterior. × 2.

7–10. *Rhizammina algaeformis* H. B. Brady. (After type figures). Fig. 7, Specimen from sandy bottom. × 5. Fig. 8, Fragment showing structure of wall. × 28. Fig. 9, Specimen from *Globigerina*-ooze. × 5. Fig. 10, Decalcified specimen from *Globigerina*-ooze. × 28.

11, 12. *Brachysiphon corbuliformis* Chapman. × 20. (After type figures). Fig. 11 *a*, from above; *b*, from side. Fig. 12, From below.

13, 14. *Psammosphaera fusca* Schultze. (After H. B. Brady). Fig. 13, Exterior. × 15. Fig. 14, Test laid open to show interior and structure of wall. × 28.

15, 16. *Psammosphaera parva* Flint. (After H. B. Brady). Fig. 15, Exterior. × 28. Fig. 16, Test laid open to show interior and structure of wall with sponge spicule around which the test is built. × 35.

17, 18. *Sorosphaera confusa* H. B. Brady. × 10. (After H. B. Brady). Fig. 17, Exterior of type specimen. Fig. 18, Showing structure of interior.

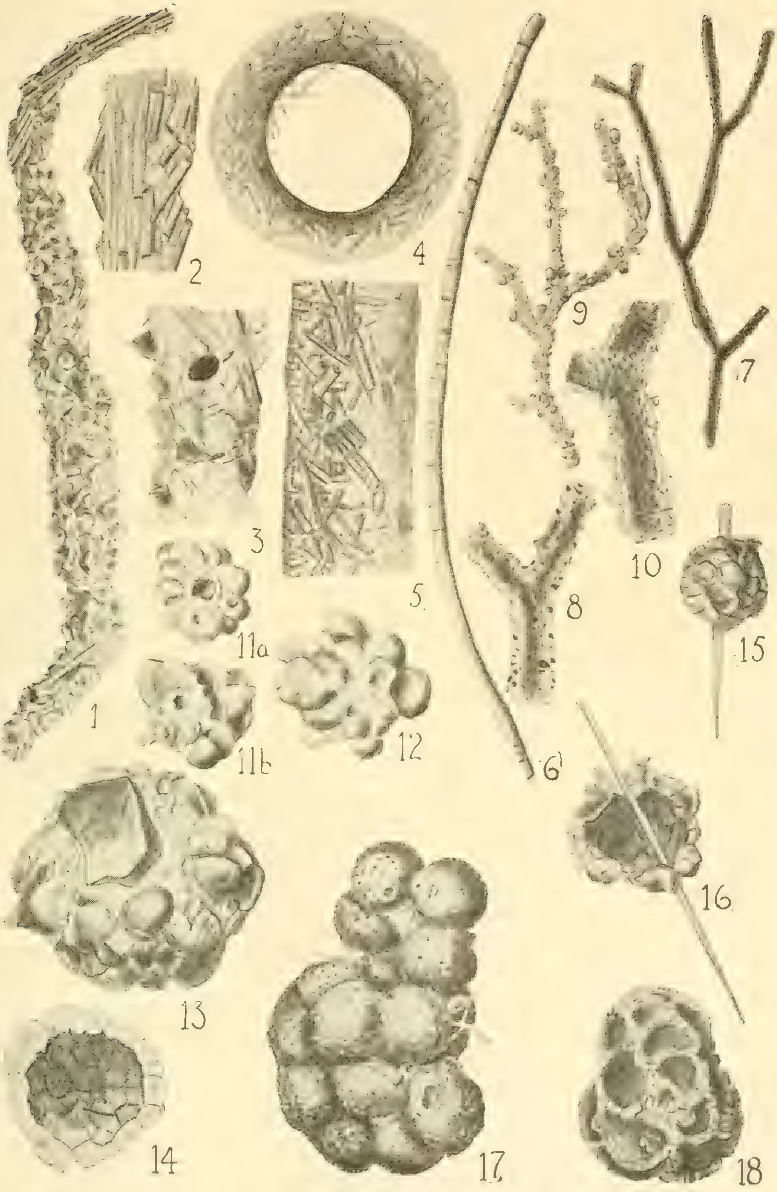

PLATE 3

FAMILY 4. SACCAMMINIDAE

Test free or attached, composed typically of a single chamber or occasionally with chambers of the same sort loosely united; wall lined with chitin, the exterior of agglutinated material of various sorts, sand grains, sponge spicules or other foraminiferal tests; aperture usually single, of various shapes.

KEY TO THE GENERA

I. Test without a definite aperture, usually free.
  A. Wall of coarse material.
    1. Test of a single globular chamber........... *Psammosphaera.*
    2. Test of a colony of similar globular chambers.... *Sorosphaera.*
  B. Wall of fine whitish material; test polygonal...... *Storthosphaera.*

II. Test with a definite aperture.
  A. Test free, usually with brownish cement.
    1. Wall of coarse material.
      a. Aperture terminal, usually with a neck.
        (1). Test globular........................ *Saccammina.*
        (2). Test flask-shaped or pyriform; neck without a lip.
          (a). Wall with little chitin, thickly encrusted. *Proteonina.*
          (b). Wall largely chitin, thinly encrusted. *Lagenammina.*
        (3). Test flask-shaped, with a flaring lip.... *Lagunculina.*
      b. Aperture terminal, without a neck, and at the broad end of the test.................................. *Urnulina.*
      c. Aperture not terminal.
        (1). Curved, in a depression................ *Millettella.*
        (2). Rounded, not in a depression......... *Marsupulina.*
    2. Wall of fine material.
      a. With two apertures close to one another. *Ammosphaeroides.*
      b. With numerous remote apertures, usually with necks. *Thurammina.*
    3. Wall entirely chitinous....................... *Pseudarcella.*
  B. Test free, usually whitish.
    1. Aperture rounded.
      a. Wall of material without definite arrangement, spicules few. .... *Pelosina.*
      b. Wall largely of spicules, definitely arranged... *Technitella.*
    2. Aperture elongate, narrow........................ *Pilulina.*

C. Test attached.
  1. Test circular, low, of very fine material; aperture at the rim. *Webbinella.*
  2. Test very irregular, of coarse material; aperture at the rim. *Iridia.*
  3. Test conical, largely of sponge spicules........*Rhaphidoscene.*
  4. Test subglobular.
    a. Apertures at ends, near base.................*Tholosina.*
    b. Apertures on upper side, in a depression......*Verrucina.*

Subfamily 1. Psammosphaerinae

Test without a definite aperture

Genus PSAMMOSPHAERA F. E. Schultze, 1875

Plate 3, figures 13-16; plate 5, figures 15, 16

Genoholotype, *Psammosphaera fusca* F. E. Schultze

Psammosphaera F. E. SCHULTZE, II Jahr. Comm. Wiss. Unt. deutsch. Meer in Kiel, 1875, p. 113.

Test free or attached, globular; wall composed of a thin layer of chitin with an outer wall of sand grains, mica flakes, sponge spicules or other foraminiferal tests, firmly cemented; aperture indefinite.

Jurassic to Recent.

There is a high degree of selection in the material of the test in the different species and also in the manner of using the materials. According to Heron-Allen and Earland (Journ. Roy. Micr. Soc., 1913, p. 16, etc.) the "protoplasm extrudes through the fine pores of the cement, and functions of digestion are carried on outside of the test." One species (Pl. 3, figs. 15, 16) chooses a long sponge spicule as the attachment for the test.

The genus *Orbulinaria* Rhumbler may belong close to *Psammosphaera.* The characters of this genus are not wholly clear, but Rhumbler himself places it next to *Psammosphaera.* It has apparently a calcareous test although made up of irregular bodies. It is largely recorded from the Cretaceous but there are apparently recent species also. I have not studied the types and prefer not to definitely place the genus.

Genus SOROSPHAERA H. B. Brady, 1879

Plate 3, figures 17, 18

Genoholotype, *Sorosphaera confusa* H. B. Brady

Sorosphaera H. B. BRADY, Quart. Journ. Micr. Sci., vol. 19, 1879, p. 28.

Test consisting of a group of more or less inflated chambers, in an aggregate; wall with a chitinous lining and the exterior of fine sand grains; apertures minute, interstitial.

Recent. In cold or deep waters, widely distributed.

The separate globular masses are apparently independent. The depressions that resemble apertures in the figure are depressions made by broken spherical bodies cemented into the test.

Genus STORTHOSPHAERA F. E. Schultze, 1875

Plate 4, figures 1, 2

Genoholotype, *Storthosphaera albida* F. E. Schultze

Storthosphaera F. E. SCHULTZE, II Jahr. Comm. Wiss. Unt. deutsch. Meer in Kiel, 1875, p. 113.

Test free, irregularly rounded, single chambered; wall thick, of whitish fine sand very loosely cemented; aperture indefinite.

Middle Oligocene to Recent.

The species are found in deep and cold waters.

Subfamily 2. Saccammininae

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

Genus SACCAMMINA M. Sars, 1869

Plate 4, figures 3-5

Genoholotype, *Saccammina sphaerica* M. Sars

Saccammina M. SARS, Forh. Vidensk.-Selsk. Christiania, 1868 (1869), p. 248 *(nomen nudum)*; in W. B. CARPENTER, Ann. Mag. Nat. Hist., ser. 4, vol. 4, 1869, p. 289.

Test typically free, sometimes attached, usually of a single spherical chamber or occasionally of several attached ones; wall with a thin chitinous inner layer and outer single layer of sand grains firmly cemented; aperture single, often with a slight neck.

Carboniferous to Recent. Typically in rather cold water.

There seems to be a distinct selection of sand grains, often garnet grains or other special sorts being used to the exclusion of others.

Genus PROTEONINA Williamson, 1858

Plate 4, figures 6-8

Genotype, by designation, *Proteonina fusiformis* Williamson

Proteonina WILLIAMSON, Rec. Foram. Great Britain, 1858, p. 1.

Reophax (part) of authors.

Difflugia EGGER, Abhandl. Kön. bay. Akad. Wiss. München, vol. 18, 1895, p. 251 (not *Difflugia* LECLERC, 1815).

Saccammina (part) EIMER and FICKERT, Zeitschr. Wiss. Zool., vol. 65, 1899, p. 671.

Test free, a fusiform or flask-shaped undivided chamber; wall of coarse sand grains, mica flakes, or other agglutinated material with a thin inner layer of chitin; aperture usually circular, often with a slight neck which may become elongate.

Carboniferous (?), Jurassic to Recent. Widely distributed mainly in cold or deep waters.

The species show a considerable amount of selectivity in the material used.

Genus LAGENAMMINA Rhumbler, 1911

Plate 4, figure 9

Genoholotype, *Lagenammina laguncula* Rhumbler

Lagenammina RHUMBLER, Foram. Plankton-Exped., pt. 1, 1911, p. 92.

Test free, bottle-shaped, with a distinct pseudochitinous substratum on which are foreign bodies usually covering the under layer; aperture circular, at the end of an elongate neck.

Recent. From the North Atlantic 1524 to 2400 meters.

This genus differs from *Proteonina* in the much more distinct interior chitinous layer.

Genus LAGUNCULINA Rhumbler, 1903

Plate 4, figure 10

Genoholotype, *Ovulina urnula* Gruber

Lagunculina RHUMBLER, Arch. Prot., vol. 3, 1903, p. 248.
Ovulina GRUBER, Nova Acta Acad. Leop., vol. 46, 1884, p. 497 (not *Ovulina* EHRENBERG, 1855).

Test free, a flask-shaped simple chamber; wall of fine sand grains; aperture circular, with a short neck and flaring lip.

Recent. Gulf of Genoa, shallow water.

EXPLANATION OF PLATE 4

SACCAMMINIDAE

FIG.

1, 2. *Storthosphaera albida* Schultze. × 15. (After H. B. Brady). Fig. 1, Exterior. Fig. 2, Test laid open to show interior and structure of wall

3–5. *Saccammina sphaerica* M. Sars. × 10. (After H. B. Brady). Fig 3, Side view. Fig. 4, Apertural view. Fig. 5, Test laid open to show interior and structure of wall.

6. *Proteonina fusiformis* Williamson. (After type figure).

7, 8. *Proteonina testacea* Flint. × 10. (After type figure). Fig. 7, Exterior. Fig. 8, Section.

9. *Lagenammina laguncula* Rhumbler. (After type figure).

10. *Lagunculina urnula* (Gruber). (After type figure).

11. *Marsupulina schultzei* Rhumbler. × 50. (After type figure).

12. *Millettella pleurostomelloides* (Millett). × 90. (After type figure). *a*, apertural view; *b*, side view.

13. *Urnulina difflugiaeformis* Gruber. (After type figure).

14. *Pseudarcella rhumbleri* Spandel. × 65. (After type figure). *a*, side view; *b*, from below; *c*, vertical section.

15. *Ammosphaeroides distoma* Cushman. × 35. (After type figure). *a*, apertural view; *b*, from side.

16–18. *Thurammina papillata* H. B. Brady. (After type figures). Fig. 16, Exterior. × 35. Fig. 17, Test laid open to show interior. × 35. Fig. 18, Large specimen from exterior. × 20.

19–21. *Pelosina variabilis* H. B. Brady. (After type figures). Figs. 19, 20. × 6. Fig. 21, Section of portion showing internal cavity.

22–24. *Pelosina rotundata* H. B. Brady. × 15. (After type figures). Fig. 24, Transverse section.


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PLATE 4

Genus MILLETTELLA Rhumbler, 1903

Plate 4, figure 12

Genoholotype, *Reophax pleurostomelloides* Millett

Millettella RHUMBLER, Arch. Prot., vol. 3, 1903, p. 250.
Reophax (part) MILLETT, Journ. Roy. Micr. Soc., 1899, p. 253.

Test free, ovate; wall arenaceous, of fine grains; aperture large, semicircular, in a depression near one end of the test and at one side.

Recent. Malay Archipelago in shallow water.

Genus MARSUPULINA Rhumbler, 1903

Plate 4, figure 11

Genoholotype, *Marsupulina schultzei* Rhumbler

Marsupulina RHUMBLER, Arch. Prot., vol. 3, 1903, p. 249.
Ovulina M. SCHULTZE, Polythalamien, 1854, p. 55 (not *Ovulina* EHRENBERG, 1854).

Test free, pouch-like, ellipsoid or kidney-shaped; wall with amorphous calcareous material; aperture circular at one side near the end of the test.

Recent. Ancona, Mediterranean, in shallow water.

Genus URNULINA Gruber, 1884

Plate 4, figure 13

Genoholotype, *Urnulina difflugiaeformis* Gruber

Urnulina GRUBER, Nova Acta Acad. Leop., vol. 46, 1884, p. 496.

Test free, obovate, initial end pointed, apertural end broad; wall thin, arenaceous; aperture terminal, large and rounded.

Recent. Gulf of Genoa. North Sea?

Genus PSEUDARCELLA Spandel, 1909

Plate 4, figure 14

Genoholotype, *Pseudarcella rhumbleri* Spandel

Pseudarcella SPANDEL, Ber. Offenb. Ver. Nat., vol. 43-50, 1901-09 (1909), p. 199.

Test planoconvex, circular from above, conical from the side, base flat, dorsal side convex; wall chitinous; aperture circular, in the middle of the ventral face.

Oligocene, (Rupelton), Mainz Basin, Germany; Northern Italy; France.

Genus AMMOSPHAEROIDES Cushman, 1910

Plate 4, figure 15

Genoholotype, *Ammosphaeroides distoma* Cushman

Ammosphaeroides CUSHMAN, Bull. 71, U. S. Nat. Mus., pt. 1, 1910, p. 51.

Test free, consisting of an elongate or subspherical chamber; wall finely arenaceous with a large portion of reddish-brown cement; aperture typically double, at the end of short tubular portions of the test.

Recent. Sea of Okohotsk, 82 fathoms.

Genus THURAMMINA H. B. Brady, 1879

Plate 4, figures 16-18

Genoholotype, *Thurammina papillata* H. B. Brady

Thurammina H. B. BRADY, Quart. Journ. Micr. Sci., vol. 19, 1879, p. 45.
Thyrammina RHUMBLER, Arch. Prot., vol. 3, 1903, p. 236.
Lituola (part) W. B. CARPENTER, The Microscope, ed. 5, 1875, p. 533.

Test typically free, usually nearly spherical but in some species compressed, chamber typically single and undivided; wall thin, of fine sand with more or less chitin; apertures several to many at the end of nipple-like protuberances of the surface, occasionally wanting.

Carboniferous to Recent. Most abundant in deep cold water, but at least one species in depths as shallow as 26 fathoms in the Gulf of Mexico.

Certain specimens seem to indicate that some of the forms assigned to this genus may degenerate from multilocular ones.

Subfamily 3. Pelosininae

Test free; wall typically of matted spicules and fine amorphous material; aperture usually single.

Genus PELOSINA H. B. Brady, 1879

Plate 4, figures 19-24

Genotype, by designation, *Pelosina variabilis* H. B. Brady

Pelosina H. B. Brady, Quart. Journ. Micr. Sci., vol. 19, 1879, p. 30.

Test free, variously formed, rounded, cylindrical or irregularly elongate; wall usually thick, composed of mud on a thin chitinous inner layer often extending out and forming the whole wall at the apertural end; aperture typically single and terminal, occasionally multiple.

Carboniferous (?) to Recent. Typically in deep or cold waters, in shallow water in Hudson Bay.

Genus TECHNITELLA Norman, 1878

Plate 5, figures 1, 2, 17

Genotype, by designation, *Technitella legumen* Norman

Technitella Norman, Ann. Mag. Nat. Hist., ser. 5, vol. 1, 1878, p. 279.

Test free, composed of a single, simple, elongate, subcylindrical, fusiform or oval chamber; wall thin, composed of sponge spicules and fine sand; aperture rounded, at the open end of the test.

Recent. Typically in cold or deep water.

In *T. legumen* the outer layer is composed of spicules arranged lengthwise of the test and the inner layer at right angles forming a rigid test.

Genus PILULINA W. B. Carpenter, 1870

Plate 5, figures 3, 4

Genoholotype, *Pilulina jeffreysii* W. B. Carpenter

Pilulina W. B. Carpenter, Desc. Cat. Objects Deep Sea Dredging, 1870, p. 5.

Test free, globular or ovate, consisting of a single, undivided chamber; wall composed of felted sponge spicules and a slight amount of fine sand with a minimum of cement; aperture narrow, elongate, in a somewhat depressed area, or occasionally with a slightly raised lip.

Recent. Two species are known, one in the North Atlantic, and the other in the North Pacific in comparatively deep cold water.

Subfamily 4. Webbinellinae

Test attached; wall of agglutinated foreign material.

Genus WEBBINELLA Rhumbler, 1903

Plate 5, figures 5, 6

Genotype, by designation, *Webbina hemisphaerica* Jones, Parker and H. B. Brady

Webbinella RHUMBLER, Arch. Prot., vol. 3, 1903, p. 228.

Webbina JONES, PARKER and H. B. BRADY, Pal. Soc. Mon., 1865, p. 27 (not *Webbina* D'ORBIGNY, 1839).

Psammosphaera EIMER and FICKERT (part), Zeitschr. Wiss. Zool., vol. 65, 1899, p. 671.

Test attached, planoconvex, circular in outline, central part convex, surrounded by a flattened border; wall of fine sand grains with much cement, smoothly finished without and within; no general aperture, pseudopodia thrust out along the basal rim.

Carboniferous to Recent. Widely distributed in the present ocean both as to temperature and depth.

Genus IRIDIA Heron-Allen and Earland, 1914

Plate 5, figures 7, 8

Genoholotype, *Iridia diaphana* Heron-Allen and Earland

Iridia HERON-ALLEN and EARLAND, Trans. Zool. Soc. London, vol. 20, pt. 12, 1914, p. 371.

Test usually attached, consisting of a single chamber lined with a chitinous, transparent membrane, the outer surface consisting of sand grains or other foreign material built up into a convex test; aperture irregular.

Recent. In shallow water, usually warm.

Genus RHAPHIDOSCENE Vaughan Jennings, 1896

Plate 5, figures 9, 10

Genoholotype, *Rhaphidoscene conica* Vaughan Jennings

Rhaphidoscene VAUGHAN JENNINGS, Journ. Linn. Soc., vol. 25, 1896, p. 320.

Test attached, conical, base broad, upper end pointed, chamber single; wall composed of sponge spicules arranged lengthwise of the test with a white cement and fine amorphous material; aperture indistinct, at the apex.

Recent. Cold waters of the North Atlantic mostly.

Genus THOLOSINA Rhumbler, 1895

Plate 5, figures 11, 12

Genoholotype, *Placopsilina bulla* H. B. Brady (in part)

Tholosina RHUMBLER, Nachr. Köngl. Ges. Wiss. Göttingen, 1895, p. 82.

Placopsilina (part) H. B. BRADY, Quart. Journ. Micr. Sci., vol. 19, 1879, p. 51.

Pseudoplacopsilina EIMER and FICKERT, Zeitschr. Wiss. Zool., vol. 65, 1899, p. 672 (genoholotype, *Placopsilina bulla* H. B. BRADY).

Test attached, hemispherical, flattened on the surface by which it is attached, chamber single, undivided; wall of fine

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EXPLANATION OF PLATE 5

SACCAMMINIDAE

FIG.

1, 2. *Technitella legumen* Norman. (After type figures). Fig. 1, Exterior. × 28. Fig. 2, Anterior portion enlarged to show structure of wall. × 65.

3, 4. *Pilulina jeffreysii* Carpenter. × 8. (After H. B. Brady). Fig. 3, *a*, apertural view; *b*, side view. Fig. 4, Test sectioned to show interior.

5, 6. *Webbinella hemisphaerica* Jones, Parker and H. B. Brady. Fig. 5. (After H. B. Brady). × 15. Fig. 6, (After type figure). × 40.

7, 8. *Iridia diaphana* Heron-Allen and Earland. (After type figures). Fig. 7, Exterior. × 12. Fig. 8, From below, showing protoplasmic body. × 14.

9, 10. *Rhaphidoscene conica* Vaughan-Jennings. × 12. (After type figures).

11, 12. *Tholosina bulla* (H. B. Brady). × 14. (After type figures). Fig. 11, From above. Fig. 12, From side.

13, 14. *Verrucina rudis* Goës. × 10. (After type figures). Fig. 13, From above. Fig. 14, From side.

15. *Psammosphaera rustica* Heron-Allen and Earland. × 28. (After type figure). Test made of sponge spicules.

16. *Psammosphaera bowmanni* Heron-Allen and Earland. × 28. (After type figure). Test made of mica flakes.

17. *Technitella thompsoni* Heron-Allen and Earland. × 50. (After type figure). Test made of ambulacral plates of brittle stars.

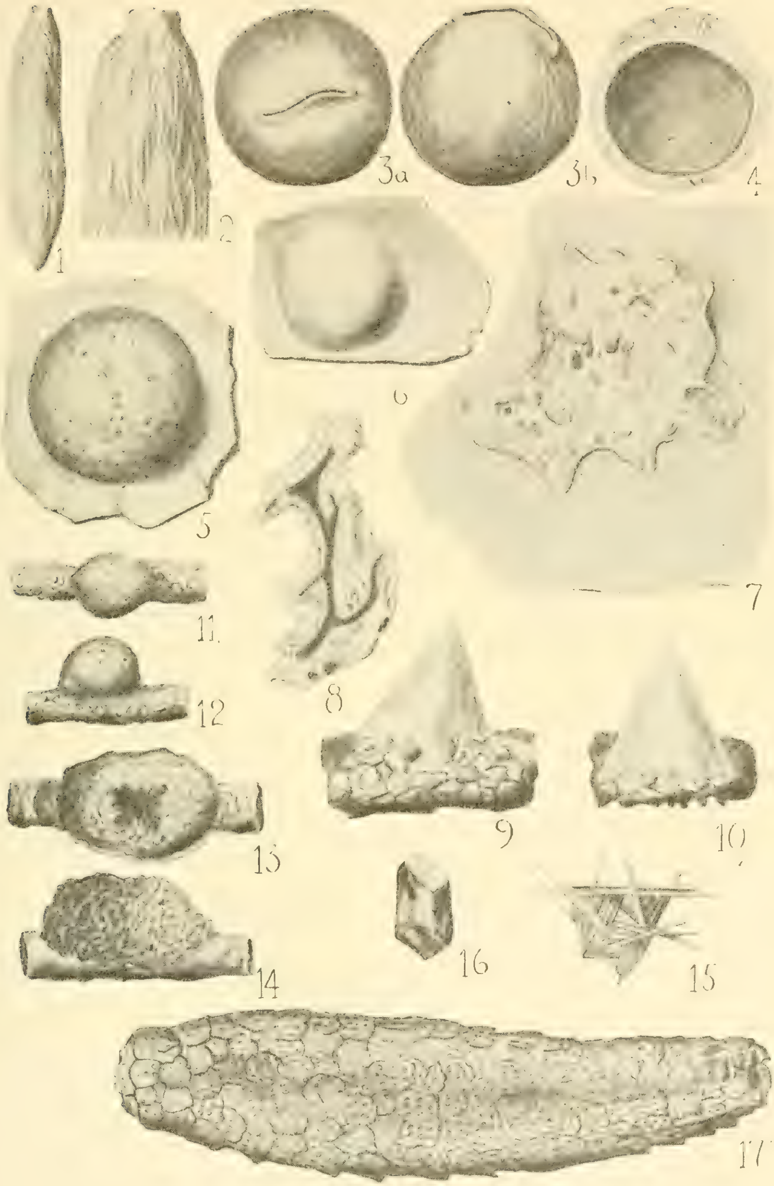

PLATE 5

sand grains with a large proportion of calcareous cement; apertures at either end just above the plane of attachment, small, circular, protuberant or irregular from the line of the base.

Reecnt. Widely distributed, usually in cold water.

Genus VERRUCINA Goës, 1896

Plate 5, figures 13, 14

Genoholotype, *Verrucina rudis* Goës

Verrucina GOËS, Bull. Mus. Comp. Zoöl., vol. 29, 1896, p. 25.

Test attached, irregular, ovoid, interior somewhat labyrinthic; wall coarsely arenaceous; aperture usually double, in a depressed area in the middle of the dorsal side.

Recent. Pacific ocean off coast of Mexico in 772 fathoms, attached to *Rhabdammina*.

FAMILY 5. HYPERAMMINIDAE

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

KEY TO THE GENERA

I. Test free, unbranched.
  - A. Elongated chamber cylindrical.
    - 1. Test chitinous, with a few sand grains........*Nubeculariella.*
    - 2. Test arenaceous.
      - a. Test single, elongated chambers usually straight. *Hyperammina.*
      - b. Tests in masses, elongated chamber twisted...*Normanina.*
  - B. Elongated chamber tapering.
    - 1. Coarsely arenaceous with little cement.............*Jaculella.*
    - 2. Very finely arenaceous with much cement......*Hippocrepina.*

II. Test usually attached, branching.
  - A. Test dichotomously branching.
    - 1. Wholly attached..................................*Sagenina.*
    - 2. Attached by proloculum only..............*Psammatodendron.*
  - B. Test irregularly branching, largely raised from surface.
    - 1. Test cylindrical, tubes with irregular spicules......*Saccorhiza.*
    - 2. Test mostly arenaceous, without spicules........*Dendrophrya.*
    - 3. Test fusiform or tapering, with many spicules, especially at outer end..................................*Haliphysema.*

C. Test irregularly branching, attached to inside of other foraminiferal tests, chitinous.
  1. Test simply branched and winding................*Ophiotuba.*
  2. Test anastomosing............................*Dendrotuba.*

D. Test a mass of anastomosing tubes, arenaceous.....*Syringammina.*

Subfamily 1. Hyperammininae

Test free, simple

Genus HYPERAMMINA H. B. Brady, 1878

Plate 6, figures 1-3

Genoholotype, *Hyperammina elongata* H. B. Brady

Hyperammina H. B. BRADY, Ann. Mag. Nat. Hist., ser. 5, vol. 1, 1878, p. 433.

Rhabdopleura (?) DAWSON, Ann. Mag. Nat. Hist., ser. 4, vol. 7, 1871, p. 86.

Bactrammina EIMER and FICKERT, Zeitschr. Wiss. Zool., vol. 65, 1899, p. 673 (genoholotype, *Hyperammina elongata* (H. B. Brady).

Test free, elongate, consisting of a proloculum and long undivided tubular second chamber; wall of sand grains, often with sponge spicules, the amount of cement varying in different species, interior with a chitinous lining and smoothly finished; aperture formed by the open end of the tube.

Cambrian (?) Silurian to Recent. Species are mostly characteristic of cold or deep water. Widely distributed. Abundant in the Pennsylvanian, and occurring in many formations to the present seas.

Genus NUBECULARIELLA Awerinzew, 1911

Plate 7, figure 7

Genoholotype, *Nuberculariella birulai* Awerinzew

Nubeculariella AWERINZEW, Mém. Acad. Sci. St. Petersbourg, ser. 8, vol. 29, pt. 3, 1911, p. 8.

Test consisting of an indistinct proloculum and curved cylindrical tube; wall of chitin with sand grains of various sizes attached to the exterior; aperture rounded with a slightly flaring lip.

Recent. Arctic.

Genus NORMANINA Cushman, 1928

Plate 7, figures 8, 9

Genoholotype, *Haliphysema confertum* Norman

Normanina CUSHMAN, Contrib. Cushman Lab. Foram. Res., vol. 4, 1928, p. 7.

Haliphysema (part) (not BOWERBANK) NORMAN, Ann. Mag. Nat. Hist., ser. 5, vol. 1, 1878, p. 279.

Test consisting of a globular proloculum and small elongate tubular second chamber, individuals gathered together in masses, the tubular portions toward the center of the mass; wall chitinous with agglutinated material on the exterior, of sand grains or other foraminiferal tests; aperture at the end of the tubular chamber.

Recent. Davis Strait in 1750 fathoms.

The genotype is the only species known, *Normanina conferta* (Norman), (Ann. Mag. Nat. Hist., ser. 5, vol. 1, 1878, p. 279, pl. 16, figs. 1, 2).

EXPLANATION OF PLATE 6

HYPERAMMINIDAE

FIG.

1–3. *Hyperammina elongata* H. B. Brady. (After type figures). Figs. 1, 2. × 28. Fig. 3, Section to show interior.

4, 5. *Jaculella acuta* H. B. Brady. × 6. (After type figures). Fig. 5, Partially laid open to show interior.

6–8. *Hippocrepina indivisa* Parker. (After H. B. Brady). Fig. 6, *a*, side view; *b*, apertural view. × 40. Fig. 7, Section showing interior. × 40. Fig. 8, Side view. × 30.

9–11. *Saccorhiza ramosa* (H. B. Brady). × 10. (After type figures). Fig. 11, Specimen showing the branching arms.

12, 13. *Dendrophrya erecta* Str. Wright. (After H. B. Brady). Fig. 12. × 15. Fig. 13, End of one of the branches. × 100.

14–16. *Haliphysema tumanowiczii* Bowerbank. Fig. 14, (After type figure). Figs. 15, 16, (After H. B. Brady). Fig. 15, Group of specimens. × 15. Fig. 16, Single specimen. × 35.

17. *Sagenina frondescens* (H. B. Brady). × 6. (After type figure).

18. *Dendrotuba nodulosa* Rhumbler. × 35. (After type figure).

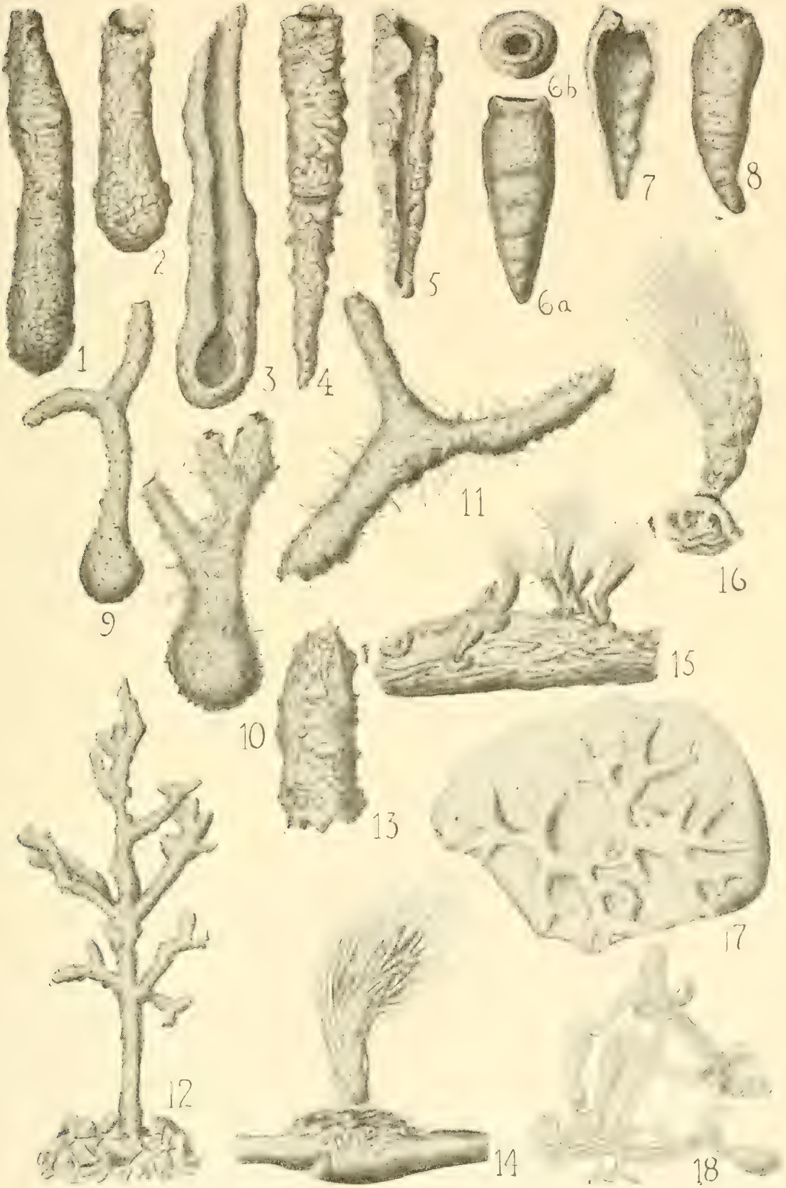

PLATE 6

Genus JACULELLA H. B. Brady, 1879

Plate 6, figures 4, 5

Genoholotype, *Jaculella acuta* H. B. Brady

Jaculella H. B. Brady, Quart. Journ. Micr. Sci., vol. 19, 1879, p. 35.

Test free, elongate conical, widest at the apertural end, opposite end closed; wall of firmly cemented sand grains, thick, rough on the exterior, smoothly finished within, with a thin chitinous layer; aperture circular, formed by the open end of the tube.

Tertiary and Recent. Typically in cold or deep water.

The distinction between proloculum and second chamber is often not well marked except in the megalospheric form.

Genus HIPPOCREPINA Parker, 1870

Plate 6, figures 6-8

Genoholotype, *Hippocrepina indivisa* Parker

Hippocrepina Parker, in Dawson, Canad. Nat., n. ser., vol. 5, 1870, p. 176.

Test free, elongate, tapering, the apertural end broad but somewhat contracted about the aperture, distinction between proloculum and second chamber often indistinct; wall thin, of fine sand grains with a yellowish-brown cement, often with fine mica flakes giving a luster to the surface; aperture curved, narrow or irregular, sometimes with a slightly raised lip.

Pliocene to Recent. Characteristic of very cold waters of the northern hemisphere, usually at shallow depths.

Subfamily 2. Dendrophryinae

Test attached, usually branching

Genus SACCORHIZA Eimer and Fickert, 1899

Plate 6, figures 9-11

Genoholotype, *Hyperammina ramosa* H. B. Brady

Saccorhiza Eimer and Fickert, Zeitschr. Wiss. Zool., vol. 65, 1899, p. 670.
Hyperammina (part) H. B. Brady, Quart. Journ. Micr. Sci., vol. 19, 1879, p. 33.

Test free, consisting of an ovoid proloculum and a branching, tubular second chamber; wall with a thin inner chitinous layer, and a thicker outer layer of sand grains often roughened by included sponge spicules; apertures formed by the open ends of the tubular chamber.

Jurassic to Recent. Most abundant in deep cold waters but not limited to such conditions.

Genus DENDROPHRYA Str. Wright, 1861

Plate 6, figures 12, 13

Genotype, by designation, *Dendrophrya erecta* Str. Wright

Dendrophrya STR. WRIGHT, Ann. Mag. Nat. Hist., ser. 3, vol. 8, 1861, p. 133.

Test attached, consisting of a proloculum and tubular second chamber, simple or branched, erect or with spreading arms; wall with a chitinous lining and an outer arenaceous layer; apertures at the ends of the tubular portion.

Cretaceous to Recent. The recent species are apparently confined to cool waters at shallow depths.

Genus DENDRONINA Heron-Allen and Earland, 1922

Plate 7, figure 3

Genotype, by designation, *Dendronina arborescens* Heron-Allen and Earland

Dendronina HERON-ALLEN and EARLAND, British Antarctic ("Terra Nova") Exped., 1910, Zool., vol. 6, no. 2, 1922, p. 78.

"Test sessile or free, unseptate, built of fine mud, sand-grains and sponge-spicules, agglutinated with varying proportions of cement and furnished with an internal or external chitinous membrane.

Initial portion of sessile specimens either a depressed amoebiform basal pad, with ramifying passages converging to a central cavity, or a more or less turgid basal chamber, with simple or labyrinthic cavity. From the basal pad or chamber rise one or more tubular outgrowths, simple or branching, diminishing in diameter towards the terminal apertures.

In free-growing specimens the basal portion is bulbous with entire or labyrinthic cavity, often of large size, from which arise one or more tubular outgrowths developing as in the sessile form.

Very fragile in the dry condition, but probably more or less flexible in the living state."

Recent. New Zealand and the Antartic.

The figured specimen is a composite figure. The genus seems to be close to *Dendrophrya* Str. Wright.

Genus HALIPHYSEMA Bowerbank, 1862

Plate 6, figures 14-16

Genoholotype, *Haliphysema tumanowiczii* Bowerbank

Haliphysema BOWERBANK, Philos. Trans., 1862, p. 1105.
Squamulina (part) CARTER, Ann. Mag. Nat. Hist., ser. 4, vol. 6, 1870, p. 346.

Test attached, with an expanded basal portion and a columnar erect portion either simple or branched; wall arenaceous, usually with numerous included sponge spicules especially near the tips of the arms or the apertural end; aperture at the free end of the chamber or at the ends of the branches, partially obscured by the irregular clustering of spicules.

Recent. Species mostly found in comparatively shallow water but widely distributed in both warm and cool waters.

Genus SAGENINA Chapman, 1900

Plate 6, figure 17

Genoholotype, *Sagenella frondescens* H. B. Brady

Sagenina CHAPMAN, Journ. Linn. Soc., vol. 28, 1900, p. 4.
Sagenella H. B. BRADY, Quart. Journ. Micr. Sci., vol. 19, 1879, p. 41 (not *Sagenella* HALL).

Test attached, consisting of a proloculum and tubular,

EXPLANATION OF PLATE 7

HYPERAMMINIDAE

FIG.
1, 2. *Psammatodendron arborescens* Norman. (After H. B. Brady). Fig. 1. × 15. Fig. 2, Tip of one of the arms. × 65.
3. *Dendronina arborescens* Heron-Allen and Earland. × 15. (After type figure). Semidiagrammatic restoration.
4–6. *Syringammina fragillissima* H. B. Brady. (After type figure). Fig. 4, From above. × ⅔. Fig. 5, From side. × ⅔. Fig. 6, Tangential section. × 5.
7. *Nubecularиella birulai* Awerinzew. (After type figure).
8, 9. *Normanina conferta* (Norman). (After type figures). Fig. 8, Showing the massed specimens. Fig. 9, An individual enlarged.

PLATE 7

dichotomously or irregularly branching second chamber; wall arenaceous, usually with calcareous cement; apertures at ends of the branches.

Silurian (?), Jurassic to Recent. The living species are found in shallow waters of tropical and subtropical portions of the Pacific.

Genus PSAMMATODENDRON Norman, 1881

Plate 7, figures 1, 2

Genoholotype, *Psammatodendron arborescens* Norman

Psammatodendron NORMAN, in H. B. BRADY, Denkschr. K. Akad. Wiss. Wien, vol. 43, 1881, p. 98.

Hyperammina (part) H. B. BRADY, Rep. Voy. *Challenger*, Zool., vol. 9, 1884, p. 262.

Test attached, consisting of a bulbous proloculum with a long tubular, dichotomously branched second chamber, of even diameter throughout; wall arenaceous with a thin chitinous lining and ferruginous cement; apertures formed by the open ends of the tubes.

Recent. Records are mostly from the North Temperate and Arctic regions but a few are from warmer waters.

Genus SYRINGAMMINA H. B. Brady, 1883

Plate 7, figures 4-6

Genoholotype, *Syringammina fragillissima* H. B. Brady

Syringammina H. B. BRADY, Proc. Roy. Soc. London, vol. 35, 1883, p. 155.

Test free or adherent, consisting of a bulbous base and many branching arms or of masses of anastomosing tubes in a rounded mass; wall of fine arenaceous particles with a small amount of cement; apertures at the ends of the tubular portions.

Recent. Faroe Channel, off the Azores and the Antarctic.

A detailed account of the type species is given by Brady in the *Challenger* Report, vol. 9, 1884, p. 243.

Genus OPHIOTUBA Rhumbler, 1894

Genoholotype, *Ophiotuba gelatinosa* Rhumbler

Ophiotuba RHUMBLER, Zeitschr. Wiss. Zool., vol. 57, 1894, p. 604.

Test attached to the interior of larger foraminiferal tests, irregularly winding; wall chitinous; aperture at the open end of the tube.

Recent. North Sea and Atlantic Ocean, 40-520 meters depth.

Genus DENDROTUBA Rhumbler, 1894

Plate 6, figure 18

Genoholotype, *Dendrotuba nodulosa* Rhumbler

Dendrotuba RHUMBLER, Zeitschr. Wiss. Zool., vol. 57, 1894, p. 606.

Test attached to the interior of other foraminifera, irregularly winding and anastomosing; wall chitinous; apertures, the open ends of the tubes.

Recent. North Sea and Atlantic Ocean, 40-520 meters depth.

The foraminifera included in this family have their beginnings well back in the Palaeozoic. The simple globular proloculum followed by an elongated, undivided second chamber is a primitive character. From forms such as *Hyperammina* by division of the tubular chamber have come the Reophacidae, a family which also developed very early in the geologic series.

FAMILY 6. REOPHACIDAE

Test consisting of either an irregular or a generally rectilinear series of chambers, typically increasing in size as added, simple or labyrinthic; wall chitinous with usually an exterior of agglutinated material, sand grains, sponge spicules or the tests of other foraminifera; aperture usually terminal, simple or multiple.

KEY TO THE GENERA

I. Chambers irregular in size and arrangement.

A. Wall chitinous, test in the interior of other foraminifera. *Hospitella.*

B. Wall mostly finely arenaceous, apertures at the end of tubular necks. ....*Aschemonella.*
C. Wall largely of cement with scattered arenaceous fragments. *Kalamopsis.*

II. Chambers usually in a regular rectilinear series.
A. Wall mostly arenaceous.
1. Chambers rounded in section.
a. Interior simple.
(1). Test usually with an outer coating.....*Nodosinella.*
(2). Test of coarsely agglutinated material.....*Reophax.*
(3). Test finely arenaceous with much cement. *Hormosina.*
b. Interior labyrinthic.........................*Haplostiche.*
2. Chambers compressed...................*Ammofrondicularia.*
B. Wall mostly chitinous.
1. Wall with some arenaceous material, aperture elongate. *Turriclavula.*
2. Wall wholly chitinous, aperture rounded...........*Nodellum.*

Subfamily 1. Aschemonellinae

Chambers irregular

Genus ASCHEMONELLA H. B. Brady, 1879

Plate 8, figures 1, 2

Genoholotype, *Aschemonella scabra* H. B. Brady (= synonym of *Astrorhiza catenata* Norman).

Aschemonella H. B. Brady, Quart. Journ. Micr. Sci., vol. 19, 1879, p. 42.
Astrorhiza (part) Norman, Proc. Roy. Soc., vol. 25, 1876, p. 213.

Test free, with several tubular or inflated chambers in a single or branching series, irregular in size and form; wall thin, arenaceous, with a large proportion of cement; apertures often several at the end of the tubular necks.

Cretaceous to Recent. In the present ocean the species are found mostly in cool or deep waters.

The genus *Psammosiphon* (Vine?) Rhumbler, if it is truly foraminiferal shows an irregular arenaceous tubular form irregularly divided as far back as the Silurian. Such forms are however not well known in detail.

Genus HOSPITELLA Rhumbler, 1913

Plate 8, figure 3

Genoholotype, *Hospitella fulva* Rhumbler

Hospitella RHUMBLER, Plankton Exped., vol. 3, 1909 (1911), p. 227.

Test a series of connected chambers in the interior of the tests of larger foraminifera; wall chitinous; aperture, the open end of the last-formed chamber.

Recent.

Genus KALAMOPSIS de Folin, 1883

Plate 8, figures 4, 5

Genoholotype, *Kalamopsis vaillanti* de Folin

Kalamopsis DE FOLIN, Congrès Scient. Dax, 1882 (1883), p. 320; Actes Soc. Linn. Bordeaux, vol. 40, 1886, p. 288.

Test free, consisting of a globular proloculum and an irregular series of linear chambers making a cylindrical test; wall with much cement and small proportion of arenaceous material; aperture rounded, at the end of the tube.

Recent. Species in cool water, shallow or deep. Coast of France and coast of California.

Subfamily 2. Reophacinae

Chambers typically in a regular rectilinear series

Genus REOPHAX Montfort, 1808

Plate 8, figures 6-8

Genoholotype, *Reophax scorpiurus* Montfort

Reophax MONTFORT, Conch. Syst., vol. 1, 1808, p. 331.
Nodosaria (part) of authors (not LAMARCK).
Lituola (part) of authors (not LAMARCK).
Haplostiche SCHWAGER, Jahr. Ver. Vet. Nat. Württemburg, vol. 21, 1865, p. 92 (not *Haplostiche* REUSS).
Nodulina RHUMBLER, Nachr. Kön. Ges. Wiss. Göttingen, 1895, p. 85.
Protoshista EIMER and FICKERT, Zeitschr. Wiss. Zool., vol. 65, 1899, p. 677 (genoholotype, *Reophax findens* PARKER).

Test free, elongate, composed of several undivided chambers, ranging from overlapping to remotely separated ones connected by stolon-like necks, in a straight or curved linear series; wall single, of agglutinated material, firmly cemented, sand grains, mica scales, sponge spicules or other foraminifera; aperture simple, terminal, sometimes with a slight neck.

Cambrian to Recent. In the present ocean the species have definite distributions both geographically and bathymetrically.

There is a high degree of selection in the material of the tests, certain materials of the bottom being used and others discarded.

Genus NODOSINELLA H. B. Brady, 1876

Plate 8, figures 9-12

Genotype, by designation, *Nodosinella digitata* H. B. Brady

Nodosinella H. B. Brady, Pal. Soc. Mon., vol. 30, 1876, p. 102.
Dentalina (part) of authors.

Test free, straight or arcuate, chambers usually distinct,

EXPLANATION OF PLATE 8

Reophacidae

Fig.

1, 2. *Aschemonella scabra* H. B. Brady. × 10. (After type figures). Fig. 2, Section showing the interior.

3. *Hospitella fulva* Rhumbler. (After type figure).

4, 5. *Kalamopsis vaillanti* de Folin. (After type figures). Fig. 5, Section showing structure of interior.

6, 7. *Reophax scorpiurus* Montfort. (After H. B. Brady). Fig. 6, Exterior. × 28. Fig. 7, Showing structure of test. × 20.

8. *Reophax nodulosus* H. B. Brady. × 7. (After type figure).

9–11. *Nodosinella digitata* H. B. Brady. × 20. (After type figure). *a*, side view; *b*, apertural view.

12. *Nodosinella cylindrica* H. B. Brady. × 20. (After type figure). Showing labyrinthic structure of test.

13–15. *Hormosina globulifera* H. B. Brady. × 15. (After type figures). Fig. 13, Megalospheric form with a single chamber. Fig. 15, Microspheric form with numerous chambers.

16. *Haplostiche foedissima* (Reuss). × 7. (After type figure).

17–19. *Haplostiche dubia* (d'Orbigny). × 10. (After H. B. Brady). *a*, front view; *b*, apertural view. Fig. 18, Transverse section. Fig. 19, Longitudinal section.

20. *Turriclavula interjecta* Rhumbler. (After type figure).

21. *Ammofrondicularia angusta* Schubert. (After type figure).

22. *Nodellum membranaceum* (H. B. Brady). × 35. (After type figure).

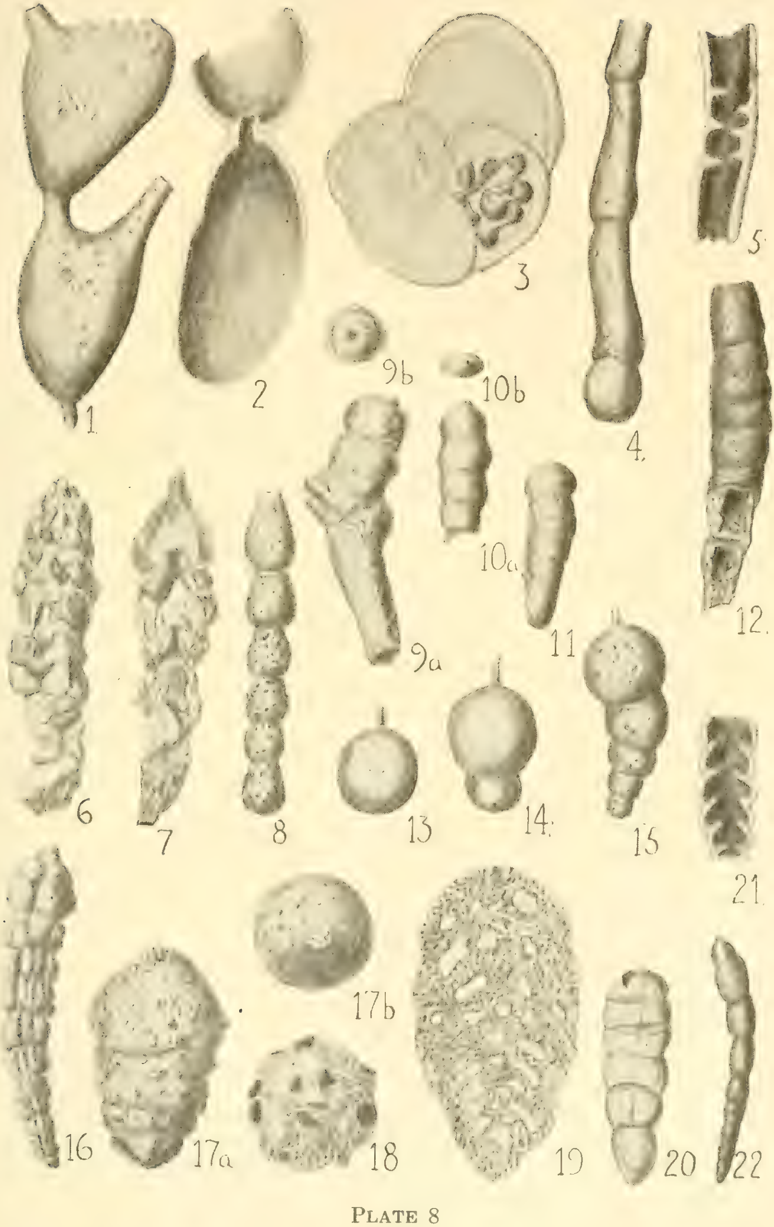

PLATE 8

typically enlarging in size as added, simple; walls finely arenaceous with much cement, with often a double wall; aperture usually simple and terminal.

Carboniferous to Cretaceous. Widely distributed.

There is often an outer wall which is largely cement, smooth, and sometimes seems to be imperforate. Specimens are often very abundant in the Pennsylvanian.

Genus HORMOSINA H. B. Brady, 1879

Plate 8, figures 13-15

Genotype, by designation, *Hormosina globulifera* H. B. Brady

Hormosina H. B. BRADY, Quart. Journ. Micr. Sci., vol. 19, 1879, p. 56.

Test free, composed of a straight, curved, or irregular linear series of subglobular, fusiform or pyriform chambers; wall finely arenaceous, with a large proportion of usually ferruginous cement; aperture circular, terminal or at one side, often with a definite neck.

Jurassic to Recent. The living species are characteristic of cold or deep waters.

The species differ from those of *Reophax* largely in the much greater amount of cement in the wall and greater development of the neck at the apertural end.

Genus HAPLOSTICHE Reuss, 1861

Plate 8, figures 16-19

Genoholotype, *Haplostiche foedissima* Reuss

Haplostiche REUSS, Sitz. Böhm. Ges. Wiss., Jahrg. 1861, p. 16.
Nodosaria (part) of authors.
Lituola (part) JONES and PARKER, Quart. Journ. Geol. Soc., vol. 16, 1860, p. 307.

Test free, cylindrical or tapering, composed of a linear series of chambers, the interior labyrinthic; walls thick, coarsely arenaceous; aperture in the early chambers simple, in the adult of several pores or dendritic, occasionally with a short neck.

Carboniferous (?), Jurassic to Recent. The living forms are characteristic of the West Indian and Indo-Pacific regions in warm rather shallow water. It differs from the several genera preceding in the labyrinthic interior and multiple apertures.

Genus AMMOFRONDICULARIA Schubert, 1902

Plate 8, figure 21

Genoholotype, *Ammofrondicularia angusta* Schubert

Ammofrondicularia SCHUBERT, Beitr. Pal. Oesterr.-Ung., vol. 14, 1902, p. 24.

Test free, compressed, elongate, consisting of a series of overlapping chambers; wall arenaceous; aperture elliptical, terminal.

Lower Oligocene. South Tyrol.

This is essentially a compressed, overlapping form in other respects resembling *Reophax*.

Genus TURRICLAVULA Rhumbler, 1911

Plate 8, figure 20

Genoholotype, *Turriclavula interjecta* Rhumbler

Turriclavula RHUMBLER, Plankton Exped., vol. 3, 1909 (1911), p. 421.

Test free, elongate, of several chambers in a rectilinear series; wall chitinous, with some scattered arenaceous material on the exterior; aperture terminal, elongate elliptical.

Recent.

Genus NODELLUM Rhumbler, 1913

Plate 8, figure 22

Genotype, by designation, *Reophax membranacea* H. B. Brady

Nodellum RHUMBLER, Plankton Exped., vol. 3, 1913, p. 473.

Reophax (part) H. B. BRADY, Quart. Journ. Micr. Sci., vol. 19, 1879, p. 53.

Test free, elongate, made up of a rectilinear series of inflated chambers; wall entirely chitinous; aperture circular, terminal.

Cretaceous, Recent. The living species in cold or deep water, widely distributed.

The various forms included in this family probably had their origin in such forms as *Hyperammina* by the division of the tubular chamber into many small chambers. The simpler more primitive genera of the family such as *Aschemonella* and *Kalamopsis* are often imperfectly divided into chambers. In the completely divided forms, there is a regular series from the simple chamber of *Reophax* to *Haplostiche* which is labyrinthic and has a cribrate aperture. The entirely chitinous *Nodellum* is found in deep water. In the largest megalospheric forms of *Hormosina*, a single chambered form is developed hardly separable from some species of *Saccammina* except by the fine material of the test and the apertural characters.

FAMILY 7. AMMODISCIDAE

Test composed of a globular proloculum and long undivided tubular second chamber, usually close coiled, at least in the young, planispiral, conical spiral or irregularly winding; wall of fine arenaceous material with much cement, usually of a yellowish- or reddish-brown color; aperture formed by the open end of the tubular chamber.

KEY TO THE GENERA

I. Test free.
  - A. Test completely coiled throughout.
    - 1. Planispiral at least in the young.
      - a. Planispiral throughout.................... *Ammodiscus.*
      - b. Planispiral in the young, later coils partially covering one side. .... *Hemidiscus.*
    - 2. Conical spiral at least in the young.
      - a. Conical spiral throughout.................. *Turritellella.*
      - b. Conical spiral in the young, later nearly planispiral. *Ammodiscoides.*
    - 3. Irregularly winding. .... *Glomospira.*
  - B. Test partially uncoiled.
    - 1. Tubular chamber not compressed................. *Lituotuba.*
    - 2. Tubular chamber compressed, complanate....... *Psammonyx.*

II. Test attached.
  - A. Early portion coiled.
    - 1. Later portion irregularly winding............. *Tolypammina.*
    - 2. Later portion bending back and forth......... *Ammovertella.*
  - B. Early portion a single chamber, remainder nearly straight. *Ammolagena.*

Subfamily 1. Ammodiscinae

Test free

Genus AMMODISCUS Reuss, 1861

Plate 9, figures 1-4

Genotype, by designation, *Operculina incerta* d'Orbigny

Ammodiscus REUSS, Sitz. Akad. Wiss. Wien, vol. 44, 1861, p. 365.
Operculina (part) D'ORBIGNY, in DE LA SAGRA, Hist. Fis. Pol. Nat. Cuba, 1839, p. 49.
Orbis STRICKLAND, Quart. Journ. Geol. Soc., vol. 2, 1848, p. 30 (not *Orbis* PHILIPPS).
Spirillina WILLIAMSON, Rec. Foram. Great Britain, 1858, p. 93 (not *Spirillina* EHRENBERG, 1841).
Trochammina (part) of authors.
Cornuspira (part) of authors.
Involutina (part), TERQUEM, Mém. Acad. Imp. Metz, 1860-61 (1862), p. 450.

Test free, planispiral, with a proloculum and long tubular undivided second chamber, coiled regularly in one plane; wall finely arenaceous with a large proportion of yellowish- or reddish-brown cement, surface smooth; aperture formed by the open end of the chamber.

Silurian to Recent. Recent species widely distributed, most abundant in colder and deeper waters, but occasionally in warm shallow water. Specimens are very abundant in the Pennsylvanian.

Genus HEMIDISCUS Schellwien, 1898

Plate 9, figures 8-10

Genoholotype, *Hemidiscus carnicus* Schellwien

Hemidiscus SCHELLWIEN, Palaeontographica, vol. 44, 1898, p. 266.

Test with proloculum and long tubular unbranched second chamber, the early chambers planispirally coiled, later ones becoming more or less involute on one face; wall arenaceous with much cement; aperture formed by the open end of the tubular chamber.

Carboniferous to Recent. Europe and America, Mediterranean.

Genus TURRITELLELLA Rhumbler, 1903

Plate 9, figures 23-25

Genotype, by designation, *Trochammina shoneana* Siddall

Turritellella RHUMBLER, Arch. Prot., vol. 3, 1903, p. 283.
Trochammina (part) SIDDALL, Proc. Chester Soc. Nat. Hist., pt. 2, 1878, p. 46.
Ammodiscus (part) of authors.
Turritellopsis RHUMBLER, Nachr. Ges. Wiss. Göttingen, 1895, p. 84 (not G. O. SARS, 1878).

Test free, consisting of a proloculum and long undivided, tubular second chamber, coiled in an elongate close spiral; wall composed of fine sand grains and much cement, smooth; aperture, the open end of the tubular chamber.

Carboniferous to Recent. Recent forms in comparatively shallow water but a few records from deep water.

EXPLANATION OF PLATE 9

AMMODISCIDAE

FIG.

1–4. *Ammodiscus incertus* (d'Orbigny). Fig. 1, (After type figure). × 135. *a*, side view; *b*, peripheral view. Figs. 2-4, (After H. B. Brady). × 10. Fig. 2, Microspheric form. Fig. 3, Showing interior. Fig. 4, Megalospheric form.

5–7. *Glomospira gordialis* (Jones and Parker). Fig. 5, (After type figure). × 35. Figs. 6, 7, (After H. B. Brady). × 50.

8–10. *Hemidiscus carnicus* Schellwien. × 135. (After type figures). Figs. 9, 10, Sections.

11, 12. *Ammovertella inversus* (Schellwien). Fig. 11, (After type figure). × 135. Fig. 12, × 50.

13–15. *Ammodiscoides turbinatus* Cushman. (After type figures). Fig. 13, *a*, side view; *b*, peripheral view. × 30. Fig. 14, Young stage. × 50. Fig. 15, Section. × 30.

16. *Tolypammina vagans* (H. B. Brady). × 10. (After type figure).

17–19. *Ammolagena clavata* (Jones and Parker). Fig. 17, (After type figure). × 35. Figs. 18, 19, (After H. B. Brady). × 15. Fig. 19, Detached specimen from lower side.

20–22. *Lituotuba lituiformis* (H. B. Brady). × 15. Fig. 20, (After type figure). Figs. 21, 22, (After H. B. Brady).

23–25. *Turritellella shoneana* (Siddall). × 65. Figs. 23, 24, (After type figures). Fig. 25, (After H. B. Brady).

26, 27. *Psammonyx vulcanicus* Doderlein. (After Rhumbler). *a*, side view; *b*, peripheral view. Fig. 26, Microspheric form. Fig. 27, Megalospheric form.

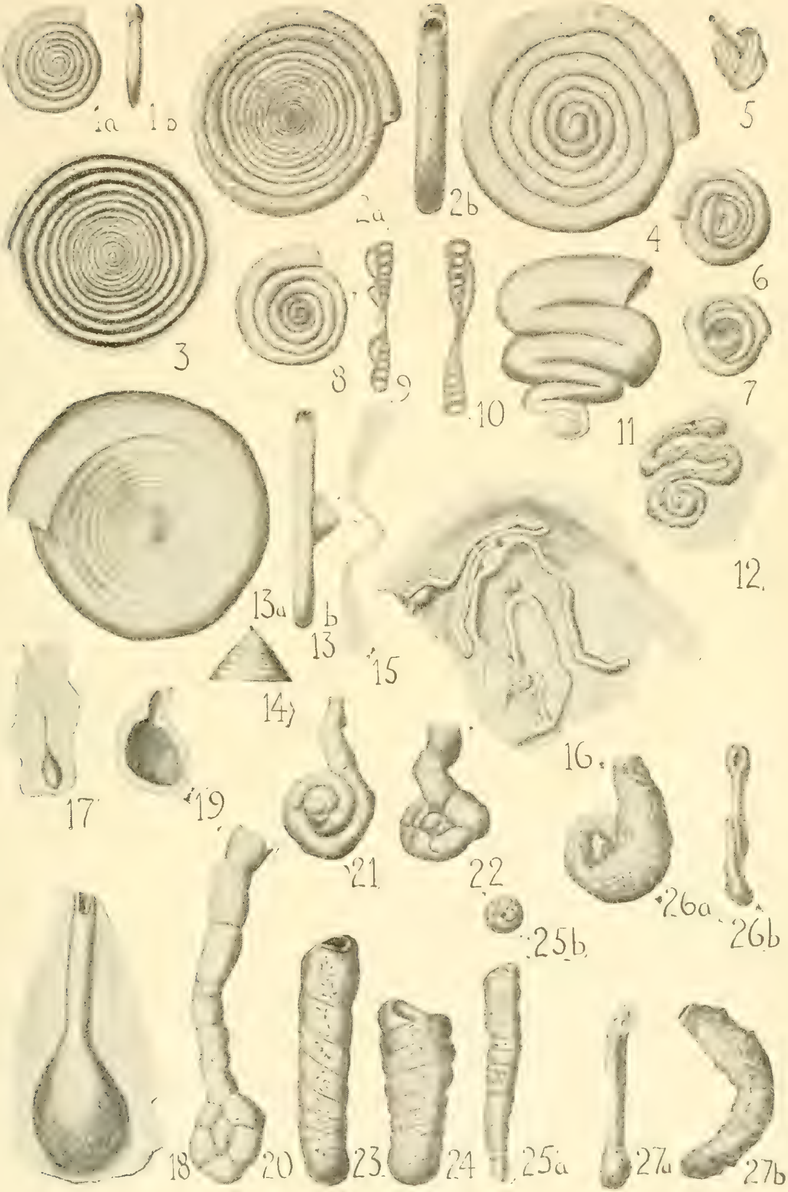
1a
1b
2a
2b
3
4
5
6
7
8
9
10
11
12
13a
b
13
14
15
16
17
18
19
20
21
22
23
24
25a
25b
26a
26b
27a
27b

PLATE 9

Genus AMMODISCOIDES Cushman, 1909

Plate 9, figures 13-15

Genoholotype, *Ammodiscoides turbinatus* Cushman

Ammodiscoides CUSHMAN, Proc. U. S. Nat. Mus., vol. 36, 1909, p. 424.

Test free, consisting of a proloculum and long undivided tubular second chamber, the early coils in a conical spire later spreading out and becoming nearly planispiral; wall finely arenaceous with a large proportion of cement, yellowish- or reddish-brown, smoothly finished; aperture formed by the open end of the tube.

Recent. Western tropical Atlantic, 196-1181 fathoms.

Genus GLOMOSPIRA Rzehak, 1888

Plate 9, figures 5-7

Genotype, by designation, *Trochammina gordialis* Jones and Parker

Glomospira RZEHAK, Verh. k. k. Geol. Reichs., 1888, p. 191.
Trochammina (part) JONES and PARKER, Quart. Journ. Geol. Soc., vol. 61, 1860, p. 304.
Ammodiscus (part) of authors.
Gordiammina RHUMBLER, Nachr. Ges. Wiss. Göttingen, 1895, p. 84 (Genotype, *Trochammina squamata*, var. *charoides* JONES and PARKER).

Test free, consisting of a proloculum and long tubular second chamber winding about its earlier coils in various planes; wall of fine arenaceous material with a large proportion of yellowish- or reddish-brown cement; aperture at the end of the tube.

Carboniferous to Recent. Recent species most common in cool waters. Very abundant in the Pennsylvanian and in some later formations.

Genus LITUOTUBA Rhumbler, 1895

Plate 9, figures 20-22

Genoholotype, *Trochammina lituiformis* H. B. Brady

Lituotuba RHUMBLER, Nachr. Köngl. Ges. Wiss. Göttingen, 1895, p. 83.
Trochammina (part) of authors.

Test composed of a proloculum and elongate undivided tubular second chamber, the early portion close coiled in various planes, the later portion uncoiled; wall arenaceous with much cement; aperture formed by the open end of the tubular chamber.

Carboniferous to Recent. The recent forms are in cool or deep waters. Specimens are abundant in some of the Pennsylvanian formations.

Genus PSAMMONYX Döderlein, 1892

Plate 9, figures 26, 27

Genoholotype, *Psammonyx vulcanicus* Döderlein

Psammonyx DÖDERLEIN, Verh. Deutsch. Zool. Ges., 1892, p. 145.

Test free, consisting of a proloculum and an undivided second chamber, loosely coiled in the early stages, later uncoiled, compressed and increasing in height toward the open end; wall of fine sand grains; aperture large, formed by the open end of the test.

Recent. Off Japan, 185-370 meters.

As in many other foraminifera, the microspheric form has the early stages most nearly complete while the megalospheric form may start the test uncoiled.

Subfamily 2. Tolypammininae

Test attached

Genus TOLYPAMMINA Rhumbler, 1895

Plate 9, figure 16

Genoholotype, *Hyperammina vagans* H. B. Brady

Tolypammina RHUMBLER, Nachr. Köngl. Ges. Wiss. Göttingen, 1895, p. 83.

Hyperammina (part) H. B. BRADY, Quart. Journ. Micr. Sci., vol. 19, 1879, p. 33.

Serpulella EIMER and FICKERT, Zeitschr. Wiss. Zool., vol. 65, 1899, p. 674 (Genoholotype, *Hyperammina vagans* H. B. BRADY).

Ammonema, l. c., p. 685 (Genoholotype, *Serpula filum* SCHMID).

Girvanella (part) of authors (not *Girvanella* NICHOLSON and ETHERIDGE, 1878).

Test, in the young stages at least, adherent, but becoming free, consisting of an elongate oval proloculum and long undivided tubular second chamber, unbranched, the earliest portion sometimes coiled; wall arenaceous with a large proportion of yellowish- or reddish-brown cement; aperture formed by the open end of the tube.

Carboniferous to Recent. Living forms are most abundant in cool or deep waters but are not confined to such habitats.

Genus AMMOVERTELLA Cushman, 1928

Plate 9, figures 11, 12

Genoholotype, *Psammophis inversus* Schellwien

Ammovertella CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 4, 1928, p. 8.

Psammophis SCHELLWIEN, Palaeontographica, vol. 44, 1898, p. 266 (not BOIE, 1827).

Test attached, consisting of proloculum and long tubular unbranched second chamber increasing in diameter, the early portion planispirally coiled, later and larger portion bending back and forth progressing forward in one general direction; wall arenaceous, usually with much cement; aperture formed by the open end of the tube.

Carboniferous to Jurassic. Europe and America.

Genus AMMOLAGENA Eimer and Fickert, 1899

Plate 9, figures 17-19

Genoholotype, *Trochammina clavata* Parker and Jones.

Ammolagena EIMER and FICKERT, Zeitschr. Wiss. Zool., vol. 65, 1899, p. 673.

Trochammina (part) of authors.

Webbina (part) H. B. BRADY, Proc. Roy. Soc. Edinburgh, vol. 11, 1862, p. 711 (not *Webbina* D'ORBIGNY, 1839).

Webbinella (part) RHUMBLER, Arch. Prot., vol. 3, 1903, p. 228.

Test attached, composed of an oval proloculum flattened on the attached side and a second long undivided tubular chamber of variable length but of nearly uniform diameter; wall with a thin chitinous layer, showing especially on the attached surface with an outer layer of finely arenaceous material with a large proportion of ferruginous cement; aperture circular, at the open end of the tube.

Carboniferous to Recent. Living forms are most common in fairly deep cold waters but are occasionally found in warmer shallower waters in some numbers.

The forms included in 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. Most of the genera of this family are now known from the Palaeozoic.

FAMILY 8. LITUOLIDAE

Test free, planispiral at least in the young, later portion in some genera uncoiled, divided into chambers, either simple or labyrinthic; wall arenaceous with varying proportions of cement in different genera and species, usually with a yellowish- or reddish-brown cement, the last-formed chamber in the adult often white; aperture simple or compound.

KEY TO THE GENERA

I. Test of simple chambers, not labyrinthic.
- A. Close coiled throughout.
  - 1. Aperture simple.
    - a. Not at all involute.................... *Trochamminoides.*
    - b. More or less involute.
      - (1). Usually coarsely arenaceous, without an exterior layer. .... *Haplophragmoides.*
      - (2). Usually finely arenaceous, with an exterior layer. *Endothyra.*
  - 2. Aperture, a series of openings at the base of the apertural face. .... *Cribrostomoides.*
- B. Later portion uncoiled.
  - 1. Aperture simple.
    - a. Chambers rounded or flattened, but not greatly expanded. *Ammobaculites.*
    - b. Chambers very broad in the adult, frondicularian. *Flabellammina.*
  - 2. Aperture multiple. .... *Haplophragmium.*

II. Test with labyrinthic chambers.
- A. Close coiled throughout.
  - 1. Only slightly compressed........................ *Cyclammina.*
  - 2. Very strongly compressed, complanate........... *Choffatella.*
  - 3. Very strongly compressed, many small chamberlets. *Dictyopsella.*
- B. Later portion uncoiled.
  - 1. Irregular in shape, interior with partitions........... *Lituola.*
  - 2. Regular in shape, interior simply labyrinthic. *Pseudocyclammina.*

Subfamily 1. Haplophragmiinae

Test composed of simple chambers, not labyrinthic

Genus TROCHAMMINOIDES Cushman, 1910

Plate 10, figures 1-3

Genoholotype, *Trochammina proteus* Karrer

Trochamminoides CUSHMAN, Bull. 71, U. S. Nat. Mus., pt. 1, 1910, p. 97.
Trochammina (part) of authors.
Ammodiscus (part) RHUMBLER, Arch. Prot., vol. 3, 1903, p. 281.

Test of several coils, not involute, divided more or less irregularly into chambers with the openings between them large; wall of fine sand with yellowish-brown cement; aperture simple at the end of the last-formed chamber.

Carboniferous to Recent. The recent species is widely distributed but never seems to be common.

Genus HAPLOPHRAGMOIDES Cushman, 1910

Plate 10, figures 4, 5

Genotype, by designation, *Nonionina canariensis* d'Orbigny

Haplophragmoides CUSHMAN, Bull. 71, U. S. Nat. Mus., pt. 1, 1910, p. 99.
Nonionina (part) D'ORBIGNY, in BARKER-WEBB and BERTHELOT, Hist. Nat. Îles Canaries, vol. 2, pt. 2, Foraminifères, 1839, p. 128.
Placopsilina (part) PARKER and JONES, Ann. Mag. Nat. Hist., ser. 2, vol. 19, 1857, p. 301.
Lituola (part) of authors.
Haplophragmium (part) of authors.
Trochammina (part) of authors.
Ammochilostoma (part) EIMER and FICKERT, Zeitschr. Wiss. Zool., vol. 65, 1899, p. 692.

Test of several coils, planispiral, usually not completely involute, chambers simple; wall single, arenaceous or with sponge spicules, firmly cemented, amount of cement varying greatly in different species; aperture simple, at the base of the apertural face of the chamber or in the face of the chamber.

Carboniferous to Recent. Recent species adapted to habitat and geographical areas, some species of deep cold waters, others abundant in shallow warmer waters.

Genus ENDOTHYRA Phillips, 1846

Plate 10, figures 6, 7

Genoholotype, *Endothyra bowmani* Phillips

Endothyra PHILLIPS, Rept. Proc. Geol. Poly. Soc. West Riding Yorkshire, 1844-45 (1846), p. 277.
Involutina (part) of authors.
Nonionina EICHWALD, Lethaea Rossica, vol. 1, 1860, p. 350 (not *Nonionina* D'ORBIGNY, 1826).

Test free, close coiled, often completely involute; chambers numerous, distinct, simple; wall arenaceous usually with a large amount of cement, the exterior smoothly finished; wall often double; aperture simple, typically at the base of the apertural face but occasionally above the base.

Carboniferous to Triassic. In the Pennsylvanian often very abundant.

Genus CRIBROSTOMOIDES Cushman, 1910

Plate 10, figure 8

Genoholotype, *Cribrostomoides bradyi* Cushman

Cribrostomoides CUSHMAN, Bull. 71, U. S. Nat. Mus., pt. 1, 1910, p. 108.
Haplophragmium (part) H. B. BRADY, Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 307.

Test free, planispiral, composed of numerous chambers in several coils, the chambers increasing gradually in size as added; wall arenaceous with much cement, light brown in color; aperture in young specimens, a simple elongate slit at the base of the apertural face, in later chambers subdivided by tooth-like processes, in the adult with a linear series of distinct rounded openings.

Recent. Widely distributed, in cool or deep water, but also common at some localities in fairly shallow warm water.

Genus AMMOBACULITES Cushman, 1910

Plate 10, figures 9-11

Genotype, by designation, *Spirolina agglutinans* d'Orbigny

Ammobaculites CUSHMAN, Bull. 71, U. S. Nat. Mus., pt. 1, 1910, p. 114.
Spirolina (part) D'ORBIGNY, For. Foss. Bass. Tert. Vienne, 1846, p. 137.
Haplophragmium (part) of authors.

Test free, the early chambers close coiled, later ones uncoiling with typically a linear series of chambers, simple; wall arenaceous with a chitinous lining; aperture in the early stages at the base of the apertural face, in the adult circular and terminal.

Carboniferous to Recent. There is a wide range of habitat in the present ocean, some species only found in cold, deep water, others in very shallow warm waters of the tropics.

Genus FLABELLAMMINA Cushman, 1928

Plate 54, figures 7, 8

Genoholotype, *Flabellammina alexanderi* Cushman

Flabellammina CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 4, 1928, p. 1.

Test much compressed, in the early stages close coiled, later

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EXPLANATION OF PLATE 10

LITUOLIDAE

FIG.

1-3. *Trochamminoides proteus* (Karrer). × 15. Fig. 1, (After type figure). Figs. 2, 3, (After H. B. Brady).

4, 5. *Haplophragmoides canariensis* (d'Orbigny). Fig. 4, (After type figure). × 65. Fig. 5, (After H. B. Brady). × 35. *a*, side view; *b*, apertural view.

6, 7. *Endothyra bowmani* Phillips. × 35. (After H. B. Brady). *a*, side view; *b*, apertural view. Fig. 7, Section.

8. *Cribrostomoides bradyi* Cushman. × 10. (After type figure).

9. *Ammobaculites agglutinans* (d'Orbigny). (After type figure). *a*, front view; *b*, side view; *c*, apertural view.

10, 11. *Ammobaculites calcareum* (H. B. Brady). (After type figures). Fig. 11, Section.

12, 13. *Haplophragmium aequalis* (Roemer). (After Reuss). Fig. 13, Section.

14, 15. *Cyclammina cancellata* H. B. Brady. × 10. (After H. B. Brady). Fig. 15, Section.

16-18. *Lituola nautiloidea* Lamarck. Fig. 16, (After type figure). Figs. 17, 18, From specimens on type slide, showing aperture.

19, 20. *Choffatella decipiens* Schlumberger. (After type figures). *a*, side view; *b*, apertural view. Fig. 20, Section.

21-23. *Pseudocyclammina lituus* (Yokoyama). Fig. 21, (After type figure). Figs. 22, 23, (After Yabe and Hanzawa). Fig. 22, Section. Fig. 23, Apertural view.


1
2
3
4a
4b
5a
5b
9c
9a-9b
6a
6b
7
8
10
12b
13b
12a
13a
14a
14b
11
20
15
16
19a
19b
17
21
22
23
18

PLATE 10

developing low broad chambers in an inverted V-shape, the outer margin convex or broadly angled; the microspheric form of the test broad, fan-shaped, the megalospheric form more elongate and narrow; wall arenaceous, of coarse fragments with a large amount of fine material and cement; aperture in the adult terminal, elliptical.

Lower Cretaceous. Texas.

Genus HAPLOPHRAGMIUM Reuss, 1860

Plate 10, figures 12, 13

Genotype, by designation, *Spirolina aequalis* Roemer

Haplophragmium REUSS, Sitz. Akad. Wiss. Wien, vol. 40, 1860, p. 218.
Spirolina ROEMER, Verst. Norddeutsch. Kreide, 1840-41, p. 98 (not *Spirolina* LAMARCK, 1804).

Test with the early chambers close coiled, the later ones in a rectilinear series, simple; wall arenaceous with a chitinous lining; aperture in the young at the base of the apertural face, becoming terminal and multiple in the uncoiled portion.

Cretaceous to Recent. Rare in the present ocean.

Subfamily 2. Lituolinae

Test composed of labyrinthic chambers

Genus CYCLAMMINA H. B. Brady, 1876

Plate 10, figures 14, 15

Genoholotype, *Cyclammina cancellata* H. B. Brady

Cyclammina H. B. BRADY, in NORMAN, Proc. Roy. Soc., vol. 25, 1876, p. 214.
Lituola (part) of authors.
Trochammina (part) of authors.

Test free, planispiral, composed of numerous chambers in a close coiled nautiloid series, usually partially or wholly involute; wall thick, of fine arenaceous material with a large proportion of reddish-brown cement, exterior smooth, interior with a secondary labyrinthic structure especially on the peripheral portion of each chamber, early chambers often completely filled by this secondary growth; aperture, a curved fissure at or near the base of the apertural face, supplemented by numerous pores in the central portion of the apertural face.

Cretaceous to Recent. Most of the recent species are characteristic of cool or deep waters.

Genus CHOFFATELLA Schlumberger, 1904

Plate 10, figures 19, 20

Genoholotype, *Choffatella decipiens* Schlumberger

Choffatella SCHLUMBERGER, Bull. Soc. Géol. France, ser. 4, vol. 4, 1904, p. 763.

Test planispiral, very much compressed, composed of numerous narrow elongate chambers, nearly completely involute, the coils increasing rapidly in height; wall arenaceous with much cement, becoming labyrinthic, especially on the sides and periphery of the chambers; aperture, an elongate series of small pores on the narrow apertural face.

Cretaceous. Portugal, France and Japan.

This genus is similar to *Cyclammina,* but is complanate and much compressed.

Genus DICTYOPSELLA Munier-Chalmas, 1899

Plate 55, figures 6-8

Genotype, by designation, *Dictyopsella kiliani* Munier-Chalmas

Dictyopsella MUNIER-CHALMAS, in SCHLUMBERGER, Bull. Soc. Géol. France, ser. 3, vol. 27, 1899, p. 462.

Test planispiral, much compressed, partially involute in the young, later becoming complanate; chambers distinct, divided in the interior into a complex net work of small chamberlets; sutures slightly depressed or flush with the surface; wall finely arenaceous.

Cretaceous.

A very peculiar new arenaceous genus *Yaberinella* just described by Dr. T. Wayland Vaughan belongs close to *Dictyopsella.*

Genus LITUOLA Lamarck, 1804

Plate 10, figures 16-18

Genotype, by designation, *Lituola nautiloidea* Lamarck

Lituola LAMARCK, Ann. Mus., vol. 5, 1804, p. 243.

Test in the early stages planispiral, the later portion typically uncoiled and straight; wall arenaceous with much cement, the interior labyrinthic; aperture in the earliest stages simple, at the base of the apertural face, later, even before uncoiling, becoming multiple and in the face itself, in the adult multiple and in the terminal face.

Carboniferous to Recent. Living specimens rare, in fairly warm waters.

Genus PSEUDOCYCLAMMINA Yabe and Hanzawa, 1926

Plate 10, figures 21-23

Genoholotype, *Cyclammina lituus* Yokoyama

Pseudocyclammina YABE and HANZAWA, Sci. Rep. Tohoku Imp. Univ., ser. 2, (Geol.), vol. 9, 1926, p. 10.

Cyclammina YOKOYAMA, in NAUMANN and NEUMAYR, Denkschr. Akad. Wiss. Wien, vol. 57, 1890, p. 26 (not *Cyclammina* H. B. BRADY).

Test free, early chambers planispiral and completely involute, later chambers uncoiling into a rectilinear series; wall thick, arenaceous with much cement, the peripheral portion labyrinthic; aperture in the adult consisting of numerous rounded pores scattered over the apertural face.

Cretaceous. Japan.

This represents an uncoiled form derived from a *Cyclammina*-like ancestry.

This family includes those arenaceous forms which are planispiral at least in their earlier stages. As end forms, there are developed partially uncoiled chambers, some of them large and with labyrinthic chambers. Most of these reached their highest development in the Cretaceous. Under the name *Endothyra* have been included in the past many forms which it seems should be placed elsewhere. From such forms as *Endothyra* have probably been developed the family of the Fusulinidae.

FAMILY 9. TEXTULARIIDAE

Test in the earliest stages, at least in primitive forms, planispiral, later in all but the most accelerated forms developing a biserial stage, final development taking various forms, usually becoming uniserial in the more specialized types; wall arenaceous, with a varying proportion of cement in different genera and species; aperture typically at the inner margin of the last-formed chamber in the biserial forms, becoming terminal and sometimes multiple in the uniserial forms.

KEY TO THE GENERA

I. A large portion of the early test planispiral, later biserial. *Spiroplectammina.*

II. Test mostly biserial, no uniserial stage.
- A. Attached. .... *Textularioides.*
- B. Free.
  - 1. Aperture simple.
    - a. Chambers not labyrinthic. .... *Textularia.*
    - b. Chambers labyrinthic. .... *Textulariella.*
  - 2. Aperture multiple.
    - a. Apertures in a row at the inner margin, test strongly compressed. .... *Cuneolina.*
    - b. Apertures in the terminal face........... *Cribrostomum.*

III. Test with both biserial and uniserial stages.
- A. Aperture simple.
  - 1. Test not compressed, aperture circular........... *Bigenerina.*
  - 2. Test much compressed, aperture elongate.......... *Vulvulina.*
- B. Aperture multiple, terminal. .... *Climacammina.*

IV. Test wholly uniserial.
- A. Aperture simple.
  - 1. Test not compressed.
    - a. Not distinctly perforate. .... *Monogenerina.*
    - b. Coarsely perforate. .... *Nodosaroum.*
  - 2. Test compressed.
    - a. Bilaterally symmetrical in sections, both sides concave. *Geinitzina.*
    - b. Unequally compressed, one side convex, one concave. *Lunucammina.*
- B. Aperture multiple, terminal. .... *Cribrogenerina.*

Subfamily 1. Spiroplectammininae

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

Genus SPIROPLECTAMMINA Cushman, 1927

Plate 11, figures 1, 2; plate 13, figure 1

Genoholotype, *Textularia agglutinans*, var. *biformis* Parker and Jones

Spiroplectammina CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 3, 1927, p. 23.
Textularia (part) PARKER and JONES (not DEFRANCE), Philos. Trans., vol. 155, 1865, p. 370.
Spiroplecta H. B. BRADY (not EHRENBERG), Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 376.

Test free, early chambers planispiral in both microspheric and megalospheric forms, later ones biserial; wall arenaceous with a yellowish-brown cement; aperture in the planispiral portion at the base of the apertural face, in the biserial portion at the inner margin of the chamber.

Carboniferous to Recent.

This genus represents a simple radicle from which the whole family of the Textulariidae has developed, the biserial portion best thought of as a spiral coiling about an elongate axis, each chamber representing a turn of 180° from the preceding, and two chambers completing a whorl.

Subfamily 2. Textulariinae

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

Genus TEXTULARIA Defrance, 1824

Plate 11, figures 3, 4; plate 13, figure 2

Genoholotype, *Textularia sagittula* Defrance

Textularia DEFRANCE, Dict. Sci. Nat., vol. 32, 1824, p. 177.
Textilaria EHRENBERG, Abhandl. Kais. Akad. Wiss. Berlin, 1839, p. 135.
Plecanium REUSS, Sitz. Akad. Wiss. Wien, vol. 44, 1861 (1862), p. 383 (genotype, by designation, *Textilaria labiata* REUSS).

Grammostomum (part) of authors.

Palaeotextularia SCHUBERT, Pal. Zeitschr., vol. 3, 1920, p. 183 (genotype, by designation, *Textularia jonesi* H. B. BRADY).

Test free, elongate, tapering, usually compressed with the zig-zag line between the chambers on the middle of the flattened sides, early chambers in the microspheric form usually planispirally coiled, later biserial, chambers simple, not labyrinthic; wall arenaceous, the relative amount of cement varying much; aperture, typically an arched slit at the inner margin of the chamber, occasionally in the apertural face.

Cambrian to Recent.

Many things have been included by various authors under *Textularia,* but it should be limited to those biserial species with typically arenaceous tests.

Genus TEXTULARIOIDES Cushman, 1911

Plate 11, figure 5; plate 13, figure 5

Genoholotype, *Textularioides inflata* Cushman

Test similar to *Textularia* but attached, the attached side somewhat flattened.

Recent. Off Japan.

Genus TEXTULARIELLA Cushman, 1927

Plate 11, figures 6-8; plate 13, figure 3

Genoholotype, *Textularia barrettii* Jones and Parker

Textulariella CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 3, 1927, p. 24.

Textularia JONES and PARKER (not DEFRANCE), Rept. British Assoc., 1863, p. 80.

Test similar to *Textularia,* but usually circular in outline and the chambers labyrinthic; wall smoothly finished due to the large proportion of cement.

Cretaceous to Recent.

The species are often of considerable size as is usual in the case of labyrinthic forms.

Genus CUNEOLINA d'Orbigny, 1839

Plate 11, figure 9; plate 13, figure 4

Genoholotype, *Cuneolina pavonia* d'Orbigny

Cuneolina D'ORBIGNY, in DE LA SAGRA, Hist. Fis. Pol. Nat. Cuba, 1839, "Foraminifères", p. 150.

Textularia (part) GOËS (not DEFRANCE), Kongl. Svensk. Vet. Akad. Handl., vol. 19, no. 4, 1882, p. 80.

Test free, similar to *Textularia*, but compressed so that the alternating series of chambers form a zig-zag line on the narrow sides of the test instead of on the broader flattened sides; chambers low and broad, labyrinthic; wall usually smooth, with a large proportion of cement; aperture very elongate, along the

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EXPLANATION OF PLATE 11

TEXTULARIIDAE

FIG.

1, 2. *Spiroplectammina biformis* Parker and Jones. × 15. (After type figures). *a*, front view. *b*, apertural view.

3, 4. *Textularia sagittula* Defrance. Fig. 3, (After type figure). Fig. 4, (After Fornasini). × 18. *a*, front view; *b*, apertural view.

5. *Textularioides inflata* Cushman. × 20. (After type figure). *a*, front view; *b*, apertural view.

6–8. *Textulariella barrettii* (Jones and Parker). (After H. B. Brady). Fig. 6, × 18. *a*, front view; *b*, apertural view. Fig. 7, × 15. Longitudinal section. Fig. 8, × 20. Section of fractured test.

9. *Cuneolina pavonia* d'Orbigny. (After type figure). *a*, front view; *b*, side view; *c*, apertural view.

10–13. *Bigenerina nodosaria* d'Orbigny. Figs. 10, 11, (After type figures). Fig. 11, Section. Figs. 12, 13, (After H. B. Brady). Fig. 12, *a*, front view; *b*, apertural view. × 25. Fig. 13, Section. × 35.

14–16. *Vulvulina pennatula* (Batsch). Figs. 14, 15, (After type figures). Fig. 15, Showing coiled young. Fig. 16, (After H. B. Brady), × 15. *a*, front view; *b*, apertural view.

17, 18. *Climacammina antiqua* H. B. Brady. × 20. (After type figures). Fig. 18, Showing apertures.

19. *Cribrostomum bradyi* Möller. × 40. (After type figure).

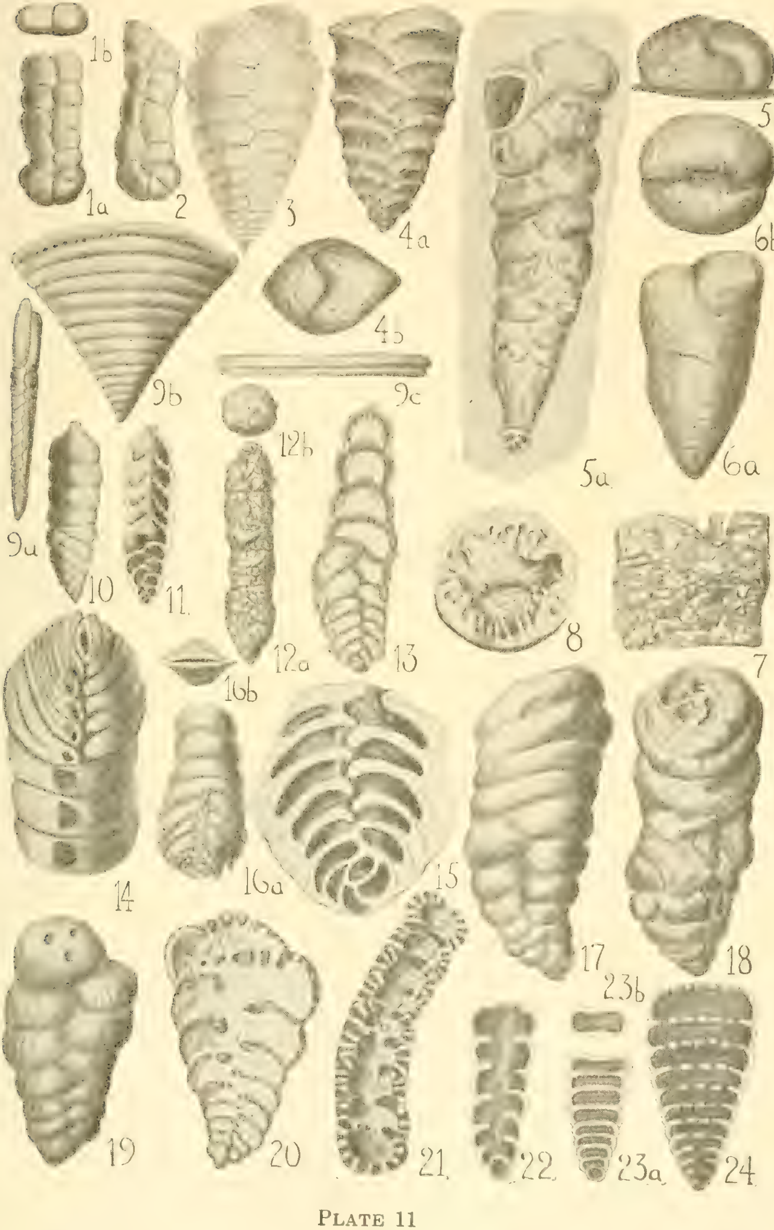
20. *Cribrostomum eximium* Eichwald. × 42. (After Möller). Section.

21. *Nodosaroum index* (Ehrenberg). × 75. (After Möller). Section.

22. *Monogenerina atava* Spandel. × 33. (After type figure). Section.

23. *Geinitzina postcarbonica* Spandel. × 75. (After type figure). *a*, longitudinal section; *b*, transverse section.

24. *Cribrogenerina*. Idealized section.


1b
1a
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3
4a
4b
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5b
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9c
10
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12a
12b
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16a
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23a
23b
24

PLATE 11

base of the inner margin, or consisting of a row of rounded pores.

Cretaceous to Recent.

Genus BIGENERINA d'Orbigny, 1826

Plate 11, figures 10-13; plate 13, figure 9

Genotype, by designation, *Bigenerina nodosaria* d'Orbigny

Bigenerina d'Orbigny, Ann. Sci. Nat., vol. 7, 1826, p. 261.

Gemmulina d'Orbigny, l. c., p. 262 (genotype, *Bigenerina (Gemmulina) digitata* d'Orbigny).

Test free, the early chambers biserial, later ones uniserial in a rectilinear series, not labyrinthic; wall usually thick, arenaceous, usually coarse but often smoothly finished; aperture in the young biserial stage at the base of the inner margin of the chamber, in the adult uniserial stage terminal, rounded or oval, simple.

Carboniferous to Recent.

In the microspheric form the earliest chambers show more or less of the planispiral coiling, but this is not usually found in the megalospheric form.

Genus VULVULINA d'Orbigny, 1826

Plate 11, figures 14-16; plate 13, figure 13

Genotype, by designation, *Vulvulina capreolus* d'Orbigny

Vulvulina d'Orbigny, Ann. Sci. Nat., vol. 7, 1826, p. 264.

Nautilus (part) Batsch, Conch. Seesandes, 1791, no. 13, pl. 4, figs. 13 *a-d*.

Bigenerina (part) of authors (not d'Orbigny).

Schizophora Reuss, Sitz. böhm. Ges. Wiss., vol. 2, 1861, p. 13 (genoholotype, *S. neugeboreni* Reuss).

Grammostomum (part) Parker and Jones (not Ehrenberg), Ann. Mag. Nat. Hist., ser. 3, vol. 11, 1863, p. 93.

Venilina Gümbel, Abhandl. Kön. bay. Akad. Wiss., Cl. II, vol. 10, 1868, p. 647 (genotype, by designation, *V. nummulina* Gümbel).

Textilaria (part) Gümbel (not Defrance), l. c., p. 647.

Trigenerina Schubert, Verhandl. k. k. Geol. Reichs., 1902, p. 84 (genotype, *Vulvulina capreolus* d'Orbigny).

Test free, much compressed throughout, early stages biserial, or slightly coiled in the microspheric form, later chambers uniserial, simple; wall finely arenaceous with a large proportion of cement; aperture elongate, elliptical, simple, terminal.

Eocene to Recent.

Genus MONOGENERINA Spandel, 1901

Plate 11, figure 22; plate 13, figure 10

Genotype, by designation, *Monogenerina atava* Spandel

Monogenerina SPANDEL, Festschr. nat. ges. Nürnberg, 1901, p. 181.

Test free, elongate, cylindrical or slightly arcuate, tapering from the initial end; chambers uniserial except occasionally biserial in the earliest stages of the microspheric form, simple; wall finely arenaceous with much cement, smoothly finished; aperture rounded, terminal, simple.

Carboniferous and Permian.

Genus GEINITZINA Spandel, 1901

Plate 11, figure 23; plate 13, figure 11

Genotype, by designation, *Textularia cuneiformis* Jones (not d'Orbigny)

Geinitzina SPANDEL, Festschr. nat. ges. Nürnberg, 1901, p. 15.

Geinitzella SPANDEL, Verlag-Instit., "General Anzeiger", Nürnberg, 1898, p. 7.

Textularia (part) JONES (not DEFRANCE), in MANTELL, Quart. Journ. Geol. Soc., vol. 6, 1850, p. 330.

Test very similar to *Monogenerina* but much compressed, the sides concave in some species, and the aperture elongate.

Carboniferous and Permian.

Genus LUNUCAMMINA Spandel, 1898

Plate 54, figure 14

Genotype, by designation, *Lunucammina permiana* Spandel

Lunucammina SPANDEL, Verlag-Instit., "General Anzeiger", Nürnberg, 1898, p. 8.

Frondicularia (part) of authors.

Similar in general to *Geinitzina* but one broad side concave, the other convex, the aperture small, rounded, nearer the concave side at the end of the test.

Permian to Jurassic.

Genus NODOSAROUM Rhumbler, 1913

Plate 11, figure 21; plate 13, figure 12

Genotype, by designation, *Nodosaria index* Ehrenberg

Nodosaroum RHUMBLER, Foram. Plankton-Exped., pt. 2, 1913, p. 443.

Nodosaria (part) EHRENBERG (not LAMARCK), Mikrogeologie, 1854, pl. 37, xi, figs. A-D, 10.

Nodosinella (part) MÖLLER (not H. B. BRADY), Mém. Acad. Imp. Sci. St. Petersbourg, ser. 7, vol. 27, no. 5, 1879, p. 74.

Test uniserial throughout; wall arenaceous and coarsely perforate; aperture relatively large, rounded, simple, terminal.

Carboniferous.

Genus CRIBROSTOMUM Möller, 1879

Plate 11, figures 19, 20; plate 13, figure 6

Genotype, by designation, *Cribrostomum textulariforme* Möller

Cribrostomum MÖLLER, Mém. Acad. Imp. Sci. St. Petersbourg, ser. 7, vol. 27, no. 5, 1879, p. 39.

Textularia (part) H. B. BRADY (not DEFRANCE), Pal. Soc., vol. 30, 1876, p. 132.

Moellerina EIMER and FICKERT, Zeitschr. Wiss. Zool., vol. 65, 1899, p. 677 (genotype, by designation, *Cribrostomum gracile* MÖLLER).

Test composed of chambers biserially arranged; wall finely arenaceous, perforate; apertures in the early portion as in *Textularia*, later becoming multiple and with a cribrate terminal face to the chamber.

Carboniferous to Permian.

Genus CLIMACAMMINA H. B. Brady, 1876

Plate 11, figures 17, 18; plate 13, figure 7

Genoholotype, *Climacammina antiqua* H. B. Brady

Climacammina H. B. BRADY, Pal. Soc. Mon., vol. 30, 1876, p. 67.

Moellerina EIMER and FICKERT (not SCHELLWIEN), Zeitschr. Wiss. Zool., vol. 65, 1899, p. 605.

Test in the early stages composed of chambers biserially arranged, later becoming uniserial; wall finely arenaceous and perforate; aperture in the early stages simple as in *Textularia*, then becoming cribrate in the adult.

Carboniferous to Permian. Tertiary and Recent (?).

The "*Bigenerina robusta* H. B. Brady" (Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 371, pl. 45, figs, 9-16) and some Tertiary species have essentially the characters of *Climacammina*, but there seems to be a very wide gap where no representatives of the genus are known if these are the same as the Palaeozoic forms.

Genus CRIBROGENERINA Schubert, 1907

Plate 11, figure 24; plate 13, figure 8

Genoholotype, *Bigenerina sumatrana* Volz

Cribrogenerina SCHUBERT, Neues Jahrb. für Min, Beil. Bd. 25, 1907, p. 245.

Test typically uniserial throughout unless the earliest chambers in the microspheric form are biserial; wall finely arenaceous; aperture in the early chambers simple, in later ones cribrate, in a terminal plate.

Carboniferous and Permian.

This family is directly derived from a planispiral ancestry such as the Lituolidae by the addition of the biserial character resulting from an elongate spiral settling down to a turn of 180° for each chamber. In the more primitive genera, the early stages in the microspheric form show the planispirally 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 forms to be possibly from a distinct ancestry.

For a further discussion of this family and the two following ones, see Cushman, Phylogenetic Studies of the Foraminifera, Part II, (Amer. Journ. Sci., vol. xiv, 1927, pp. 317-324).

FAMILY 10. VERNEUILINIDAE

Test, at least in the early stages, triserial, later biserial in some genera and in most specialized ones becoming uniserial; wall arenaceous, the amount of cement varying in different genera and species; aperture simple or multiple.

KEY TO THE GENERA

I. Test triserial throughout.
  A. Generally rounded in section, aperture at the margin of the chamber. .... *Verneuilina.*
  B. Sharply angled in section, aperture terminal............ *Tritaxia.*

II. Early stages triserial, adult biserial.
  A. Aperture at or near the base of the chamber margin.... *Gaudryina.*
  B. Aperture terminal, with a neck.................. *Heterostomella.*

III. Early stages triserial, adult uniserial.
  A. Chambers simple. .... *Clavulina.*
  B. Chambers labyrinthic or divided..................... *Tritaxilina.*

EXPLANATION OF PLATE 12

Verneuilinidae, Valvulinidae

Fig.

1. *Verneuilina tricarinata* d'Orbigny. (After type figure). *a*, side view; *b*, apertural view.

2, 3. *Verneuilina propinqua* H. B. Brady. (After type figures). Fig. 2, Front view. × 15. Fig. 3, Apertural view. × 10.

4, 5. *Tritaxia tricarinata* Reuss. (After type figures).

6. *Gaudryina rugosa* d'Orbigny. (After type figure). *a*, side view; *b*, apertural view.

7. *Gaudryina subrotunda* Schwager. × 15. (After H. B. Brady). *a*, side view; *b*, apertural view.

8. *Heterostomella rugosa* (d'Orbigny). (After type figure). *a*, side view; *b*, apertural view.

9–11. *Tritaxilina caperata* (H. B. Brady). × 10. (After type figures). Fig. 10, Longitudinal section. Fig. 11, Transverse section.

12. *Clavulina angularis* d'Orbigny. (After type figure).

13, 14. *Clavulina communis* d'Orbigny. (After H. B. Brady). Fig. 13, *a*, side view; *b*, apertural view. × 15. Fig. 14, Longitudinal section. × 20.

15. *Clavulina parisiensis* d'Orbigny. (After d'Orbigny's Model).

16. *Valvulina triangularis* d'Orbigny. (After d'Orbigny's Model). *a*, side view; *b*, apertural view.

17. *Arenobulimina presli* (Reuss). (After Reuss). *a*, side view showing aperture; *b*, reverse side.

18–20. *Ataxophragmium variabile* (d'Orbigny). (After type figures). Fig. 18, *a*, side showing aperture; *b*, reverse side. Fig. 19, Specimen with aperture nearly closed at edge. Fig. 20, With aperture withdrawn from edge.

21, 22. *Cribrobulimina mixta* (Parker and Jones). × 20. Fig. 21, Specimen with simple aperture. Fig. 22, Specimen with complex aperture.

23, 24. *Lituonella roberti* Schlumberger. × 5. (After type figures). *a*, side view; *b*, front view; *c*, apertural view.

25, 26. *Lituonella liburnica* Schubert. Fig. 25, (After type figure). × 10. Fig. 26, × 8. *a*, side view; *b*, apertural view.

27. *Coskinolina liburnica* Stache. × 7. (After Schubert). *a*, side view; *b*, apertural view.


1b
3
4a
4b
5b
6b
7b
5a
6a
1a
2
12
b
13
14
15
7a
8b
9b
10
13a
16b
11
17a
8a
9a
20
21
17b
16a
18a
18b
19
23b
24
26b
27b
22
23a
23c
25
26a
27a

PLATE 12

EXPLANATION OF PLATE 13

Textulariidae, Verneuilinidae, Valvulinidae

Fig.

1. *Spiroplectammina 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. *Geinitzina postcarbonica* Spandel. (After Spandel). Sections. *a*, longitudinal; *b*, transverse.
12. *Nodosaroum lahuseni* (Möller). (After Möller). Sections. *a*, longitudinal; *b*, transverse.
13. *Vulvulina pennatula* (Batsch). (After H. B. Brady). *a*, front view; *b*, end view.
14. *Verneuilina 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.

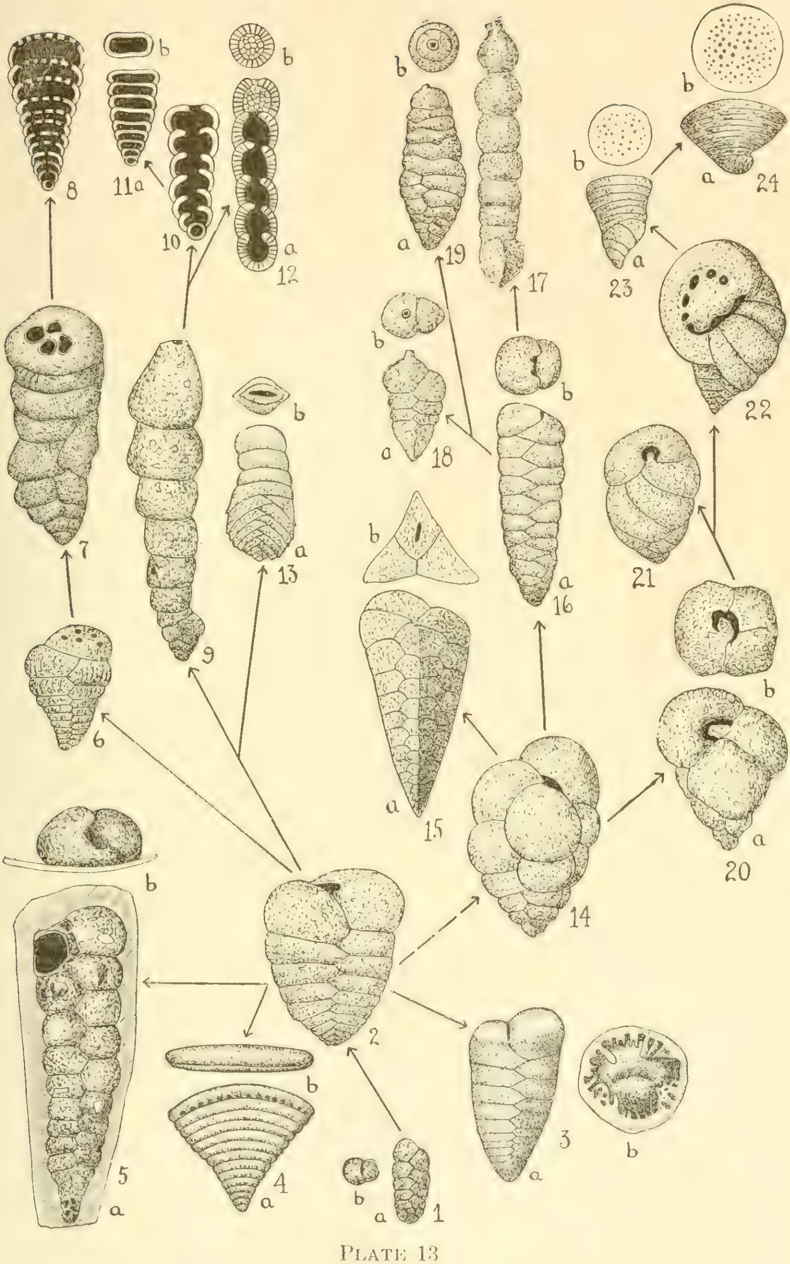

PLATE 13

Genus VERNEUILINA d'Orbigny, 1840

Plate 12, figures 1-3; plate 13, figure 14

Genoholotype, *Verneuilina tricarinata* d'Orbigny

Verneuilina D'ORBIGNY, Mém. Soc. Géol. France, ser. 1, vol. 4, 1840, p. 39.
Bulimina (part) of authors.
Polymorphina (part) SCHULTZE, Organ. Polythal., 1854, p. 61.
Textularia (part) of authors.

Test usually free, sometimes attached, more or less elongate, tapering, transverse section rounded or triangular; chambers spirally arranged with three chambers making a whorl and the chambers arranged in three vertical columns; wall arenaceous; aperture, a low opening at the base of the inner margin of the chamber.

Lower Cretaceous to Recent.

Genus TRITAXIA Reuss, 1860

Plate 12, figures 4, 5; plate 13, figure 15

Genoholotype, *Tritaxia tricarinata* Reuss

Tritaxia REUSS, Sitz. Akad. Wiss. Wien, vol. 40, 1860, p. 228.
Textularia (part) REUSS, Verst. Böhm. Kreid., pt. 1, 1845, p. 39.

Test triserial, usually triangular in transverse section; wall arenaceous, often with much cement and smoothly finished; aperture, an elongate opening at the base of the margin of the chamber, becoming rounded and terminal in some species.

Lower Cretaceous to Recent (?).

Genus GAUDRYINA d'Orbigny, 1839

Plate 12, figures 6, 7; plate 13, figure 16

Genotype, by designation, *Gaudryina rugosa* d'Orbigny

Gaudryina D'ORBIGNY, in DE LA SAGRA, Hist. Fis. Pol. Nat. Cuba, 1839, "Foraminifères", p. 109.

Test in the early stages triserial, later biserial, transverse section angled or rounded; wall coarsely or finely arenaceous often with a large proportion of cement; aperture, typically a low opening at the base of the inner margin of the chamber, or in the wall of the apertural face.

Lower Cretaceous to Recent.

Genus HETEROSTOMELLA Reuss, 1865

Plate 12, figure 8; plate 13, figure 18

Genotype, by designation, *Gaudryina siphonella* Reuss

Heterostomella REUSS, Sitz. Akad. Wiss. Wien, vol. 52, pt. 1, 1865, p. 448.
Gaudryina (part) REUSS, Zeitschr. deutsch. Geol. Ges., vol. 3, 1851, p. 78 (and later authors).
Plectina MARSSON, Mitth. Nat. Ver. Neu-Vorpommern u Rügen, Jahrg. 10, 1878, p. 160 (genotype, by designation, *Gaudryina ruthenica* REUSS).

Test with at least the early stages triserial, later biserial; wall arenaceous; aperture in the young as in *Gaudryina*, later with a terminal aperture with a neck and occasionally a slight lip.

Cretaceous to Recent.

Genus TRITAXILINA Cushman, 1911

Plate 12, figures 9-11; plate 13, figure 19

Genoholotype, *Clavulina caperata* H. B. Brady

Tritaxilina CUSHMAN, Bull. 71, U. S. Nat. Mus., pt. 2, 1911, p. 71.
Clavulina (part) H. B. BRADY, Quart. Journ. Micr. Sci., vol. 21, 1881, p. 54 (not D'ORBIGNY, 1826).
Tritaxia (part) H. B. BRADY, Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 390 (not REUSS, 1860).
Clavulinella SCHUBERT, Pal. Zeitschr., vol. 3, 1920, p. 181 (genoholotype, *Clavulina caperata* H. B. BRADY).

Test in its early stage triserial, later becoming biserial and finally uniserial; chambers numerous, distinct, interior labyrinthic; wall arenaceous; aperture, in the early stages, a narrow opening at the base of the inner margin of the chamber, later becoming terminal and central, with a slight lip, usually with a series of peripheral teeth projecting in and partially closing the opening.

Eocene to Recent.

Genus CLAVULINA d'Orbigny, 1826

Plate 12, figures 12-15; plate 13, figure 17

Genotype, by designation, *Clavulina parisiensis* d'Orbigny

Clavulina D'ORBIGNY, Ann. Sci. Nat., vol. 7, 1826, p. 268.
Verneuilina (part) of authors.

Valvulina (part) of authors.
Tritaxia (part) of authors.

Test elongate, cylindrical or angled, early portion consisting of chambers arranged triserially, in most species quickly followed by a uniserial series, but in some primitive species with a biserial stage between; wall arenaceous; aperture, in the early stages, a simple opening at or near the inner margin, later becoming terminal, often with a neck, in some species with an apertural tooth.

Cretaceous to Recent.

This family is very closely related to and derived from the biserial Textulariidae. The triserial character is shoved back by acceleration, 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 annular; chambers simple or in the higher forms labyrinthic; aperture simple or cribrate.

KEY TO THE GENERA

I. Test coiled throughout.
  A. Triserial throughout. ....*Valvulina*.
  B. Early stage triserial, later several chambers in a whorl.
    1. Aperture simple.
      a. Aperture at the margin of the chamber....*Arenobulimina*.
      b. Aperture extending into or included in the face. *Ataxophragmium*.
    2. Aperture cribrate. ....*Cribrobulimina*.
  C. Later chambers annular, test conical.
    1. Test elongate, early stages prominent.............*Lituonella*.
    2. Test broad, early stages inconspicuous..........*Coskinolina*.

Genus VALVULINA d'Orbigny, 1826

Plate 12, figure 16; plate 13, figure 20

Genotype, by designation, *Valvulina triangularis* d'Orbigny

Valvulina d'Orbigny, Ann. Sci. Nat., vol. 7, 1826, p. 270.
Rotalina (part) Williamson, Rec. Foram. Great Britain, 1858, p. 55.

Test triserial, conical, umbilicate, usually attached; wall arenaceous, usually fairly smooth and with much cement; aperture at the inner margin of the chamber with a simple valvular tooth.

Carboniferous to Recent.

Genus ARENOBULIMINA Cushman, 1927

Plate 12, figure 17; plate 13, figure 21

Genoholotype, *Bulimina presli* Reuss

Arenobulimina CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 2, 1927, p. 80.

Bulimina (part) REUSS, Verstein. Böhm. Kreide, 1845-46, pt. 1, p. 38, (and later authors).

Test with the earlier chambers triserial, the angles rounded, later chambers spirally arranged with many chambers to a whorl, close coiled; wall finely arenaceous usually with a large proportion of cement and smoothly finished; aperture with a broad rounded tooth.

Cretaceous.

Genus ATAXOPHRAGMIUM Reuss, 1861

Plate 12, figures 18-20

Genotype, by designation, *Bulimina variabilis* d'Orbigny

Ataxophragmium REUSS, Verz. Gypsmodellen Foraminiferen, (1861) nos. 8, 9.

Bulimina (part) D'ORBIGNY, Mém. Soc. Géol. France, ser. 1, vol. 4, 1840, p. 40, (and later authors).

Test in the very early portion triserial, later with a spreading coil of several chambers; wall arenaceous with much cement; aperture extending in from the edge in young until in the adult it may become enclosed in the apertural face.

Cretaceous.

Genus CRIBROBULIMINA Cushman, 1927

Plate 12, figures 21, 22; plate 13, figure 22

Genoholotype, *Valvulina mixta* Parker and Jones

Cribrobulimina CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 2, 1927, p. 80.

Valvulina (part) PARKER and JONES, in CARPENTER, PARKER and JONES, Introd. Foram., 1862, p. 146.

Test in the early stages trihedral, angled, the sides flattened; chambers triserially arranged, adult chambers in a loose spiral, five or more in a coil; wall arenaceous with much cement; aperture in the young as in *Valvulina* later developing an opening in the plate-like tooth and in the adult a series of small openings forming a cribrate plate.

Tertiary and Recent.

Genus LITUONELLA Schlumberger and H. Douvillé

Plate 12, figures 23-26; plate 13, figure 23

Genoholotype, *Lituonella roberti* Schlumberger

Lituonella SCHLUMBERGER and H. DOUVILLÉ, Bull. Soc. Géol. France, ser. 4, vol. 5, 1905, p. 297.

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 increased surface divisions; aperture cribrate, on the flattened face.

Eocene.

Genus COSKINOLINA Stache, 1875

Plate 12, figure 27; plate 13, figure 24

Genoholotype, *Coskinolina liburnica* Stache

Coskinolina STACHE, Verh. k. k. Geol. Reichs., 1875, p. 335.

Test conical, the early chambers at least in the microspheric form consisting of chambers in a low spiral, later with the chambers forming annuli, roughly divided into chamberlets; wall finely arenaceous with much cement; aperture cribrate on the flattened outer face of the chamber.

Eocene.

This family forms a distinct group which if it were not for the intermediate stages and those shown in the microspheric form of the more complex genera would hardly be supposed to have been derived from the Verneuilinidae and Textulariidae. It is only by the study of the young of the microspheric form of such types as *Lituonella* and *Coskinolina* that their relationships to the other members of the family may be seen. The superficial resemblance to the Buliminidae has caused some of the genera to be placed with that group by some of the earlier workers.

FAMILY 12. FUSULINIDAE

I am greatly indebted to my friend, Professor Yoshiaki Ozawa, for writing the part on this family and for choosing the illustrations.

Test bilaterally symmetrical, entirely involute; wall composed essentially of two layers, imperforate median lamella on the exterior and perforate mesh-structure on the interior; aperture, a single elongate slit, or row of rounded openings, at the basal margin of the apertural face.

Subfamily 1. Fusulininae

Test lenticular to fusiform; wall and septa in primitive forms with deposition or supplementary layers on both their sides and mesh-structure obsolete; aperture single.

Genus STAFFELLA Ozawa, 1925

Plate 14, figure 1

Genoholotype, *Fusulina sphaerica* Abich

Staffella OZAWA, Journ. Coll. Sci. Imp. Univ. Tokyo, vol. 45, art. 4, 1925, p. 24.

Fusulina (part) ABICH, Mém. Acad. Imp. Sci., St. Pétersbourg, ser. 6, vol. 7, 1859, p. 418.

Fusulinella (part) MÖLLER, l. c., ser. 7, vol. 25, no. 9, 1878, p. 114.

Fusulinella STAFF, Neues Jahrb., Beil. Bd. 27, 1909, p. 486 (not of MÖLLER).

Test lenticular or spheroidal; axis of the volutions making the smaller diameter; wall composed of median lamella, mesh-structure and deposition layers, of which the mesh-structure is often indistinct or obsolete, septa almost plane and pierced by a relatively large, single buccal aperture.

Carboniferous to Permian.

Genus FUSULINELLA Möller, 1878

Plate 14, figures 2, 3

Genotype, by designation, *Fusulinella bocki* Möller

Fusulinella (part) MÖLLER, Mém. Acad. Imp. Sci. St. Pétersbourg, ser. 7, vol. 25, no. 9, 1878, p. 101.

Schubertella STAFF and WEDEKIND, Bull. Geol. Inst. Univ. Upsala, vol. 10, 1910, p. 121.
Girtyina STAFF, Paleontographica, vol. 59, 1912, p. 164.
Neofusulinella (part) DEPRAT, C. R. Acad. Sci., vol. 154, 1912, p. 548.
Fusulinella OZAWA, Journ. Coll. Sci. Imp. Univ. Tokyo, vol. 45, pt. 4, 1925, p. 24.

Test fusiform; wall and septa composed of median lamella and well developed deposition layers, mesh-structure obscured; septa strongly folded or almost not at all; aperture single, large, no septal perforation.

Carboniferous to Permian.

Genus FUSULINA Fisher v. Waldheim, 1829

Genotype, by designation, *Fusulina cylindrica* Fischer v. Waldheim

Fusulina FISCHER V. WALDHEIM, Bull. Soc. Imp. Nat. Moscou, vol. 1, 1829, p. 330.

Test globular, fusiform or cylindrical; earlier whorls almost symmetrical; wall composed essentially of thin lamella and mesh-structure, deposition layers rarely developed; septal perforation present or absent.

Carboniferous to Permian.

EXPLANATION OF PLATE 14

FUSULINIDAE

FIG.

1. *Staffella yobarensis* Ozawa. × 30. Section modified from type figure.

2, 3. *Fusulinella itoi* Ozawa. Fig. 2, Longitudinal section modified from type figure. × 30. Fig. 3, Transverse section modified from type figure. × 25.

4, 5. *Fusulina prisca* (Ehrenberg). × 10. Fig. 4, Transverse section, modified from Ozawa's figure. Fig. 5, Longitudinal section, (After Ozawa). 5*a*, central portion modified.

6–8. *Schwagerina princeps* (Ehrenberg). × 9. Figs. 6, 7, (After Schwager). Fig. 6, Transverse section. Fig. 7, Longitudinal section. Fig. 8, (After Beede and Kniker), Transverse section.

9, 10. *Depratella phairayensis* (Colani). × 25. (After Ozawa). Fig. 9, Transverse section. Fig. 10, Longitudinal section.

11, 12. *Verbeekina claudiae* (Deprat). × 12. (After Ozawa). Fig. 11, Transverse section; 11*a*, detail. Fig. 12, Longitudinal section, 12*a*, detail.

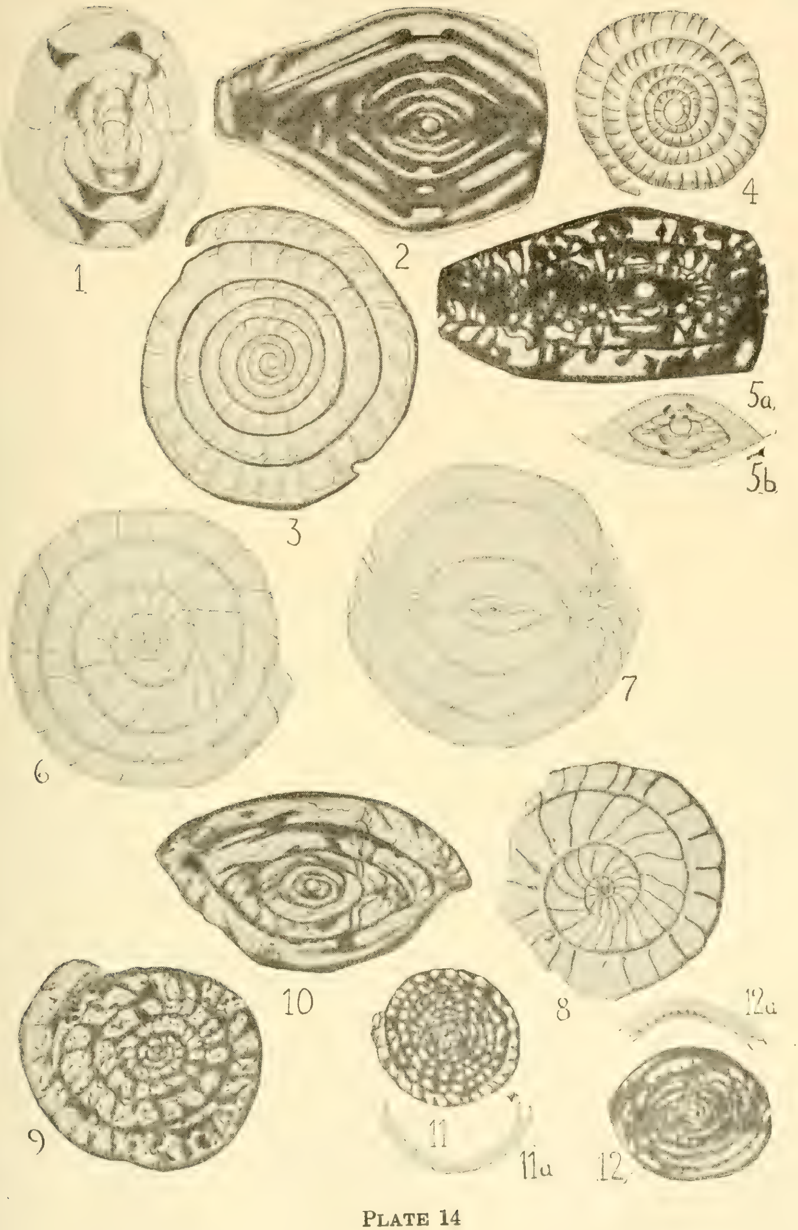

Plate 14

Subgenus FUSULINA s. str.

Plate 14, figures 4, 5

Subgenotype, by designation, *Fusulina cylindrica* Fischer v. Waldheim

Fusulina MÖLLER, Mém. Acad. Imp. Sci. St. Pétersbourg, ser. 7, vol. 25, no. 9, 1878, p. 51.

Melonia, Borelis and *Alveolina* (part) EHRENBERG, Bericht. k. preuss. Akad. Wiss. Berlin, 1842, p. 74, and Mikrogeologie, 1854.

Hemifusulina MÖLLER, Mém. Acad. Imp. Sci. St. Pétersbourg, ser. 7, vol. 25, no. 9, 1878, p. 76.

Triticites GIRTY, Amer. Journ. Sci., vol. 17, 1904, p. 234.

Schellwienia STAFF and WEDEKIND, Bull. Geol. Inst. Univ. Upsala, vol. 10, 1910, p. 113.

Paleofusulina DEPRAT, C. R. Acad. Sci., vol. 154, 1912, p. 1548.

Grabauina J. S. LEE, Bull. Geol. Soc. China, vol. 3, 1924, p. 51.

Test globular, fusiform or cylindrical; wall and septa rather thick and mesh-structure generally distinct, deposition layers often partly developed; septal perforation present or absent.

Carboniferous to Permian.

Subgenus SCHWAGERINA Möller

Plate 14, figures 6-8

Subgenotype, *Borelis princeps* Ehrenberg

Schwagerina MÖLLER, Neues Jahrb., 1877, p. 143.

Borelis (part) EHRENBERG, Bericht. k. preuss. Akad. Wiss. Berlin, 1842, p. 274 (not of MONTFORT).

Test globular or fusiform; wall thin, 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 single, septal perforation usually present.

Carboniferous to Permian.

Genus DEPRATELLA Ozawa, 1928

Plate 14, figures 9, 10

Genoholotype, *Neofusulinella phairayensis* Colani

Depratella OZAWA, Contr. Cushman Lab. Foram. Res., vol. 4, 1928, p. 9.

Neofusulinella (part) DEPRAT, Mém. Serv. Geol. Indochine, vol. 5, 1915.

Neofusulinella OZAWA, Journ. Coll. Sci. Imp. Univ. Tokyo, vol. 45, pt. 4, 1925, p. 24.

Schubertella LANGE (not STAFF and WEDEKIND), Verh. Geol. Mjn. Gen. Nederland, Geol. Ser., vol. 7, 1925, p. 254.

Test globular or fusiform, generally very small, the longest axis lying in the axis of the whorls; early volutions endothyrian, spherical and asymmetrical; wall thin and mesh-structure often obsolete, deposition layers rarely developed; septa almost plane; buccal aperture relatively large, no septal perforations.

Permian.

This may be directly derived from *Endothyra.*

Subfamily 2. Verbeekininae

Test spheroidal 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.

Permian.

Genus VERBEEKINA Staff, 1909

Plate 14, figures 11, 12

Genotype, *Fusulina verbeeki* Geinitz

Verbeekina STAFF, Neues Jahrbuch, Beil. Bd. 27, 1909, p. 476.
Fusulina GEINITZ (not MÖLLER), Paleontographica, vol. 22, 1876, p. 400.
Schwagerina (part) MÖLLER, Mém. Acad. Imp. Sci. St. Pétersbourg, ser. 7, vol. 27, no. 5, 1879, p. 73.
Möllerina (part) SCHELLWIEN, Paleontographica, vol. 44, 1898, p. 258.
Doliolina (part) SCHELLWIEN, in FUTTERER'S "Durch Asien", vol. 3, 1902.

Test spheroidal to ellipsoidal, earlier volutions like *Endothyra;* wall composed of thin lamella and mesh-structure; basal skeletons indistinct in earlier whorls.

Permian.

Genus DOLIOLINA Schellwien, 1902

Plate 15, figures 1, 2

Genotype, *Schwagerina lepida* Schwager

Doliolina (part) SCHELLWIEN, in FUTTERER'S "Durch Asien", vol. 3, 1902, p. 125.
Doliolina STAFF, Neues Jahrb. Beil. Bd. 27, 1909, p. 476.
Möllerina SCHELLWIEN, Paleontographica, vol. 44, 1898, p. 258.
Schwagerina (part) SCHWAGER, in RICHTOFEN'S China, vol. 4, 1883, p. 138.

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

Permian.

Genus NEOSCHWAGERINA Yabe, 1903

Genotype, *Schwagerina craticulifera* Schwager

Neoschwagerina YABE, Journ. Geol. Soc. Tokyo, vol. 10, 1903.

Schwagerina (part) SCHWAGER, in RICHTOFEN'S China, vol. 4, 1883, p. 140.

Test globular or fusiform; whorls numerous, generally more than ten, early whorls spheroidal and closely resembling those of the genus *Verbeekina;* primary meridional and primary equatorial septa always present, false septa often well developed; wall and primary septa composed of thin lamella and mesh-structure.

Permian.

Subgenus NEOSCHWAGERINA s. str.

Plate 15, figures 5-7

Subgenotype, *Schwagerina craticulifera* Schwager

Neoschwagerina OZAWA, Journ. Fac. Imp. Univ. Tokyo, ser. 2, vol. 2, pt. 3, 1927, p. 161.

Schwagerina (part) SCHWAGER, in RICHTOFEN'S China, vol. 4, 1889, p. 140.

EXPLANATION OF PLATE 15

FUSULINIDAE

FIG.

1, 2. *Doliolina lepida* (Schwager). (After Schwager). Fig. 1, Longitudinal section. Fig. 2, Transverse section.

3, 4. *Cancellina primigena* Hayden. × 30. (Modified from Ozawa). Fig. 3, Transverse section. Fig. 4, Longitudinal section; 4*a*, detail.

5. *Neoschwagerina craticulifera* (Schwager). × 10. (After Ozawa). Fig. 5, Longitudinal section. 5*a*, detail.

6. *Neoschwagerina minoensis* Deprat. × 10. (After Ozawa). Fig. 6, Transverse section. 6*a*, detail.

7. *Neoschwagerina katoi* Ozawa. × 25. (After Ozawa). Part of section.

8, 9. *Sumatrina annae* Volz. × 10. (After Hayden). Fig. 8, Longitudinal section. 8*a*, detail. Fig. 9, Idealized transverse section.

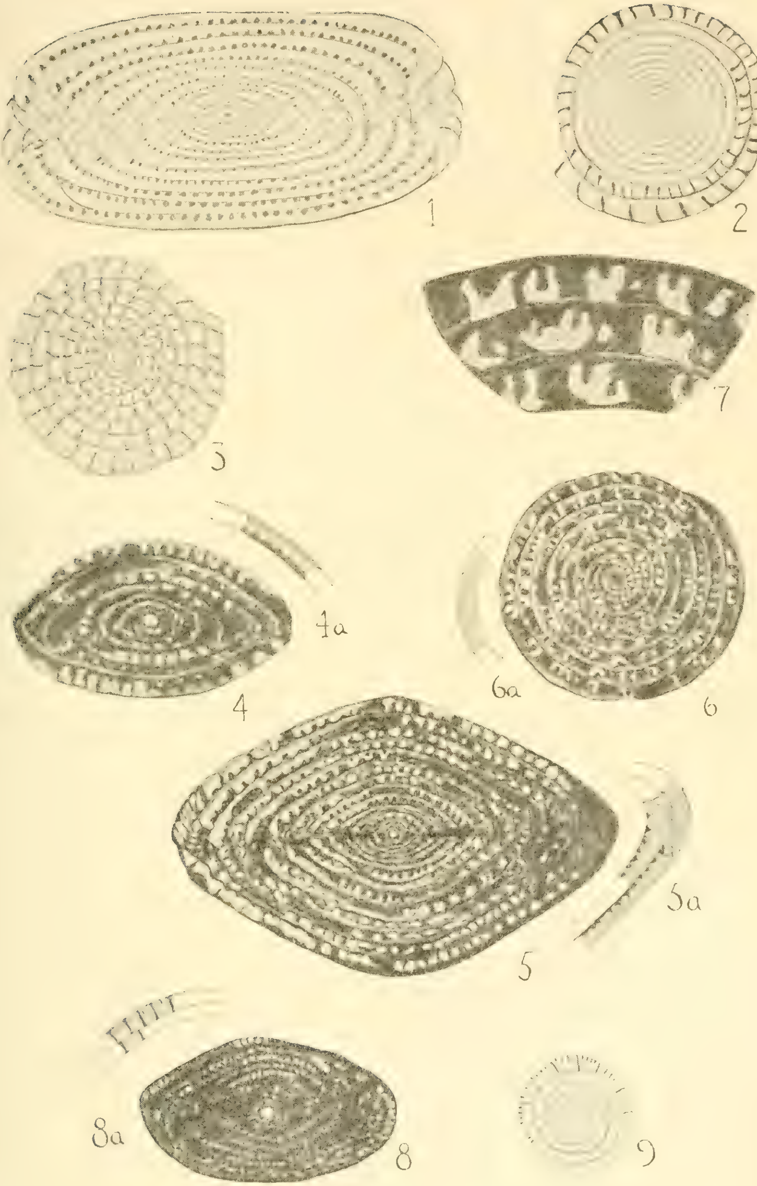

PLATE 15

Möllerina (part) SCHELLWIEN, Paleontographica, vol. 44, 1898, p. 258.
Doliolina (part) SCHELLWIEN, in FUTTERER'S "Durch Asien", vol. 3, 1903, p. 125.
Yabeina DEPRAT, Mém. Serv. Geol. Indochine, vols. 1-3, 1912.

Test large, spheroidal to fusiform, whorls numerous, always more than twelve in adult specimens; septa and wall rather thick, but in advanced forms conspicuously slender.

Permian.

Subgenus CANCELLINA Hayden, 1909

Plate 15, figures 3, 4

Subgenotype, *Cancellina primigena* Hayden

Cancellina HAYDEN, Rec. Geol. Surv. India, vol. 38, 1909, p. 244.—OZAWA, Journ. Fac. Sci. Imp. Univ. Tokyo, ser. 2, vol. 2, pt. 3, 1927, p. 161.
Doliolina (part) DEPRAT, Mém. Serv. Geol. Indochine, vol. 2, 1913.

Test small, ellipsoidal to fusiform; whorls not numerous, generally less than thirteen in adult specimens; septa and wall rather thin.

Permian.

Genus SUMATRINA Volz, 1904

Plate 15, figures 8, 9

Genotype, *Sumatrina annae* Volz

Sumatrina VOLZ, Geol. Pal. Abhandl., Bd. 10, 1904, p. 98.—OZAWA, Journ. Coll. Sci. Imp. Univ. Tokyo, vol. 45, pt. 4, 1925, p. 25.
Neoschwagerina (part) YABE, Journ. Coll. Sci. Imp. Univ. Tokyo, vol. 21, art. 5, 1906.

Test cylindrical; mesh-structure obscurbed, four kinds of septa well developed; central chamber spherical; wall with median lamella and mesh-structure.

Upper Permian.

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 in the younger Visean time, but no species evidently ascribable to the group has been reported in the Lower Carboniferous.

With the beginning of the Upper Carboniferous, one line of the group—Fusulininae, developed with great rapidity. In Spitzbergen, Russia, Southern Europe, North America and especially in Asia, there have been found very many species of the genera and subgenera of the Fusulininae with the exception of *Depratella*, which is found only in the Permian.

With the Permian a great change in the Fusulinidae occurred. All the Carboniferous genera have come to a decline and are replaced by a new group—Verbeekininae, derived directly from *Endothyra*. The Verbeekininae having complex structure are envolved rapidly in the Permian, therefore they are very useful for precise age determinations (see Ozawa's paper, Journ. Fac. Sci. Imp. Univ. Tokyo, ser. 2, vol. 2, pt. 3, 1927). They have been found only in Southern Europe and Asia.

FAMILY 13. LOFTUSIIDAE

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

Genus LOFTUSIA H. B. Brady, 1869

Plate 16, figure 1

Genoholotype, *Loftusia persica* H. B. Brady

Loftusia H. B. Brady, in Carpenter and H. B. Brady, Phil. Trans., 1869, p. 721.

Test fusiform, coiled about the elongate axis; chambers of the early portion more rounded, later with the axis greatly increasing in length, interior labyrinthic; wall arenaceous; apertures near the base along the apertural face of the chamber.

Eocene.

This is one of the largest of the foraminifera. Beautifully sectioned specimens studied at the British Museum show that the early stages are much more compressed along the line of the axis and indicate that this family is the outgrowth of such a form as *Cyclammina* by the elongation of the axis similar to the development of the Fusulinidae from such forms as *Endothyra*. It has been the usual custom to bring *Parkeria* in close relationship with *Loftusia*. Excellent sections of *Parkeria* in the British Museum and at Cambridge seem to show that the structure is very different.

FAMILY 14. NEUSINIDAE

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

Genus NEUSINA Goës, 1892

Plate 16, figures 2-4

Genoholotype, *Neusina agassizii* Goës

Neusina GOËS, Bull. Mus. Comp. Zoöl., vol. 23, 1892, p. 195.

Test in the early stages irregularly planispiral, later uncoiled and very much compressed and of varying shape; wall arenaceous with much chitin, flexible, with root-like processes of chitin from portions of the periphery; apertures numerous, along the periphery of the chamber.

Recent. Pacific.

EXPLANATION OF PLATE 16

LOFTUSIDAE, NEUSINIDAE, SILICINIDAE

FIG.

1. *Loftusia persica* H. B. Brady. × 1. (After type figure).

2–4. *Neusina agassizi* Goës. Figs. 2, 3 (After type figures). Fig. 2, × ¼. Fig. 3, Transverse section. × 8. Fig. 4, Specimen showing coiled young. × ⅔.

5–7. *Botellina labyrinthica* H. B. Brady. × 7. (After type figures). Fig. 6, Longitudinal section. Fig. 7, Transverse section.

8–10. *Botellina pinnata* Pearcey. (After type figures). Figs. 8, 9, About natural size. Fig. 10, Longitudinal section. × 3.

11–14. *Jullienella foetida* Schlumberger. (After type figures). Figs. 11, 12, × ⅔. Fig. 13, Transverse section. × 8. Fig. 14, Longitudinal section of tip. × 8.

15. *Rzehakina epigona* (Rzehak). (After type figure). *a*, side view; *b*, peripheral view; *c*, section.

16. *Silicina limitata* (Terquem). × 25. (After type figure). *a*, side view; *b*, peripheral view.

17. *Involutina silicea* (Terquem). × 8. (After type figure). *a*, side view; *b*, peripheral view.

18. *Problematina delongschampsi* (Terquem). × 50. (After type figure). *a*, side view; *b*, peripheral view.

PLATE 16

Genus BOTELLINA W. B. Carpenter, 1869

Plate 16, figures 5-10

Genoholotype, *Botellina labyrinthica* W. B. Carpenter

Botellina W. B. Carpenter, Proc. Roy. Soc. London, vol. 18, 1869, p. 444.

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. Atlantic.

Genus JULLIENELLA Schlumberger, 1890

Plate 16, figures 11-14

Genoholotype, *Jullienella foetida* Schlumberger

Jullienella Schlumberger, Mém. Soc. Zool. France, vol. 3, 1890, p. 213.

Large, early portion of the test obscure, later spreading in a flattened irregular manner with the periphery ending in simple or branched processes; wall arenaceous, interior with tubular openings, the interior somewhat labyrinthic.

Recent. Coast of Africa (Liberia).

The genera included in this family are very peculiar in their characters, of rather large size, giving indications of being somewhat attached to the substratum on which they live. They are very limited in their known distribution, but are usually very abundant where found. Their relationships are not at all clear.

FAMILY 15. SILICINIDAE

Test usually planispiral, consisting of a proloculum and long closely coiled tubular second chamber either undivided or partially divided into chamberlets, the flattened sides building up masses of secondary shell material; wall arenaceous, usually siliceous, sometimes partially calcareous; aperture at the end of the tubular chamber or the open end of the last-formed chamber where division occurs.

Genus SILICINA Bornemann, 1874

Plate 16, figure 16

Genotype, by designation, *Involutina polymorpha* Terquem

Silicina BORNEMANN, Zeitschr. deutsch. geol. Ges., vol. 26, 1874, p. 731.

Test planispiral, either open or slightly divided; wall arenaceous, usually siliceous and imperforate; aperture formed by the open end of the tubular chamber.

Lias.

Genus RZEHAKINA Cushman, 1927

Plate 16, figure 15

Genoholotype, *Silicina epigona* Rzehak

Rzehakina CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 3, 1927, p. 31.

Silicina (part) RZEHAK (not BORNEMANN), Annal. k. k. Naturhist. Hofmuseums, vol. 10, 1895, p. 214.

Test planispiral, compressed, especially the central portion of each side; chambers forming a half coil; wall thick, finely arenaceous, usually siliceous; aperture narrow, constricted.

Upper Cretaceous and lowest Eocene.

Genus INVOLUTINA Terquem, 1862

Plate 16, figure 17

Genoholotype, *Involutina silicea* Terquem

Involutina TERQUEM, Mém. Acad. Imp. Metz, vol. 42, 1862, p. 450.

Test planispiral, or sometimes conical, the tubular chamber partially divided by incomplete walls, sides of the test built up with secondary additions; wall calcareous, arenaceous at least on the surface; aperture circular at the end of the tubular chamber.

Jurassic.

Genus PROBLEMATINA Bornemann, 1874

Plate 16, figure 18

Genotype, by designation, *Involutina deslongchampsi* Terquem

Problematina BORNEMANN, Zeitschr. deutsch. geol. Ges., vol. 26, 1874, p. 733.

Involutina (part) TERQUEM, Mém. Acad. Imp. Metz, vol. 44, 1863, p. 432.

Test planispiral, the tubular chamber partially divided, the sides of the test built up with secondary shell material; wall arenaceous, with much cement; aperture circular at the end of the tubular chamber.

Lias.

This is an especially interesting family as it is closely related to the Miliolidae, especially the more primitive characters in that group. The character of developing a siliceous test is found in the primitive Miliolidae as well as in the Silicinidae.

FAMILY 16. MILIOLIDAE

Test typically coiled about an elongate axis in various planes, at least in the microspheric young of even the specialized genera; chambers usually a half coil in length, simple in most genera in a few with complex interiors, in the adult of many forms variously arranged; wall normally calcareous, imperforate, in some species of the more primitive genera with included sand grains on the exterior, under acid conditions developing a siliceous or chitinous test; aperture terminal, simple or cribrate, usually with a tooth.

KEY TO THE GENERA

I. Test not divided into chambers, irregularly winding..... *Agathammina.*
II. Test chambered.
- A. Test not reaching a triloculine stage.
  - 1. Quinqueloculine throughout.
    - a. Aperture simple, with a simple tooth..... *Quinqueloculina.*
    - b. Aperture cribrate.
      - (1). Entirely calcareous, chambers completely involute. *Miliola.*
      - (2). Exterior arenaceous, chambers not completely involute. .... *Schlumbergerina.*
  - 2. Later chambers of various shapes.
    - a. Later chambers two to a coil, laterally spreading.
      - (1). Quinqueloculine stage prominent, flattened chambers few. .... *Massilina.*
      - (2). Quinqueloculine stage reduced, flattened chambers many. .... *Spiroloculina.*
      - (3). Quinqueloculine stage prominent, later chambers sigmoid. .... *Sigmoilina.*

b. Later chambers more than two in a coil.
  (1). Aperture simple, with a broad tooth. *Nummoloculina.*
  (2). Aperture cribrate. .... *Hauerina.*
c. Later chambers elongate.
  (1). Quinqueloculine stage prominent, uniserial chambers few. .... *Articulina.*
  (2). Quinqueloculine stage reduced, uniserial chambers many.
    (a). Chambers indistinct, without a tooth. *Tubinella.*
    (b). Chambers distinct, with a distinct tooth. *Nubeculina.*

B. Test reaching a triloculine stage but not a biloculine one.
  1. Triloculine throughout.
    a. Interior simple, aperture with a simple or bifid tooth. *Triloculina.*
    b. Interior with secondary growth, aperture cribrate. *Trillina.*
  2. Later stages in one plane, not uncoiled.............. *Flintina.*
  3. Later stages uncoiling and becoming uniserial. *Ptychomiliola.*

C. Test reaching a biloculine stage.
  1. Adult biloculine.
    a. Aperture simple with a broad tooth, interior simple.
      (1). Completely involute throughout............. *Pyrgo.*
      (2). Later stages becoming evolute and spiroloculine. *Flintia.*
    b. Aperture cribrate, interior labyrinthic........ *Fabularia.*
  2. Adult exterior mostly formed by the last-formed chamber.
    a. Penultimate chamber showing as a small basal area.
      (1). Aperture of simple radiate form, chamber much elongate. .... *Nevillina.*
      (2). Aperture complex, radiate in form, chamber broadly ovate. .... *Idalina.*
    b. Penultimate chamber not visible.
      (1). Test subglobular. .... *Periloculina.*
      (2). Test strongly compressed............... *Lacazina.*

Genus AGATHAMMINA Neumayr, 1887

Plate 17, figures 1, 2; plate 19, figure 1

Genotype, by designation, *Serpula pusilla* Geinitz

Agathammina NEUMAYR, Sitz. Akad. Wiss. Wien, vol. 95, pt. 1, 1887, p. 171.

Serpula (part) GEINITZ (not LINNÉ), Verst. Deutsch. Zechst. Roth., Heft 1, 1846, p. 6.

Trochammina (part) of authors.

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 tubular chamber.

Carboniferous to Jurassic.

Genus QUINQUELOCULINA d'Orbigny, 1826

Plate 17, figures 3, 4; plate 19, figure 2

Genotype, by designation, *Serpula seminulum* Linné

Quinqueloculina D'ORBIGNY, Ann. Sci. Nat., vol. 7, 1826, p. 301.
Serpula (part) LINNÉ, Syst. Nat., ed. 10, 1758, p. 786.
Adelosina D'ORBIGNY, Ann. Sci. Nat., vol. 7, 1826, p. 303 (genotype, by designation, *A. striata* D'ORBIGNY).
Uniloculina D'ORBIGNY, Foram. Foss. Bass. Tert. Vienne, 1846, p. 261 (genoholotype, *U. indica* D'ORBIGNY).
Miliolina (part) WILLIAMSON, Rec. Foram. Great Britain, 1858, p. 83, (and later authors).

EXPLANATION OF PLATE 17

MILIOLIDAE

FIG.

1, 2. *Agathammina pusilla* (Geinitz). (After H. B. Brady). Fig. 1, Carboniferous specimen. × 35. Fig. 2, Permian specimen. × 15.

3, 4. *Quinqueloculina seminulum* (Linné). Fig. 3, (After H. B. Brady). × 40. *a*, *b*, from opposite sides; *c*, apertural view. Fig. 4, (After Schlumberger). × 65. Transverse section.

5. *Miliola saxorum* Lamarck. (After Terquem). *a*, side view; *b*, apertural view, showing cribrate aperture.

6, 7. *Massilina secans* (d'Orbigny). (After Schlumberger). Fig. 6, × 12. Fig. 7, Section. × 20.

8–10. *Spiroloculina depressa* (d'Orbigny). Fig. 8, (After Schlumberger). Figs. 9, 10, (After Martinotti). × 50. Fig. 9, Megalospheric form with nearly all chambers in one plane. Fig. 10, Form with the early chambers quinqueloculine.

11–13. *Nummoloculina contraria* (d'Orbigny). Figs. 11, 12, (After H. B. Brady). × 15. Fig. 12, Section in horizontal plane. Fig. 13, (After Steinmann). Section in vertical plane.

14. *Hauerina bradyi* Cushman. × 35. (After H. B. Brady). *a*, side view; *b*, peripheral view.

15. *Sigmoilina caelata* (Costa). × 35. (After H. B. Brady). *a*, side view; *b*, peripheral view.

16. *Sigmoilina sigmoidea* (H. B. Brady). × 50. (After Schlumberger). Transverse section.

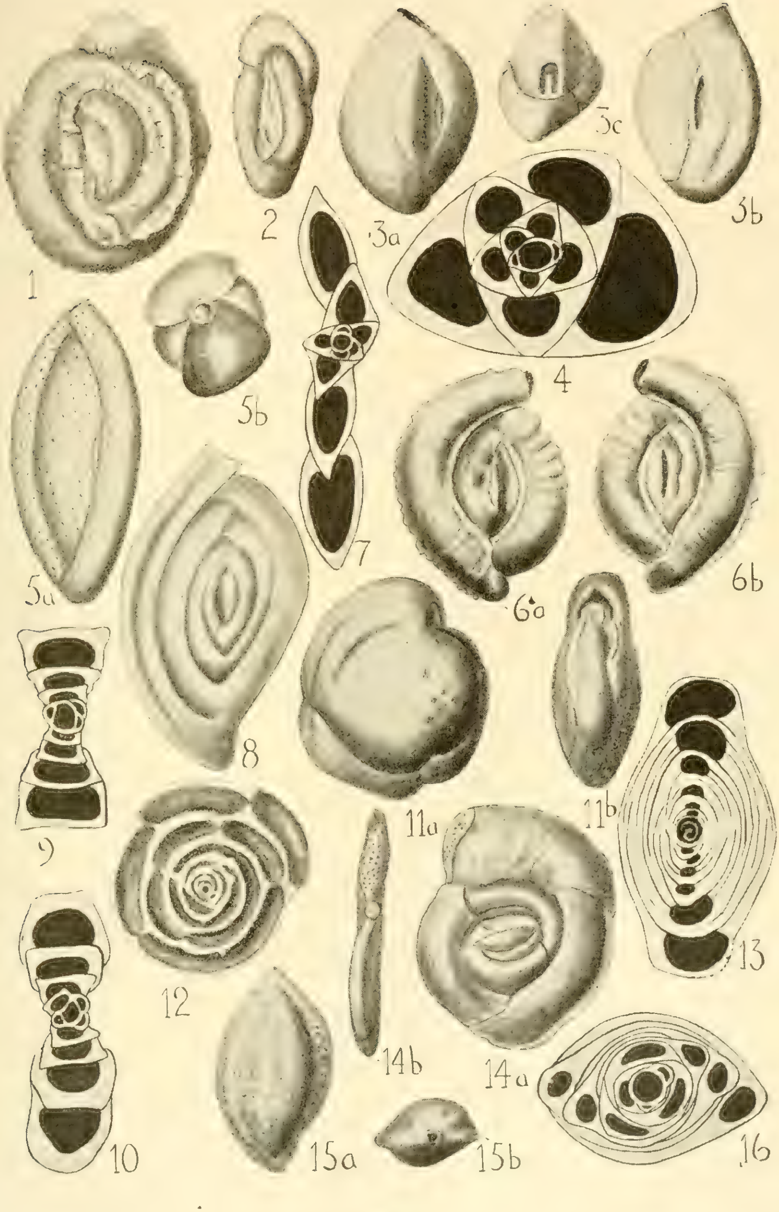

PLATE 17

Test with the coiling in five planes, the chambers a half coil in length and added successively in planes 144° apart, five chambers completing a cycle, each chamber 72° from its adjacent one, but 144° from the immediately preceding one; wall imperforate, calcareous, often with arenaceous material on the exterior and in deep or brackish water occasionally becoming siliceous; aperture usually with a simple tooth.

Carboniferous (?) to Recent.

Genus MILIOLA Lamarck, 1804

Plate 17, figure 5; plate 19, figure 3

Genotype, by designation, *Miliola saxorum* Lamarck

Miliola (part) LAMARCK, Ann. Mus., vol. 5, 1804, p. 349.
Quinqueloculina (part) D'ORBIGNY, Ann. Sci. Nat., vol. 7, 1826, p. 301.
Pentellina MUNIER-CHALMAS and SCHLUMBERGER, Bull. Soc. Géol. France, ser. 4, vol. 5, 1905, p. 116 (genotype, by designation, *P. heberti* SCHLUMBERGER).

Test in its structure similar to *Quinqueloculina* but the aperture cribrate.

Eocene.

Genus SCHLUMBERGERINA Munier-Chalmas, 1882

Plate 53, figures 8-10

Genoholotype, *Schlumbergerina areniphora* Munier-Chalmas

Schlumbergerina MUNIER-CHALMAS, Bull. Soc. Géol. France, ser. 3, vol. 10, 1882, p. 424.
Miliolina (part) of authors.
Massilina (part) of authors.

Test typically quinqueloculine, the chambers narrowing so that frequently more than five chambers may be visible from the exterior; wall calcareous, imperforate, the exterior thickly coated with sand grains; aperture cribrate.

Late Tertiary and Recent.

The young of some of the species with arenaceous exterior frequently assigned to *Massilina* are close to this. The *Miliolina alveoliniformis* H. B. Brady described in 1879 is probably the same as Munier-Chalmas' species and belongs here. This species is often abundant in shallow water tropical collections.

Genus MASSILINA Schlumberger, 1893

Plate 17, figures 6, 7; plate 19, figure 9

Genotype, by designation, *Quinqueloculina secans* d'Orbigny

Massilina SCHLUMBERGER, Mém. Soc. Zool. France, 1893, p. 218.
Quinqueloculina (part) D'ORBIGNY, Ann. Sci. Nat., vol. 7, 1826, p. 303.
Miliolina (part) of authors.

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; aperture simple, with a bifid tooth.

Cretaceous to Recent (probably older).

Genus SPIROLOCULINA d'Orbigny, 1826

Plate 17, figures 8-10; plate 19, figure 10

Genotype, by designation, *Spiroloculina depressa* d'Orbigny

Spiroloculina D'ORBIGNY, Ann. Sci. Nat., vol. 7, 1826, p. 298.
Miliola (part) LAMARCK, Ann. Mus., vol. 5, 1805, p. 352, (and later authors).

Test with the early chambers in the microspheric form quinqueloculine, later ones in a single plane, chambers a half coil in length; apertural end usually with a neck and lip, simple, with a simple or bifid tooth.

Permian (?) to Recent.

Genus NUMMOLOCULINA Steinmann, 1881

Plate 17, figures 11-13; plate 19, figure 4

Genoholotype, *Biloculina contraria* d'Orbigny

Nummoloculina STEINMANN, Neues Jahrb., 1881, p. 31.
Biloculina (part) D'ORBIGNY, Foram. Foss. Bass. Tert. Vienne, 1846, p. 266.
Planispirina (part) H. B. BRADY (not SEGUENZA), Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 195.

Test with the earliest chambers quinqueloculine, later ones in a single plane, several making up a coil; aperture rounded with a flat semicircular tooth.

Jurassic to Recent.

Genus HAUERINA d'Orbigny, 1839

Plate 17, figure 14; plate 19, figure 5

Genoholotype, *Hauerina compressa* d'Orbigny

Hauerina D'ORBIGNY, in DE LA SAGRA, Hist. Fis. Pol. Nat. Cuba, 1839, "Foraminifères", p. xxxviii.

Heterillina MUNIER-CHALMAS and SCHLUMBERGER, Bull. Soc. Géol. France, ser. 4, vol. 5, 1905, p. 131 (genotype, by designation, *H. guespellensis* SCHLUMBERGER).

Test with the early chambers quinqueloculine, later ones more or less in one plane, making a half coil, later in some species gradually shortening so that more than two make up one coil; aperture cribrate.

Tertiary and Recent.

Genus SIGMOILINA Schlumberger, 1887

Plate 17, figures 15, 16; plate 19, figure 8

Genotype, by designation, *Planispirina sigmoidea* H. B. Brady

Sigmoilina SCHLUMBERGER, Bull. Soc. Zool. France, vol. 12, 1887, p. 118.

Spiroloculina (part) COSTA (not D'ORBIGNY), Mem. Accad. Sci. Napoli, vol. 2, 1855 (1857), p. 126.

Planispirina (part) H. B. BRADY (not SEGUENZA), Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 197.

Test with the early chambers quinqueloculine, later ones added in planes slightly more than 180° from one another making a continuously revolving spiral and in transverse section producing a sigmoid appearance; aperture simple with a simple tooth; exterior very often with a superficial layer of arenaceous material.

Tertiary and Recent.

Genus ARTICULINA d'Orbigny, 1826

Plate 18, figure 1; plate 19, figure 6

Genoholotype, *Articulina nitida* d'Orbigny

Articulina D'ORBIGNY, Ann. Sci. Nat., vol. 7, 1826, p. 300.

Nautilus BATSCH (not LINNÉ), Conch. des Seesandes, 1791, p. 3.

Vertebralina (part) PARKER, JONES and H. B. BRADY (not D'ORBIGNY), Ann. Mag. Nat. Hist., ser. 3, vol. 16, 1865, p. 22.

Test with the early chambers quinqueloculine or triloculine, later ones in a rectilinear series; aperture in the adult a rounded, usually elliptical opening, at the end of a short neck with a phialine lip.

Lower Eocene to Recent.

Genus TUBINELLA Rhumbler, 1906

Plate 18, figures 2, 3; plate 19, figure 7

Genotype, by designation, *Articulina inornata* H. B. Brady

Tubinella RHUMBLER, Zool. Jahrb., Abteil. Syst., vol. 24, 1906, p. 25.
Articulina (part) H. B. BRADY (not D'ORBIGNY), Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 185.

Test with an ovoid early portion, the remainder of the test nearly straight, cylindrical; partially divided; aperture, the open end of the last chamber; color, bluish-white.

Recent.

Genus NUBECULINA Cushman, 1924

Plate 18, figures 4-6

Genoholotype, *Nubecularia divaricata* H. B. Brady

Nubeculina CUSHMAN, Publ. 342, Carnegie Inst. Washington, 1924, p. 52.
Sagrina (part) H. B. BRADY (not D'ORBIGNY), Quart. Journ. Micr. Sci., vol. 19, 1879, p. 276.
Nubecularia (part) H. B. BRADY (not DEFRANCE), Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 133.

Test elongate, uniserial; initial end coiled or milioline; chambers distinct, simple; wall imperforate, porcellanous, with sand grains attached to the exterior; aperture at the end of an elongated tubular neck with an everted phialine lip, the apertural opening with a series of inwardly pointing teeth.

Recent.

Genus TRILOCULINA d'Orbigny, 1826

Plate 18, figures 7, 8; plate 19, figure 11

Genotype, by designation, *Miliola trigonula* Lamarck

Triloculina D'ORBIGNY, Ann. Sci. Nat., vol. 7, 1826, p. 299.
Miliola (part) LAMARCK, Ann. Mus., vol. 5, 1804, p. 351.
Miliolina (part) WILLIAMSON, Rec. Foram. Great Britain, 1858, p. 83, (and later authors).

Test with the early chambers quinqueloculine, at least in the microspheric form, later ones added in planes 120° from one another, the third of each series added in the plane of the third preceding and covering it so that the surface of the test is composed of but three visible chambers, interior not labyrinthic; aperture simple, typically with a bifid tooth.

Triassic to Recent.

EXPLANATION OF PLATE 18

Miliolidae

Fig.

1. *Articulina sagra* d'Orbigny. × 35. (After H. B. Brady). *a*, side view; *b*, apertural view.

2. *Tubinella inornata* (H. B. Brady). × 20. (After type figure).

3. *Tubinella funalis* (H. B. Brady). × 20. (After type figure).

4-6. *Nubeculina divaricata* (H. B. Brady). × 40. (After type figures). Fig. 5, Apertural end from side. Fig. 6, Showing aperture and teeth.

7, 8. *Triloculina laevigata* d'Orbigny. (After Schlumberger). Fig. 7, *a*, *b*, opposite sides; *c*, apertural view. × 28. Fig. 8, Transverse section. × 65.

9. *Trillina howchini* Schlumberger. × 35. (After type figure). Transverse section.

10. *Flintina triquetra* Cushman. × 7. (After type figure).

11, 12. *Pyrgo sarsi* (Schlumberger). (After type figures). Fig. 11, *a*, front view; *b*, side view; *c*, apertural view. × 12. Fig. 12, Transverse section. × 20.

13, 14. *Fabularia discolithes* Defrance. (After Schlumberger). Fig. 13, *a*, side view; *b*, apertural view. × 35. Fig. 14, Transverse section of megalospheric form. × 30.

15, 16. *Nevillina coronata* (Millett). × 18. (After Sidebottom). Fig. 15, Interior. Fig. 16, *a*, side view; *b*, apertural view.

17. *Idalina antiqua* (d'Orbigny). × 8. (After Munier-Chalmas and Schlumberger).

18, 19. *Periloculina zitteli* Munier-Chalmas and Schlumberger. (After type figures). Fig. 18, *a*, side view; *b*, apertural view. × 12. Fig. 19, Transverse section. × 16.

20. *Lacazina compressa* (d'Orbigny). × 3. (After Munier-Chalmas and Schlumberger). *a*, apertural view; *b*, side view.


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16b
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17b
18a
17a
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20b
20a

PLATE 18

Genus TRILLINA Munier-Chalmas and Schlumberger, 1893

Plate 18, figure 9; plate 19, figure 12

Genoholotype, *Trillina howchini* Schlumberger

Trillina MUNIER-CHALMAS and SCHLUMBERGER, Bull. Soc. Géol. France, ser. 3, vol. 21, 1893, p. 118.

Test similar in plan of development to *Triloculina*, but with the chambers labyrinthic and the aperture cribrate.

Eocene.

Genus FLINTINA Cushman, 1921

Plate 18, figure 10; plate 19, figure 13

Genoholotype, *Flintina bradyana* Cushman

Flintina CUSHMAN, Bull. 100, U. S. Nat. Mus., vol. 4, 1921, p. 465.

Miliolina (part) H. B. BRADY, Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, pp. 169, 184.

Test in the early stages, at least of the microspheric form, quinqueloculine, followed very early by a triloculine stage and in the adult planispiral, usually taking three chambers to make a complete cycle; aperture with a large orifice with a thickened border and large complex tooth.

Recent.

Genus PTYCHOMILIOLA Eimer and Fickert, 1899

Plate 54, figures 1-3

Genoholotype, *Miliolina separans* H. B. Brady

Ptychomiliola EIMER and FICKERT, Zeitschr. Wiss. Zool., vol. 65, 1899, p. 687.

Miliolina (part) H. B. BRADY, Quart. Journ. Micr. Sci., vol. 21, 1881, p. 45.

Test in the early stages triloculine completely involute, in the later stages with the chambers uncoiling, and in fully developed specimens with the last chambers tending to become uniserial; aperture with a distinct tooth, typically bifid.

Recent. Shallow waters of the tropical Indo-Pacific.

This genus develops from such forms as *Flintina* by adding the loosely coiled development followed by a uniserial stage in the final development. The next stage would be a completely uncoiled development in the megalospheric stage at least, and such forms are to be looked for.

Genus PYRGO Defrance, 1824

Plate 18, figures 11, 12; plate 19, figure 14

Genoholotype, *Pyrgo laevis* Defrance

Pyrgo DEFRANCE, Dict. Sci. Nat., vol. 32, 1824, p. 273.
Miliola (part) LAMARCK, Ann. Mus., vol. 5, 1804, p. 351.
Biloculina D'ORBIGNY, Ann. Sci. Nat., vol. 7, 1826, p. 297 (genotype, by designation, *B. bulloides* D'ORBIGNY). (MODÈLES, 1824?).

Test with the early chambers at least in the microspheric form quinqueloculine, followed by a triloculine series, and in the adult added in planes 180° apart and involute, the interior simple, the exterior of the test composed of but two chambers; aperture typically with a broad bifid tooth.

Lias to Recent.

Genus FABULARIA Defrance, 1820

Plate 18, figures 13, 14; plate 19, figure 15

Genoholotype, *Fabularia discolithes* Defrance

Fabularia DEFRANCE, Dict. Sci. Nat., vol. 16, 1820, p. 103.

Test similar to *Pyrgo* but the chambers labyrinthic and the aperture cribrate.

Eocene to Miocene.

Dillina proposed by Munier-Chalmas and Schlumberger probably belongs here.

Genus FLINTIA Schubert, 1911

Plate 53, figure 14

Genoholotype, *Spiroloculina robusta* H. B. Brady

Flintia SCHUBERT, Abhandl. k. k. Geol. Reichs., vol. 20, pt. 4, 1911, p. 124.
Spiroloculina (part) of authors (not D'ORBIGNY).

Test in the early stages completely involute like *Biloculina*, only two chambers making up the exterior, later the chambers not completely involute, not covering the early chambers at the sides of the test and in the adult spiroloculine; wall calcareous, imperforate; aperture with a broad, flat tooth with curved ends.

Tertiary and Recent.

This genus while it resembles *Spiroloculina* in the adult has evidently been derived from *Biloculina* by the development of open coils as an adult character.

Genus NEVILLINA Sidebottom, 1905

Plate 18, figures 15, 16; plate 19, figure 16

Genoholotype, *Nevillina coronata* Sidebottom

Nevillina Sidebottom, Mem. Proc. Manchester Lit. and Philos. Soc., vol. 49, pt. 2, no. 11, 1905, p. 1.

Test similar to *Pyrgo* in the young, but in the adult the last-formed chamber almost completely embracing the earlier ones;

EXPLANATION OF PLATE 19

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. *Nummoloculina 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. *Pyrgo bradyi* (Schlumberger). *a*, front view; *b*, apertural view; *c*, section.
15. *Fabularia discolithes* Defrance. (Section after Schlumberger).
16. *Nevillina coronata* (Millett). (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.

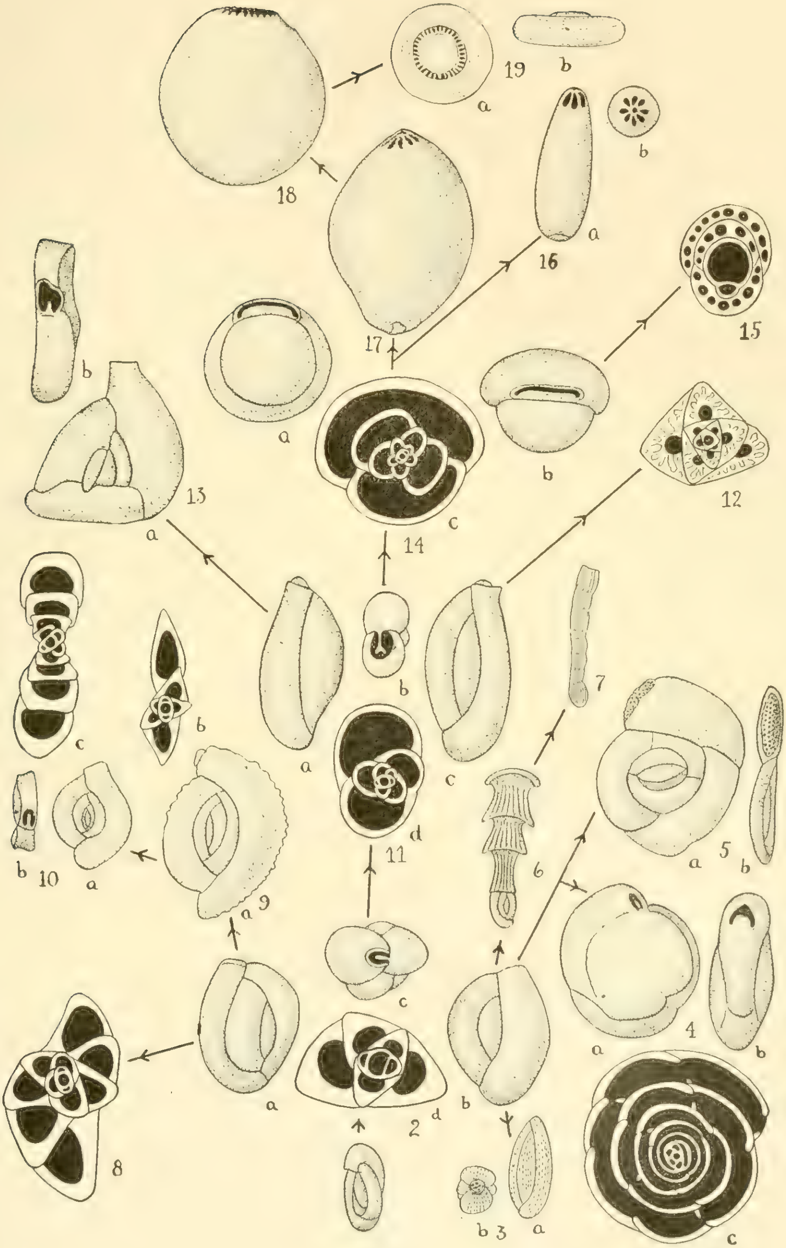
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PLATE 19

aperture circular, complex, formed by numerous incurved lamellae meeting centrally; chambers not labyrinthic.

Recent.

Genus IDALINA Schlumberger and Munier-Chalmas, 1884

Plate 18, figure 17; plate 19, figure 17

Genoholotype, *Biloculina antiqua* d'Orbigny

Idalina SCHLUMBERGER and MUNIER-CHALMAS, Bull. Soc. Géol. France, ser. 3, vol. 12, 1884, p. 629.

Biloculina (part) D'ORBIGNY, Prod. Pal., vol. 2, 1850, p. 210.

Test in the microspheric form quinqueloculine, followed by a triloculine, then biloculine series and in the adult with the penultimate chamber showing as a narrow strip at one side near the base and the final chamber making up the remainder of the surface of the test; aperture cribrate but the chambers not labyrinthic.

Upper Cretaceous.

Genus PERILOCULINA Munier-Chalmas and Schlumberger, 1885

Plate 18, figures 18, 19; plate 19, figure 18

Genoholotype, *Periloculina zitteli* Munier-Chalmas and Schlumberger

Periloculina MUNIER-CHALMAS and SCHLUMBERGER, Bull. Soc. Géol. France, ser. 3, vol. 13, 1885, p. 308.

Test similar to *Idalina*, but the last-formed chamber completely involute, the chambers labyrinthic; aperture complex, cribrate.

Upper Cretaceous.

Genus LACAZINA Munier-Chalmas, 1882

Plate 18, figure 20; plate 19, figure 19

Genoholotype, *Alveolina compressa* d'Orbigny

Lacazina MUNIER-CHALMAS, Bull Soc. Géol. France, ser. 3, vol. 10, 1882, p. 472.

Test in the young similar to *Periloculina*, but in the adult 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 and continuous 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 and their sequence 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 forms now living are found in the Indo-Pacific. A few genera, notably *Pyrgo* and *Sigmoilina*, have in some species become adapted to deeper and colder waters. Under deep sea conditions or in brackish water, siliceous and chitinous tests may be formed showing the relationships to the Silicinidae and the earlier chitinous groups. The habitat of incorporating sand grains in the outer layer of the test in the primitive form of the Miliolidae also indicates their close relationships to the arenaceous group.

FAMILY 17. OPHTHALMIDIIDAE

Test calcareous, imperforate; early chambers at least planispiral, except in degenerate forms; wall without an arenaceous coating; aperture typically open, without a tooth.

KEY TO THE GENERA

I. Test free.
  - A. Early chambers at least planispiral, undivided, no chambers a half coil in length.
    - 1. Test of proloculum and long undivided tubular chamber, close coiled.
      - a. Planispiral throughout.
        - (1). Evolute. .... *Cornuspira.*
        - (2). Involute. .... *Vidalina.*
      - b. Early stages not entirely planispiral........ *Hemigordius.*
    - 2. Test in the adult fan-shaped, becoming bilaterally symmetrical. *Cornuspiroides.*

3. Test in the adult with long peripheral extensions. *Cornuspirella.*
4. Test in the adult with chambers in a rectilinear series. *Nodobacularia.*

B. Some at least of the chambers a half coil in length.
1. Test with a thin plate between the coils.
a. Two chambers in a coil in the adult....*Spiropthalmidium.*
b. More than two chambers in the adult.
(1). Chambers simple, not annular......*Ophthalmidium.*
(2). Chambers divided into chamberlets, annular. *Discospirinia.*

C. Test generally planispiral divided into chambers.
1. Several to a coil, not complanate................*Planispirina.*
2. Test broadly complanate, becoming annular.........*Renulina.*
3. Test somewhat complanate, becoming rectilinear. *Vertebralina.*

II. Test attached or becoming free.
A. Early chambers somewhat coiled, later irregular.
1. Later chambers irregularly coiled..............*Nubecularia.*
2. Later portions narrow, branching, tubular.....*Cornuspiramia.*

B. Early chambers not definitely coiled.
1. Several chambers.
a. Branched. ....*Calcituba.*
b. Irregular inflated chambers. ....*Silvestria.*
2. A single chamber. ....*Squamulina.*

Subfamily 1. Cornuspirinae

Test made up of a proloculum and an elongate, planispiral, tubular second chamber.

Genus CORNUSPIRA Schultze, 1854

Plate 20, figures 1, 2; plate 21, figure 1

Genotype, by designation, *Cornuspira planorbis* Schultze

Cornuspira SCHULTZE, Organismus Polythal., 1854, p. 40.

Orbis (part) PHILIPPI, Enum. Moll. Siciliae, vol. 2, 1844, p. 147.

Operculina (part) CZJZEK, in HAIDINGER'S Nat. Abhandl., vol. 2, 1848, p. 146.

Spirillina (part) WILLIAMSON, Rec. Foram. Great Britain, 1858, p. 91.

Test consisting of a proloculum followed by a long planispirally coiled second chamber, rounded or complanate; wall calcareous, imperforate; aperture formed by the open end of the chamber, sometimes constricted and with a thickened lip. Carboniferous (?) Jurassic to Recent.

Genus HEMIGORDIUS Schubert, 1908

Plate 53, figures 5-7

Genoholotype, *Cornuspira schlumbergeri* Howchin

Hemigordius SCHUBERT, Jahrb. k. k. Geol. Reichs., vol. 58, 1908, p. 381.
Cornuspira HOWCHIN (not SCHULTZE), Trans. Roy. Soc. South Australia, vol. 19, 1895, p. 195.

Test in the early coils not entirely planispiral, later ones planispiral and completely involute but test not umbonate; wall apparently calcareous, somewhat laminated.

Carboniferous. Australia, Japan and America.

Genus CORNUSPIROIDES Cushman, 1928

Plate 54, figures 12, 13

Genoholotype, *Cornuspira striolata* H. B. Brady

Cornuspiroides CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 4, 1928, p. 3.
Cornuspira (part) of authors.

Test in the early stages planispiral, the coils of fairly uniform height, in the adult the height of the coil greatly increasing and no longer truly coiled but spreading out in a fan-shape; interior not divided into chambers; wall calcareous, imperforate, showing distinct lines of growth; aperture in the adult very elongate, on the peripheral margin of the growing edge.

Recent. Cold water of the North Atlantic.

Genus CORNUSPIRELLA Cushman, 1928

Plate 53, figures 16, 17

Genoholotype, *Cornuspira difformis* Heron-Allen and Earland

Cornuspirella CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 4, 1928, p. 4.
Cornuspira (part) of authors.

Test in the early stages planispiral, close coiled, the coils of fairly even diameter, later the height of the coil expanding and in the adult with long branching or flattened peripheral extensions; interior not divided into distinct chambers; wall calcareous, imperforate, with depressed lines of growth on the exterior;

aperture in the adult elongate, narrow, at the ends of the peripheral portions.

Recent. Atlantic.

As noted by Heron-Allen and Earland, this is to be considered a specialized form and representing an end form in the *Cornuspira*-like series.

Genus VIDALINA Schlumberger, 1899

Plate 20, figures 3, 4; plate 21, figure 2

Genoholotype, *Vidalina hispanica* Schlumberger

Vidalina SCHLUMBERGER, Bull. Soc. Géol. France, ser. 3, vol. 27, 1899, p. 459.

Test similar to *Cornuspira*, but completely involute, the umbonal region thickened.

Cretaceous.

EXPLANATION OF PLATE 20

OPHTHALMIDIIDAE, FISCHERINIDAE

FIG.

1. *Cornuspira planorbis* Schultze. × 65. (After type figure).
2. *Cornuspira involvens* Reuss. × 20. (After H. B. Brady). *a*, side view; *b*, peripheral view.

3, 4. *Vidalina hispanica* Schlumberger. (After type figures). Fig. 3, Horizontal section. × 30. Fig. 4, Vertical section. × 55.

5. *Nodobacularia tibia* (Jones and Parker). (After type figure).
6. *Ophthalmidium inconstans* H. B. Brady. × 35. (After H. B. Brady).
7. *Spiropthalmidium acutimargo* (H. B. Brady). × 35. (After type figure). *a*, side view; *b*, apertural view.
8. *Discospirinia tenuissima* (Carpenter). × 12. (After H. B. Brady). a, from flat side; b, from periphery.

9, 10. *Planispirina communis* Seguenza. × 12. Fig. 9, (After type figure). Fig. 10, (After H. B. Brady), Section.

11. *Renulina opercularia* Lamarck. (After type figure).
12. *Vertebralina striata* d'Orbigny. (After d'Orbigny's Model).
13. *Nubecularia lucifuga* Defrance. × 12. (After H. B. Brady). *a*, from above; *b*, from below.
14. *Squamulina laevis* Schultze. × 50. (After type figure).
15. *Calcituba polymorpha* Roboz. (After type figure).
16. *Fischerina rhodiensis* Terquem. × 28. (After type figure). *a*, dorsal view; *b*, ventral view; *c*, apertural view.

17, 18. *Fischerina helix* Heron-Allen and Earland. × 65. (After type figures). *a*, dorsal view; *b*, apertural view. Fig. 18, From below, by transmitted light.

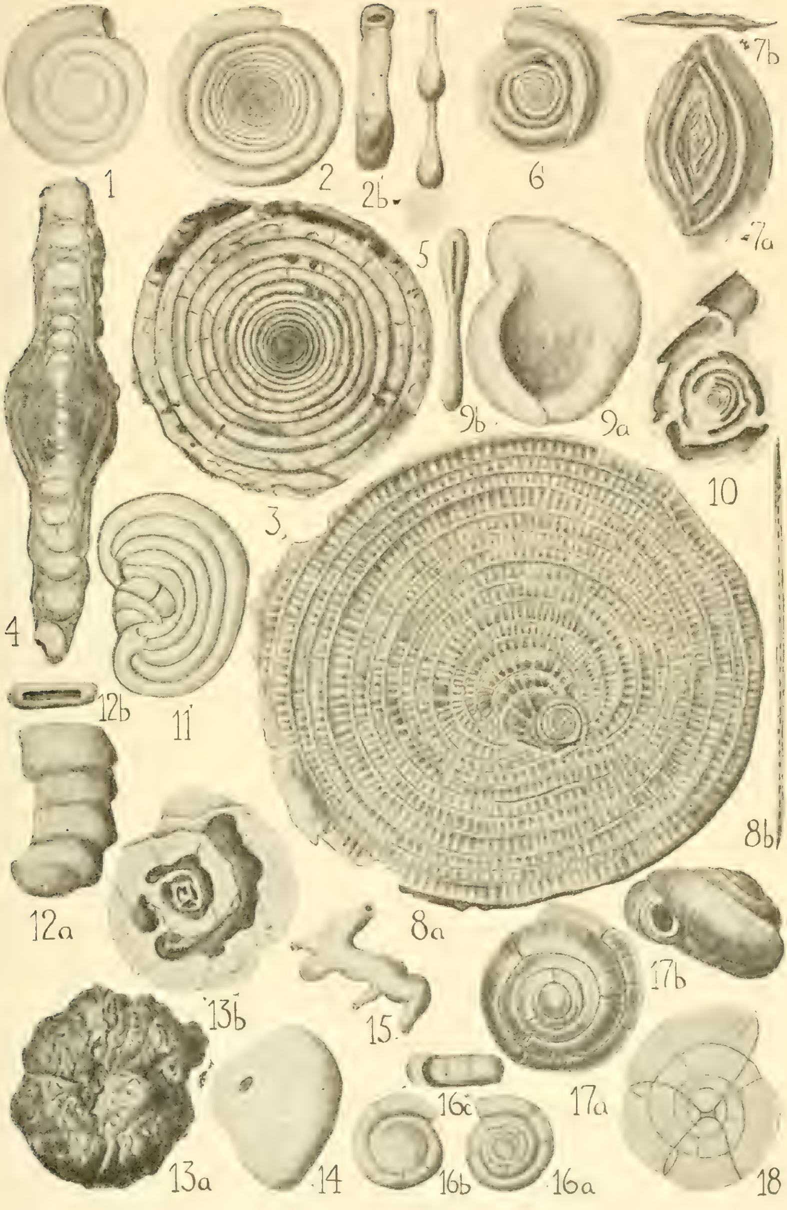
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PLATE 20

Subfamily 2. Nodobaculariinae

Early portion as in *Cornuspira,* followed by chambers in a rectilinear series.

Genus NODOBACULARIA Rhumbler, 1895

Plate 20, figure 5; plate 21, figure 3

Genoholotype, *Nubecularia tibia* Jones and Parker

Nodobacularia RHUMBLER, Nachr. Ges. Wiss. Göttingen, 1895, p. 87.
Nubecularia (part) JONES and PARKER (not DEFRANCE), Quart. Journ. Geol. Soc., vol. 16, 1860, p. 455.

Test with a globular proloculum followed by a planispiral tubular second chamber, the adult chambers in a rectilinear series; aperture simple, with a lip.

Lias to Recent.

Genus CORNUSPIRAMIA Cushman, 1928

Plate 55, figures 1, 2

Genoholotype, *Nubecularia antillarum* Cushman

Cornuspiramia CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 4, 1928, p. 4.
Nubecularia CUSHMAN (not DEFRANCE), Publ. 311, Carnegie Inst. Washington, 1922, p. 58.

Test attached, in the early stages with a proloculum and one or more coils of an undivided tubular chamber about it followed by irregularly branching tubular portions with the base flattened and the upper side arched; wall calcareous, imperforate; apertures formed by the open ends of the tubes.

Recent. Tropical, in shallow water.

Subfamily 3. Ophthalmidiinae

Test free, planispiral, in the later stages usually two or more chambers making up a coil, later chambers variously arranged in different genera.

Genus OPHTHALMIDIUM Zwingli and Kübler, 1870

Plate 20, figure 6; plate 21, figure 4

Genotype, by designation, *Ophthalmidium porosum* Zwingli and Kübler

Ophthalmidium ZWINGLI and KÜBLER, Foram. Schweiz. Jura, 1870, p. 46.

Hauerina (part) H. B. BRADY (not D'ORBIGNY), Quart. Journ. Micr. Sci., vol. 19, 1879, p. 268.

Hauerinella SCHUBERT, Pal. Zeitschr., vol. 3, 1920, p. 162 (genoholotype, *Ophthalmidium inconstans* H. B. BRADY).

Test planispiral, compressed, not involute, consisting of a globular proloculum followed by a planispiral tubular chamber of usually two or more coils, the following chambers decreasing in relative length, loose coiled, the intermediate area filled with a thin, shelly plate; aperture at the open end of the chamber, rounded, without lip or tooth.

Genus SPIROPTHALMIDIUM Cushman, 1927

Plate 20, figure 7; plate 21, figure 5

Genoholotype, *Spiroloculina acutimargo* H. B. Brady (part)

Spiropthalmidium CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 3, 1927, p. 37.

Spiroloculina (part) H. B. BRADY (not D'ORBIGNY), Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 154.

Test similar to *Ophthalmidium*, but accelerated, the stage having two chambers in a coil quickly reached; plate between the chambers usually present; aperture simple, without teeth.

Lias to Recent.

Genus DISCOSPIRINIA Munier-Chalmas, 1902

Plate 20, figure 8; plate 21, figure 6

Genotype, by designation, *Orbitolites tenuissima* W. B. Carpenter

Discospirinia MUNIER-CHALMAS, Bull. Soc. Géol. France, ser. 4, vol. 2, 1902, p. 352.

Cyclophthalmidium LISTER, in LANKESTER, A Treatise on Zoology, pt. 1, fasc. II, 1903, p. 110 (footnote) (genoholotype, *Orbitolites tenuissima* W. B. CARPENTER).

Orbitolites (part) of authors.

Test in the young similar to *Ophthalmidium*, later chambers annular with incomplete divisions into chamberlets; apertures at the periphery of the very thin test.

Tertiary and Recent.

Genus PLANISPIRINA Seguenza, 1880

Plate 20, figures 9, 10; plate 21, figure 7

Genotype, by designation, *Planispirina communis* Seguenza

Planispirina SEGUENZA, Atti R. Accad. Lincei, ser. 3, vol. 6, 1880, p. 310.

Test in the early stages like *Cornuspira*, later divided into chambers, several to a coil; aperture simple, without a tooth.

Cretaceous to Recent.

Genus RENULINA Lamarck, 1804

Plate 20, figure 11; plate 21, figure 8

Genoholotype, *Renulina opercularia* Lamarck

Renulina LAMARCK, Ann. Mus., vol. 5, 1804, p. 354.

Test in the early stages planispiral, in the adult chambers becoming relatively shorter and broader, one side of the test nearly a straight line, the opposite end extending back to the earlier coils, in final stages of complete specimens the chambers extending back to the earlier coils on both ends and becoming annular.

Eocene.

EXPLANATION OF PLATE 21

OPHTHALMIDIIDAE, 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. *Spiropthalmidium acutimargo* (H. B. Brady). (After H. B. Brady).
6. *Discospirinia 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.

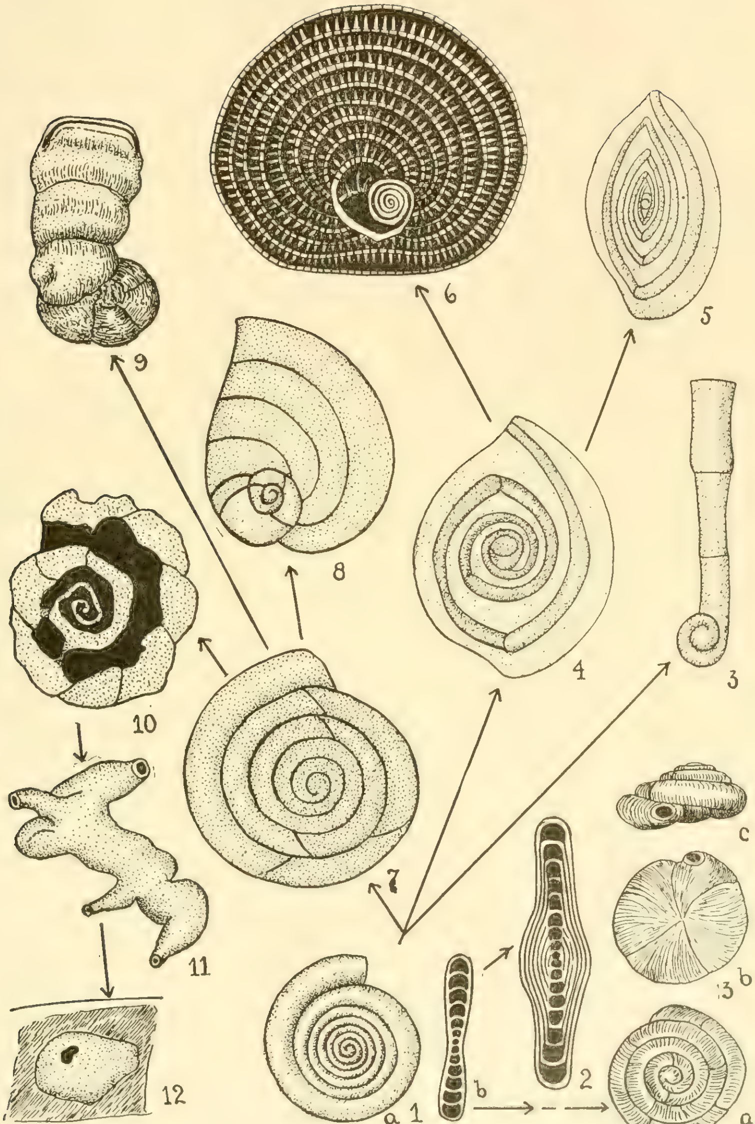


PLATE 21

Genus VERTEBRALINA d'Orbigny, 1826

Plate 20, figure 12; plate 21, figure 9

Genoholotype, *Vertebralina striata* d'Orbigny

Vertebralina d'Orbigny, Ann. Sci. Nat., vol. 7, 1826, p. 283.

Test with the early chambers planispiral, later ones in a rectilinear series; aperture simple, a long narrow slit either at the outer end of the chamber or somewhat laterally placed, typically with a definite lip.

Eocene to Recent.

Subfamily 4. Nubeculariinae

Test typically attached at least in the early stages, coiled in the young, later irregular or consisting of a single attached chamber.

Genus NUBECULARIA Defrance, 1825

Plate 20, figure 13; plate 21, figure 10

Genoholotype, *Nubecularia lucifuga* Defrance

Nubecularia Defrance, Dict. Sci. Nat., vol. 35, 1825, p. 210.
Amorphina Parker, Ann. Mag. Nat. Hist., ser. 2, vol. 19, 1857, p. 278 (fide Sherborn).

Test typically coiled, planispiral, free or usually attached, consisting of an oval proloculum, with a second coiled tubular chamber followed in the adult by irregular chambers varying more or less with the attached surface.

Lias to Recent.

Genus CALCITUBA Roboz, 1883

Plate 20, figure 15; plate 21, figure 11

Genoholotype, *Calcituba polymorpha* Roboz

Calcituba Roboz, Sitz. Akad. Wiss. Wien, vol. 88, pt. 1, 1883 (1884), p. 420.

Test adherent, branched, of irregular chambers, more or less cylindrical; wall imperforate; apertures simple, at the ends of the branches.

Recent. Pacific and Mediterranean.

Genus SILVESTRIA Schubert, 1920

Plate 53, figures 11-13

Genoholotype, *Nubecularia inflata* H. B. Brady (not TERQUEM) = *N. bradyi* Millett

Silvestria SCHUBERT, Pal. Zeitschr., vol. 3, 1920, p. 166.
Nubecularia (part) of authors.

Test with the early chambers similar to *Calcituba*, the later ones inflated, irregularly coiled; wall calcareous, imperforate; aperture rounded, irregularly placed.

Recent.

Genus SQUAMULINA Schultze, 1854

Plate 20, figure 14; plate 21, figure 12

Genoholotype, *Squamulina laevis* Schultze

Squamulina SCHULTZE, Organismus Polythal., 1854, p. 56.

Test adherent, consisting of a single inflated chamber with the wall calcareous and imperforate; aperture simple, on the convex surface.

Recent.

In this family all the forms are planispiral 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 distinguishable 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 *Spiropthalmidium* 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 simple genera of the Miliolidae.

FAMILY 18. FISCHERINIDAE

Test coiled, earlier ones somewhat planispiral, later ones trochoid, all coils visible from the dorsal side only, the last-formed one from the ventral side; chambers distinct but not inflated, usually four or five making up the last-formed coil; wall calcareous, imperforate; aperture rounded, formed by the open end of the last-formed chamber.

Genus FISCHERINA Terquem, 1878

Plate 20, figures 16-18; plate 21, figure 13

Genoholotype, *Fischerina rhodiensis* Terquem

Fischerina TERQUEM, Mém. Soc. Géol. France, ser. 3, vol. 1, 1878, p. 80.

Test coiled in a low conical spiral; chambers few in each coil, all visible from the dorsal side, only those of the last-formed coil from the ventral side; wall calcareous, imperforate; aperture formed by the open end of the last-formed chamber, simple.

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 porcellanous groups.

FAMILY 19. TROCHAMMINIDAE

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

KEY TO THE GENERA

I. Test typically trochoid, not involute.
 A. Test arenaceous.
  1. Without an outer layer. .... *Trochammina.*
  2. With a distinct outer layer.................... *Globivalvulina.*
 B. Test of cement with distinct fusiform bodies............ *Carterina.*
 C. Test of matted spicules above, chitin below......... *Rotaliammina.*

II. Test irregularly spiral with globose chambers, not involute. *Globotextularia.*

III. Test with the adult chambers more or less involute.
  A. Test coarsely arenaceous.
    1. Aperture at the umbilical border.........*Ammosphaeroidina.*
    2. Aperture terminal; test elongate...................*Nouria.*
  B. Test finely arenaceous with much cement; aperture at the base or in the face of the last-formed chamber.........*Ammochilostoma.*

Subfamily 1. Trochammininae

Test trochoid, chambers in spiral whorls; aperture ventral.

Genus TROCHAMMINA Parker and Jones, 1860

Plate 22, figure 1

Genotype, by designation, *Nautilus inflatus* Montagu

Trochammina PARKER and JONES, Quart. Journ. Geol. Soc., vol. 16, 1860, p. 304.

Nautilus (part) MONTAGU (not LINNÉ), Test. Brit., Suppl., 1808, p. 81.

Rotalina (part) WILLIAMSON (not D'ORBIGNY), Rec. Foram. Great Britain, 1858, p. 56.

Lituola (part) PARKER and JONES (not LAMARCK), Philos. Trans., vol. 155, 1865, p. 407.

Haplophragmium (part) SIDDALL (not REUSS), Cat. British Rec. Foram., 1879, p. 4.

Ammoglobigerina EIMER and FICKERT, Zeitschr. Wiss. Zool., vol. 65, 1899, p. 704 (genoholotype, *Haplophragmium globigeriniforme* PARKER and JONES).

Tritaxis SCHUBERT, Pal. Zeitschr., vol. 3, 1920, p. 180 (genotype, by designation, *Rotalina fusca* WILLIAMSON).

Test free or adherent, spiral, trochoid, all chambers visible from the dorsal side, only those of the last-formed coil from the ventral; wall arenaceous; aperture, an arched slit on the inner margin of the ventral side of the chamber.

Carboniferous to Recent.

Genus GLOBIVALVULINA Schubert, 1920

Plate 53, figures 3, 4

Genoholotype, *Valvulina bulloides* H. B. Brady

Globivalvulina SCHUBERT, Pal. Zeitschr., vol. 3, 1920, p. 153.

Valvulina (part) H. B. BRADY (not D'ORBIGNY), Pal. Soc. Mon. 30, 1876, p. 89.

Test trochoid, subglobular or plano-convex, the ventral side flattened, dorsal side strongly convex; periphery rounded; chambers inflated, few; wall finely arenaceous with much cement, the main wall perforate, occasionally appearing with a thin outer layer; aperture low, arched, at the umbilical margin of the last-formed chamber.

Palaeozoic. Pennsylvanian and Permian.

Genus ROTALIAMMINA Cushman, 1924

Plate 22, figures 4, 5

Genoholotype, *Rotaliammina mayori* Cushman

Rotaliammina CUSHMAN, Publ. 342, Carnegie Inst. Washington, 1924, p. 11.

Test trochoid, attached by the ventral side, all chambers visible from above, only those of the last-formed coil from below; dorsal wall of matted spicules, ventral wall of thin chitin; aperture ventral, along the edge of the chamber.

Recent. Samoa, attached in shallow water.

Subfamily 2. Globotextulariinae

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

Genus GLOBOTEXTULARIA Eimer and Fickert, 1899

Plate 22, figure 6

Genoholotype, *Haplophragmium anceps* H. B. Brady

Globotextularia EIMER and FICKERT, Zeitschr. Wiss. Zool., vol. 65, 1899, p. 679.

Haplophragmium (part) H. B. BRADY (not REUSS), Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 313.

Test irregularly spiral, chambers globose, the last-formed ones increasing rapidly in size; wall arenaceous; aperture in the open umbilical area.

Recent.

Genus CARTERINA H. B. Brady, 1884

Plate 22, figures 2, 3

Genoholotype, *Rotalia spiculotesta* Carter

Carterina H. B. BRADY, Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 345.

Rotalia CARTER (not D'ORBIGNY), Ann. Mag. Nat. Hist., ser. 4, vol. 20, 1877, p. 470.

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.

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 AMMOSPHAEROIDINA Cushman, 1910

Plate 22, figure 7

Genoholotype, *Haplophragmium sphaeroidiniformis* H. B. Brady

Ammosphaeroidina CUSHMAN, Bull. 71, U. S. Nat. Mus., pt. 1, 1910, p. 128.

Haplophragmium (part) H. B. BRADY (not REUSS), Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 313.

Test in the early stages trochoid, in the adult globose with the last three chambers making up the entire surface; wall coarsely arenaceous; aperture arched, at the umbilical border of the chamber.

Recent.

Genus AMMOCHILOSTOMA Eimer and Fickert, 1899

Plate 22, figure 8

Genotype, by designation, *Trochammina pauciloculata* H. B. Brady

Ammochilostoma EIMER and FICKERT, Zeitschr. Wiss. Zool., vol. 65, 1899, p. 692.

Trochammina (part) H. B. BRADY (not PARKER and JONES), Quart. Journ. Micr. Soc., vol. 19, 1879, p. 58.

Haplophragmium (part) H. B. BRADY, l. c., vol. 21, 1881, p. 50.

Test subglobose, adult with but two or three chambers making up the surface of the test; 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

Plate 22, figures 9, 10

Genotype, by designation, *Nouria polymorphinoides* Heron-Allen and Earland

Nouria HERON-ALLEN and EARLAND, Trans. Zool. Soc. London, vol. 20, 1914, p. 375.

EXPLANATION OF PLATE 22

TROCHAMMINIDAE, PLACOPSILINIDAE

FIG.

1. *Trochammina inflata* (Montagu). × 35. (After H. B. Brady). *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

2, 3. *Carterina spiculotesta* (Carter). (After H. B. Brady). Fig. 2, Dorsal view. × 35. Fig. 3, Fragment of test showing spicular bodies. × 65.

4, 5. *Rotaliammina mayori* Cushman. × 65. (After type figures). Fig. 4, Dorsal view. Fig. 5, Ventral view.

6. *Globotextularia anceps* (H. B. Brady). × 12. (After type figure).

7. *Ammosphaeroidina sphaeroidiniformis* (H. B. Brady). × 12.

8. *Ammochilostoma pauciloculata* (H. B. Brady). × 35. (After type figure). *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

9, 10. *Nouria polymorphinoides* Heron-Allen and Earland. (After type figures).

11, 12. *Placopsilina cenomana* d'Orbigny. (After Reuss).

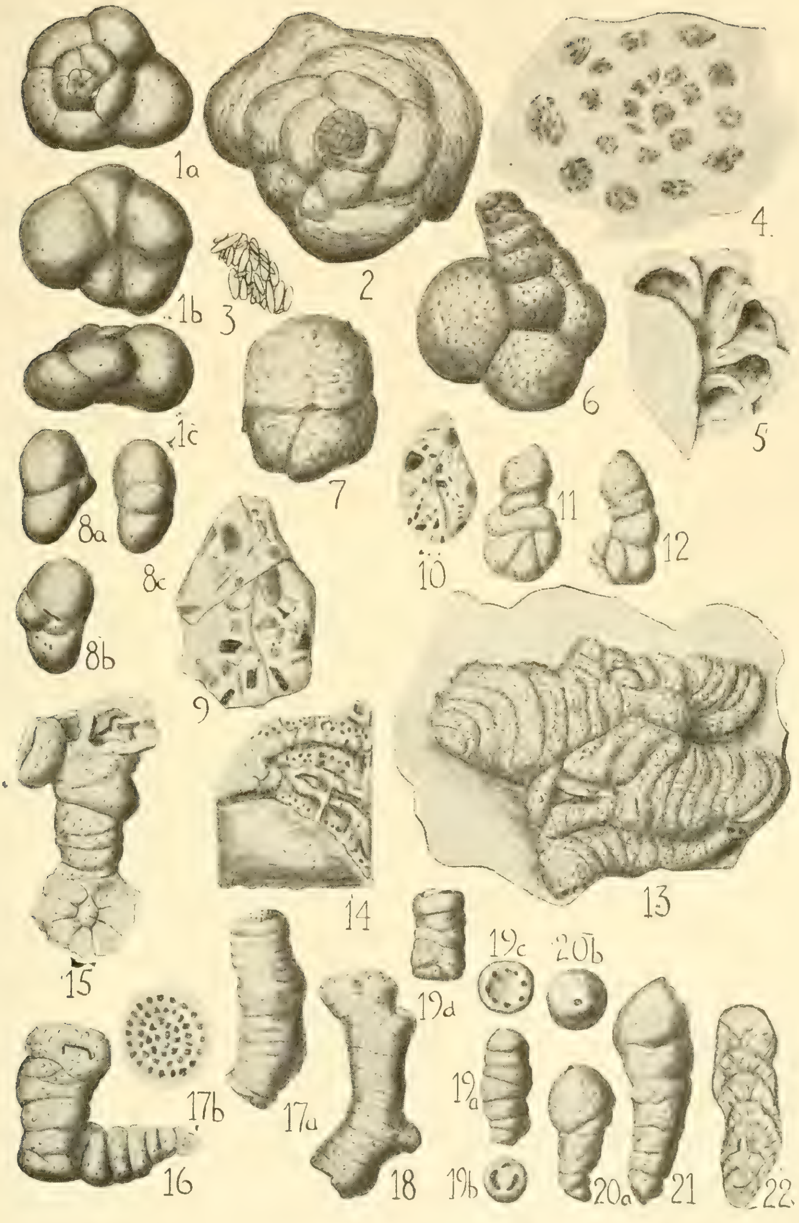
13, 14. *Bdelloidina aggregata* Carter. (After H. B. Brady). Fig. 13, Exterior. × 10. Fig. 14, Interior. × 20.

15, 16. *Haddonia torresiensis* Chapman. (After type figures).

17, 18 *Polyphragma cribrosum* Reuss. Fig. 17, (After Reuss). *a*, side view; *b*, apertural view. Fig. 18, (After Perner). Branching form.

19. *Stylolina lapugyensis* Karrer. (After type figure). *a*, *d*, side views; *b*, *c*, sections showing apertural features.

20–22. *Stacheia marginulinoides* H. B. Brady. (After type figures). Fig. 20, *a*, side view; *b*, apertural view. × 35. Fig. 21, Side view. × 35. Fig. 22, Section showing subdivision of the chambers. × 25.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20b
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22.

PLATE 22

Test free, of several chambers, irregularly arranged; wall arenaceous; aperture simple, terminal.

Recent.

This family includes those arenaceous forms which are typically trochoid at least in the early stages. In *Nouria*, the trochoid character is not so marked, but in some species at least there seems to be a loose spiral.

FAMILY 20. PLACOPSILINIDAE

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

KEY TO THE GENERA

I. Chambers simple, not labyrinthic.
  A. Early chambers close coiled, later uncoiled in a linear series, aperture simple. .... *Placopsilina.*
  B. Test spreading, apertures numerous, peripheral....... *Bdelloidina.*
II. Chambers labyrinthic.
  A. Aperture simple.
    1. Aperture, a crescent-shaped slit. .... *Haddonia.*
    2. Aperture rounded, often with a neck................ *Stacheia.*
  B. Aperture cribrate, test cylindrical. .... *Polyphragma.*
  C. Aperture, a ring of pores, test cylindrical............... *Stylolina.*

Subfamily 1. Placopsilininae

Chambers simple, not labyrinthic

Genus PLACOPSILINA d'Orbigny, 1850

Plate 22, figures 11, 12

Genoholotype, *Placopsilina cenomana* d'Orbigny

Placopsilina D'ORBIGNY, Prodr. Pal., vol. 2, 1850, p. 96.

Lituola JONES and PARKER (not LAMARCK), Quart. Journ. Geol. Soc., vol. 16, 1860, p. 302.

Test attached, composed of numerous chambers, early portion close coiled, later portions uncoiled 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

Plate 22, figures 13, 14

Genoholotype, *Bdelloidina aggregata* Carter

Bdelloidina CARTER, Ann. Mag. Nat. Hist., ser. 4, vol. 19, 1877, p. 201.

Test attached, of irregular chambers, broad and low, early ones more or less coiled; wall arenaceous, with sponge spicules; apertures numerous, rounded, on the outer face of the chamber.

Jurassic to Recent.

Subfamily 2. Polyphragminae

Chambers labyrinthic

Genus HADDONIA Chapman, 1898

Plate 22, figures 15, 16

Genoholotype, *Haddonia torresiensis* Chapman

Haddonia CHAPMAN, Journ. Linn. Soc. London, Zool., vol. 26, 1898, p. 453.

Test attached, 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. Tropical. Indo-Pacific.

Genus POLYPHRAGMA Reuss, 1871

Plate 22, figures 17, 18

Genoholotype, *Polyphragma cribrosum* Reuss

Polyphragma REUSS, Sitz. Akad. Wiss. Wien, vol. 64, pt. 1, 1871, p. 277.

Test attached, later portion standing above the attached surface, cylindrical, often branched, 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

Plate 22, figure 19

Genoholotype, *Stylolina lapugyensis* Karrer

Stylolina Karrer, Abhandl. k. k. Geol. Reichs., vol. 9, 1877, p. 371.

Test attached, 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

Plate 22, figures 20-22

Genotype, by designation, *Stacheia marginulinoides* H. B. Brady

Stacheia H. B. Brady, Pal. Soc. Mon. 30, 1876, p. 107.

Test attached, early chambers suggesting a spiral arrangement, later ones irregular, labyrinthic; wall arenaceous, with an outer imperforate layer; 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 *Haddonia* in which the early stages are Textularian. If these are really the same, *Haddonia* 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; wall finely arenaceous, siliceous or calcareous; apertures on the basal side of the test, multiple in higher forms.

KEY TO THE GENERA

I. Test high conical, not divided into chambers. . . . . *Howchinia.*
II. Test conical, divided into chambers, aperture not cribrate.
  A. Chambers not labyrinthic. . . . . *Tetrataxis.*
  B. Chambers labyrinthic but without distinct chamberlets. . *Ruditaxis.*
  C. Chambers labyrinthic, two rows of chamberlets in each chamber. *Valvulinella.*
III. Test conical-chambered, aperture cribrate.
  A. Mostly siliceous, lower side usually concave.
    1. Apertures on the ventral side. . . . . *Orbitolina.*
    2. Apertures on the periphery. . . . . *Cyclolina.*
  B. Mostly calcareous, lower side flat or convex.
    1. Without pillars.
      a. Exterior with a finely reticulate structure with two sets of outer chamberlets. . . . . *Dictyoconus.*
      b. Exterior with a finely reticulate structure, with a single set of outer chamberlets. . . . . *Cushmania.*
      c. Exterior without a finely reticulate structure, partitions between chamberlets double. . . . . *Chapmania.*
    2. With pillars. . . . . *Dictyoconoides.*

Genus HOWCHINIA Cushman, 1927

Plate 23, figures 1-4

Genoholotype, *Patellina bradyana* Howchin

Howchinia CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 3, 1927, p. 42.

Patellina HOWCHIN (not WILLIAMSON), Journ. Roy. Micr. Soc., 1888, p. 544.

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

Plate 23, figures 5-7

Genoholotype, *Tetrataxis conica* Ehrenberg

Tetrataxis EHRENBERG, Bericht. Preuss. Akad. Wiss. Berlin, 1843, p. 106.

Valvulina (part) H. B. BRADY (not D'ORBIGNY), Pal. Soc. Mon. 30, 1876, p. 81.

Test conical, consisting of a proloculum and elongate second chamber, later broken up into elongate, crescentic chambers which may be divided into chamberlets in some species; aperture elongate, at the margin of the umbilical border of the chamber.

Carboniferous and Permian.

Genus RUDITAXIS Schubert, 1920

Plate 53, figures 1, 2

Genoholotype, *Valvulina rudis* H. B. Brady

Ruditaxis SCHUBERT, Pal. Zeitschr., vol. 3, 1920, p. 180.
Valvulina (part) H. B. BRADY (not D'ORBIGNY), Pal. Soc. Mon. 30, 1876, p. 90.

Test in general structure like *Tetrataxis* but the chambers labyrinthic; the wall more roughly and coarsely arenaceous.

Pennsylvanian and Permian.

EXPLANATION OF PLATE 23

ORBITOLINIDAE

FIG.

1–4. *Howchinia bradyana* (Howchin). × 35. (After type figures). Figs. 1, 3, Side views. Fig. 2, Vertical section. Fig. 4, Ventral view.

5. *Tetrataxis maxima* Schellwien. × 15. (After type figure). Partial section.

6, 7. *Tetrataxis palaeotrochus* Ehrenberg. × 30. (After H. B. Brady). Fig. 6, *a*, dorsal view; *b*, ventral view; *c*, peripheral view. Fig. 7, Vertical section.

8–11. *Valvulinella youngi* (H. B. Brady). × 30. (After type figures). Fig. 8, Peripheral view. Fig. 9, Dorsal view. Fig. 10, Vertical section. Fig. 11, Transverse section.

12, 13. *Orbitolina concava* Parker and Jones. (After Egger). Fig. 12, Vertical section. Fig. 13, Horizontal section.

14. *Dictyoconus puilboreauensis* Woodring. × 12. (After type figure). Vertical section.

15. *Chapmania gassinensis* A. Silvestri. × 22. (After A. Silvestri). Vertical section.

16. *Cushmania americana* (Cushman). × 22. (After type figure). Vertical section.

17. *Cyclolina cretacea* d'Orbigny. × 4. (After type figure). *a*, dorsal view; *b*, peripheral view; *c*, same enlarged.

18–23. *Dictyoconoides cooki* (Carter). Figs. 18–21, (After Carter). Figs. 22, 23, (After Nuttall). Fig. 18, Exterior. Fig. 19, Dorsal view. Fig. 20, Portion of base. Fig. 21, Portion of vertical section. Fig. 22, Portion of surface layer. Fig. 23, Vertical section.

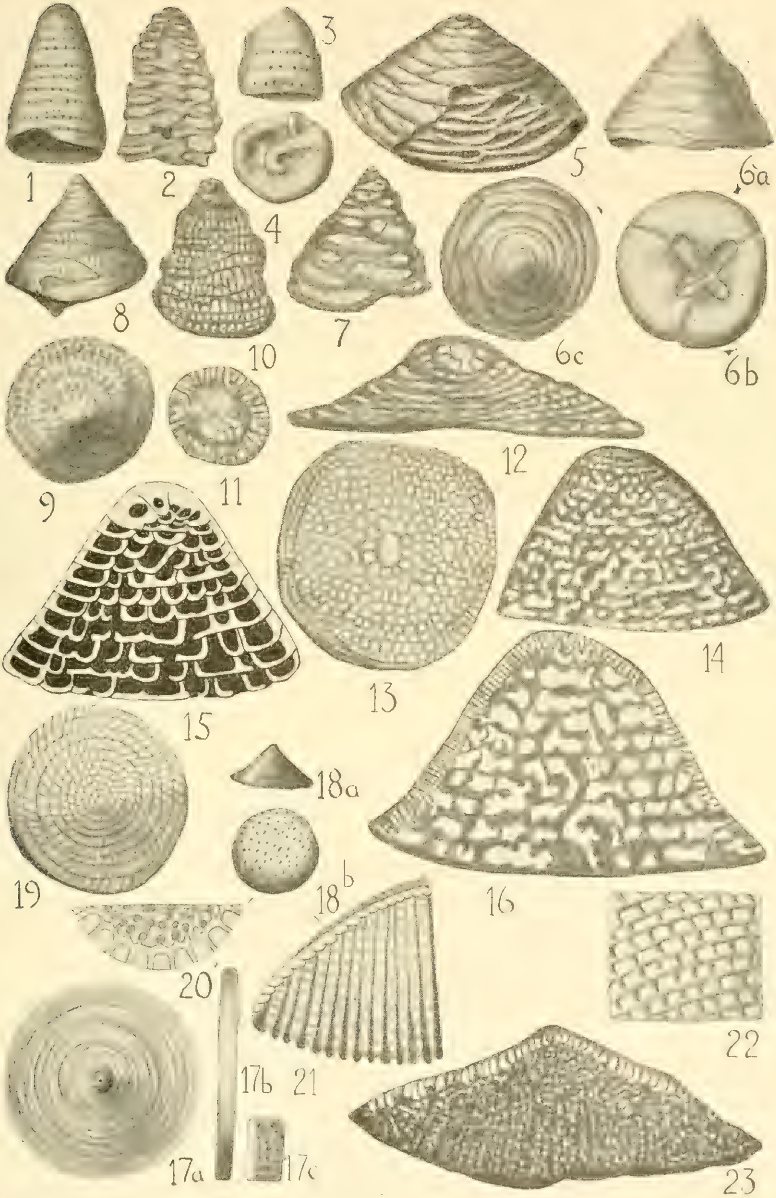
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Plate 23

Genus VALVULINELLA Schubert, 1907

Plate 23, figures 8-11

Genotype, by designation, *Valvulina youngi* H. B. Brady

Valvulinella SCHUBERT, Verh. k. k. Geol. Reichs., 1907, p. 211.
Valvulina (part) of authors (not PARKER and JONES).

Test conical, similar to *Tetrataxis* in general form, the interior labyrinthic, two horizontal series of chamberlets developed in each chamber, the divisions appearing through the thin outer coating; aperture not cribrate.

Carboniferous.

Genus ORBITOLINA d'Orbigny, 1847

Plate 23, figures 12, 13

Genotype, by designation, *Orbitolina gigantea* d'Orbigny

Orbitolina D'ORBIGNY, Prodr. Pal., vol. 2, 1850, p. 143.

Test depressed, conical, lower side usually concave; outer portion of each chamber subdivided by secondary partitions; wall of agglutinated siliceous particles; aperture in the adult consisting of numerous pores on the basal side.

Cretaceous.

Genus DICTYOCONUS Blanckenhorn, 1900

Plate 23, figure 14

Genoholotype, *Patellina aegyptiensis* Chapman

Dictyoconus BLANCKENHORN, Zeitschr. Deutsch. Geol. Ges., vol. 52, 1900, p. 433.

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

Eocene.

Genus CUSHMANIA Silvestri, 1926

Plate 23, figure 16

Genoholotype, *Conulites americana* Cushman

Cushmania SILVESTRI, Mem. Pont. Accad. Sci. Nuovi Lincei, vol. 9, 1926, p. 7.

Conulites CUSHMAN (not FISCHER), Publ. 291, Carnegie Inst. Washington, 1919, p. 43.

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

Plate 23, figure 15

Genoholotype, *Patellina aegyptiensis* Chapman [?]

Chapmania PREVER and SILVESTRI, Boll. Soc. Geol. Ital., vol. 23, 1905, p. 477.

Test conical, finely arenaceous, calcareous, chambers annular, divided into chamberlets but without the finely reticulate subepidermic layer of *Dictyoconus*, partitions between the chamberlets double throughout except in the very earliest chambers; median chambers in horizontal layers; apertures basal, circular or crescentic.

Eocene.

Genus CYCLOLINA d'Orbigny, 1846

Plate 23, figure 17

Genoholotype, *Cyclolina cretacea* d'Orbigny

Cyclolina D'ORBIGNY, Foram. Foss. Bass. Tert. Vienne, 1846, p. 139.

Test free, discoidal, very much compressed, circular in outline; chambers annular; apertures numerous, rounded, on the periphery of the chamber.

Cretaceous.

Genus DICTYOCONOIDES Nuttall, 1925

Plate 23, figures 18-23

Genoholotype, *Conulites cooki* Carter

Dictyoconoides NUTTALL, Ann. Mag. Nat. Hist., ser. 9, vol. 16, 1925, p. 384.

Conulites CARTER (not FISCHER), Journ. Bombay Branch Roy. Asiatic Soc., vol. 6, 1861 (1862), p. 53.

Test conical, chambers of the outer layer rectangular, arranged in spiral whorls, each with an opening at the base communicating with the interior of the test which is filled with columnar chambers and vertical pillars; wall calcareous, that of the outer surface thin, imperforate; apertures numerous on the ventral face.

Eocene. India.

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 as further developed in *Howchinia.* *Tetrataxis* represents an early stage in the series where the division into chambers has taken place. In *Valvulinella* there is a further division into chamberlets. In the higher forms, the flattened chambers are taken on with the aperture on the broad flattened face consisting of numerous pores. *Dictyoconoides* is a very peculiar form, and probably has its affinities with the Rotaliidae or related families, but is left here until more is known of its relationships.

FAMILY 22. LAGENIDAE

Test vitreous, with a glassy lustre; chambers simple, neither biserial, trochoid, nor irregularly spiral, planispiral when coiled; wall calcareous with very fine perforations; aperture typically radiate but in a few genera simple, in the radiate apertured forms with a small chamberlet below the radiate aperture opening into the main chamber by a simple rounded orifice.

KEY TO THE GENERA

I. Test mostly close coiled.
  - A. Aperture with a rounded opening at the outer angle of the apertural face. .... *Robulus.*
  - B. Aperture entirely radiate.
    1. Sides typically convex. .... *Lenticulina.*
    2. Sides typically flattened or concave. .... *Planularia.*

II. Test coiled in the early stages at least in the microspheric form.
  - A. Test much compressed.
    1. Aperture entirely radiate.
       - a. Later chambers extending obliquely back on one side. *Vaginulina.*

b. Later chambers extending back on both sides.
(1). Early stages distinctly spiral in both forms. *Flabellina.*
(2). Early stages spiral usually in microspheric form only. .... *Frondicularia.*
c. Later chambers inflated, rectilinear........ *Amphicoryne.*
2. Aperture elliptical. .... *Lingulina.*
B. Test very little compressed, aperture radiate......... *Marginulina.*
C. Test in later stages triangular in section............. *Saracenaria.*

III. Test with the early stages not coiled.
A. Chambers multiple.
1. Not involute.
a. Sutures oblique, aperture at the peripheral angle. *Dentalina.*
b. Sutures directly transverse, aperture terminal, central. *Nodosaria.*
2. Involute. .... *Glandulina.*
B. Chambers single. .... *Lagena.*

Subfamily 1. Nodosariinae

Test multilocular

Genus ROBULUS Montfort, 1808

Plate 24, figures 1, 2; plate 25, figure 1

Genoholotype, *Robulus cultratus* Montfort

Robulus MONTFORT, Conch. Syst., vol. 1, 1808, p. 215, 54th genre.

Phonemus MONTFORT, l. c., p. 11 (genoholotype, "Le phoneme tranchant". *Nautilus vortex* FICHTEL and MOLL).

Pharamum MONTFORT, l. c., p. 35 (genoholotype, "Le Pharame perle". *Nautilus calcar* (part)).

Patrocles MONTFORT, l. c., p. 219 (genoholotype, *Patrocles querelans* MONTFORT, *Nautilus calcar* (part)).

Spincterules MONTFORT, l. c., p. 223 (genoholotype, *Nautilus costatus* FICHTEL and MOLL).

Herion MONTFORT, l. c., p. 231 (genoholotype, *Nautilus calcar* (part)).

Rhinocurus MONTFORT, l. c., p. 235 (genoholotype, *Rhinocurus araneosus* MONTFORT).

Lampas MONTFORT, l. c., p. 243 (genoholotype, *Nautilus calcar* (part)).

Scortimus MONTFORT, l. c., p. 251 (genoholotype, *Scortimus navicularis* MONTFORT).

Linthuris MONTFORT, l. c., p. 255 (genoholotype, *Linthuris cassidatus* MONTFORT, *Nautilus cassis* (part)).

Astacolus (?) MONTFORT, l. c., p. 263 (genoholotype, *Astacolus crepidulatus* MONTFORT, *Nautilus crepidulus* FICHTEL and MOLL).

Periples MONTFORT, l. c., p. 271 (genoholotype, *Periples elongatus* MONTFORT).
Robulina D'ORBIGNY, Ann. Sci. Nat., vol. 7, 1826, p. 287 (genotype, by designation, *Robulus cultratus* MONTFORT).
Cristellaria (part) of authors.

Test planispiral, bilaterally symmetrical, typically close coiled, usually involute; chambers numerous, triangular in side view; wall very finely perforate, glassy; aperture, an elongate slit on the median line of the usually somewhat concave apertural face in addition to the radiate aperture of the outer peripheral angle.

Jurassic to Recent.

From the very poor figures and descriptions given by Montfort, it is very difficult to know whether the supplementary aperture of *Robulus* is present or not in some of the genera erected by him. Some of these very evidently have it. Others such as *Astacolus* have it in his figure, but it is doubtful in the others referred to by Montfort.

Genus LENTICULINA Lamarck, 1804

Plate 24, figure 8; plate 25, figure 4

Genotype, by designation, *Lenticulina rotulata* Lamarck

Lenticulina LAMARCK, Ann. Mus., vol. 5, 1804, p. 186.
Antenor MONTFORT, Conch. Syst., vol. 1, 1808, p. 71 (genoholotype, *Antenor diaphaneus* MONTFORT).
Oreas (?) MONTFORT, l. c., p. 95 (genoholotype, *Oreas subulatus* MONTFORT=*Nautilus acutauricularis* FICHTEL and MOLL).
Clisiphontes (?) MONTFORT, l. c., p. 227 (genoholotype, *Clisiphontes calcar* MONTFORT).
Cristellaria LAMARCK, Extract Cours Zool., 1812, p. 122 (and later authors).

Test planispiral, bilaterally symmetrical, typically close coiled or in many species tending to become uncoiled; wall very finely perforate, glassy, smooth or variously ornamented; aperture radiate, typically with a small chamberlet below with a simple rounded aperture opening into the larger cavity of the chamber.

Upper Cambrian (?) to Recent.

Genus PLANULARIA Defrance, 1824

Genoholotype, *Planularia auris* Defrance

Planularia DEFRANCE, Dict. Sci. Nat., vol. 32, 1824, p. 178.
Cristellaria (part) of authors.

Test planispiral, bilaterally symmetrical, very much compressed laterally, the sides nearly parallel; aperture at the peripheral angle, radiate, sometimes with the ventral slit expanded.

Jurassic to Recent.

Genus MARGINULINA d'Orbigny, 1826

Plate 24, figures 9, 10; plate 25, figure 5

Genotype, by designation, *Marginulina glabra* d'Orbigny

Marginulina D'ORBIGNY, Ann. Sci. Nat., vol. 7, 1826, p. 258.

Test subcylindrical, very early portion close coiled, later uncoiled, final chambers often inflated; aperture in the early coiled portion as in *Lenticulina*, in the uncoiled portion becoming central and terminal.

Cambrian (?) to Recent.

Genus DENTALINA d'Orbigny, 1826

Plate 24, figures 11, 12; plate 25, figure 6

Genotype, by designation, *Nodosaria (Dentalina) obliqua* d'Orbigny

Dentalina D'ORBIGNY, Ann. Sci. Nat., vol. 7, 1826, p. 254.

Test arcuate, elongate, of numerous chambers in a linear series; sutures usually oblique, at least in the early portion; aperture radiate, at least in the early stages, at or near the periphery but becoming more nearly central in the last chambers.

Jurassic to Recent.

Genus NODOSARIA Lamarck, 1812

Plate 24, figure 13; plate 25, figure 7

Genotype, by designation, *Nautilus raphanistrum* Linné

Nodosaria LAMARCK, Extract Cours Zool., 1812, p. 121.

Test with the chambers in a straight linear series, the chambers distinct, not strongly embracing; sutures normally at right angles to the axis; wall calcareous, finely perforate, glassy; aperture central and terminal, radiate, often with a chamberlet below with a rounded opening into the main cavity of the chamber.

Cambrian (?) to Recent.

Genus GLANDULINA d'Orbigny, 1826

Plate 24, figure 14; plate 25, figure 8

Genotype, by designation, *Nodosaria (Glandulina) laevigata* d'Orbigny
Glandulina D'ORBIGNY, Ann. Sci. Nat., vol. 7, 1826, p. 251.
Nodosaria (part) of authors.

EXPLANATION OF PLATE 24

LAGENIDAE

FIG.

1, 2. *Robulus cultratus* Montfort. Fig. 1, (After type figure). Fig. 2, (After d'Orbigny). *a*, side view; *b*, apertural view.

3–5. *Saracenaria italica* Defrance. (After H. B. Brady). Fig. 3, Side view. × 10. Figs. 4, 5, End views. × 12.

6. *Lingulina carinata* d'Orbigny. × 10. (After d'Orbigny). *a*, front view; *b*, apertural view.

7. *Lingulina carinata* d'Orbigny, var. *seminuda* Hantken. × 8. (After H. B. Brady). *a*, side view; *b*, apertural view.

8. *Lenticulina rotulata* Lamarck. (From type specimen). *a*, side view; *b*, apertural view.

9. *Marginulina glabra* d'Orbigny. (After d'Orbigny's Model). *a*, side view; *b*, front view; *c*, apertural view.

10. *Marginulina costata* (Batsch). × 12. (After H. B. Brady). *a*, side view; *b*, apertural view.

11. *Dentalina obliqua* (Linné). (After d'Orbigny's Model). *a*, side view; *b*, front view; *c*, apertural view.

12. *Dentalina inornata* d'Orbigny. (After d'Orbigny's Model). *a*, side view; *b*, apertural view.

13. *Nodosaria raphanus* (Linné). × 10. (After H. B. Brady). *a*, side view; *b*, apertural view.

14. *Glandulina laevigata* d'Orbigny. (After type figure). *a*, side view; *b*, apertural view; *c*, section.

15. *Lagena striata* (Walker and Jacob). (After type figure).

16. *Lagena clathrata* H. B. Brady. × 50. (After type figure).

17. *Lagena radiato-marginata* Parker and Jones. × 60. (After H. B. Brady). *a*, front view; *b*, apertural view.

18–20. *Amphicoryne falx* (Jones and Parker). × 35–40. (After H. B. Brady).

21, 22. *Vaginulina legumen* (Linné). Fig. 21, (After Plancus, 1760). Fig. 22, (After Gualtieri).

23. *Vaginulina truncata* Reuss. × 30. (After Chapman). *a*, side view; *b*, peripheral view.

24, 25. *Frondicularia complanata* Defrance. Fig. 24, (After Fornasini). × 8. Fig. 25, (After type figure). × 5.

26, 27. *Frondicularia alata* d'Orbigny. × 12. (After H. B. Brady). Specimens showing "flabelline" stage.


1
2a
2b
3
4
5
6a
6b
7a
7b
8a
8b
9a
9b
9c
10a
10b
11a
11b
11c
12a
12b
13a
13b
14a
14b
14c
15
16
17a
17b
18
19
20
21
22
23a
23b
24
25
26
27

PLATE 24

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.

Psecadium Reuss probably is a synonym of *Glandulina*.

Genus AMPHICORYNE Schlumberger, 1881

Plate 24, figures 18-20; plate 25, figure 10

Genoholotype, *Marginulina falx* Jones and Parker

Amphicoryne SCHLUMBERGER, Comptes Rendus, 1881, p. 881.
Marginulina (part) JONES and PARKER, Quart. Journ. Geol. Soc., vol. 16, 1860, p. 302.

Test in the young like a compressed *Lenticulina* loosely coiled, the last-formed chambers like *Nodosaria*.

Tertiary and Recent.

Genus SARACENARIA Defrance, 1824

Plate 24, figures 3-5; plate 25, figure 2

Genoholotype, *Saracenaria italica* Defrance

Saracenaria DEFRANCE, Dict. Sci. Nat., vol. 32, 1824, p. 177.
Cristellaria (part) of authors.

EXPLANATION OF PLATE 25

LAGENIDAE

FIG.

1. *Robulus crassus* 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. *Lenticulina 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* Jones and Parker. (After H. B. Brady).
11. *Vaginulina patens* H. B. Brady. (After H. B. Brady).
12. *Frondicularia alata* d'Orbigny. (After H. B. Brady).

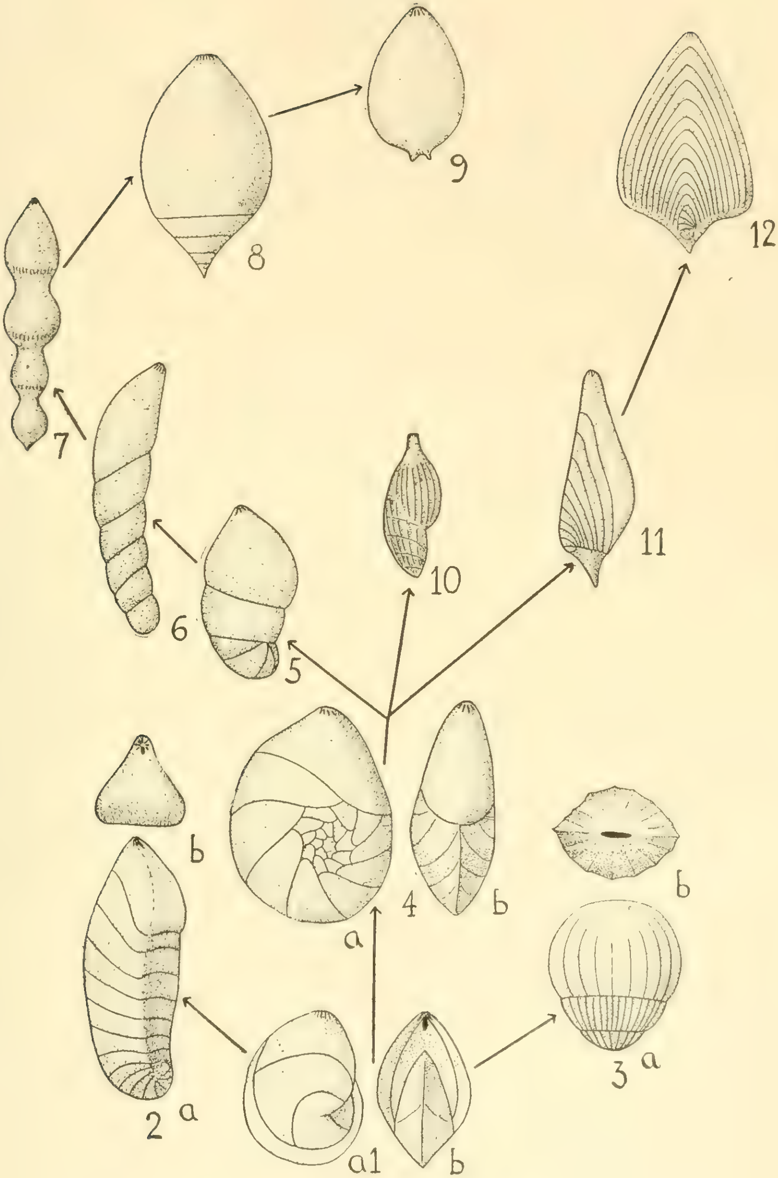

PLATE 25

Test with the earliest chambers close coiled, later uncoiling, usually triangular in transverse section; aperture as in *Robulus*.

Jurassic to Recent.

Genus LINGULINA d'Orbigny, 1826

Plate 24, figures 6, 7; plate 25, figure 3

Genotype, by designation, *Lingulina carinata* d'Orbigny

Lingulina D'ORBIGNY, Ann. Sci. Nat., vol. 7, 1826, p. 256.

Nodosaria (Mucronina) D'ORBIGNY, l. c., p. 256 (genoholotype, *Nodosaria (Mucronina) hastata* D'ORBIGNY).

Lingulinopsis REUSS, Sitz. K. böhm. Ges. Wiss., 1860, p. 23 (genoholotype, *Lingulinopsis bohemica* REUSS).

Test in the early stages, at least in the microspheric form, planispiral, later ones in a rectilinear series, compressed; aperture becoming elongate, elliptical.

Permian to Recent.

Genus VAGINULINA d'Orbigny, 1826

Plate 24, figures 21-23; plate 25, figure 11

Genotype, by designation, *Nautilus legumen* Linné

Vaginulina D'ORBIGNY, Ann. Sci. Nat., vol. 7, 1826, p. 257.

Nautilus (part) LINNÉ, Syst. Nat., Ed. 10, 1758, p. 711.

Test compressed, usually with one side of the test straight, representing the periphery in the coiled forms, the other typically convex; sutures oblique, highest on the straight side of the test; aperture at or near the peripheral angle.

Jurassic to Recent.

Genus FRONDICULARIA Defrance, 1824

Plate 24, figures 24-27; plate 25, figure 12

Genoholotype, *Frondicularia complanata* Defrance

Frondicularia DEFRANCE, Dict. Sci. Nat., vol. 32, 1824, p. 178.

Test much compressed, in the early stages planispiral, 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 early stages peripheral, gradually becoming terminal, radiate.

Permian to Recent.

Genus FLABELLINA d'Orbigny, 1839

Plate 55, figure 9

Genotype, by designation, *Flabellina rugosa* d'Orbigny

Flabellina D'ORBIGNY, in DE LA SAGRA, Hist. Fis. Pol. Nat. Cuba, 1839, "Foraminifères", p. 42.

Frondiculina VON MÜNSTER, in ROEMER, Neues Jahrb. für Min., 1838, p. 382 (genotype, by designation, *Frondiculina oblonga* VON MÜNSTER).

Test similar to *Frondicularia*, but the early chambers coiled both in the microspheric and megalospheric forms.

Cretaceous.

Subfamily 2. Lageninae

Test consisting of a single chamber; aperture typically radiate, but elliptical or rounded in many species.

Genus LAGENA Walker and Jacob, 1798

Plate 24, figures 15-17; plate 25, figure 9

Genotype, by designation, *Serpula (Lagena) sulcata* Walker and Jacob

Lagena WALKER and JACOB, in KANNMACHER'S ed. of Adams' Essays Micr., 1798, p. 634.

Vermiculum MONTAGU, Test. Brit., 1803, p. 517 (genotype, by designation, *Vermiculum perlucidum* MONTAGU).

Lagenula (?) MONTFORT, Conch. Syst., 1808, p. 311 (genoholotype, *Lagenula flosculu* MONTFORT).

Oolina D'ORBIGNY, Voy. Amér. Mérid., 1839, vol. 5, pt. 5, "Foraminifères", p. 18 (genotype, by designation, *Oolina laevigata* D'ORBIGNY).

Amphorina D'ORBIGNY, in CHAS. D'ORBIGNY'S, Dict. Univ. d'Hist. Nat., vol. 5, 1849, p. 666 (genotype, by designation, *Amphorina gracilis* COSTA).

Fissurina REUSS, Deutschr. Akad. Wiss. Wien, vol. 1, 1850, p. 366 (genoholotype, *Fissurina laevigata* REUSS).

Ovulina EHRENBERG, Mikrogeologie, 1854, pl. 32, pt. 2, fig. 2 *b* (genoholotype, *Ovulina clava* EHRENBERG).

Phialina COSTA, Atti Accad. Pontaniana, vol. 7, 1856, p. 122 (genotype, by designation, *Phialina piriformis* COSTA).

Hyaleina COSTA, l. c., pl. 18, figs. 22-25 (no description and no specific names).

Tetragonulina SEGUENZA, Foram. Monot. Mioc. Messina, 1862, p. 53 (genoholotype, *Tetragonulina prima* SEGUENZA).

Trigonulina SEGUENZA, l. c., p. 74 (genotype, by designation, *Trigonulina oblonga* SEGUENZA).

Obliquina (?) SEGUENZA, l. c., p. 75 (genoholotype, *Obliquina acuticosta* SEGUENZA).

Ovolina TERQUEM, Six. Mém. Foram. Lias, 1866, p. 473 (genotype, by designation, *Ovolina trigonula* TERQUEM).

Lagenulina TERQUEM, Essai Anim. plage Dunkerque, pt. 2, 1876, p. 67 (genotype, by designation, *Entosolenia costata* WILLIAMSON).

Capitellina MARSSON, Mitth. Nat. Ver. Neu-Vorpommern u. Rügen, vol. 10, 1878, p. 122 (genoholotype, *Capitellina multistriata* MARSSON).

Test unilocular; aperture typically radiate, rounded or elliptical, terminal, central; wall vitreous, very finely perforate, variously ornamented; chambers typically 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 equal 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.

There are very many generic names that have been proposed by Schubert and others for various modifications in the Lagenidae. As it is well known that the Lagenidae form one of the most plastic groups of the foraminifera and that polymorphism or trimorphism is present to a large extent, generic characters are much harder to define than in some of the more stable families.

It is undoubtedly true that broad frondicularian chambers are formed in the adults of several generic forms. Whether these represent microspheric or megalospheric forms is not always known nor what are the limits of range in these various "genera". A study particularly of Jurassic material where the Lagenidae are especially abundant will help to settle such problems. With abundant Jurassic and Cretaceous material it would make an excellent problem for critical research to work out carefully the relationships in this group.

Hemicristellaria Stache, 1864 and *Hemirobulina* Stache, 1864 were erected for the uncoiled forms with radiate and robuline apertures. They merge into *Marginulina* and *Saracenaria*.

Frondovaginulina Dettmer has the early chambers much compressed and bilaterally symmetrical but the later chambers are added at one side as in *Vaginulina*. *Staffia* Schubert has the early chambers *Nodosaria*-like, and later ones frondicularian. *Tribrachia* Schubert has *Rhabdogonium*-like early chambers and the later ones frondicularian. *Spirofrondicularia* Schubert has the early chambers *Polymorphina*-like, and the later ones frondicularian. *Flabellinella* Schubert has the early chambers *Vaginulina*-like, and the later ones frondicularian.

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 Cretaceous and has developed few new characters since that time. *Frondicularia* and allied forms reached their climax in the Cretaceous.

FAMILY 23. POLYMORPHINIDAE

Test spiral or sigmoid in the earlier stages, later in some genera becoming biserial, uniserial, or irregularly branching; chambers simple, not labyrinthic; wall calcareous, very finely perforate; aperture radiate except in the more degenerate genera where there is a simple, rounded opening.

KEY TO THE GENERA

I. Test with the chambers in a closed spiral or sigmoid series at least in the early stages.
    A. Test not compressed, wholly spiral.
        1. Test rounded or elliptical with short chambers.....*Guttulina.*
        2. Test elongate, fusiform with elongate chambers...*Pyrulinella.*
    B. Test slightly compressed.
        1. Test spiral, becoming biserial...........*Pseudopolymorphina.*
        2. Test spiral, becoming uniserial..................*Dimorphina.*
    C. Test strongly compressed, becoming biserial........*Polymorphina.*
II. Test with the chambers in an open sigmoid series.
    A. Test elongate, chambers not reaching the base of the preceding ones, slightly involute. ....*Sigmoidella.*
    B. Test ovate, chambers extending beyond the base of the preceding ones, strongly involute. ....*Sigmomorpha.*
III. Test irregular, of globular chambers with stolon-like connections.
    A. Free, very irregularly branching, stolons elongate......*Ramulina.*
    B. Attached, chambers distinct, stolons short...........*Vitriwebbina.*

Subfamily 1. Polymorphininae

Test with the chambers in a closed spiral or sigmoid series at least in the early stages, later becoming in some genera biserial or uniserial.

Genus GUTTULINA d'Orbigny, 1826

Plates 26, figures 1, 2, 4

Genotype, by designation, *Polymorphina (Guttulina) communis* d'Orbigny

Guttulina d'Orbigny, Ann. Sci. Nat., vol. 7, 1826, p. 266 (as a subgenus of *Polymorphina*).

Polymorphina (part) of authors (not d'Orbigny), s. str.

Test rounded, spherical to fusiform; chambers spheroidal to ellipsoidal or clavate, not at all compressed, arranged more or less in an elongate spiral series so that they form generally a clockwise close sigmoid series viewed from the base, successive chambers added in planes less than 180°, three or four chambers in a cycle; sutures distinct; aperture radiate.

Jurassic to Recent.

The following three subgenera may be distinguished by the sutures and form.

Guttulina s. str. having much depressed sutures.

Pyrulina d'Orbigny, Ann. Sci. Nat., vol. 7, 1826, p. 267, (subgenotype, monotypic, *Polymorphina* (*Pyrulina*) *gutta* d'Orbigny) characterized by an elongated test and non-depressed sutures.

Globulina d'Orbigny, Ann. Sci. Nat., vol. 7, 1826, p. 266 (subgenotype, by designation, *Polymorphina* (*Globulina*) *gibba* d'Orbigny) characterized by a generally globular test and non-depressed sutures.

Genus PSEUDOPOLYMORPHINA Cushman and Ozawa, 1928

Plate 26, figure 5

Genoholotype, *Pseudopolymorphina hanzawai* Cushman and Ozawa

Pseudopolymorphina CUSHMAN and OZAWA, Contr. Cushman Lab. Foram. Res., vol. 4, 1928, p. 15.
Polymorphina (part) of authors.

Test elongate, often somewhat compressed; chambers rounded, generally as long as broad, arranged in a closed sigmoid series in the earlier stages, becoming biserial in the adult; sutures distinct, depressed; aperture radiate.

Jurassic to Recent.

Genus PYRULINELLA Cushman and Ozawa, 1928

Plate 26, figure 3

Genoholotype, *Polymorphina lanceolata* Reuss

Pyrulinella CUSHMAN and OZAWA, Contr. Cushman Lab. Foram. Res., vol. 4, 1928, p. 16.
Polymorphina (part) of authors.

Test fusiform or cylindrical; chambers rounded in the earlier *Guttulina* stage but often elongate in the later biserial stage; the arrangement of the chambers sometimes tending to become uniserial; sutures distinct, not depressed.

Jurassic to Recent.

Genus DIMORPHINA d'Orbigny, 1826

Plate 26, figure 6

Genoholotype, *Dimorphina tuberosa* d'Orbigny

Dimorphina D'ORBIGNY, Ann. Sci. Nat., vol. 7, 1826, p. 264.

Test cylindrical; chambers rounded, arranged at first in a closed sigmoid series, becoming uniserial in the adult; sutures distinct, depressed.

Cretaceous to Recent.

Genus POLYMORPHINA d'Orbigny, 1826

Plate 26, figures 9, 10

Genotype, by designation, *Polymorphina burdigalensis* d'Orbigny

Polymorphina D'ORBIGNY, Ann. Sci. Nat., vol. 7, 1826, p. 265.

Test generally compressed, elliptical in side view, often much elongated; chambers cylindrical or much compressed, arranged

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EXPLANATION OF PLATE 26

POLYMORPHINIDAE

FIG.

1. *Guttulina orientalis* Cushman and Ozawa. From side and base.
2. *Guttulina (Pyrulina) gutta* d'Orbigny. (After d'Orbigny). From side and base.
3. *Pyrulinella lanceolata* (Reuss). From side and front.
4. *Guttulina (Globulina) gibba* d'Orbigny. (After d'Orbigny). From side and apertural end.
5. *Pseudopolymorphina doanei* (Galloway and Wissler). From side and apertural end.
6. *Dimorphina tuberosa* d'Orbigny. (After d'Orbigny). From side.
7. *Vitriwebbina sollasi* Chapman. (After Chapman).
8. *Ramulina globulifera* H. B. Brady. (After H. B. Brady).
9. *Polymorphina charlottensis* Cushman. Megalospheric form. From side and apertural end.
10. *Polymorphina burdigalensis* d'Orbigny. (After d'Orbigny's Model). From two sides and base.
11. *Sigmomorpha sadoensis* Cushman and Ozawa. From two sides and base.
12. *Sigmomorpha (Sigmomorphina) frondicularis* (Galloway and Wissler).
13. *Sigmoidella (Sigmoidina) pacifica* Cushman and Ozawa. From two sides.
14. *Sigmoidella kagaensis* Cushman and Ozawa.
15. *Sigmoidella elegantissima* (Parker and Jones).

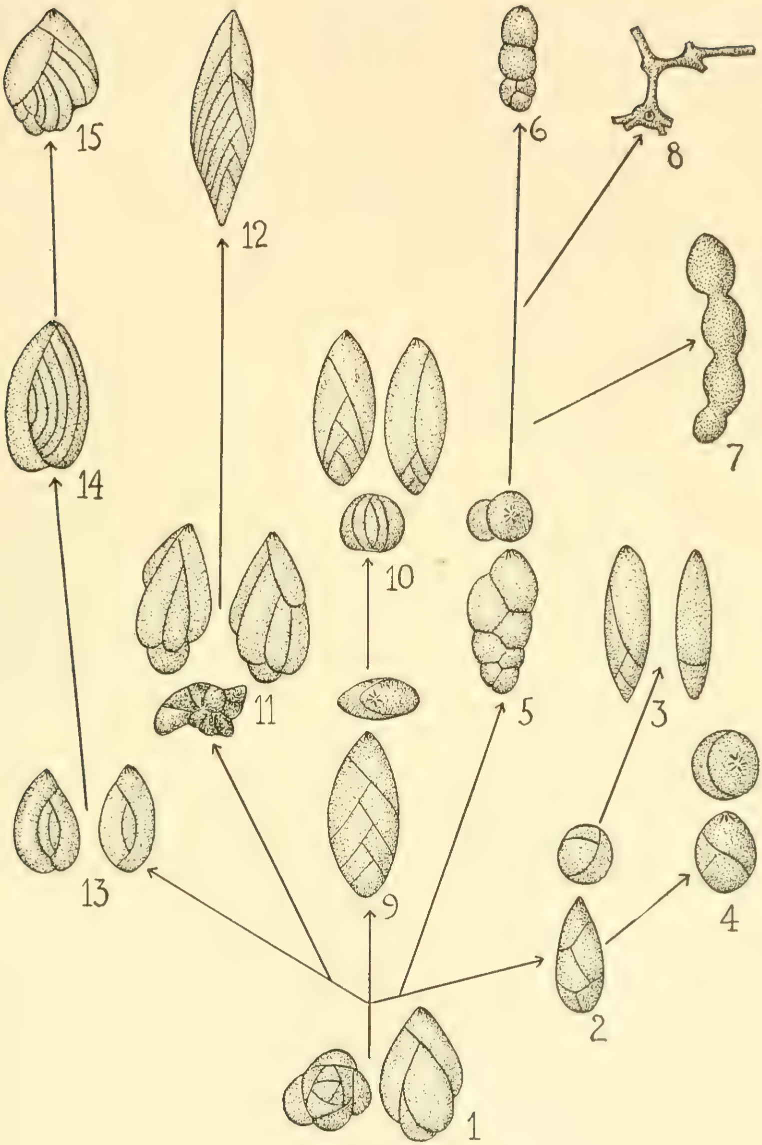


PLATE 26

in a clockwise sigmoid series at least in the early stages of the microspheric form, later becoming biserial in the microspheric form or entirely so in the megalospheric; sutures depressed or not, often limbate.

Genus SIGMOMORPHA Cushman and Ozawa, 1928

Plate 26, figures 11, 12

Genoholotype, *Sigmomorpha sadoensis* Cushman and Ozawa

Sigmomorpha CUSHMAN and OZAWA, Contr. Cushman Lab. Foram. Res., vol. 4, 1928, p. 17.

Polymorphina (part) of authors.

Test flattened, oval to subelliptical in side view; chambers elongate, angular in transverse section, arranged at first like *Guttulina,* then open sigmoidal; sutures distinct, depressed.

This genus may be divided into two subgenera:

Sigmomorpha s. str.

Rounded chambers are arranged in a more or less closed sigmoid series, and five or six chambers of each series complete one cycle.

Sigmomorphina CUSHMAN and OZAWA, 1928.

Subgenotype, *Sigmomorphina yokoyamai* CUSHMAN and OZAWA.

Sigmomorphina CUSHMAN and OZAWA, Contr. Cushman Lab. Foram. Res., vol. 4, 1928, p. 17.

Chambers much compressed, triangular in section and the successive chambers added in planes of more than 180°, often much twisted.

Genus SIGMOIDELLA Cushman and Ozawa, 1928

Plate 26, figures 13-15

Genoholotype, *Sigmoidella kagaensis* Cushman and Ozawa

Sigmoidella CUSHMAN and OZAWA, Contr. Cushman Lab. Foram. Res., vol. 4, 1928, p. 18.

Polymorphina (part) of authors.

Test ovate to elliptical in side view, compressed; chambers elongate, angular, regularly arranged in open sigmoid series, gradually increasing in length in the later ones which include the earlier ones, but often the adult chambers not reaching the base; sutures distinct.

The following two subgenera may be distinguished:

Sigmoidella s. str.

Having much compressed chambers arranged in planes more than 180° from one another similar to *Sigmoilina* in the Miliolidae.

Sigmoidina CUSHMAN and OZAWA.

Subgenoholotype, *Sigmoidella (Sigmoidina) pacifica* CUSHMAN and OZAWA.

Sigmoidina CUSHMAN and OZAWA, Contr. Cushman Lab. Foram. Res., vol. 4, 1928, p. 18.

Having rather rounded chambers arranged in a sigmoid series, added successively in planes 180° apart, five or six chambers completing a cycle.

Subfamily 2. Ramulininae

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

Genus RAMULINA Rupert Jones, 1875

Plate 26, figure 8

Genotype, by designation, *Ramulina laevis* Rupert Jones

Ramulina RUPERT JONES, in J. WRIGHT, Rept. Proc. Belfast Nat. Field Club, 1873-74, App. III, 1875, p. 88 (90).

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

Jurassic to Recent.

Genus VITRIWEBBINA Chapman, 1892

Plate 26, figure 7

Genotype, by designation, *Vitriwebbina sollasi* Chapman

Vitriwebbina CHAPMAN, Geol. Mag., dec. 3, vol. 9, 1892, p. 53.

Test attached, consisting of a series of rounded chambers with tubular connections; wall very finely perforate; early chambers sometimes polymorphine.

Cretaceous and Eocene.

FAMILY 24. NONIONIDAE

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

KEY TO THE GENERA

I. Adult test typically close coiled, planispiral, bilaterally symmetrical.
  A. Apertures at the base of the apertural face.
    1. Single, sutures simple. .... *Nonion.*
    2. Usually several, sutures with bridges............. *Elphidium.*
  B. Apertures partly in the apertural face.
    1. Aperture, a single rounded opening in the middle of the face. *Orbignyna.*
    2. Aperture consisting of numerous rounded pores... *Cribrospira.*
    3. Aperture with concentric rows of elongate pits..... *Bradyina.*

II. Adult test somewhat trochoid.
  A. Last-formed chambers extending toward and often covering the umbilicus at one side. .... *Nonionella.*
  B. Test in the adult typically trochoid, planoconvex.
    1. Dorsally convex, ventrally flattened. .... *Polystomellina.*
    2. Dorsally flattened, ventrally convex.............. *Faujasina.*

EXPLANATION OF PLATE 27

Nonionidae

Fig.

1. *Nonion incrassatus* (Fichtel and Moll). (After type figure). *a*, side view; *b*, peripheral view.
2. *Nonion turgidus* (Williamson). × 50. (After H. B. Brady). *a*, side view; *b*, apertural view.
3. *Nonion umbilicatulus* (Montagu). × 50. (After H. B. Brady). *a*, side view; *b*, apertural view.
4. *Cribrospira panderi* Möller. × 20. (After type figure). *a*, apertural view; *b*, from opposite periphery; *c*, side view.
5. *Bradyina rotula* (Eichwald). × 20. (After Möller). *a*, apertural view; *b*, side view.

6, 7. *Bradyina nautiliformis* Möller. (After type figures). Fig. 6, × 12. Fig. 7, Section. × 20.

8. *Nonionella miocenica* Cushman. × 50. (After type figure). *a*, dorsal view; *b*, ventral view; *c*, apertural view.
9. *Elphidium macellus* (Fichtel and Moll). (After type figure). *a*, side view; *b*, apertural view.
10. *Elphidium craticulatus* (Fichtel and Moll). (After H. B. Brady). *a*, side view; *b*, apertural view.
11. *Polystomellina discorbinoides* Yabe and Hanzawa. × 40. (After type figure). *a*, dorsal view; *b*, ventral view; *c*, peripheral view.
12. *Faujasina carinata* d'Orbigny. (After type figure). *a*, ventral view; *b*, dorsal view; *c*, peripheral view.

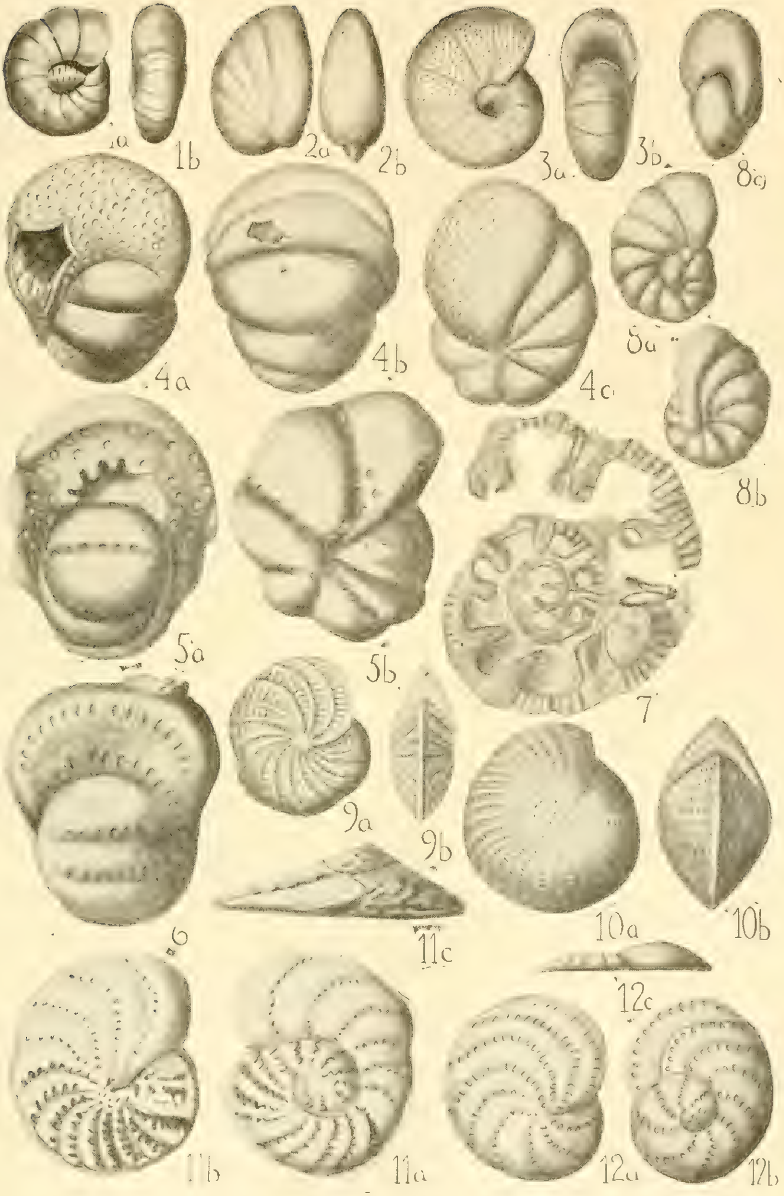

1a
1b
2a
2b
3a
3b
8c
4a
4b
4c
8a
8b
5a
5b
7
6
9a
9b
10a
10b
11c
12c
11b
11a
12a
12b

PLATE 27

Genus NONION Montfort, 1808

Plate 27, figures 1-3; plate 28, figure 1

Genoholotype, *Nautilus incrassatus* Fichtel and Moll

Nonion MONTFORT, Conch. Syst., vol. 1, 1808, p. 211.
Melonis MONTFORT, l. c., p. 67 (genoholotype, *Nautilus pompiloides* FICHTEL and MOLL).
Florilus MONTFORT, l. c., p. 135 (genoholotype, *Nautilus asterizans* FICHTEL and MOLL).
Pulvinulus (part) LAMARCK, 1816.
Placentula (part) LAMARCK, 1822.
Cristellaria (part) LAMARCK, 1822.
Lenticulina (part) DEFRANCE, 1824 (not LAMARCK).
Polystomella (part) DEFRANCE and authors (not LAMARCK).
Nonionina D'ORBIGNY, Ann. Sci. Nat., vol. 7, 1826 (genotype, by designation, *Nonionina umbilicata* D'ORBIGNY).

Test free, planispiral, more or less involute, bilaterally symmetrical, periphery broadly rounded to acute; chambers numerous; wall finely perforate; aperture, an arched, usually narrow opening between the base of the apertural face and the preceding coil.

Carboniferous (?) to Recent.

Genus ORBIGNYNA Hagenow, 1842

Plate 54, figure 5

Genoholotype, *Orbignyna ovata* Hagenow

Orbignyna HAGENOW, Neues Jahrb. für Min., 1842, p. 573.

Test planispiral, involute; chambers distinct, later ones with the sides continuing back over the umbilical area; wall calcareous, finely perforate; aperture in the adult, rounded, in the middle of the apertural face.

Cretaceous of Europe and America.

Genus CRIBROSPIRA Möller, 1878

Plate 27, figure 4; plate 28, figure 2

Genoholotype, *Cribrospira panderi* Möller

Cribrospira MÖLLER, Mém. Acad. Imp. Sci. St. Pétersbourg, ser. 7, vol. 25, no. 9, 1878, p. 86.

Test mostly involute, bilaterally symmetrical at least in the adult; aperture cribrate, the numerous rounded openings in a

more or less concentric grouping on the apertural face.
Carboniferous to Cretaceous (?).

Genus NONIONELLA Cushman, 1926

Plate 27, figure 8; plate 28, figure 3

Genoholotype, *Nonionella miocenica* Cushman

Nonionella CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 2, 1926, p. 64.
Nonionina (part) of authors.

Test subtrochoid, the dorsal side only partially involute, ventral side completely so, close coiled; chambers especially in the adult inaequilateral, the ventral side developing a distinct elongate lobe at the umbilical end, which covers the umbilicus itself; wall calcareous, finely perforate; aperture at the base of the apertural face of the chamber, low and elongate, extending from the peripheral border toward the ventral side.
Cretaceous to Recent.

Genus BRADYINA Möller, 1878

Plate 27, figures 5-7; plate 28, figure 4

Genotype, by designation, *Bradyina nautiliformis* Möller

Bradyina MÖLLER, Mém. Acad. Imp. Sci. St. Pétersbourg, ser. 7, vol. 25, no. 9, 1878, p. 78.
Nonionina (part) EICHWALD, 1860 (not D'ORBIGNY).
Lituola (part) H. B. BRADY, 1876 (not LAMARCK).

Test mostly involute, bilaterally symmetrical at least in the adult; aperture, a single opening or series of openings at the base of the apertural chamber in the middle line with a supplementary series in a crescentic line near the peripheral margin of the apertural face, connecting with the exterior after new chambers are added by a row of pits along the sutural lines.
Carboniferous.

Genus ELPHIDIUM Montfort, 1808

Plate 27, figures 9, 10; plate 28, figure 5

Genoholotype, *Nautilus macellus* Fichtel and Moll (part)

Elphidium MONTFORT, Conch. Syst., vol. 1, 1808, p. 15.
Geophonus MONTFORT, l. c., p. 19 (genoholotype, *Nautilus macellus* FICHTEL and MOLL (part)).

Pelorus MONTFORT, l. c., p. 23 (genoholotype, *Nautilus ambiguus* FICHTEL and MOLL (part)).
Andromedes MONTFORT, l. c., p. 39 (genoholotype, *Nautilus strigillatus* FICHTEL and MOLL (part)).
Sporilus MONTFORT, l. c., p. 43 (genoholotype, *Nautilus strigillatus* FICHTEL and MOLL (part)).
Themeon MONTFORT, l. c., p. 203 (genoholotype, *Themeon rigatus* MONTFORT=*Nautilus crispus* LINNÉ).
Cellanthus MONTFORT, l. c., p. 207 (genoholotype, *Nautilus craticulatus* FICHTEL and MOLL).
Vorticialis LAMARCK, Extrait Cours Zool., 1812, p. 122 (genotype, by designation, *Nautilus craticulatus* FICHTEL and MOLL).
Polystomella LAMARCK, Hist. Anim. sans Vert., vol. 7, 1822, p. 625 (genotype, by designation, *Nautilus crispus* LINNÉ).
Robulina (part) MÜNSTER, 1838.
Geoponus EHRENBERG, Abhandl. k. Akad. Wiss. Berlin, for 1839 (1841), p. 132 (genoholotype, *Geoponus stella-borealis* EHRENBERG).
Nonionina (part) BOLL, 1846.
Helicozoa MOEBIUS, Beitr. Meeresfauna Insel. Mauritius, 1880, p. 103 (genoholotype, *Nautilus craticulatus* FICHTEL and MOLL).

Test typically planispiral, bilaterally symmetrical, mostly involute; chambers numerous with distinct sutures either depressed or raised and limbate, with septal bridges and depressions; wall calcareous, perforate; apertures one or more at the base of the apertural face.

Jurassic to Recent.

EXPLANATION OF PLATE 28

NONIONIDAE

FIG.

1. *Nonion incisus* 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 macellus* (Fichtel and Moll). *a*, side view; *b*, apertural view.
6. *Polystomellina discorbinoides* 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.

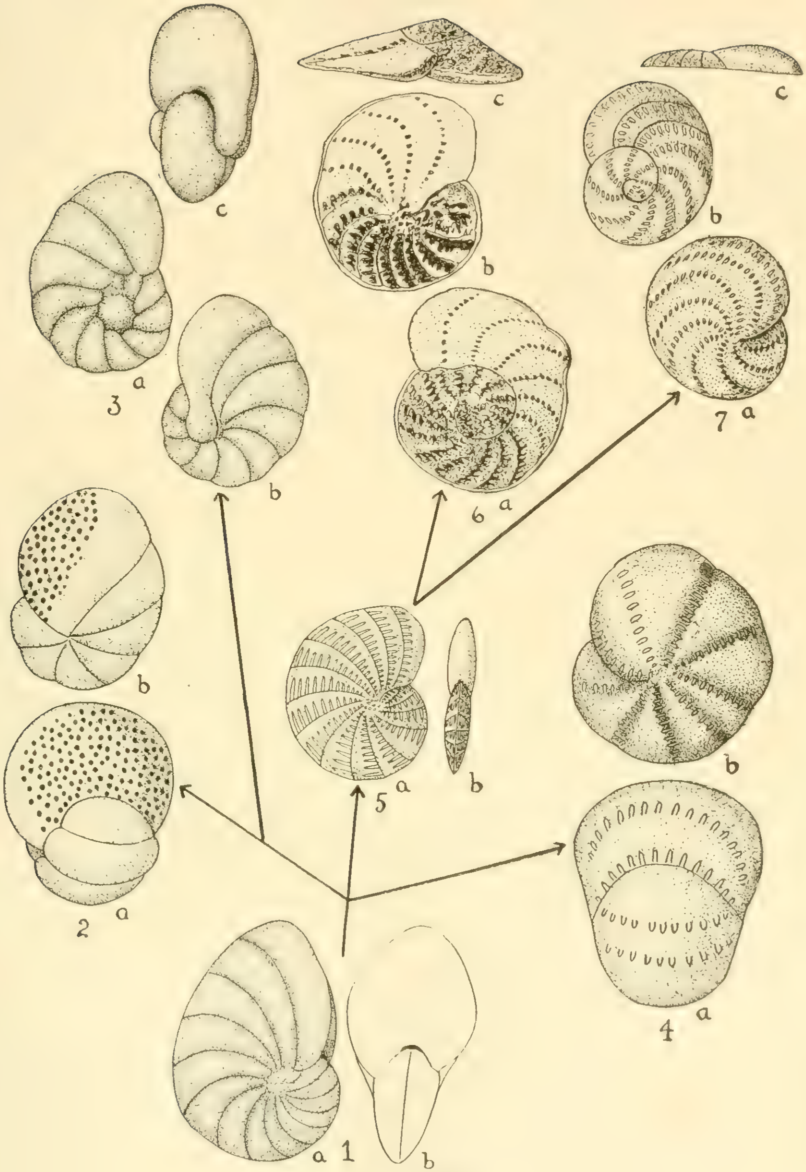


PLATE 28

Genus POLYSTOMELLINA Yabe and Hanzawa, 1923

Plate 27, figure 11; plate 28, figure 6

Genoholotype, *Polystomella (Polystomellina) discorbinoides* Yabe and Hanzawa

Polystomellina Yabe and Hanzawa, Jap. Journ. Geol. Geog., vol. 2, 1923, p. 99.

Test similar to *Elphidium* in general structure but trochoid, planoconvex, ventral side flattened, dorsal side convex.

Tertiary and Recent.

Genus FAUJASINA d'Orbigny, 1839

Plate 27, figure 12; plate 28, figure 7

Genoholotype, *Faujasina carinata* d'Orbigny

Faujasina d'Orbigny, in De la Sagra, Hist. Fis. Pol. Nat. Cuba, 1839, "Foraminifères", p. 109.

Test similar to *Elphidium* but trochoid, planoconvex, dorsal side flattened, ventral side convex.

Cretaceous to Recent.

This small family includes *Bradyina* and *Cribrospira*, two Palaeozoic genera which seem allied to *Nonion* and *Elphidium*, but the fuller study of their complete development may change this view as their early stages are possibly not planispiral. The trochoid forms, *Nonionella*, with simple sutures, and *Polystomellina* and *Faujasina* have apparently developed from the planispiral forms. The structure in some of the larger species of *Elphidium* becomes complex.

FAMILY 25. CAMERINIDAE

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

KEY TO THE GENERA

I. Test with a long undivided second chamber............. *Archaediscus.*
II. Test with numerous chambers, not divided into chamberlets.

A. Test involute throughout.
  1. Test without secondary skeleton or canal system. *Nummulostegina.*
  2. Test with secondary skeleton and canal system.....*Camerina.*
B. Test evolute, not campanulate and spreading............*Assilina.*
C. Test campanulate.
  1. Early test lenticular, later campanulate.......*Operculinella.*
  2. Test campanulate throughout, much compressed...*Operculina.*

III. Test with chamberlets.
A. Adult without annular chambers.
  1. Early chambers simple, later ones divided into chamberlets. ***Heterostegina.***
  2. Early chambers divided into chamberlets as well as the adult. *Spiroclypeus.*
B. Adult with annular chambers.
  1. Coiled early chambers in both microspheric and megalospheric forms, annular chambers in adult...........*Heteroclypeus.*
  2. Megalospheric form with annular chambers directly after the proloculum. ....*Cycloclypeus.*

Subfamily 1. Archaediscinae

Test not broken up into chambers

Genus ARCHAEDISCUS H. B. Brady, 1873

Plate 29, figures 1, 2; plate 30, figure 1

Genoholotype, *Archaediscus karreri* H. B. Brady

Archaediscus H. B. Brady, Ann. Mag. Nat. Hist., ser. 4, vol. 12, 1873, p. 286.

Test lenticular, consisting of a proloculum and long undivided second chamber, close coiled; wall thick, calcareous, finely perforate, upper and lower surfaces thickened; aperture at the open end of the chamber.

Carboniferous.

Subfamily 2. Camerininae

Test with numerous chambers

Genus NUMMULOSTEGINA Schubert, 1907

Plate 29, figure 3; plate 30, figure 2

Genoholotype, *Nummulostegina velibitana* Schubert

Nummulostegina Schubert, Verhandl. k. k. Geol. Reichs., 1907, p. 212.

Test lenticular, planispiral, bilaterally symmetrical, divided into chambers, without complex secondary skeleton or canal system; wall calcareous, perforate; aperture narrow, at the base of the apertural face.

Carboniferous.

Genus CAMERINA Brugière, 1792

Plate 29, figures 4-6, 15; plate 30, figure 3

Genotype, by designation, *Camerina laevigata* Brugière

Camerina BRUGIÈRE, Ency. Method., "Vers", pt. 1, 1792, p. 395.

Nautilus (part) of authors.

Phacites BLUMENBACH, Abbild. Nat. Gegenstände, heft 4, no. 40, 1799, pl. 40 (genoholotype, *Phacites fossilis* BLUMENBACH).

Nummulites LAMARCK, Syst. Anim. sans Vert., vol. 9, 1801, p. 101 (genoholotype, *Camerina laevigata* BRUGIÈRE).

Lenticulina LAMARCK (part), Ann. Mus., vol. 5, 1804, p. 186.

Nummulites MONTFORT, Conch. Syst., vol. 1, 1808, p. 155 (genoholotype, *Nummulites denarius* MONTFORT).

Lycophris MONTFORT, l. c., p. 159 (genoholotype, *Nautilus lenticularis* FICHTEL and MOLL (part)).

EXPLANATION OF PLATE 29

CAMERINIDAE

FIG.

1, 2. *Archaediscus karreri* H. B. Brady. × 25. (After type figure). Fig. 1, *a*, side view; *b*, peripheral view. Fig. 2, Section.

3. *Nummulostegina velibitana* Schubert. (After type figure). *a*, side view; *b*, peripheral view.

4–6. *Camerina elegans* (Sowerby). (After Jones). Fig. 4, Exterior, side view. × 6. Fig. 5, Section. × 12. Fig. 6, Part of section. × 35.

7. *Assilina undata* d'Orbigny. (After d'Orbigny). *a*, side view; *b*, peripheral view.

8, 9. *Operculinella cumingii* (Carpenter). (After type figure). Fig. 8, Young. Fig. 9, Adult, *a*, side view; *b*, peripheral view.

10. *Operculina granulosa* Leymerie. × 8. (After H. B. Brady). *a*, side view; *b*, peripheral view.

11, 12. *Heterostegina depressa* d'Orbigny. × 8. (After H. B. Brady). *a*, side view; *b*, peripheral view.

13. *Cycloclypeus guembelianus* H. B. Brady. × 20. (After H. B. Brady). *a*, side view; *b*, peripheral view.

14. *Spiroclypeus*, idealized figure. (After Van der Vlerk and Umbgrove).

15. *Camerina*, idealized figure. (After Van der Vlerk and Umbgrove).

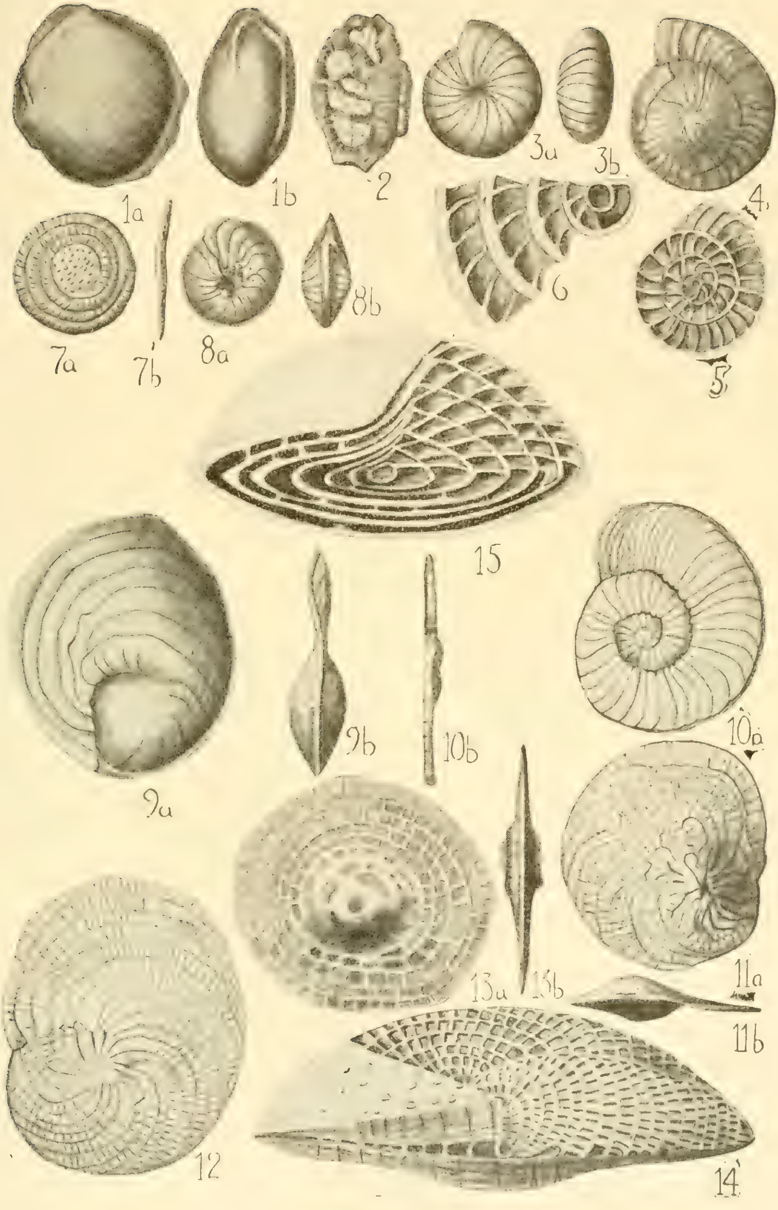


PLATE 29

Egeon MONTFORT, l. c., p. 167 (genoholotype, *Nautilus lenticularis* FICHTEL and MOLL (part)).
Nummulina D'ORBIGNY, Ann. Sci. Nat., vol. 7, 1826, p. 295 (genotype, by designation, *Camerina laevigata* BRUGIÈRE).
Nummularia SOWERBY, Min. Conch., vol. 6, 1826, p. 76 (genotype, by designation, *Camerina laevigata* BRUGIÈRE).
Amphistegina (part) REUSS, 1855.

Test lenticular, planispiral, bilaterally symmetrical, involute; wall perforate, calcareous, with a secondary skeleton and complicated canal system; aperture simple at the base of the apertural face, median.

Carboniferous (?) to Oligocene.

There are many subgeneric names for this and the following not given here.

Genus ASSILINA d'Orbigny, 1826

Plate 29, figure 7; plate 30, figure 5

Genotype, by designation, *Assilina discoidalis* d'Orbigny

Assilina D'ORBIGNY, Ann. Sci. Nat., vol. 7, 1826, p. 296 (as a subgenus of *Nummulina*).
Nummulites (part) of authors.

Test similar to *Camerina* but the test flattened, the chambers usually not completely involute so that the earlier coils are not covered, or with the wall very thin so that the earlier coils are visible from the exterior.

Eocene.

Genus OPERCULINELLA Yabe, 1918

Plate 29, figures 8, 9; plate 30, figure 4

Genoholotype, *Amphistegina cumingii* W. B. Carpenter

Operculinella YABE, Sci. Rep. Tohoku Imp. Univ., ser. 2, (Geol.), vol. 4, 1918, p. 122.
Amphistegina W. B. CARPENTER, 1859 (not D'ORBIGNY).
Nummulites H. B. BRADY, 1884 (not LAMARCK).

Test lenticular and involute in the young, bilaterally symmetrical, in the adult with a broadly flaring complanate border; chambers simple; aperture at the base of the apertural face, median.

Late Tertiary and Recent. Indo-Pacific.

Genus OPERCULINA d'Orbigny, 1826

Plate 29, figure 10; plate 30, figure 6

Genotype, by designation, *Operculina complanata* d'Orbigny

Operculina D'ORBIGNY, Ann. Sci. Nat., vol. 7, 1826, p. 281.
Nautilus (part) of authors.
Lenticulites (part) DEFRANCE, 1822.
Amphistegina (part) D'ORBIGNY, 1826.
Nonionina (part) WILLIAMSON, 1852.
Nummulina (part) PARKER and JONES, 1865.

Test bilaterally symmetrical, planispiral, complanate, usually all the coils visible from the exterior, earlier coils sometimes involute; wall calcareous, perforate, smooth or ornamented with bosses; aperture single, at the base of the apertural face, median.

Lower Cretaceous to Recent.

Genus HETEROSTEGINA d'Orbigny, 1826

Plate 29, figures 11, 12; plate 30, figure 7

Genotype, by designation, *Heterostegina depressa* d'Orbigny

Heterostegina D'ORBIGNY, Ann. Sci. Nat., vol. 7, 1826, p. 305.

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

Plate 29, figure 14

Genotype, by designation, *Spiroclypeus orbitoideus* H. Douvillé

Spiroclypeus H. DOUVILLÉ, Bull. Soc. Géol. France, ser. 4, vol. 4, 1905, p. 458.

Test somewhat similar to *Heterostegina* but more accelerated, the curved chambers divided into chamberlets beginning almost immediately after the proloculum, lateral chambers and pillars developed at each side of the test.

Miocene of the East Indies.

Genus HETEROCLYPEUS Schubert, 1906

Genoholotype, *Heterostegina cycloclypeus* A. Silvestri

Heteroclypeus SCHUBERT, Centralbl. für Min., 1906, p. 640.

Test similar to *Heterostegina* in the young but the chambers becoming annular in the later development.

Tertiary.

Genus CYCLOCLYPEUS W. B. Carpenter, 1856

Plate 29, figure 13; plate 30, figure 8

Genotype, by designation, *Cycloclypeus carpenteri* H. B. Brady

Cycloclypeus W. B. CARPENTER, Phil. Trans., 1856, p. 555.

Test in the microspheric form like *Heterostegina* in the early stages, later with the chambers becoming annular, divided by radial portions into rectangular chamberlets, the test discoidal and much compressed.

Miocene to Recent.

EXPLANATION OF PLATE 30

CAMERINIDAE

FIG.

1. *Archaediscus 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 guembelianus* H. B. Brady. (After H. B. Brady). *a*, side view; *b*, edge view.

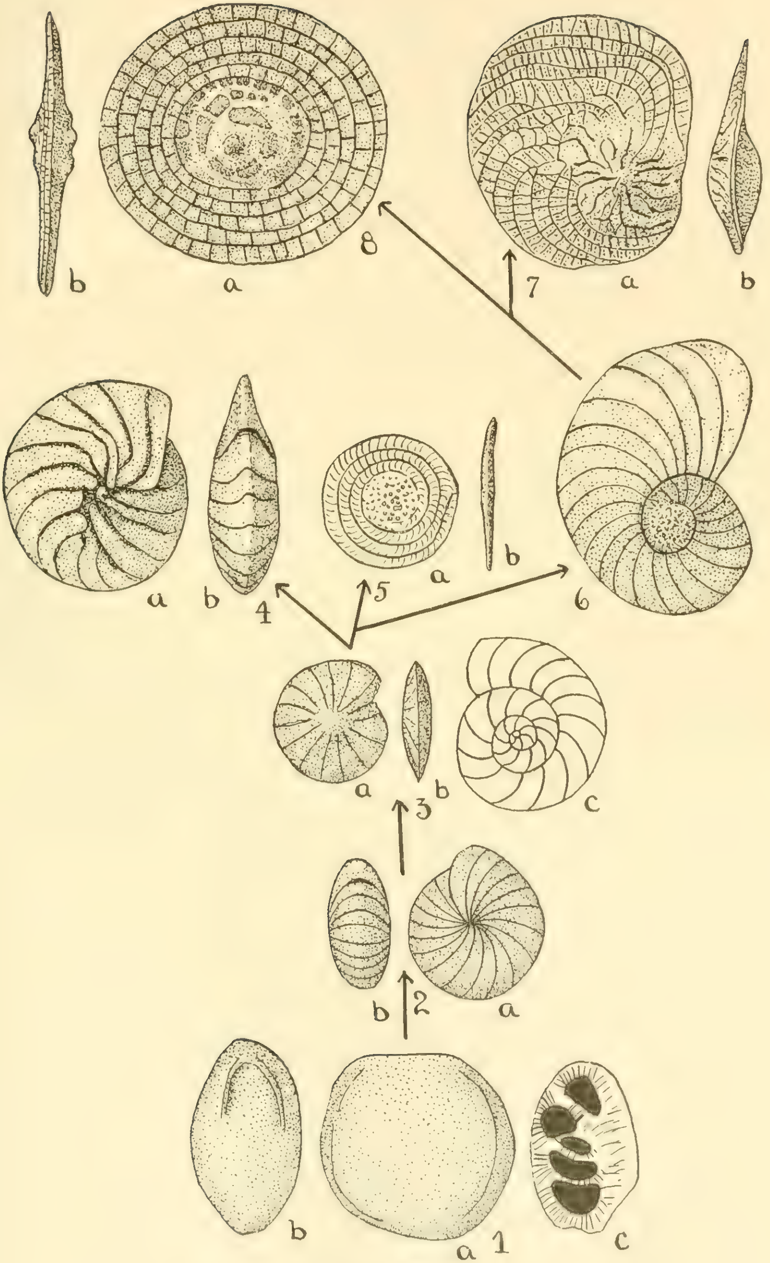


PLATE 30

FAMILY 26. PENEROPLIDAE

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

KEY TO THE GENERA

I. Chambers simple, without chamberlets, close coiled at least in the young, becoming uncoiled in the adult.
  A. Test more or less compressed, mostly coiled.
    1. Aperture elongate, slit-like, or a linear series of rounded openings. . . . . *Peneroplis.*
    2. Aperture dendritic. . . . . *Dendritina.*
  B. Test mostly uncoiled except in the earliest stages, aperture terminal.
    1. Wall thick, chambers of equal size, aperture without a neck and lip. . . . . *Spirolina.*
    2. Wall very thin, chambers usually enlarging as added, aperture typically with a neck and lip. . . . . *Monalysidium.*

II. Chambers divided into chamberlets.
  A. Annular chambers only in the adult if at all developed.
    1. Growing edge peripheral in the adult.
      a. Annular chambers not developed, chambers involute. *Fallotia.*
      b. Annular chambers in the adult, chambers in adult not involute. . . . . *Archaias.*
    2. Growing edge meandering on the flat faces of the test. *Meandropsina.*
  B. Annular chambers very early developed.
    1. Chamberlets in a single plane.
      a. Not completely divided. . . . . *Praesorites.*
      b. Completely divided. . . . . *Sorites.*
    2. Chamberlets usually in two planes, aperture in one or two lines. . . . . *Amphisorus.*
    3. Chamberlets complex, no lateral layers of shell material.
      a. Adjacent chambers in each annular chamber connecting. *Marginopora.*
      b. Adjacent chambers in each annular chamber not connecting. . . . . *Orbitolites.*
    4. Chamberlets complex, flat sides of the test with a thick imperforate layer. . . . . *Opertorbitolites.*

Subfamily 1. Spirolininae

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

Genus PENEROPLIS Montfort, 1808

Plate 31, figure 1

Genoholotype, *Peneroplis lanatus* Montfort=*Nautilus planatus* Fichtel and Moll

Peneroplis MONTFORT, Conch. Syst., vol. 1, 1808, p. 259.
Coscinospira EHRENBERG, Abhandl. k. Akad. Wiss. Berlin, 1838, p. 131 (genotype, by designation, *Coscinospira hemprichii* EHRENBERG).

Test free, planispiral, close coiled in the young, usually involute, in the adult becoming variously shaped, close coiled, flaring, annular or commencing to uncoil; chambers undivided; wall calcareous, imperforate except in the proloculum and sometimes the following chamber; aperture simple at the base of the apertural face, or long and slit-like, occasionally divided.

Cretaceous (?) Tertiary and Recent.

Genus DENDRITINA d'Orbigny, 1826

Plate 31, figure 2

Genotype, by designation, *Dendritina arbuscula* d'Orbigny

Dendritina D'ORBIGNY, Ann. Sci. Nat., vol. 7, 1826, p. 285.
Peneroplis (part) of authors.

Test similar to *Peneroplis*, the test usually thick and showing a tendency to uncoil; aperture dendritic, in the apertural face.

Eocene to Recent.

Genus SPIROLINA Lamarck, 1804

Plate 31, figures 3, 4

Genotype, by designation, *Spirolina cylindracea* Lamarck

Spirolina LAMARCK, Ann. Mus., vol. 5, 1804, p. 244.
Peneroplis (part) of authors.

Test similar to *Peneroplis*, thick, early chambers close coiled, usually not completely involute, later ones uncoiled; aperture rounded, terminal.

Cretaceous (?) to Recent.

Genus MONALYSIDIUM Chapman, 1900

Plate 31, figures 5, 6

Genotype, by designation, *Monalysidium sollasi* Chapman

Monalysidium CHAPMAN, Journ. Linn. Soc. Zool., vol. 28, 1900, p. 3 (as a subgenus of *Peneroplis*).

Test with the early chambers close coiled, later ones uncoiled in a rectilinear series; wall imperforate, smooth or with vertical rows of minute tubercles; aperture circular, terminal, sometimes with a short neck and lip.

Recent.

Subfamily 2. Archaiasinae

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

Genus FALLOTIA H. Douvillé, 1902

Plate 31, figure 7

Genoholotype, *Fallotia jacquoti* H. Douvillé

Fallotia H. DOUVILLÉ, Bull. Soc. Géol. France, ser. 4, vol. 2, 1902, p. 298.

EXPLANATION OF PLATE 31

PENEROPLIDAE

FIG.

1. *Peneroplis planatus* (Fichtel and Moll). × 35. (After H. B. Brady). *a*, side view; *b*, apertural view.
2. *Dendritina arbuscula* d'Orbigny. (After d'Orbigny's Model).

3, 4. *Spirolina cylindracea* Lamarck. × 40. (After H. B. Brady).

5. *Monalysidium polita* Chapman. × 35. (After type figure).
6. *Monalysidium sollasi* Chapman. × 35. (After type figure).
7. *Fallotia jacquoti* H. Douvillé. × 5. (After type figure).
8. *Meandropsina vidali* Schlumberger. × 3. (After type figure). *a*, portion of surface enlarged.
9. *Archaias angulatus* (Fichtel and Moll). × 20. (After H. B. Brady). *a*, side view; *b*, peripheral view.
10. *Archaias aduncus* (Fichtel and Moll). × 12. (After H. B. Brady).

11, 12. *Praesorites moureti* H. Douvillé. Fig. 11, (After type figure). × 5. 11, *a*, surface eroded, showing partitions. Fig. 12, Equatorial section. × 18.

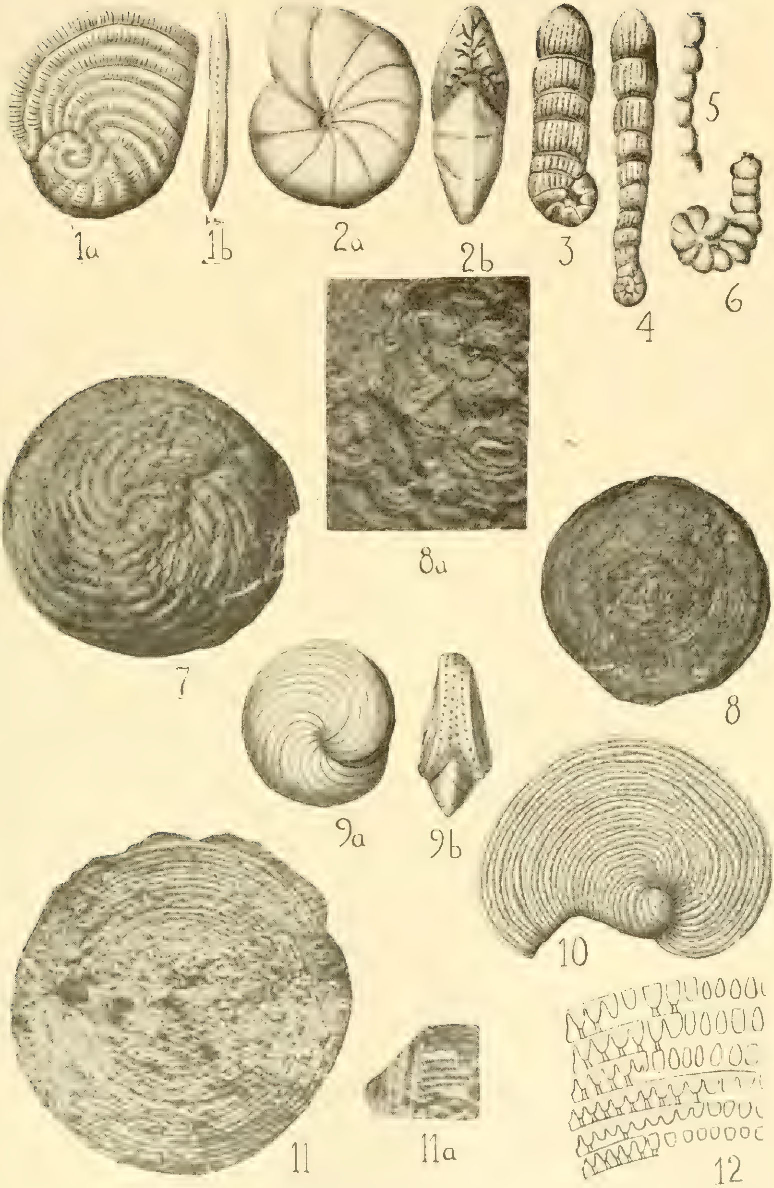


PLATE 31

Test discoid nummulitoid throughout the growth, the growing edge always peripheral; chambers involute, V-shaped, divided into chamberlets.

Upper Cretaceous.

Genus MEANDROPSINA Munier-Chalmas, 1899

Plate 31, figure 8

Genoholotype, *Meandropsina vidali* Schlumberger

Meandropsina MUNIER-CHALMAS, in SCHLUMBERGER, Bull. Soc. Géol. France, ser. 3, vol. 27, 1899, p. 336.

Test discoid, the growing edge variously meandering over the flattened faces of the test; chambers with many chamberlets; apertures rounded, in linear rows.

Upper Cretaceous.

Genus ARCHAIAS Montfort, 1808

Plate 31, figures 9, 10

Genoholotype, *Archaias spirans* Montfort=*Nautilus angulatus* Fichtel and Moll

Archaias MONTFORT, Conch. Syst., vol. 1, 1808, p. 191.

Helenis MONTFORT, l. c., p. 195 (genoholotype, *Helenis spatosus* MONTFORT=*Nautilus aduncus* FICHTEL and MOLL).

Ilotes MONTFORT, l. c., p. 199 (genoholotype, *Ilotes rotalitatus* MONTFORT =*Nautilus orbiculus* FICHTEL and MOLL).

Orbiculina LAMARCK, Ency. Method., pt. 23, 1816, p. 468 (genotype, by designation, *Nautilus aduncus* FICHTEL and MOLL).

Test in the early stages planispiral and lenticular, bilaterally symmetrical, in later stages becoming flaring, even annular; wall imperforate except in the very earliest chambers which are perforate, divided into chamberlets; apertures in several rows on the apertural face.

Miocene to Recent.

Subfamily 3. Orbitolitinae

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

Genus PRAESORITES H. Douvillé, 1902

Plate 31, figures 11, 12

Genoholotype, *Praesorites moureti* H. Douvillé

Praesorites H. DOUVILLÉ, Bull. Soc. Géol. France, ser. 4, vol. 2, 1902, p. 291.

Test in the early stages planispiral, at least in the microspheric form, later annular; chambers in a single plane, not completely divided into chamberlets; apertures numerous.

Cretaceous.

Genus SORITES Ehrenberg, 1838

Plate 32, figures 5, 8, 9

Genotype, by designation, *Sorites dominicensis* Ehrenberg

Sorites EHRENBERG, Abhandl. k. Akad. Wiss. Berlin, 1838, p. 134.
Orbitolites (part) of authors (not LAMARCK).

Test discoid, planispiral in the early stages at least of the microspheric form, later annular, completely divided into chamberlets; typically in a single layer, those of each annular chamber communicating with the adjacent ones as with those of the preceding and succeeding annular chambers; wall imperforate except in the very earliest chambers; apertures in a single line along the periphery.

Miocene to Recent.

Taramellina Munier-Chalmas is probably a synonym of *Sorites*.

Genus AMPHISORUS Ehrenberg, 1838

Plate 32, figure 10

Genoholotype, *Amphisorus hemprichii* Ehrenberg

Amphisorus EHRENBERG, Abhandl. k. Akad. Wiss. Berlin, 1838, p. 130.
Orbitolites (part) of authors (not LAMARCK).

Test discoid, planispiral in the early stages at least of the microspheric form, later annular, completely divided into chamberlets; typically in two layers, those of each annular chamber communicating with the adjacent ones of the preceding and succeeding annular chambers and those of the two layers communicating; wall imperforate except in the very earliest chambers; apertures in a double, alternating line along the periphery.

Miocene to Recent.

Bradyella Munier-Chalmas is probably a synonym of *Amphisorus*.

Genus MARGINOPORA Quoy and Gaymard, 1834

Plate 32, figures 1-4

Genoholotype, *Marginopora vertebralis* Quoy and Gaymard

Marginopora QUOY and GAYMARD, Voyage de l'Astrolabe, 1833 fide BLAINVILLE, Man. Actin., 1834, p. 412.
Orbitolites (part) of authors (not LAMARCK).

Test in the early stages similar to *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. Indo-Pacific.

Genus ORBITOLITES Lamarck, 1801

Plate 32, figure 6

Genotype, by designation, *Orbitolites complanata* Lamarck

Orbitolites LAMARCK, Syst. Anim. sans Vert., 1801, p. 376.
Discolites (?) MONTFORT, Conch. Syst., vol. 1, 1808, p. 187 (genoholotype, *Discolites concentricus* MONTFORT).
Orbulites LAMARCK, Extrait Cours Zool., 1812, p. 26 (genoholotype, *Orbitolites complanata* LAMARCK).

Test discoidal, the earliest chambers in the microspheric form coiled, later annular, divided into chamberlets, those of the same annular chamber not connecting with each other but with those of the adjacent preceding and succeeding annular chambers; wall imperforate except in the very earliest chambers which are perforate; apertures numerous, rounded on the periphery of the test.

Eocene.

Genus OPERTORBITOLITES Nuttall, 1925

Plate 32, figure 7

Genoholotype, *Opertorbitolites douvillei* Nuttall

Opertorbitolites NUTTALL, Quart. Journ. Geol. Soc., vol. 81, 1925, p. 447.

Test circular, lenticular, consisting of a median chamber-layer resembling that of *Orbitolites* with a thick imperforate lamina of shelly material on each side of the median layer.

Eocene. India.

Genus CRATERITES Heron-Allen and Earland, 1924

Plate 32, figure 20

Genoholotype, *Craterites rectus* Heron-Allen and Earland

Craterites HERON-ALLEN and EARLAND, Journ. Linn. Soc. Zool., vol. 35, 1924, p. 611.

Test probably attached in life, the whole composed of numerous layers of chambers, the basal layer without trace of spiral development, form in side view contracted above the base, and the outer end broadening and convex; chambers very numerous; wall calcareous; outer surface with numerous small rounded openings.

The type specimen is the only one known. It is from shallow water off Lord Howe Island, South Pacific. Through the courtesy of the authors, I was enabled to study the holotype now in the Heron-Allen and Earland Collection in the British Museum. It is very difficult to understand the full relationships of this peculiar form until more specimens are found. In some respects it resembles *Gypsina* and its allies, but it is here left where the authors placed it, near *Orbitolites*.

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 but 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 planispiral form and in many ways show a close resemblance to the Camerinidae.

Broeckina Munier-Chalmas and *Orbitopsella* Munier-Chalmas have been placed in this family but it is to be suspected that their relationships are elsewhere. A study of microspheric forms in their early stages is essential to their final disposition.

The two very peculiar genera *Rhapydionina* Stache, 1912, and *Rhipidionina* Stache, 1912, may be connected with this family. Their developmental stages are not fully known and until they are studied in detail, their relationships must remain obscure.

FAMILY 27. ALVEOLINELLIDAE

Test imperforate except the proloculum and second chamber; general shape of the test fusiform, coiled about an elongate axis; chambers completely involute, divided into chamberlets;

EXPLANATION OF PLATE 32

PENEROPLIDAE, ALVEOLINELLIDAE, KERAMOSPHAERIDAE

FIG.

1–4. *Marginopora vertebralis* Quoy and Gaymard. Figs. 1–3, (After H. B. Brady). × 12. Fig. 1, Viewed from broad surface. Fig. 2, Peripheral view. Fig. 3, Section. Fig. 4, (After Carpenter). Portion of ideal section.

5. *Sorites*. Idealized median section. (After H. Douvillé).

6. *Orbitolites*. Idealized median section. (After H. Douvillé).

7. *Opertorbitolites douvillei* Nuttall. × 10. (After type figure).

8, 9. *Sorites orbiculus* (Forskal). (After Ehrenberg). Fig. 8, From flat side. Fig. 9, From periphery.

10. *Amphisorus hemprichii* Ehrenberg. (After type figure).

11–14. *Borelis melo* (Fichtel and Moll). × 35. (After H. B. Brady). Fig. 11, Side view. Fig. 12, End view. Fig. 13, Transverse section. Fig. 14, Longitudinal section.

15, 16. *Flosculina globosa* (Leymerie). × 3. (After Nuttall). Fig. 15, Transverse section. Fig. 16, Longitudinal section.

17–19. *Alveolinella boscii* (Defrance). (After H. B. Brady). Fig. 17, Side view. Fig. 18, End view. × 10. Fig. 19, Transverse section. × 15.

20. *Craterites rectus* Heron-Allen and Earland. × 20. (After type figure). *a*, side view; *b*, from above.

21, 22. *Keramosphaera murrayi* H. B. Brady. (After type figures). Fig. 21, Exterior. × 15. Fig. 22, Section. × 65.

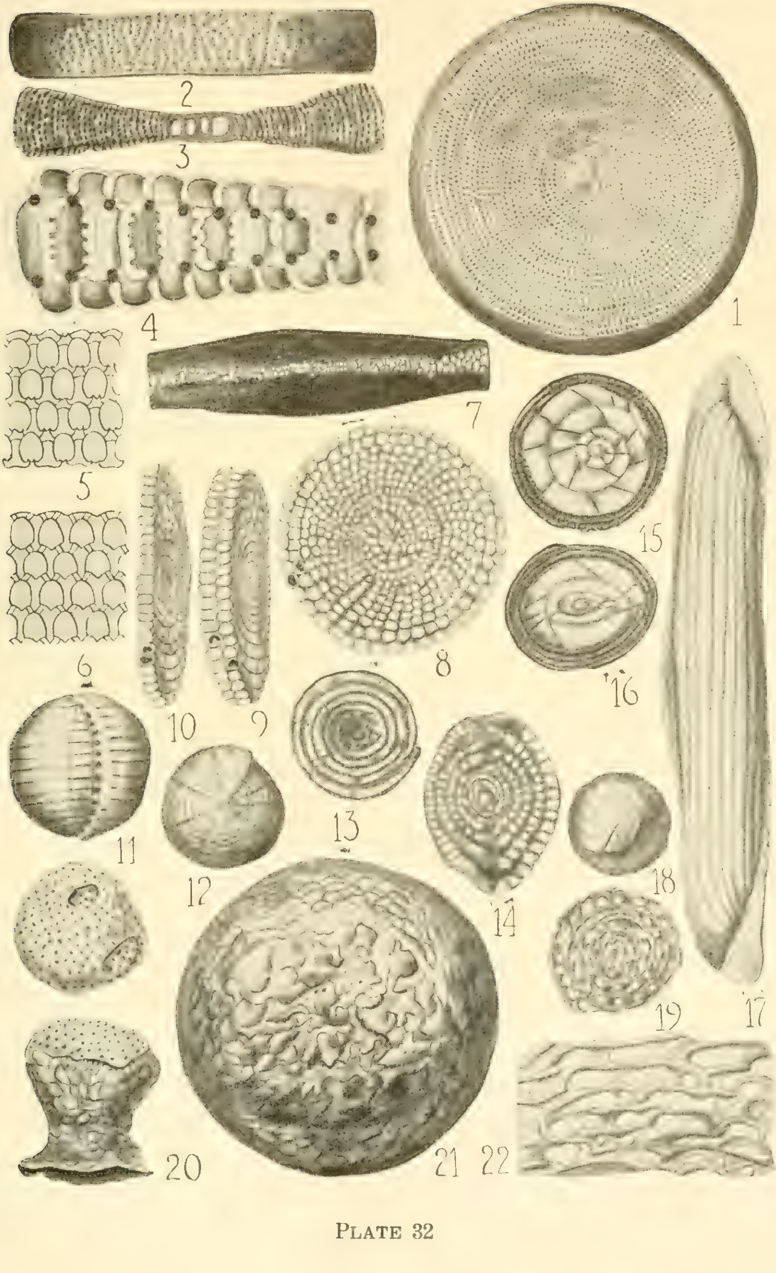


PLATE 32

apertures numerous, in one or more rows on the face of the last-formed chamber.

See, Altpeter, Beiträge zur Anatomie und Physiologie von Alveolina (Marburg, 1911).

Genus FLOSCULINA Stache, 1880

Plate 32, figures 15, 16

Genotype, by designation, *Alveolina subpyrenaica*, var. *globosa* Leymerie

Flosculina STACHE, Verhandl. k. k. Geol. Reichs., 1880, p. 199.
Alveolina (part) of authors.

Test globular or fusiform, planispiral; chambers completely involute, divided into chamberlets, the early coils high and of few chambers, later ones low and many chambered; wall imperforate except in the very earliest chambers which are finely perforate; apertures numerous, in a single row on the long apertural face.

Eocene.

Genus FLOSCULINELLA Schubert, 1910

Genotype, by designation, *Flosculina bontangensis* Rutten

Flosculinella SCHUBERT, Neues Jahrb., Beilage-Band 29, 1910, p. 533.
Alveolina (part) of authors.
Flosculina (part) of authors.

Test differing from *Flosculina* in having more than one row of chambers in the last-formed whorls; the outer added chambers smaller than those proximal to them.

Oligocene and Miocene.

Genus BORELIS Montfort, 1808

Plate 32, figures 11-14

Genoholotype, *Borelis melonoides* Montfort=*Nautilus melo* Fichtel and Moll (part)

Borelis MONTFORT, Conch. Syst., vol. 1, 1808, p. 171.
Clausulus MONTFORT, l. c., p. 179 (genoholotype, *Clausulus indicata* MONTFORT=*Nautilus melo* FICHTEL and MOLL (part)).
Melonites LAMARCK, Extrait Cours Zool., 1812, p. 122 (genotype, by designation, *Melonites sphaerica* LAMARCK).
Oryzaria DEFRANCE, Dict. Sci. Nat., vol. 16, 1820, p. 106 (genoholotype, *Oryzaria boscii* DEFRANCE).

Melonia DEFRANCE, Dict. Sci. Nat., vol. 32, 1824, p. 176 (genotype, by designation, *Melonites sphaerica* LAMARCK).

Alveolina D'ORBIGNY, Ann. Sci. Nat., vol. 7, 1826, p. 306 (genotype, by designation, *Oryzaria boscii* DEFRANCE).

Test globular or fusiform, coiled planispirally about an axis, early coils as well as later ones low; chambers divided into chamberlets; apertures usually in a single row.

Eocene to Recent.

Genus ALVEOLINELLA H. Douvillé, 1906

Plate 32, figures 17-19

Genoholotype, *Alveolina quoyi* d'Orbigny

Alveolinella H. DOUVILLÉ, Bull. Soc. Géol. France, ser. 4, vol. 6, 1906, p. 585.

Alveolina (part) D'ORBIGNY, 1826.

Test fusiform, planispirally coiled about an axis, all coils low; apertures very numerous, 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

Plate 32, figures 21, 22

Genoholotype, *Keramosphaera murrayi* H. B. Brady

Keramosphaera H. B. BRADY, Ann. Mag. Nat. Hist., ser. 5, vol. 10, 1882, p. 245.

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

Recent.

In this same group has been placed *Bradya* Stache, later called *Keramosphaerina* Stache. These are Cretaceous forms, and by some authors have been held not to be foraminifera. *Parkeria* has also been placed with these same forms. For a detailed discussion of the evidence, the reader is referred to Silvestri, Sulla "*Bradya tergestina*" Stache (Riv. Ital. Pal., Ann. 30, 1924, pp. 17-26, 1 plate).

FAMILY 29. HETEROHELICIDAE

Test in the more primitive forms planispiral in the young, later becoming biserial, in the more specialized genera the spiral and biserial stages reduced or wanting and the relationships shown only by other characters; wall calcareous, perforate, ornamentation in specialized genera bilaterally symmetrical; aperture when simple, usually large for the size of the test, without teeth, in some forms with an apertural neck and phialine lip.

KEY TO THE GENERA

I. Coiled stage in the young prominent.
  - A. Biserial chambers few, increasing in size as added.....*Heterohelix*.
  - B. Biserial chambers many, of nearly uniform size.
    - 1. No uniserial chambers developed.............*Spiroplectoides*.
    - 2. Uniserial chambers developed in the adult....*Spiroplectinata*.

II. Biserial stage in the young prominent.
  - A. Biserial throughout.
    - 1. Chambers more or less globular.................*Gümbelina*.
    - 2. Chambers compressed.
      - a. Periphery much thickened. ....*Bolivinoides*.
      - b. Periphery concave and with sharp keels.......*Bolivinita*.
      - c. Periphery sharp, chambers elongate,,,........*Bolivinella*.

B. Later chambers variously arranged.
  1. Uniserial.
    a. Test elongate, compressed, chambers becoming high. .... *Plectofrondicularia.*
    b. Test broad, compressed, chambers becoming low, sometimes annular. .... *Pavonina.*
  2. Multiserial.
    a. Test in later development spiral........ *Pseudotextularia.*
    b. Test in later development spiral, later with numerous globular chambers in one plane......... *Planoglobulina.*
    c. Test in later development with a fan-shaped series directly after the biserial stage. .... *Ventilabrella.*
  3. Triserial. .... *Eouvigerina.*

III. Early stages triserial.
  A. Triserial throughout. .... *Pseudouvigerina.*
  B. Triserial in the young, later uniserial.......... *Siphogenerinoides.*

IV. Test wholly uniserial.
  A. Early portion compressed, aperture without a lip.
    1. Early portion concave. .... *Amphimorphina.*
    2. Early portion somewhat compressed, not concave. .... *Nodomorphina.*
  B. Not compressed, aperture with a lip............... *Nodogenerina.*

Subfamily 1. Heterohelicinae

Test in the early stages distinctly planispiral, later chambers biserial; aperture large, at the inner margin of the chamber.

Genus HETEROHELIX Ehrenberg, 1843

Plate 33, figure 1; plate 34, figure 1

Genotype, by designation, *Spiroplecta americana* Ehrenberg

Heterohelix Ehrenberg, Abhandl. k. Akad. Wiss. Berlin, 1841 (1843), p. 429.

Spiroplecta Ehrenberg, Bericht. k. Akad. Wiss. Berlin, 1844, p. 75 (genotype, by designation, *Spiroplecta americana* Ehrenberg=*Heterohelix*).

Test in the early stages planispiral forming a considerable part of the test, the few adult chambers biserial; wall calcareous, perforate, thin; aperture large, on the inner margin of the last-formed chamber, median.

Cretaceous.

Subfamily 2. Pavonininae

Test with the planispiral 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

Plate 33, figure 2; plate 34, figure 2

Genoholotype, *Pavonina flabelliformis* d'Orbigny

Pavonina d'Orbigny, Ann. Sci. Nat., vol. 7, 1826, p. 260.

Test much compressed, the very early stages in the microspheric form showing traces of coiling, followed by chambers arranged biserially, and in the adult by uniserial chambers becoming laterally extended, even forming annuli; wall calcareous, coarsely perforate; apertures in the adult, many rounded openings in the periphery.

Upper Cretaceous (?), Eocene to Recent.

See Cushman, Foraminifera of the Genera Siphogenerina and Pavonina (Proc. U. S. Nat. Mus., vol. 67, Art. 25, 1926, pp. 1-24, pls. 1-6).

Subfamily 3. Gümbelininae

Test in the early stages of the microspheric form planispiral, often skipped in the megalospheric form, followed by a biserial stage which may be continued or may be followed by globular chambers variously arranged.

Genus GÜMBELINA Egger, 1899

Plate 33, figures 3, 4; plate 34, figure 3

Genotype, by designation, *Textularia globulosa* Ehrenberg

Gümbelina Egger, Abhandl. kön. bay. Akad. Wiss. München, Cl. II, vol. 21, 1899, p. 31.

Textularia (part) of authors (not Defrance).

Test with the early chambers planispiral, at least in the microspheric form, later chambers biserial; wall calcareous, perforate; aperture large and open, arched, at the base of the inner margin of the last-formed chamber, without teeth.

Cretaceous.

Genus PSEUDOTEXTULARIA Rzehak, 1886

Plate 33, figures 5-7; plate 34, figure 4

Genoholotype, *Pseudotextularia varians* Rzehak

Pseudotextularia RZEHAK, Ver. Nat. Ver. Brünn, vol. 24, 1885 (1886), Sitz., p. 8.

Gümbelina (part) of authors.

Test with the early chambers as in *Gümbelina* 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 (America) to Lower Eocene (Europe).

Genus PLANOGLOBULINA Cushman, 1927

Plate 33, figures 8, 9; plate 34, figure 5

Genoholotype, *Gümbelina acervulinoides* Egger

Planoglobulina CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 2, 1927, p. 77.

Gümbelina (part) of authors.

Test with the earliest chambers in the microspheric form planispiral followed by a series arranged biserially, and in the adult by a series of globular chambers, the earliest ones as in *Pseudotextularia,* later ones 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.

Genus VENTILABRELLA Cushman, 1928

Plate 33, figure 10

Genoholotype, *Ventrilabrella eggeri* Cushman

Ventilabrella CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 4, 1928, p. 2.

Gümbelina (part) of authors.

Test in the early stages biserial, later with an increase in the number of chambers but all in one plane, spread out in a fan-shape; chambers globular; wall calcareous, perforate, smooth or variously ornamented; aperture in the biserial stage single, at the base of the inner margin, in the adult two apertures in each chamber, at opposite sides near the base in the median line.

Upper Cretaceous.

EXPLANATION OF PLATE 33

Heterohelicidae

Fig.

1. *Heterohelix americana* (Ehrenberg). (After type figure).
2. *Pavonina flabelliformis* d'Orbigny. × 50. (After Heron-Allen and Earland).
3. *Gümbelina decurrens* (Chapman). (After Egger).
4. *Gümbelina globifera* (Reuss). (After Egger). *a*, side view; *b*, apertural view.

5, 6. *Pseudotextularia varians* Rzehak. (After type figure). **Fig. 6,** Longitudinal section.

7. *Pseudotextularia fruticosa* (Egger). (After type figure). *a*, front view; *b*, apertural view.

8, 9. *Planoglobulina acervulinoides* (Egger). (After type figure). Fig. 9, By transmitted light.

10. *Ventilabrella eggeri* Cushman. (After Egger). *a*, side view; *b*, end view of early stage.
11. *Bolivinoides draco* (Marsson). (After type figure). *a*, side view; *b*, apertural view.

12-14. *Bolivinita quadrilatera* (Schwager). Fig. 12, (After type figure). *a*, front view; *b*, side view. Figs. 13, 14, (After H. B. Brady). × 25.

15, 16. *Bolivinella folium* (Parker and Jones). Fig. 15, (After type figure). Fig. 16, (After H. B. Brady). × 40. *a*, front view; *b*, apertural view.

17, 18. *Spiroplectoides rosula* (Ehrenberg). Fig. 17, (After type figure). Fig. 18, × 55.

19. *Plectofrondicularia concava* Liebus. (After type figure).

20, 21. *Plectofrondicularia californica* Cushman and Stewart. (After type figure). Fig. 20, Section of microspheric young. × 50. **Fig.** 21, Exterior. × 35.

22. *Amphimorphina haueriana* Neugeboren. (After type figure). *a*, side view; *b*, apertural view; *c*, section near base; *d*, section near apex.
23. *Nodomorphina compressiuscula* (Neugeboren). (After type figure).
24. *Eouvigerina americana* Cushman. × 75. (After type figure). *a*, front view; *b*, side view; *c*, apertural view.
25. *Pseudouvigerina cristata* (Marsson). (After type figure). *a*, section.
26. *Pseudouvigerina plummerae* Cushman. × 65. (After type figure). *a*, side view; *b*, apertural view.
27. *Siphogenerinoides plummeri* (Cushman). × 40. (After type figure). *a*, side view; *b*, apertural view.
28. *Nodogenerina bradyi* Cushman. × 50. (After type figure).

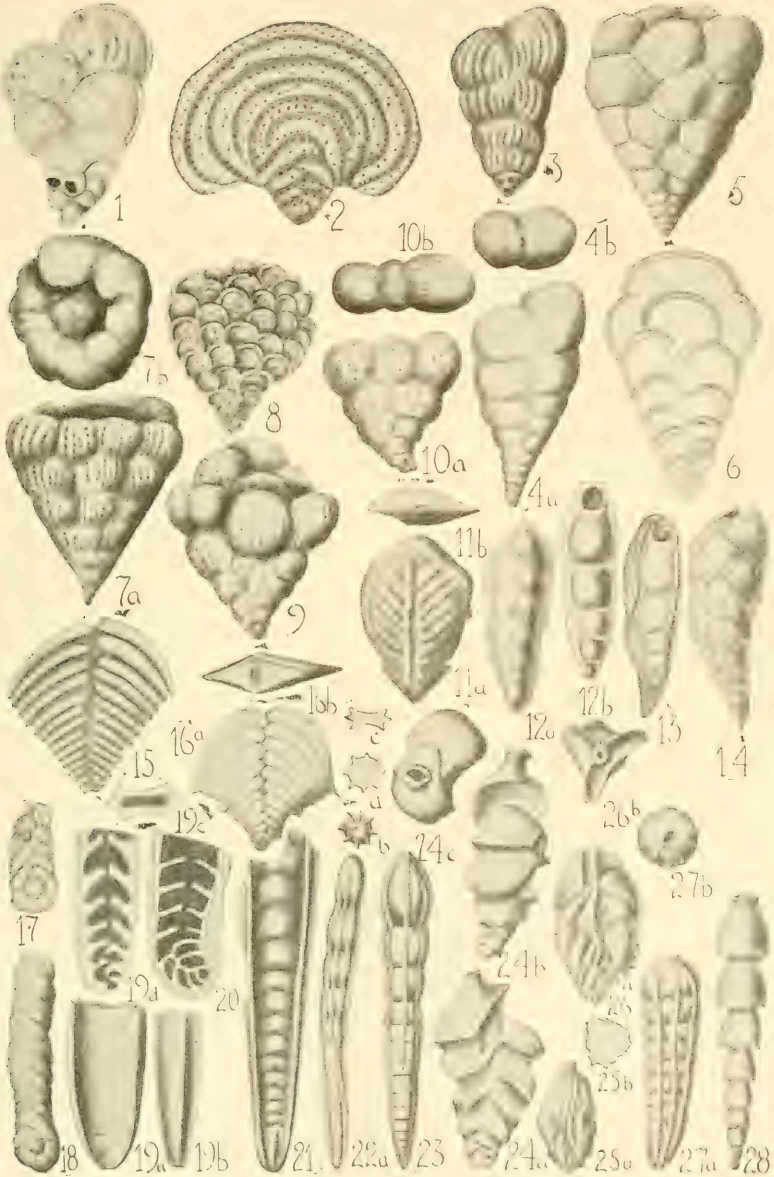


PLATE 33

Subfamily 4. Bolivinitinae

Test in the adult biserial, compressed; aperture in the median line, at the base of the inner margin.

Genus BOLIVINOIDES Cushman, 1927

Plate 33, figure 11; plate 34, figure 6

Genoholotype, *Bolivina draco* Marsson

Bolivinoides CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 2, 1927, p. 89.
Bolivina (part) of authors.

Test compressed, rhomboid, the thickest portion near the apertural end usually appearing like a thickened lip without ornamentation, ornamentation in general at right angles to the sutures, test mainly biserial; wall calcareous, finely perforate; aperture fairly large, in the median line at the base of the inner margin of the chamber.

Upper Cretaceous.

Genus BOLIVINITA Cushman, 1927

Plate 33, figures 12-14; plate 34, figure 7

Genoholotype, *Textularia quadrilatera* Schwager

Bolivinita CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 2, 1927, p. 90.
Textularia (part) of authors.
Bolivina (part) of authors.

Test with the chambers biserial, the periphery and broader sides all concave with strongly developed angles giving a quadrate end view to the test; wall calcareous, perforate; aperture large, at the base of the inner margin of the chamber in the median line.

Upper Cretaceous to Recent.

Genus BOLIVINELLA Cushman, 1927

Plate 33, figures 15, 16; plate 34, figure 8

Genoholotype, *Textularia folium* Parker and Jones

Bolivinella CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 2, 1927, p. 79.
Textularia (part) of authors.

Test much compressed, the proloculum in the megalospheric form rectangular, in the microspheric form the young apparently planispiral, later chambers biserial, chambers long and recurved, not overlapping; wall calcareous, perforate; aperture transverse to the compression of the test with numerous papillae at the base of the opening.

Eocene to Recent.

Subfamily 5. Spiroplectinatinae

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

Genus SPIROPLECTOIDES Cushman, 1927

Plate 33, figures 17, 18; plate 34, figure 9

Genoholotype, *Spiroplecta rosula* Ehrenberg

Spiroplectoides CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 2, 1927, p. 77.
Spiroplecta (part) of authors.

Test with the early chambers planispiral, later ones biserial, the test elongate, sides nearly parallel and the biserial chambers very numerous; wall calcareous, finely perforate; aperture elliptical, terminal or nearly so in the adult.

Cretaceous to Recent.

Genus SPIROPLECTINATA Cushman, 1927

Plate 34, figure 10

Genoholotype, *Textularia annectens* Parker and Jones

Spiroplectinata CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 3, 1927, p. 62.
Textularia (part) of authors.
Spiroplectina CUSHMAN (not SCHUBERT), Contr. Cushman Lab. Foram. Res., vol. 2, 1927, p. 78.

Test with the early chambers planispiral, 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.

There is some doubt as to this form. The specimens from the Gault apparently are arenaceous and related to *Gaudryina*.

Subfamily 6. Plectofrondicularinae

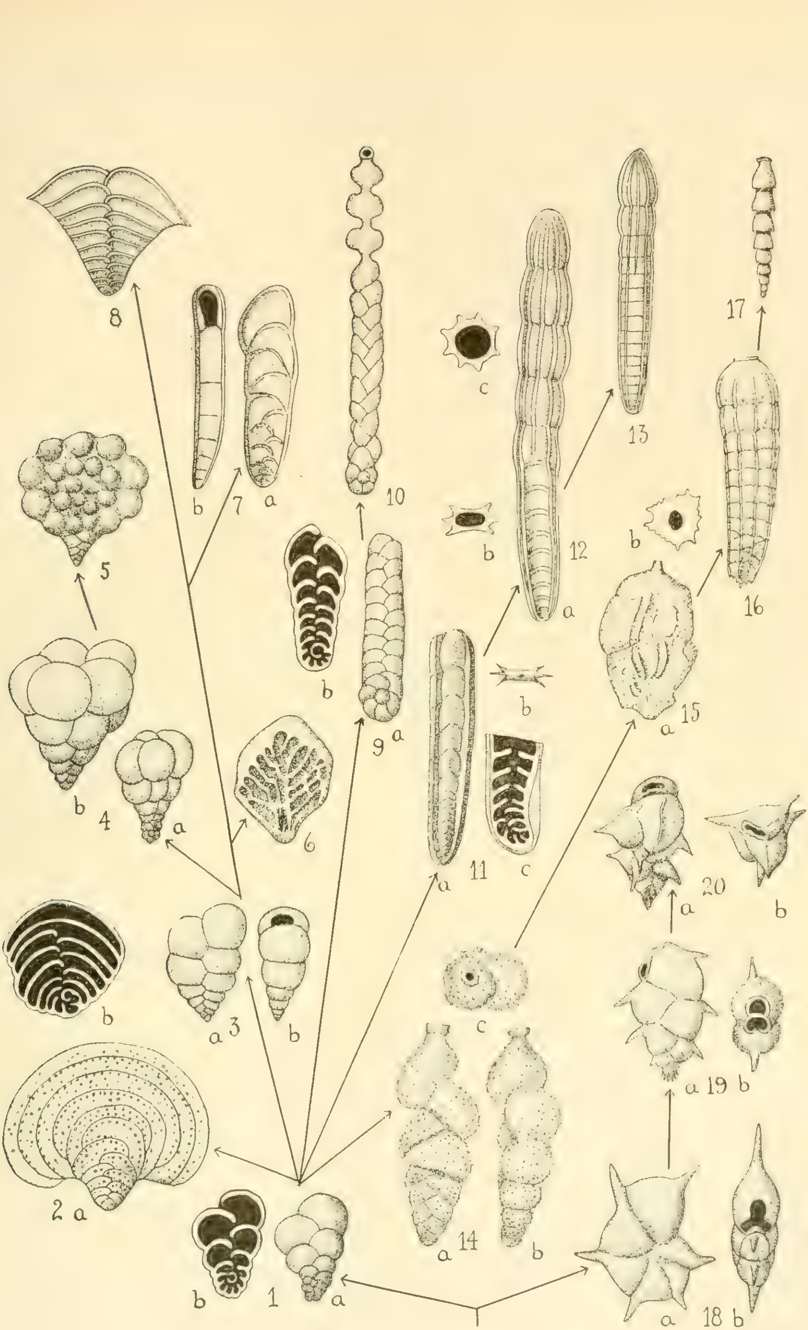
Test in the microspheric form planispiral in the early stages, later biserial and then uniserial or in the higher forms starting as uniserial tests; ornamentation bilaterally symmetrical; aperture rounded or elliptical, terminal.

EXPLANATION OF PLATE 34

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. *Gümbelina globulosa* (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 annectens* (Parker and Jones). (After Parker and Jones).
11. *Plectofrondicularia mexicana* (Cushman). *a*, front view; *b*, apertural view; *c*, section.
12. *Amphimorphina haueriana* 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.



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a
a 18 b

PLATE 34

Genus PLECTOFRONDICULARIA Liebus, 1903

Plate 33, figures 19-21; plate 34, figure 11

Genoholotype, *Plectofrondicularia concava* Liebus

Plectofrondicularia LIEBUS, Jahrb. k. k. Geol. Reichs., vol. 52, 1903, p. 76.
Frondicularia (part) of authors.

Test elongate, compressed, in the microspheric form with the early chambers planispiral, then biserial, the adult with chambers in a rectilinear series and much compressed; aperture in the young at the inner margin of the chamber in the median line, in the adult terminal, elliptical.

Cretaceous to Recent.

Genus AMPHIMORPHINA Neugeboren, 1850

Plate 33, figure 22; plate 34, figure 12

Genoholotype, *Amphimorphina haueriana* Neugeboren

Amphimorphina NEUGEBOREN, Verh. Mitth. siebenbürg. Ver. Nat., vol. 1, 1850, p. 125.

Test elongate, 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; the aperture in the young elliptical, later circular.

Miocene.

Genus NODOMORPHINA Cushman, 1927

Plate 33, figure 23; plate 34, figure 13

Genoholotype, *Nodosaria compressiuscula* Neugeboren

Nodomorphina CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 2, 1927, p. 80.
Nodosaria (part) of authors.

Test elongate, compressed, especially in the earlier portion; chambers numerous, early ones quadrilateral in section, later ones more nearly circular; sutures distinct, slightly depressed, especially between the later chambers; wall ornamented by numerous raised costae in pairs at either side of the median line giving a bilateral symmetry to the test; aperture circular or elliptical without teeth or radiate fissures, terminal.

Miocene.

Subfamily 7. Eouvigerininae

Test in the earliest stages biserial, later triserial or in the most specialized genera uniserial after the triserial stage or throughout.

Genus EOUVIGERINA Cushman, 1926

Plate 33, figure 24; plate 34, figure 14

Genoholotype, *Eouvigerina americana* Cushman

Eouvigerina CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 2, 1926, p. 4.

Sagrina (part) of authors.

Test elongate, the early chambers at least in the microspheric form planispiral, later chambers becoming biserial, final chambers irregularly triserial; aperture circular or rhomboid at the end of a definite neck, usually with a phialine lip.

Upper Cretaceous.

Genus PSEUDOUVIGERINA Cushman, 1927

Plate 33, figures 25, 26; plate 34, figure 15

Genoholotype, *Uvigerina cristata* Marsson

Pseudouvigerina CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 2, 1927, p. 81.

Uvigerina (part) of authors.

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, 1927

Plate 33, figure 27; plate 34, figure 16

Genoholotype, *Siphogenerina plummeri* Cushman

Siphogenerinoides CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 3, 1927, p. 63.

Siphogenerina (part) CUSHMAN, 1926 (not SCHLUMBERGER).

Test elongate, slightly tapering, in the early stages biserial, later uniserial; wall calcareous, perforate, with longitudinal costae; aperture with a neck and phialine lip but typically without siphons between the chambers.

Cretaceous.

Genus NODOGENERINA Cushman, 1927

Plate 33, figure 28; plate 34, figure 17

Genoholotype, *Nodogenerina bradyi* Cushman

Nodogenerina CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 2, 1927, p. 79.

Sagrina (part) of authors.

Test elongate, uniserial, straight, chambers increasing in size as added, distinct, inflated; sutures depressed; 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 planispiral coiled ancestry of calcareous perforate type such as *Spirillina*. In *Heterohelix*, the biserial portion is becoming the adult character as it is in a few of the other genera which are primitive ones in the family. On this biserial stage are built the adult characters, broad low chambers becoming annular in *Pavonina*, globular chambers, spiral in *Pseudotextularia* or in a plane, in *Planoglobulina*, or triserial in *Eouvigerina* and *Pseudouvigerina* 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 planispiral beginning will distinguish these from the Buliminidae, and the perforate calcareous test will separate them from the Textulariidae which are arenaceous.

For a more detailed discussion of the relationships in this family, see Cushman, Phylogenetic Studies of the Foraminifera (Amer. Journ. Sci., vol. 13, 1927, pp. 321-326).

FAMILY 30. HANTKENINIDAE

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

Genus HANTKENINA Cushman, 1924

Plate 34, figure 18; plate 35, figures 1-3

Genoholotype, *Hantkenina alabamensis* Cushman

Hantkenina CUSHMAN, Proc. U. S. Nat. Mus., vol. 66, Art. 30, 1924, p. 1.
Siderolina HANTKEN (not DEFRANCE).
Nonionina (part) of authors.

Test planispiral throughout, close coiled; chambers distinct, usually nearly or completely 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 and lowest Oligocene.

See Cushman, A New Genus of Eocene Foraminifera (Proc. U. S. Nat. Mus., vol. 66, Art. 30, 1924, pp. 1-4, pls. 1, 2).

Genus MIMOSINA Millett, 1900

Plate 34, figure 19; plate 35, figure 4

Genotype, by designation, *Mimosina hystrix* Millett

Mimosina MILLETT, Journ. Roy. Micr. Soc., 1900, p. 547.

Test at least in the microspheric young apparently planispiral, later chambers biserial, chambers with a single acicular spine at the outer angle; wall calcareous, vesicular, somewhat spongy; aperture compound, consisting of two parts, one rounded and nearly terminal, the other below near the inner rim of the chamber, more elongate, arched.

Recent. Indo-Pacific.

Genus TRIMOSINA Cushman, 1927

Plate 34, figure 20; plate 35, figure 5

Genoholotype, *Mimosina spinulosa* Millett, var.

Trimosina CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 3, 1927, p. 64.
Mimosina MILLETT (part).

Test in the early stages biserial, later triserial; chambers each with a single acicular spine, or these obsolete; wall calcareous, vesicular; aperture elongate, removed from the edge, sometimes with a series of rounded pores in addition along the basal rim of the apertural face of the chamber.

Recent. Indo-Pacific.

The relationships of the Recent Indo-Pacific genera with *Hantkenina* of the Upper Eocene are seen not only in the spinose character of the large acicular spine in each chamber, and the planispiral early development, but also in the apertural characters, that of the specimen of *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, divided into chambers, in the specialized genera biserial or uniserial or even monothalamous; wall calcareous, perforate; aperture loop-like or rounded and terminal, usually with some sort of apertural tooth or spiral connected with the interior tubular siphons connecting the apertures.

KEY TO THE GENERA

I. Test, an elongate spiral, the spiral suture prominent.
  - A. Test consisting of proloculum and long undivided tubular second chamber. .... *Terebralina.*
  - B. Test of numerous chambers, usually more than three to a whorl.
    - 1. Aperture with a broad base. .... *Turrilina.*
    - 2. Aperture comma-shaped.
      - a. Chambers in a single series. .... *Buliminella.*
      - b. Chambers in a double series.................. *Robertina.*
    - 3. Aperture rounded, terminal. .... *Buliminoides.*

II. Test triserial, at least in the early stages.
  - A. Aperture comma-shaped.
    - 1. Chambers subglobular, test rounded in section.
      - a. Chambers strongly involute at the base.... *Globobulimina.*
      - b. Chambers not strongly involute at the base, triserial throughout. .... *Bulimina.*
      - c. Chambers not strongly involute at the base, later biserial. *Neobulimina.*
    - 2. Chambers angled, test triangular in section......... *Reussia.*
  - B. Aperture cribrate.
    - 1. Triserial throughout. .... *Chrysalidina.*
    - 2. Young triserial, adult uniserial.............. *Chrysalidinella.*
  - C. Aperture with a collar typically open at one side and a prominent tooth. .... *Uvigerinella.*

D. Aperture with a cylindrical neck and phialine lip.
1. Triserial throughout.
a. Test distinctly angled in section............*Angulogerina.*
b. Test rounded in section. ....*Uvigerina.*
2. Later stages uniserial.
a. Test distinctly angled in section...............*Trifarina.*
b. Test rounded in section..................*Siphogenerina.*

III. Test uniserial throughout.
A. Rounded in section throughout.
1. Aperture cribrate. ....*Chrysalogonium.*
2. Aperture with a neck and phialine lip........*Siphonodosaria.*
3. Aperture irregular, sometimes at the side....*Sporadogenerina.*
B. Early stages angled, later rounded................*Dentalinopsis.*

IV. Test consisting of a single chamber with an internal tube and rounded terminal aperture. ....*Entosolenia.*

V. Test biserial in the adult or at least in the early stages.
A. Test biserial in the adult.
1. Aperture comma-shaped, not in the median line.....*Virgulina.*
2. Aperture in the median line, reaching the base of the chamber. ....*Bolivina.*
B. Test becoming uniserial in the adult, aperture terminal.
1. Only the last chambers failing to be biserial, aperture usually broader at one end. ....*Loxostomum.*
2. Typically uniserial in the adult.
a. Aperture single, terminal.
(1). Chambers of the adult somewhat compressed, neck very slightly if at all developed.....*Rectobolivina.*
(2). Chambers not compressed in the adult, neck and lip strongly developed. ....*Bifarina.*
b. Aperture cribrate or a circle of pores.....*Tubulogenerina.*

Subfamily 1. Terebralininae

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

Genus TEREBRALINA Terquem, 1866

Plate 35, figure 6; plate 37, figure 1

Genoholotype, *Terebralina regularis* Terquem.

Terebralina TERQUEM, Sixième Mém. Foram. Lias, 1866, p. 473.

Test consisting of a proloculum and elongate undivided tubular second chamber in an elongate close spiral; wall calcareous, perforate; aperture rounded, terminal.

Jurassic.

Subfamily 2. Turrilininae

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

EXPLANATION OF PLATE 35

HANTKENINIDAE, BULIMINIDAE

FIG.

1, 2. *Hantkenina alabamensis* Cushman. (After type figure). Fig. 1, × 40. Fig. 2, Peripheral view. × 50.

3. *Hantkenina mexicana* Cushman. × 50. (After type figure).

4. *Mimosina hystrix* Millett. × 50. (After type figure). *a*, front view; *b*, side view; *c*, apertural view.

5. *Trimosina milletti* Cushman. × 60. (After type figure). *a*, front view; *b*, apertural view.

6. *Terebralina regularis* Terquem. × 50. (After type figure).

7. *Turrilina andreaei* Cushman. × 65. (After type figure). *a*, *b*, from opposite sides.

8. *Turrilina alsatica* Andreae. × 65. (After type figure). *a*, *b*, from opposite sides; *c*, apertural view.

9. *Turrilina alsatica* Andreae, var. *producta* Andreae. × 65. (After type figure).

10. *Buliminella elegantissima* (d'Orbigny). × 135. (After type figure). *a*, *b*, from opposite sides.

11, 12. *Buliminoides williamsoniana* (H. B. Brady). × 55. (After type figures). Fig. 11, *a*, front view; *b*, apertural view. Fig. 12, *a*, front view; *b*, side view.

13. *Robertina arctica* d'Orbigny. (After type figure). *a*, *b*, from opposite sides.

14. *Robertina charlottensis* (Cushman). × 25. (After type figure). *a*, *b*, from opposite sides.

15. *Bulimina marginata* d'Orbigny. (After type figures). *a*, *b*, from opposite sides.

16. *Bulimina elegans* d'Orbigny. × 35. (After H. B. Brady).

17. *Bulimina aculeata* d'Orbigny. × 40. (After H. B. Brady).

18. *Bulimina buchiana* d'Orbigny. × 55. (After H. B. Brady).

19. *Globobulimina pacifica* Cushman. × 50. (After type figure).

20. *Entosolenia globosa* (Reuss). (After Williamson). *a*, side view; *b*, apertural view; *c*, interior.

21. *Entosolenia staphyllearia* (Schwager). × 30. (After H. B. Brady).

22. *Entosolenia orbignyana* (Schwager). (After Williamson).


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4b
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15a
15b
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19a
19b
20a
20b
20c
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22

PLATE 35

Genus TURRILINA Andreae, 1884. Emend

Plate 35, figures 7-9; plate 37, figure 2

Genoholotype, *Turrilina alsatica* Andreae

Turrilina ANDREAE, Abhandl. Geol. Special Karte Elsass-Lothr., vol. 2, Heft. 3, 1884, p. 120.
Bulimina (part) of authors.

Test, an elongate close spiral, the chambers three or more in a coil, the spiral suture marked and even; wall calcareous, perforate; aperture with a broad base at the basal margin of the chamber, little if at all twisted.

Jurassic to Recent.

Genus BULIMINELLA Cushman, 1911

Plate 35, figure 10; plate 37, figure 3

Genoholotype, *Bulimina elegantissima* d'Orbigny

Buliminella CUSHMAN, Bull. 71, U. S. Nat. Mus., pt. 2, 1911, p. 88.
Bulimina (part) of authors.

Test, an elongate close spiral, the spiral suture marked; chambers three or usually more in a coil; wall calcareous, perforate; aperture elongate, very slightly twisted.

Cretaceous to Recent.

Genus BULIMINOIDES Cushman, 1911

Plate 35, figures 11, 12; plate 37, figure 5

Genoholotype, *Bulimina williamsoniana* H. B. Brady

Buliminoides CUSHMAN, Bull. 71, U. S. Nat. Mus., pt. 2, 1911, p. 90.
Bulimina (part) of authors.

Test subcylindrical, elongate, spirally twisted; chambers from the surface indistinct due to the ornamentation; wall calcareous, perforate; aperture terminal, central, circular, situated in a depression of the apertural end of the test.

Recent.

Genus ROBERTINA d'Orbigny, 1846

Plate 35, figures 13, 14; plate 37, figure 4

Genoholotype, *Robertina arctica* d'Orbigny

Robertina D'ORBIGNY, Foram. Foss. Bass. Tert. Vienne, 1846, p. 202.
Bulimina (part) of authors.
Cassidulina (part) of authors.

Test, an elongate close spiral, the spiral suture marked; the chambers in each whorl several, forming a double series; aperture elongate, curved.

Recent.

The species of *Robertina* are found largely in cold water of the Arctic and North Temperate regions.

Subfamily 3. Buliminінae

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

Genus BULIMINA d'Orbigny, 1826

Plate 35, figures 15-18; plate 37, figure 6

Genotype, by designation, *Bulimina marginata* d'Orbigny

Bulimina D'ORBIGNY, Ann. Sci. Nat., vol. 7, 1826, p. 269.

Pleurites EHRENBERG, Mikrogeologie, 1854, pl. xxvii, fig. 32 (genotype, by designation, *Pleurites cretae* EHRENBERG).

Cucurbitina COSTA, Atti Accad. Pontaniana, vol. 7, pt. 2, 1856, p. 363 (genoholotype, *Cucurbitina cruciata* COSTA).

Test, an elongate spiral, generally triserial; chambers inflated, spiral suture more or less obsolete; wall calcareous, perforate; aperture loop-shaped with a tooth or plate at one side and an internal spiral tube connecting through the chambers between the apertures.

Jurassic to Recent.

Genus NEOBULIMINA Cushman and Wickenden, 1928

Plate 54, figure 6

Genoholotype, *Neobulimina canadensis* Cushman and Wickenden

Neobulimina CUSHMAN and WICKENDEN, Contr. Cushman Lab. Foram. Res., vol. 4, 1928, p. 12.

Test in the early stages of both microspheric and megalospheric forms triserial, later biserial, not compressed; chambers distinct, subglobular, inflated throughout, simple; wall calcareous, perforate; aperture in the triserial stage elongate, oblique, narrowest near the base of the chamber, widest near the inner end, in the biserial stage much less oblique, broader, its elongate axis nearly at right angles to the base of the chamber.

Cretaceous.

Genus GLOBOBULIMINA Cushman, 1927

Plate 35, figure 19; plate 37, figure 12

Genoholotype, *Globobulimina pacifica* Cushman

Globobulimina CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 3, 1927, p. 67.

Bulimina (part) of authors.

Test spiral, early chambers tending to elongate, later ones extending backward and finally each chamber extending further back and enclosing the preceding ones in its series, the last three chambers making up the whole exterior; wall thin, calcareous, finely perforate; aperture loop-shaped with a tooth or plate and internal tube.

Tertiary and Recent.

Genus ENTOSOLENIA Ehrenberg, 1848

Plate 35, figures 20-22; plate 37, figure 13

Genotype, by designation, *Entosolenia lineata* Williamson

Entosolenia EHRENBERG, in WILLIAMSON, Ann. Mag. Nat. Hist., ser. 2, vol. 1, 1848, p. 5.

Cenchridium EHRENBERG, Bericht. k. preuss. Akad. Wiss. Berlin, 1845, p. 357 (genoholotype, *Cenchridium sphaerula* EHRENBERG, not figured).

Lagena (part) of authors.

Test monothalamous, the single chamber with an internal tube free at the inner end; wall usually thin, finely perforate; aperture elliptical or circular.

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

Plate 36, figures 1, 2; plate 37, figure 7

Genoholotype, *Virgulina squammosa* d'Orbigny

Virgulina D'ORBIGNY, Ann. Sci. Nat., vol. 7, 1826, p. 267.

Strophoconus EHRENBERG, Bericht. k. preuss. Akad. Wiss. Berlin, 1843, p. 166 (genotype, by designation, *Strophoconus auricula* EHRENBERG).

Grammobotrys EHRENBERG, l. c., 1845, p. 368 (genoholotype, *Grammobotrys africana* EHRENBERG).
Bulimina (part) of authors.
Polymorphina (part) of authors.

Test elongate, more or less compressed fusiform, the early chambers spiral about the elongate axis, triserial, later ones becoming irregularly biserial, whole test usually twisted; wall calcareous, finely perforate; aperture elongate, loop-shaped, usually with an apertural tooth or plate and internal spiral tube.

Lower Cretaceous to Recent.

Genus BOLIVINA d'Orbigny, 1839

Plate 36, figures 3-6; plate 37, figure 8

Genotype, by designation, *Bolivina plicata* d'Orbigny

Bolivina D'ORBIGNY, Voy. Amér. Mérid., vol. 5, pt. 5, 1839, p. 61.
Sagrina (?) D'ORBIGNY, in DE LA SAGRA, Hist. Fis. Pol. Nat. Cuba, 1839, "Foraminifères", p. 149 (genoholotype, *Sagrina pulchella* D'ORBIGNY).
Grammostomum EHRENBERG, Abhandl. k. Akad. Wiss. Berlin, 1838 (1840), p. 119 (genotype, by designation, *Grammostomum tenue* EHRENBERG).
Proroporus EHRENBERG, Bericht. k. preuss. Akad. Wiss. Berlin, 1844, p. 75 (genoholotype, *Proroporus lingua* EHRENBERG).
Brizalina COSTA, Atti Accad. Pontaniana, vol. 7, pt. 2, 1856, p. 296 (genoholotype, *Brizalina aenariensis* COSTA).
Clidostomum EHRENBERG, l. c., 1845, p. 358 (genoholotype, *Clidostomum polystigma* EHRENBERG).
Vulvulina (part) of authors.
Virgulina (part) of authors.

Test elongate, usually somewhat compressed, tapering from the subacute or rounded initial end, which is often twisted; chambers typically biserial; wall calcareous, perforate; aperture elongate, usually oblique to the median plane, elongate, reaching to the base of the chamber, often with a plate-like tooth connecting with an internal tube.

Cretaceous to Recent.

Genus RECTOBOLIVINA Cushman, 1927

Plate 36, figures 7, 8; plate 37, figure 11

Genoholotype, *Sagrina bifrons* H. B. Brady

Rectobolivina CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 3, 1927, p. 68.

EXPLANATION OF PLATE 36

Buliminidae

Fig.

1. *Virgulina squammosa* d'Orbigny. (After d'Orbigny's Model).
2. *Virgulina* sp. Showing internal spiral tube. (After Rhumbler).
3. *Bolivina plicata* d'Orbigny. (After type figure).
4. *Bolivina hantkeniana* H. B. Brady. × 40. (After type figure).
5. *Bolivina nitida* H. B. Brady. × 55. (After type figure). *a, b*, opposite sides.
6. *Bolivina subangularis* H. B. Brady. × 40. (After type figure). *a*, front view; *b*, apertural view.

7, 8. *Rectobolivina bifrons* (H. B. Brady). × 35. (After type figures). *a*, front view; *b*, apertural view.

9. *Loxostomum subrostratum* Ehrenberg. (After type figure).
10. *Loxostomum karreriana* (H. B. Brady). × 40. (After type figure). *a*, front view; *b*, apertural view.
11. *Loxostomum mayori* (Cushman). × 65. (After type figure).
12. *Bifarina saxipara* (Ehrenberg). (After type figure).
13. *Bifarina fimbriata* Millett. × 28. (After type figure). *a*, front view; *b*, apertural view.
14. *Reussia spinulosa* (Reuss). (After type figure). *a*, side view; *b*, front view; *c*, apertural view.

15, 16. *Chrysalidinella dimorpha* H. B. Brady. Fig. 15, (After type figure). × 50. *a*, front view; *b*, apertural view. Fig. 16, (After Millett). × 40. *a*, front view; *b*, apertural view.

17. *Chrysalidina gradata* (d'Orbigny). (After type figure). *a*, side view; *b*, apertural view.
18. *Chrysalogonium polystoma* (Schwager). (After type figure). *a*, side view; *b*, apertural view.
19. *Uvigerinella californica* Cushman. × 50. (After type figure). *a*, side view; *b*, apertural view.
20. *Uvigerina pigmea* d'Orbigny. (After type figure). *a, b*, opposite sides.

21, 22. *Trifarina bradyi* Cushman. × 50. (After type figures).

23, 24. *Siphonodosaria abyssorum* (H. B. Brady). × 15. (After type figures).

25, 26. *Angulogerina angulosa* (Williamson). Fig. 25, (After type figure). Fig. 26, (After H. B. Brady). × 40.

27. *Uvigerina tenuistriata* Reuss. × 30. (After H. B. Brady). *a*, side view; *b*, apertural view.
28. *Uvigerina porrecta* H. B. Brady. × 50. (After type figure).

29, 30. *Siphogenerina raphanus* (Parker and Jones). Fig. 29, (After type figure). Fig. 30, Section showing internal tube.

31. *Dentalinopsis semitriquetra* Reuss. (After type figure).

32, 33. *Sporadogenerina flintii* Cushman. × 20. (After type figures).

PLATE 36

Sagrina (part) of authors.
Siphogenerina (part) of authors.

Test elongate, somewhat compressed, in the young biserial, in the adult uniserial; wall calcareous, finely perforate; aperture in the adult terminal, rounded, with a slight lip and internal tube.

Tertiary and Recent.

Genus LOXOSTOMUM Ehrenberg, 1854

Plate 36, figures 9-11; plate 37, figure 9

Genotype, by designation, *Loxostomum subrostratum* Ehrenberg

Loxostomum Ehrenberg, Mikrogeologie, 1854, pl. xxvii, fig. 19.
Proroporus of authors (not Ehrenberg, 1844).
Bolivina (part) of authors.

Test elongate, usually compressed, early portion often slightly twisted, early chambers biserial with the aperture as in *Bolivina* reaching to the previous chamber but in the adult tending to become uniserial and the aperture failing to reach the base of the chamber, finally becoming terminal.

Cretaceous to Recent.

Genus TUBULOGENERINA Cushman, 1927

Plate 55, figures 3-5

Genoholotype, *Textularia (Bigenerina) tubulifera* Parker and Jones

Tubulogenerina Cushman, Contr. Cushman Lab. Foram. Res., vol. 2, 1927, p. 78.
Textularia (part) of authors.
Bigenerina (part) of authors.
Clavulina (part) of authors.

Test with the early chambers biserial, later ones uniserial, compressed or rounded in transverse section; wall often with numerous tubuli extending out from the test, either open or closed, forming lobular connections with the chamber, wall calcareous; aperture elongate, narrow, or in the adult with numerous rounded openings in the terminal face, the interior of the chambers at least in some species with a curved structure from roof to floor in the biserial portion.

Cretaceous to Miocene.

Genus BIFARINA Parker and Jones, 1872

Plate 36, figures 12, 13; plate 37, figure 10

Genoholotype, *Dimorphina saxipara* Ehrenberg

Bifarina PARKER and JONES, Ann. Mag. Nat. Hist., vol. 10, 1872, p. 198.
Dimorphina EHRENBERG, 1854 (not D'ORBIGNY).

Test with the earlier chambers biserial, later ones uniserial, the uniserial portion making up the larger part of the test in most species; wall calcareous, perforate; aperture in the young as in *Bolivina*, later terminal and rounded.

Cretaceous to Recent.

Subfamily 5. Reussiinae

Test distinctly triserial, at least in the young of most forms, in specialized forms becoming uniserial; aperture in the simpler forms and in the young, elongate, in the uniserial forms and some of the triserial ones, cribrate.

Genus REUSSIA Schwager, 1877

Plate 36, figure 14; plate 37, figure 14

Genoholotype, *Verneuilina spinulosa* Reuss

Reussia SCHWAGER, Boll. R. Com. Geol. Ital., vol. 8, 1877, p. 26.
Verneuilina (part) of authors (not D'ORBIGNY).

Test distinctly triserial, triangular in transverse section, broadest at the apertural end; wall calcareous, perforate; aperture elongate, oblique, in the triangular apertural face.

Cretaceous to Recent.

Genus CHRYSALIDINA d'Orbigny, 1839

Plate 36, figure 17; plate 37, figure 15

Genoholotype, *Chrysalidina gradata* d'Orbigny

Chrysalidina D'ORBIGNY, in DE LA SAGRA, Hist. Fis. Pol. Nat. Cuba, vol. 5, 1839, "Foraminifères", p. 107.

Test elongate, tapering, broadest near the apertural end, triserial, chambers more or less globular; wall arenaceous, thick; aperture in the adult, cribrate, consisting of a series of small rounded openings on the middle portion of the apertural face.

Cretaceous to Recent.

Genus CHRYSALIDINELLA Schubert, 1907

Plate 36, figures 15, 16; plate 37, figure 16

Genoholotype, *Chrysalidina dimorpha* H. B. Brady

Chrysalidinella SCHUBERT, Neues Jahrb. für Min., vol. 25, 1907, p. 242.
Chrysalidina of authors (not D'ORBIGNY).

Test tapering, triangular in transverse section, early chambers triserial, later ones becoming uniserial; wall calcareous, perforate; aperture in the adult, cribrate, consisting of numerous rounded openings scattered over the triangular apertural face.

Miocene to Recent.

EXPLANATION OF PLATE 37

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. *Loxostomum plaitum* (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.

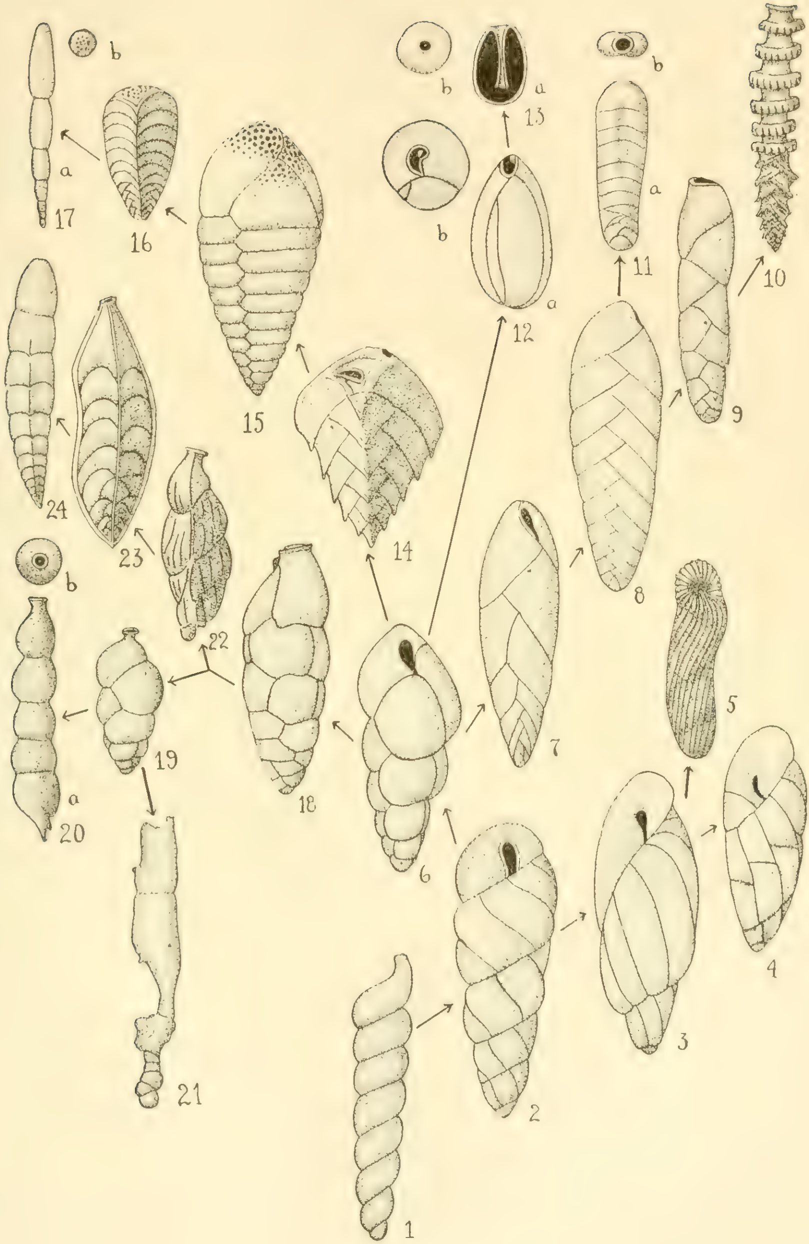

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PLATE 37

Genus CHRYSALOGONIUM Schubert, 1907

Plate 36, figure 18; plate 37, figure 17

Genoholotype, *Nodosaria polystoma* Schwager

Chrysalogonium SCHUBERT, Neues Jahrb. für Min., vol. 25, 1907, p. 243.
Nodosaria (part) SCHWAGER, 1866.

Test uniserial throughout, the chambers in a rectilinear series; wall calcareous, perforate; aperture cribrate, terminal, consisting of a group of rounded openings.

Pliocene.

Subfamily 6. Uvigerininae

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

Genus UVIGERINELLA Cushman, 1926

Plate 36, figure 19; plate 37, figure 18

Genoholotype, *Uvigerina (Uvigerinella) californica* Cushman

Uvigerinella CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 2, 1926, p. 58.
Uvigerina (part) of authors.

Test generally triserial, tapering or fusiform; chambers distinct and inflated; wall calcareous, perforate; aperture typically 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

Plate 36, figures 20, 27, 28; plate 37, figure 19

Genotype, by designation, *Uvigerina pigmea* d'Orbigny

Uvigerina D'ORBIGNY, Ann. Sci. Nat., vol. 7, 1826, p. 269.

Test generally triserial, elongate, fusiform, rounded in transverse section; chambers distinct and inflated; wall calcareous, perforate; 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

Plate 36, figures 29, 30

Genotype, by designation, *Siphogenerina costata* Schlumberger

Siphogenerina Schlumberger, Feuille Jeun. Nat., 1883, p. 117.
Sagrina (part) of authors (not d'Orbigny).

Test elongate, cylindrical, with the early stages typically triserial, rounded in section, later uniserial; wall calcareous, perforate; aperture in the adult terminal, with a distinct neck, phialine lip and internal tube.

Cretaceous (?) Eocene to Recent.

See Cushman, Foraminifera of the Genera Siphogenerina and Pavonina (Proc. U. S. Nat. Mus., vol. 67, Art. 25, 1926, pp. 1-24, pls. 1-6).

Genus SIPHONODOSARIA A. Silvestri, 1924

Plate 36, figures 23, 24; plate 37, figure 20

Genoholotype, *Nodosaria camerani* Dervieux

Siphonodosaria A. Silvestri, Boll. Soc. Geol. Ital., vol. 42, 1923 (1924), p. 18.
Nodosaria (part) of authors.
Sagrina (part) of authors.

Test elongate; chambers in a rectilinear, uniserial arrangement, inflated, generally globular; wall calcareous, perforate; aperture large, rounded, with a neck and phialine lip.

Tertiary and Recent.

Genus ANGULOGERINA Cushman, 1927

Plate 36, figures 25, 26; plate 37, figure 22

Genoholotype, *Uvigerina angulosa* Williamson

Angulogerina Cushman, Contr. Cushman Lab. Foram. Res., vol. 3, 1927, p. 69.
Uvigerina (part) of authors.

Test triserial, elongate, the whole test angled, with three flattened sides and distinct angles; wall calcareous, perforate; aperture at the end of a short neck, with a phialine lip.

Cretaceous (?) Eocene to Recent.

Genus TRIFARINA Cushman, 1923

Plate 36, figures 21, 22; plate 37, figure 23

Genoholotype, *Trifarina bradyi* Cushman

Trifarina Cushman, Bull. 104, U. S. Nat. Mus., pt. 4, 1923, p. 99.
Rhabdogonium of authors (not Reuss).
Triplasia of authors (not Reuss).

Test elongate, triangular in transverse section; the early chambers in an irregular spire or triserial, later ones becoming uniserial; wall calcareous, perforate; aperture terminal in the adult, rounded, with a short neck and phialine lip and internal tube.

Cretaceous (?) Eocene to Recent.

See Cushman, *Trifarina* in the American Eocene and Elsewhere (Contr. Cushman Lab. Foram. Res., vol. 1, 1926, pp. 86-88).

Genus DENTALINOPSIS Reuss, 1860

Plate 36, figure 31; plate 37, figure 24

Genoholotype, *Dentalinopsis semitriquetra* Reuss

Dentalinopsis Reuss, Sitz. k. böhm. Ges. Wiss., Jahrg., 1860, p. 91.

Test uniserial; the chambers in a generally straight or slightly curved linear series, early chambers angled and triangular in section, later ones rounded; wall calcareous, perforate; aperture rounded, terminal.

Cretaceous.

Genus SPORADOGENERINA Cushman, 1927

Plate 36, figures 32, 33; plate 37, figure 21

Genoholotype, *Sporadogenerina flintii* Cushman

Sporadogenerina Cushman, Contr. Cushman Lab. Foram. Res., vol. 2, 1927, p. 95.

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 definite 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 here 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 described as *Trigonulina* and here referred to *Lagena* may be end forms from such genera as *Trifarina*. For a more detailed discussion of the relationships in this family see Cushman, Phylogenetic Studies of the Foraminifera (Amer. Journ. Sci., vol. 13, 1927, pp. 318-321).

The form described by H. B. Brady as *Sagrina* (?) *tessellata*, (*Challenger*, 1884, p. 585, pl. 76, figs. 17-19) is a very peculiar one. It was given the name of *Millettia* by Schubert in 1911, and *Schubertia* by A. Silvestri in 1912. It may belong near *Siphogenerina*, but although I have seen the original types figured by Brady, there is so little structure shown by the specimens which are megalospheric that it is not possible to more than guess at the actual relationships of this form. Millett in his Malay work shows that the chambers have numerous divisions. A study of microspheric specimens is needed to obtain the developmental stages.

FAMILY 32. ELLIPSOIDINIDAE

Test with the wall calcareous, finely perforate, variously formed, the aperture usually narrow, elongate, curved in the outline of a semiellipse, 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.

KEY TO THE GENERA

I. Test of numerous chambers.
  A. Chambers biserial throughout.................... *Pleurostomella.*
  B. Early chambers biserial, later uniserial.
    1. Completely involute in the adult............. *Ellipsobulimina.*
    2. Not completely involute.
      a. Later chambers forming an elongate test.... *Nodosarella.*
      b. Later chambers forming a glanduline test. *Ellipsopleurostomella.*
  C. All chambers uniserial.
    1. Not involute.
      a. Test not compressed, aperture semielliptical. *Ellipsonodosaria.*
      b. Test not compressed, aperture broad with a large flat tooth. .... *Pleurostomellina.*
      c. Test compressed, aperture elliptical..... *Ellipsolingulina.*
    2. Partially involute.
      a. Test not compressed, aperture semielliptical. *Ellipsoglandulina.*
      b. Test somewhat compressed, aperture elliptical. *Gonatosphaera.*
    3. Completely involute. .... *Ellipsoidina.*
II. Test monothalamous. .... *Ellipsolagena.*

Genus PLEUROSTOMELLA Reuss, 1860

Plate 38, figure 1

Genotype, by designation, *Pleurostomella subnodosa* Reuss

Pleurostomella REUSS, Sitz. Akad. Wiss. Wien, vol. 40, 1860, p. 203.
Nodosaria (part) REUSS, 1850.
Dentalina (part) REUSS, 1850.

Test usually elongate, biserial; wall calcareous, perforate; aperture, an arched opening on the inner side of the chamber, partially closed by two broad teeth at either side at the base with a narrow vertical slit between.

Cretaceous to Recent.

See Cushman and Harris, Notes on the Genus *Pleurostomella* (Contr. Cushman Lab. Foram. Res., vol. 3, 1927, pp. 128-135, pl. 25).

Genus PLEUROSTOMELLINA Schubert, 1911

Plate 54, figure 4

Genoholotype, *Pleurostomella barroisi* Berthelin

Pleurostomellina SCHUBERT, Abhandl. k. k. Geol. Reichs., vol. 20, pt. 4, 1911, p. 59.

Pleurostomella (part) BERTHELIN, Mém. Soc. Géol. France, ser. 3, vol. 1, 1880, p. 30.

Test with the general characters of *Pleurostomella* but quickly becoming uniserial instead of continuing the biserial character in the adult.

Upper Cretaceous.

Genus ELLIPSOPLEUROSTOMELLA A. Silvestri, 1903

Plate 38, figure 2

Genoholotype, *Ellipsopleurostomella schlichti* A. Silvestri

Ellipsopleurostomella A. SILVESTRI, Atti R. Accad. Sci. Torino, vol. 39, 1903, p. 216.

Rostrolina SCHLICHT, Foram. Septarienzone Pietzpuhl, 1870, p. 72, pl. 26, figs. 1-9.

Test with the early chambers biserial, later ones uniserial; wall calcareous, perforate; aperture narrow, subelliptical, subterminal.

Cretaceous and Tertiary.

Genus ELLIPSOBULIMINA A. Silvestri, 1903

Plate 38, figure 3

Genoholotype, *Ellipsobulimina seguenzai* A. Silvestri

Ellipsobulimina A. SILVESTRI, Atti R. Accad. Sci. Torino, vol. 39, 1903, p. 11.

Test with the early chambers somewhat biserial, but entirely involute, the last-formed chamber making up nearly the entire exterior of the test; wall calcareous, perforate; aperture narrow, semicircular.

Miocene.

Genus NODOSARELLA Rzehak, 1895

Plate 38, figure 4

Genotype, by designation, *Lingulina tuberosa* Gümbel

Nodosarella RZEHAK, Ann. k. k. Nat. Hofmuseums, vol. 10, 1895, p. 220.

Nodosaria (part) of authors.
Lingulina (part) of authors.

Test elongate, with the early chambers showing traces of the biserial ancestry but the later ones in a rectilinear series, very slightly involute; wall calcareous, perforate; aperture narrow, subterminal, semielliptical.

Cretaceous and Tertiary.

Genus ELLIPSONODOSARIA A. Silvestri, 1900

Plate 38, figure 5

Genoholotype, *Lingulina rotundata* d'Orbigny

Ellipsonodosaria A. SILVESTRI, Atti Rend. Accad. Sci. Let. Art. Zelanti Stud. Acireale, vol. 10, 1899-1900 (1900), p. 4.
Nodosaria (part) D'ORBIGNY, 1846.

Test elongate, with all the chambers in a rectilinear series, rounded; wall calcareous, perforate; aperture narrow, subterminal, subelliptical.

Cretaceous and Tertiary.

EXPLANATION OF PLATE 38

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 salmojraghii* 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.

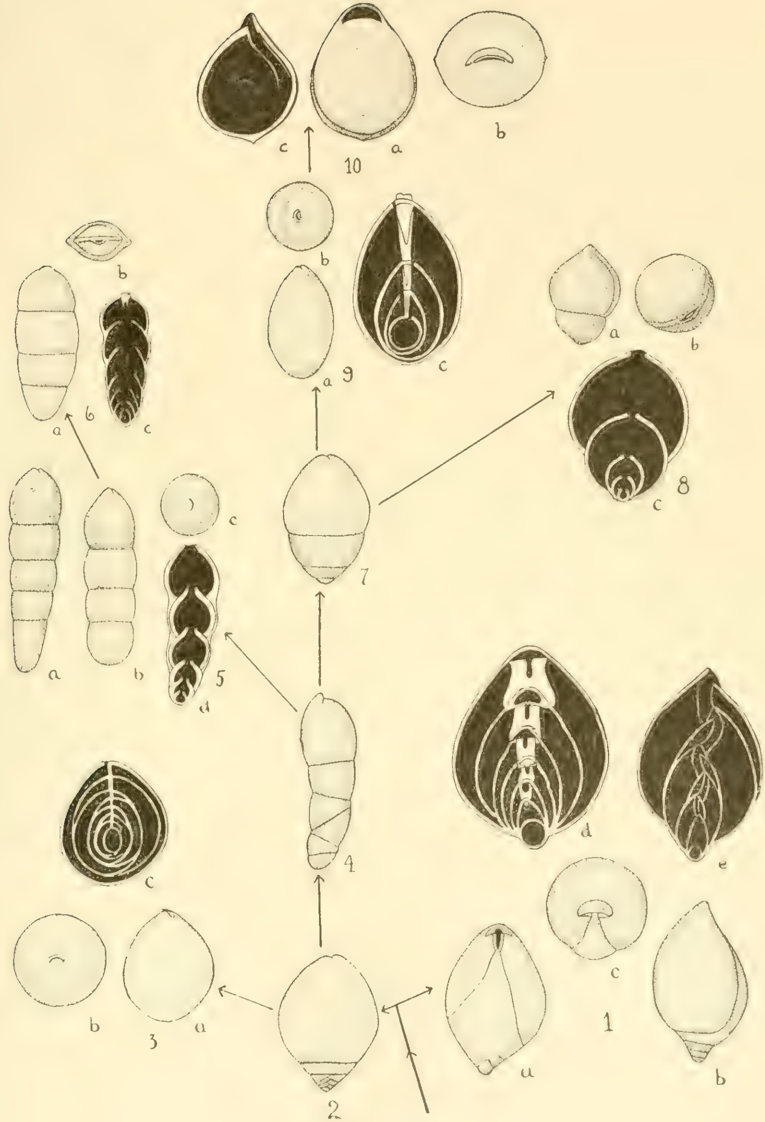


Plate 38

Genus ELLIPSOLINGULINA A. Silvestri, 1907

Plate 38, figure 6

Genoholotype, *Lingulina impressa* Terquem

Ellipsolingulina A. SILVESTRI, Riv. Ital. Pal., vol. 13, fasc. 2, 1907, p. 69.
Lingulina (part) of authors (not D'ORBIGNY).

Test elongate, somewhat compressed, with all the chambers in a rectilinear series; wall calcareous, perforate; aperture subterminal, narrow, semielliptical, sometimes with an internal tube.

Tertiary.

Genus ELLIPSOGLANDULINA A. Silvestri, 1900

Plate 38, figure 7

Genoholotype, *Ellipsoglandulina laevigata* A. Silvestri

Ellipsoglandulina A. SILVESTRI, Atti Rend. Accad. Sci. Let. Art. Zelanti Stud. Acireale, vol. 10, 1899-1900 (1900), p. 4.

Test with the chambers in a rectilinear series becoming involute; wall calcareous, perforate; aperture narrow, subterminal, semielliptical.

Cretaceous and Tertiary.

Genus GONATOSPHAERA Guppy, 1904

Plate 38, figure 8

Genoholotype, *Gonatosphaera prolata* Guppy

Gonatosphaera GUPPY, Geol. Mag., sec. 5, vol. 1, 1904, p. 241.

Test similar to *Ellipsoglandulina* but compressed; aperture elliptical.

Tertiary.

Genus ELLIPSOIDINA Seguenza, 1859

Plate 38, figure 9

Genotype, by designation, *Ellipsoidina ellipsoides* Seguenza

Ellipsoidina SEGUENZA, Eco Peloritans, ser. 2, vol. 5, 1859, fasc. 9 (10).

Test with the chambers in a rectilinear series, but completely involute, a hollow tubular structure between the sutures and successive chambers; aperture semicircular, narrow, subterminal.

Cretaceous and Tertiary.

Genus ELLIPSOLAGENA A. Silvestri, 1923

Plate 38, figure 10

Genotype, by designation, *Lagena ventricosa* A. Silvestri

Ellipsolagena A. SILVESTRI, Mem. Pont. Accad. Rom. Nuovi Lincei, ser. 2, vol. 6, 1923, p. 265 (name only).
Lagena (part) of authors.

Test monothalamous, with an internal tube at one side of the chamber from the aperture which is elongate, subterminal, curved, with one side raised into a protecting hood.

Tertiary and Recent.

This family for which a number of other generic names have been proposed is peculiar in the distinct 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 ocean. The relationship to the genera of the Lagenidae is not as 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 generally trochoid except in *Spirillina*, all the chambers visible from the dorsal side except in a very few genera which become partially involute, only those of the last-formed whorl usually visible from the ventral side; wall calcareous, usually rather coarsely perforate; aperture typically on the ventral side of the test.

KEY TO THE GENERA

I. Test consisting of proloculum and tubular coiled undivided second chamber.
   - A. Test planispiral. .... *Spirillina*.
   - B. Test trochoid.
     1. Ventral side open showing the earlier coils..... *Turrispirillina*.
     2. Ventral side with the chamber completely involute. *Conicospirillina*.

II. Test consisting of numerous chambers, usually but two in each whorl.
- A. Periphery acute, chambers with internal incomplete septae. *Patellina.*
- B. Periphery rounded, chambers without internal septae. *Patellinella.*

III. Test of numerous chambers, several in a whorl.
- A. Umbilicus usually open, not filled.
  - 1. Ventral side with a prolongation of the chamber over or toward the umbilicus.
    - a. Test typically planoconvex, umbilicus deep.
      - (1). Ventral side smooth and polished...... *Lamarckina.*
      - (2). Ventral side with chambers projecting to the umbilicus. .... *Discorbis.*
    - b. Test strongly biconvex. .... *Valvulineria.*
  - 2. Ventral side without prolongations across the umbilicus.
    - a. Test in a low spire......................... *Gyroidina.*
    - b. Test in a high spire. .... *Rotaliatina.*
- B. Umbilicus usually filled, not open.
  - 1. With a distinct umbilical plug...................... *Rotalia.*
  - 2. Without a distinct umbilical plug.
    - a. Apertural face with a distinct thin plate.
      - (1). Aperture simple.
        - (a). Test not involute on the dorsal side... *Cancris.*
        - (b). Test strongly involute on the dorsal side. *Baggina.*
      - (2). Aperture cribrate. .... *Neocribrella.*
    - b. Apertural face without a thin plate.
      - (1). Aperture simple, without a neck and without a supplementary aperture near the periphery. *Eponides.*
      - (2). Aperture with a neck and lip.
        - (a). Test globular. .... *Siphoninoides.*
        - (b). Test biconvex, close coiled. .... *Siphonina.*
        - (c). Test biconvex, uncoiling in the adult. *Siphoninella.*
      - (3). Test with supplementary apertures near the periphery without a neck. .... *Epistomina.*
      - (4). Test with supplementary apertures on the dorsal side. .... *Epistomella.*
      - (5). Test in the adult greatly spreading and irregular. *Planopulvinulina.*

Subfamily 1. Spirillininae

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

Genus SPIRILLINA Ehrenberg, 1841

Plate 39, figures 1, 2

Genoholotype, *Spirillina vivipara* Ehrenberg

Spirillina EHRENBERG, Abhandl. k. Akad. Wiss. Berlin, 1841, p. 422.
Operculina (part) REUSS, 1849.
Cornuspira (part) SCHULTZE, 1854.
Cyclolina EGGER, 1857 (not D'ORBIGNY).

Test typically free, occasionally attached, planispiral, composed of a subglobular or ovoid proloculum and a long undivided tubular second chamber, close coiled in one plane; wall calcareous, perforate, surface smooth or variously ornamented; aperture formed by the open end of the tube.

Cambrian to Recent.

Subfamily 2. Turrispirillininae

Test simple, consisting of a proloculum and spirally coiled, undivided second chamber, conical in shape.

Genus TURRISPIRILLINA Cushman, 1927

Plate 39, figure 3; plate 41, figure 1

Genoholotype, *Spirillina conoidea* Paalzow

Turrispirillina CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 3, 1927, p. 73.
Spirillina (part) of authors.

Test composed of a proloculum and elongate, tubular, undivided second chamber in a hollow conical spire, the coils not appreciably involute; aperture, a semicircular opening at the periphery.

Jurassic to Recent.

Genus CONICOSPIRILLINA Cushman, 1927

Plate 39, figure 4; plate 41, figure 2

Genoholotype, *Spirillina trochoides* Berthelin

Conicospirillina CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 3, 1927, p. 73.
Spirillina BERTHELIN, 1879 (not EHRENBERG).

Test coiled in a conical spiral chamber completely involute on the ventral side; wall calcareous, perforate; aperture, a narrow slit on the ventral 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 whorl visible from the ventral side; aperture ventral, not extending out to the periphery.

Genus PATELLINA Williamson, 1858

Plate 39, figures 6-8; plate 41, figure 3

Genoholotype, *Patellina corrugata* Williamson

Patellina WILLIAMSON, Rec. Foram. Gt. Britain, 1858, p. 46.

Test conical or planoconvex, early whorls undivided, and oc-

EXPLANATION OF PLATE 39

ROTALIIDAE

FIG.

1, 2. *Spirillina vivipara* Ehrenberg. Fig. 1, (After type figure). Fig. 2, (After H. B. Brady). × 65. *a*, side view; *b*, apertural view.

3. *Turrispirillina conoidea* (Paalzow). (After type figure). *a*, side view; *b*, ventral view.

4. *Conicospirillina trochoides* (Berthelin). (After type figure). *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

5. *Discorbis scalariformis* Paalzow. (After type figure). *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

6–8. *Patellina corrugata* Williamson. (After H. B. Brady). Fig. 6, *a*, side view; *b*, dorsal view. × 80. Fig. 7, Ventral view. × 80. Fig. 8 *a*, side view. × 80. 8 *b*, dorsal view. × 100.

9. *Discorbis rosacea* (d'Orbigny). × 65. (After H. B. Brady). *a*, dorsal view; *b*, ventral view; *c*, side view.

10. *Discorbis vesicularis* Lamarck. × 20. (From specimen from type locality). *a*, ventral view; *b*, dorsal view; *c*, side view.

11. *Lamarckina erinacea* (Karrer). (After type figure). *a*, dorsal view; *b*, ventral view; *c*, side view.

12. *Valvulineria californica* Cushman. × 40. (After type figure). *a*, dorsal view; *b*, ventral view; *c*, side view.

13. *Gyroidina soldanii* d'Orbigny. × 30. (After H. B. Brady). *a*, dorsal view; *b*, ventral view; *c*, side view.

14. *Rotaliatina mexicana* Cushman. × 40. (After type figure). *a*, dorsal view; *b*, ventral view; *c*, side view.


3a
4c
2b
2a
4b
4a
3b
3a
2a
5a
5b
5c
6b
7
8b
9a
9c
9b
10c
10b
11c
11a
11b
10a
12b
12c
12a
14a
13c
14b
13a
13b
14c

PLATE 39

casionally entire specimens without divisions and like *Spirillina*, later ones usually divided into long chambers often with internal sinuous septa; wall calcareous, perforate, thin; aperture elongate at the base of the ventral side of the chamber.

Lower Cretaceous to Recent.

Genus PATELLINELLA Cushman, 1928

Plate 53, figure 15

Genoholotype, *Textularia inconspicua* H. B. Brady

Patellinella CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 4, 1928 p. 5.

Textularia (part) of authors (not DEFRANCE).

Discorbis (part) CUSHMAN (not LAMARCK).

Test conical, trochoid; chambers in the adult with two making up each whorl; wall calcareous, perforate; aperture on the ventral side, umbilical.

Tertiary and Recent.

Genus DISCORBIS Lamarck, 1804

Plate 39, figures 5, 9, 10; plate 41, figure 4

Genotype, by designation, *Discorbis vesicularis* Lamarck

Discorbis LAMARCK, Ann. Mus., vol. 5, 1804, p. 183.

Rosalina D'ORBIGNY, Ann. Sci. Nat., vol. 7, 1826, p. 271 (genotype, by designation, *Rosalina globularis* D'ORBIGNY).

Turbinulina (part) D'ORBIGNY, 1826.

Allotheca EHRENBERG, Abhandl. k. Akad. Wiss. Berlin, 1841, p. 407 (genoholotype, *Allotheca megathyra* EHRENBERG).

Phanerostomum EHRENBERG, l. c., p. 409 (genotype, by designation, *Phanerostomum integerrimum* EHRENBERG).

Platyoecus EHRENBERG, Mikrogeologie, 1854, pl. 30, fig. 28 (genoholotype, *Platyoecus squama* EHRENBERG).

Aristerospira EHRENBERG, Monatsber. k. preuss. Akad. Wiss. Berlin, 1858, p. 11 (genotype, by designation, *Aristerospira isoderma* EHRENBERG).

Discorbina PARKER and JONES, in CARPENTER, PARKER and JONES, Introd. Foram., 1862, p. 203 (genotype, *Rotalia (Trochulina) turbo* D'ORBIGNY).

Test typically planoconvex, the ventral side flattened, early portion sometimes showing a long *Spirillina*-like second chamber before division; chambers often produced to partially cover the umbilical area; wall calcareous, perforate; aperture at the base of the umbilical margin on the ventral side of the chamber.

Lower Cretaceous to Recent—possibly Carboniferous.

Genus LAMARCKINA Berthelin, 1881

Plate 39, figure 11; plate 41, figure 6

Genoholotype, *Pulvinulina crinacea* Karrer

Lamarckina BERTHELIN, Comptes Rendus Assoc. Franc. (REIMS, 1880) 1881, p. 555.
Megalostomina RZEHAK, Ann. k. k. Nat. Hofmuseums, vol. 10, 1895, p. 228 (genoholotype, *Megalostomina fuchsi* RZEHAK).
Pulvinulina (part) of authors.
Rotalina (part) of authors.
Discorbina (part) of authors.
Valvulina (part) of authors.

Test trochoid, evidently attached, dorsal side convex, ventral side usually flattened or concave, dorsal side usually ornamented, ventral side very smooth and highly polished; chambers distinct on the dorsal side, less so on the ventral, each often with an umbilical projection; wall finely perforate, calcareous, ventral side thickened; aperture at the umbilical end of the chamber, often enlarged by resorption.

Upper Cretaceous to Recent.

See Cushman, The Genus *Lamarckina* and its American Species (Contr. Cushman Lab. Foram. Res., vol. 2, 1926, pp. 7-14, pl. 4).

Genus VALVULINERIA Cushman, 1926

Plate 39, figure 12; plate 41, figure 5

Genoholotype, *Valvulineria californica* Cushman

Valvulineria CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 2, 1926, p. 59.
Rosalina (part) of authors.

Test usually trochoid, close coiled, all chambers of the several coils visible from the dorsal side, only those of the last-formed coil from the ventral side, umbilicate; chambers numerous; wall calcareous, finely perforate; aperture ventral, large, extending from the umbilical end of the chamber nearly to the periphery and covered by a thin, membrane-like plate which largely fills the umbilical area, in the adult the aperture often extending into the ventral or peripheral face of the chamber, sometimes becoming tripartite.

Cretaceous to Recent.

Genus GYROIDINA d'Orbigny, 1826

Plate 39, figure 13; plate 41, figure 7

Genotype, by designation, *Gyroidina orbicularis* d'Orbigny

Gyroidina D'ORBIGNY, Ann. Sci. Nat., vol. 7, 1826, p. 278.
Rotalina (part) of authors.

Test trochoid, usually 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; wall calcareous, finely perforate; aperture, a low arched opening on the ventral side toward the umbilical area.

Lower Cretaceous to Recent.

Genus ROTALIATINA Cushman, 1925

Plate 39, figure 14; plate 41, figure 8

Genoholotype, *Rotaliatina mexicana* Cushman

Rotaliatina CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 1, 1925, p. 4.
Rotalina (part) of authors (not D'ORBIGNY).

Test free, trochoid, close coiled, composed of about three volutions, the last one composed of numerous chambers, all visible from the dorsal side, only those of the last-formed coil from the ventral side, ventrally umbilicate; wall calcareous, finely perforate; aperture, an arched slit between the base of the apertural face and the previous coil.

Eocene.

Subfamily 4. Rotaliinae

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

Genus EPONIDES Montfort, 1808

Plate 40, figures 1, 2; plate 41, figure 9

Genoholotype, *Nautilus repandus* Fichtel and Moll

Eponides MONTFORT, Conch. Syst., vol. 1, 1808, p. 127.
Nautilus (part) of authors.

Rotalia (part) of authors.
Rotalina (part) of authors.
Pulvinulina PARKER and JONES, in CARPENTER, PARKER and JONES, Introd. Foram., 1862, p. 201 (genotype, by designation, *Nautilus repandus* FICHTEL and MOLL).
Placentula (part) BERTHELIN (not LAMARCK).
Cyclospira EIMER and FICKERT, Zeitschr. Wiss. Zool., vol. 65, 1899, p. 702 (genoholotype, *Rotalina schreibersii* D'ORBIGNY).

Test trochoid, usually biconvex, umbilical area closed but not typically with a plug; wall calcareous, perforate; aperture, a low opening between the periphery and umbilical area, usually well away from the peripheral margin.

Carboniferous (?) Jurassic to Recent.

Genus PLANOPULVINULINA Schubert, 1920

Plate 53, figure 18

Genotype, by designation, *Pulvinulina dispansa* H. B. Brady

Planopulvinulina SCHUBERT, Pal. Zeitschr., vol. 3, 1920, p. 153.
Pulvinulina (part) H. B. BRADY, Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 687.

Test trochoid in the early stages, later becoming very irregular in form but the chambers not annular; ventral face of the chambers with large pores which apparently serve as the apertures.

Late Tertiary and Recent.

This is apparently a genus which has its nearest relationships, as suggested by Brady, with *Eponides punctulatus* (d'Orbigny). With it, Schubert included *Planorbulina vermiculata* d'Orbigny, a form closely related to *Cibicides* and later made the genotype of *Cyclocibicides* Cushman. The development and relationships of the two forms are very different.

Genus ROTALIA Lamarck, 1804

Plate 40, figures 3-5; plate 41, figure 16

Genoholotype, *Rotalia trochidiformis* Lamarck

Rotalia LAMARCK, Ann. Mus., vol. 5, 1804, p. 184.
Nautilus (part) of authors.
Streblus FISCHER, Mém. Soc. Imp. Nat. Moscou, vol. 5, 1817, p. 449 (genoholotype, *Streblus tortuosus* FISCHER).
Turbinulina D'ORBIGNY, Ann. Sci. Nat., vol. 7, 1826, p. 275 (genotype, by

designation, *Rotalia (Turbinulina) beccarii* (LINNÉ) =*Nautilus beccarii* LINNÉ).
Rosalina (part) of authors.
Truncatulina (part) of authors.

Test trochoid, usually biconvex, the umbilical area closed, usually having a conical plug of clear shell material; sutures on the ventral side usually deeply depressed and often ornamented along the sides, dorsal side usually limbate; wall calcareous, perforate, 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 early stages, umbilical area filled, supplementary apertures near the periphery and just below it on the ventral side, sometimes with a neck and lip.

EXPLANATION OF PLATE 40

ROTALIIDAE

FIG.

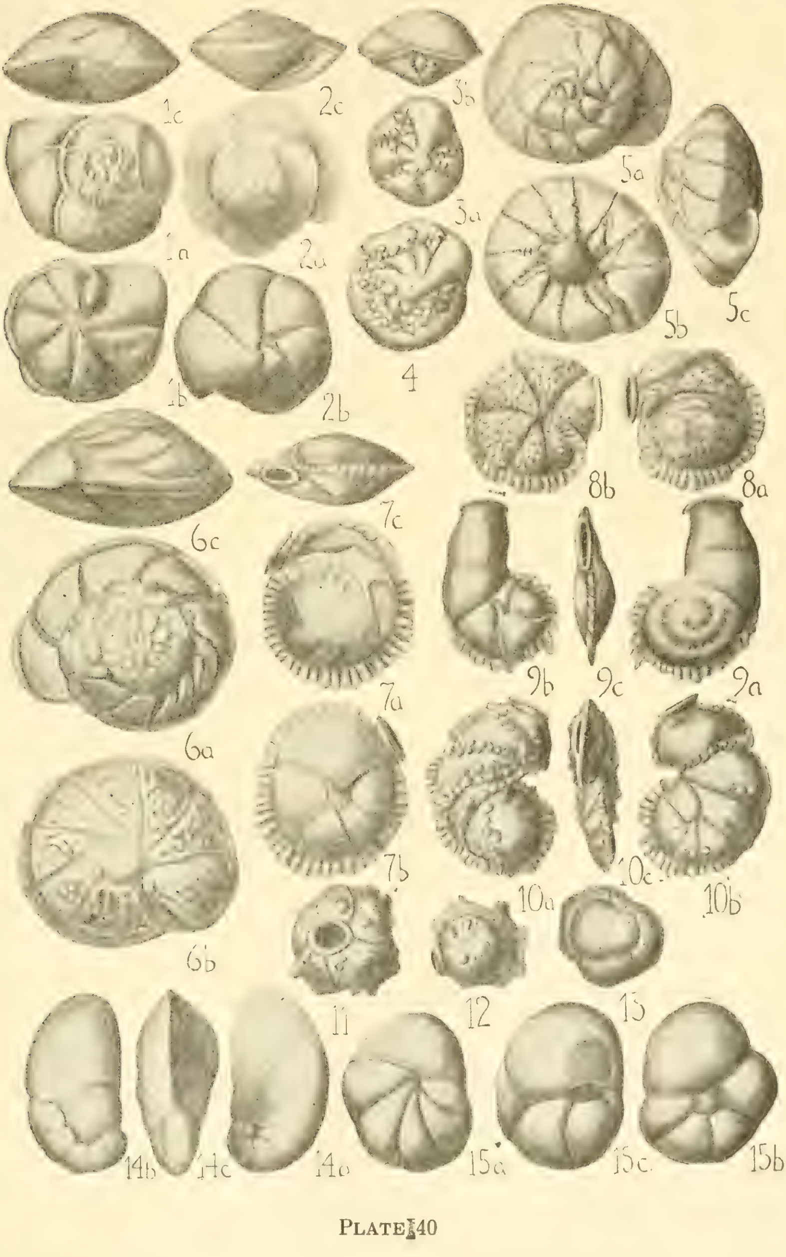
1. *Eponides repandus* (Fichtel and Moll). × 20. (After H. B. Brady).
2. *Eponides tenera* (H. B. Brady). × 50. (After type figure).

3, 4. *Rotalia trochidiformis* Lamarck. × 20. Fig. 3, Young specimen. *a,* ventral view; *b,* side view. Fig. 4, Older specimen, ventral view.

5. *Rotalia beccarii* (Linné), var. × 35. (After H. B. Brady).
6. *Epistomina elegans* (d'Orbigny). × 25. (After H. B. Brady).
7. *Siphonina tubulosa* Cushman. × 50.
8. *Siphonina howei* Cushman. × 65. (After type figure).
9. *Siphoninella claibornensis* Cushman and Howe. × 65. (After type figure).
10. *Siphoninella soluta* (H. B. Brady). × 65. (After type figure).

11–13. *Siphoninoides echinata* (H. B. Brady). × 65. (After type figures).

14. *Cancris auriculus* (Fichtel and Moll). × 30. (After H. B. Brady).
15. *Baggina californica* Cushman. × 40. (After type figure). (In all figures where not mentioned: *a,* dorsal view; *b,* ventral view; *c,* peripheral view).


1c
2c
3b
5a
1a
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5c
5b
4
1b
2b
8b
8a
6c
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6a
7a
9b
9c
9a
6b
7b
10a
10c
10b
11
12
13
14b
14c
14a
15a
15c
15b

PLATE 40

Genus EPISTOMINA Terquem, 1883

Plate 40, figure 6; plate 41, figure 10

Genotype, by designation, *Epistomina regularis* Terquem

Epistomina TERQUEM, Bull. Soc. Géol. France, ser. 3, vol. 11, 1883, p. 37.
Rotalia (Turbinulina) (part) D'ORBIGNY, 1826.
Pulvinulina (part) of authors.
Placentula BERTHELIN, 1882 (not LAMARCK).

Test trochoid, biconvex, umbilical area filled, all whorls visible from the dorsal side, only the last-formed coil from the ventral side; sutures usually limbate; wall calcareous, perforate; apertures of two sorts, one at the inner margin of the ventral side of the chamber or in the face itself, the other elongate, just below the periphery and in the axis of coiling, in later growth usually filled with clear shell material.

Jurassic to Recent.

Genus EPISTOMELLA Cushman, 1928

Plate 54, figure 9

Genoholotype, *Discorbina rimosa* Parker and Jones

Epistomella CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 4, 1928, p. 6.

EXPLANATION OF PLATE 41

ROTALIIDAE

FIG.

1. *Turrispirillina conoidea* (Paalzow). (After Paalzow).
2. *Conicospirillina trochoides* (Berthelin). (After Berthelin).
3. *Patellina corrugata* Williamson. (After Williamson).
4. *Discorbis rosacea* (d'Orbigny). (After H. B. Brady).
5. *Valvulineria californica* Cushman.
6. *Lamarckina glabrata* (Cushman).
7. *Gyroidina soldanii* d'Orbigny. (After d'Orbigny).
8. *Rotaliatina mexicana* Cushman.
9. *Eponides repandus* (Fichtel and Moll). (After H. B. Brady).
10. *Epistomina elegans* (d'Orbigny). (After H. B. Brady).
11. *Siphonina reticulata* (Czjzek). (After H. B. Brady).
12. *Siphoninoides echinata* (H. B. Brady). (After H. B. Brady).
13. *Siphoninella soluta* (H. B. Brady). (After H. B. Brady).
14. *Cancris auriculus* (Fichtel and Moll). (After H. B. Brady).
15. *Baggina californica* Cushman.
16. *Rotalia trochidiformis* Lamarck. (After Terquem).

(In all figures: *a*, ventral view; *b*, peripheral view; *c*, dorsal view).

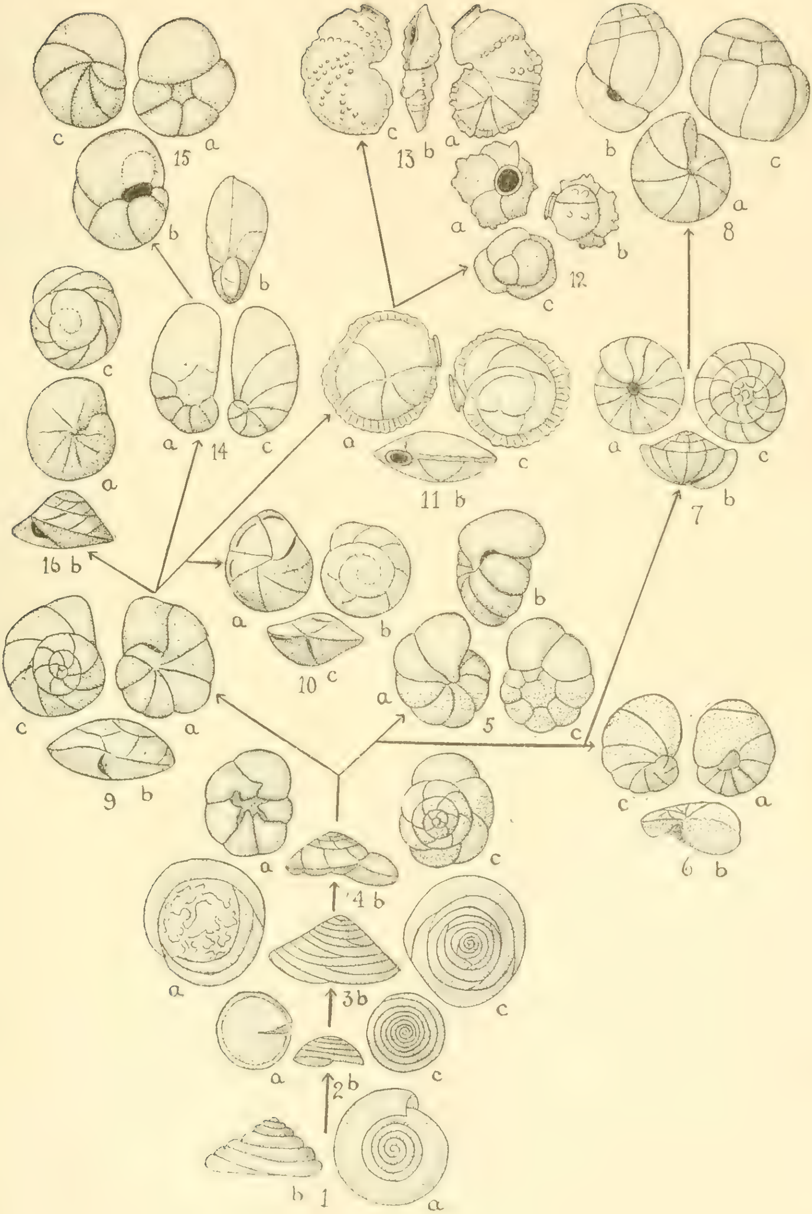

Plate 41

Discorbina (part) PARKER and JONES, Phil. Trans., vol. 155, 1865, pp. 385, 421.

Test trochoid, the dorsal side with regular chambers, the ventral side with supplementary chambers or alar projections toward the umbilicus which is covered; wall calcareous, finely perforate; apertures on the ventral side at the periphery of the secondary chambers and supplementary apertures on the dorsal side at the inner edge of the chamber along the suture between it and the preceding chamber, narrow and elongate.

Eocene to Recent.

Genus SIPHONINA Reuss, 1849

Plate 40, figures 7, 8; plate 41, figure 11

Genoholotype, *Siphonina fimbriata* Reuss

Siphonina REUSS, Denkschr. k. Akad. Wiss. Wien, vol. 1, 1850, p. 372.
Rotalia (part) CZJZEK (not LAMARCK).
Planorbulina (part) PARKER and JONES, 1865 (not D'ORBIGNY).
Truncatulina (part) of authors.

Test trochoid, biconvex, umbilical region typically closed; wall calcareous, coarsely perforate; aperture just ventral to 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.

See Cushman, Foraminifera of the Genus *Siphonina* and Related Genera (Proc. U. S. Nat. Mus., vol. 72, Art. 20, 1927, pp. 1-15, pls. 1-4).

Genus SIPHONINOIDES Cushman, 1927

Plate 40, figures 11-13; plate 41, figure 12

Genoholotype, *Planorbulina echinata* H. B. Brady

Siphoninoides CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 3, 1927, p. 77.
Planorbulina H. B. BRADY, 1879 (not D'ORBIGNY).
Truncatulina of authors (not D'ORBIGNY).
Siphonina (part) of authors (not REUSS).

Test in the adult generally globular; chambers irregularly trochoid, becoming strongly involute in the adult; wall calcareous, perforate; aperture circular, with a very short neck and flaring lip.

Tertiary and Recent.

Genus SIPHONINELLA Cushman, 1927

Plate 40, figures 9, 10; plate 41, figure 13

Genoholotype, *Truncatulina soluta* H. B. Brady

Siphoninella CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 3, 1927, p. 77.
Truncatulina H. B. BRADY, 1881 (not D'ORBIGNY).

Test in the early stages similar to *Siphonina*, in the later development with the chambers becoming uncoiled; wall calcareous, perforate; aperture in the adult terminal, elliptical, with a neck and lip.

Eocene to Recent.

Subfamily 6. Bagginìnae

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

Genus CANCRIS Montfort, 1808

Plate 40, figure 14; plate 41, figure 14

Genoholotype, *Nautilus auriculus* Fichtel and Moll

Cancris MONTFORT, Conch. Syst., vol. 1, 1808, p. 267.
Nautilus (part) FICHTEL and MOLL, 1798 (not LINNÉ).
Rotalina (part) WILLIAMSON, 1858 (not D'ORBIGNY).
Pulvinulina (part) of authors.

Test trochoid, nearly equally biconvex, compressed; chambers few, rapidly enlarging as added; wall calcareous, perforate; umbilical area with a clear plate of rather large dimensions for the size of the test; aperture narrow, on the inner border of the ventral side of the last-formed chamber.

Tertiary and Recent.

Genus BAGGINA Cushman, 1926

Plate 40, figure 15; plate 41, figure 15

Genoholotype, *Baggina californica* Cushman

Baggina CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 2, 1926, p. 63.
Pulvinulina (part) of authors.

Test subglobular, trochoid; chambers relatively few, dorsal side with the chambers in the adult more or less involute, the ventral side completely so; chambers large and inflated; wall calcareous, perforate, with a clear lunate space of small size on the chamber above the aperture; aperture broadly oval on the ventral side of the last-formed chamber, without a lip.

Miocene to Recent.

Genus NEOCRIBRELLA Cushman, 1928

Plate 54, figures 10, 11

Genoholotype, *Discorbina globigerinoides* Parker and Jones

Neocribrella CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 4, 1928, p. 6.

Discorbina (part) PARKER and JONES, Phil. Trans., vol. 155, 1865, pp. 385, 421.

Test trochoid but becoming somewhat involute in the later stages; chambers comparatively few, inflated; wall calcareous, perforate; aperture in the adult composed of several small rounded pores in a slight depression of the ventral face of the chamber.

Eocene. France.

As restricted here, the Rotaliidae includes those calcareous perforate forms which are trochoid, with definite dorsal and ventral sides and the aperture wholly ventral. The genera make a natural grouping closely related to one another and the steps between the genera often well filled by the simpler or more complex species. The family may be derived through the conical forms of *Spirillina* and the simple and more primitive forms of *Patellina* and *Discorbis*. The more primitive genera have the umbilicus open, but this is filled in the higher forms. The earlier genera have simple walls, the higher ones as in *Rotalia* with double walls and a secondary canal system. There is a gradual progression from very simple structures to those foreshadowing the specialized families which are derived from the Rotaliidae.

FAMILY 34. AMPHISTEGINIDAE

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

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

Genus ASTERIGERINA d'Orbigny, 1839

Plate 42, figure 1; plate 44, figure 4

Genotype, by designation, *Asterigerina carinata* d'Orbigny

Asterigerina D'ORBIGNY, Voy. Amér. Mérid., vol. 5, pt. 5, 1839, "Foraminifères", p. 55.

Test trochoid, biconvex, the ventral side usually more strongly so than the dorsal, dorsal side with the chambers appearing regularly coiled, on the ventral side with angular supplementary chambers coming in between the regular series, large and regularly rhomboid in shape; sutures on the dorsal side a simple curve; aperture on the ventral side at the base of the chamber margin.

Eocene to Recent.

Genus AMPHISTEGINA d'Orbigny, 1826

Plate 42, figures 2, 3; plate 44, figure 5

Genotype, by designation, *Amphistegina lessonii* d'Orbigny

Amphistegina D'ORBIGNY, Ann. Sci. Nat., vol. 7, 1826, p. 304.

Omphalophacus EHRENBERG, Abhandl. k. Akad. Wiss. Berlin, 1838, p. 132 (genoholotype, *Omphalophacus hemprichii* EHRENBERG).

Test usually lenticular, trochoid, 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; aperture small, ventral, the wall granular about the opening.

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 of *Amphistegina* from the Palaeozoic but they are not wholly satisfactory and probably represent some other genus.

FAMILY 35. CALCARINIDAE

Test trochoid in the early stages, 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, the test developing bosses of shell material which are the surface end of pillars, and large spines independent of the individual chambers; wall calcareous, coarsely perforate; aperture in the early trochoid stages like *Rotalia*, later consisting of numerous smaller openings; supplementary canal system well developed.

Genus CALCARINA d'Orbigny, 1826

Plate 42, figure 4; plate 44, figure 1

Genotype, by designation, *Nautilus spengleri* Linné

Calcarina d'Orbigny, Ann. Sci. Nat., vol. 7, 1826, p. 276.
Nautilus (part) of authors.

Test trochoid, biconvex, with radial spines independent of the individual chambers, usually in the plane of coiling, in the early stages with the test simple, later with a supplementary mass of shell material over which the new chambers are laid on the ventral side; wall calcareous, perforate, with pillars; aperture in the adult typically a row of small openings along the inner ventral margin of the chamber.

Cretaceous to Recent.

EXPLANATION OF PLATE 42

Amphisteginidae, Calcarinidae

Fig.
1. *Asterigerina carinata* d'Orbigny. × 30. (After type figures).
2, 3. *Amphistegina lessonii* d'Orbigny. Fig. 2 (After type figures). Fig. 3 (After H. B. Brady). × 20.
4. *Calcarina spengleri* (Linné). × 20. (After H. B. Brady).
5–7. *Siderolites calcitrapoides* Lamarck. (After Hofker). Fig. 5, Exterior. Fig. 6, Section. Fig. 7, Showing structure of interior.
8–12. *Baculogypsina sphaerulatus* (Parker and Jones). Figs. 8–10 (After Carpenter). Fig. 8, Exterior. × 35. Fig. 9, Section. × 8. Fig. 10, Young stage. × 35. Figs. 11, 12 (After Hofker). Young megalospheric specimens. × 80.

(In all figures: *a*, dorsal view; *b*, ventral view; *c*, peripheral view).

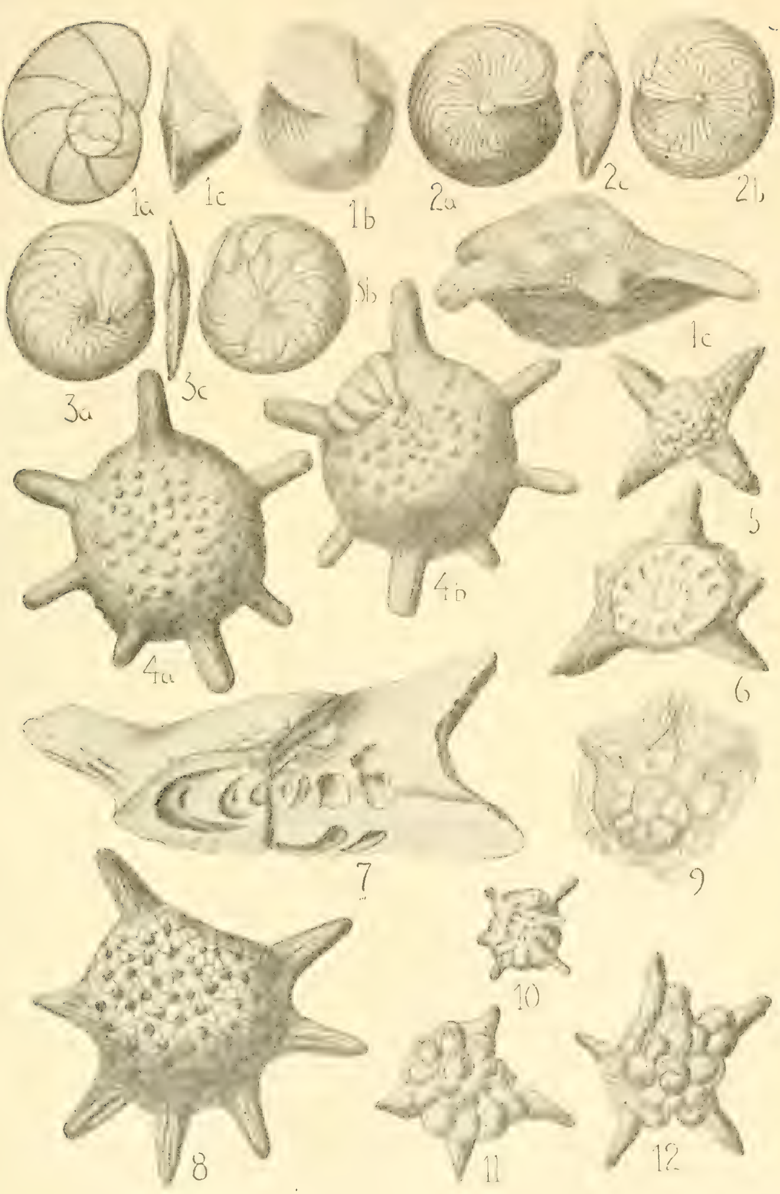

PLATE 42

Genus SIDEROLITES Lamarck, 1801

Plate 42, figures 5-7; plate 44, figure 2

Genoholotype, *Siderolites calcitrapoides* Lamarck

Siderolites LAMARCK, Syst. Anim. sans Vert., 1801, p. 376.
Siderolina DEFRANCE, Dict. Sci. Nat., vol. 32, 1824, p. 180.
Calcarina (part) of authors.

Test in the early chambers similar to *Calcarina*, spines later added at right angles to the peripheral ones, chambers soon covering the dorsal side; wall calcareous, perforate, with pillars in some species ending at the surface in raised bosses; aperture in the adult at the basal edge of each chamber, finally represented by the larger circular openings of the chamber wall.

Cretaceous to Recent.

Genus PELLATISPIRA Boussac, 1906

Plate 55, figures 12-15

Genotype, by designation, *Pellatispira douvillei* Boussac

Pellatispira BOUSSAC, Bull. Soc. Géol. France, ser. 4, vol. 6, 1906, p. 91.
Nummulites (part) HANTKEN, 1876 (not LAMARCK).

Test planispiral, bilaterally symmetrical, the earliest coil with the chambers close coiled, later ones loosely coiled with a mass of shell material between, separating the coils; lateral walls with pillars, appearing as bosses at the surface.

Tertiary.

Genus BACULOGYPSINA Sacco, 1893

Plate 42, figures 8-12; plate 44, figure 3

Genotype, by designation, *Orbitolina sphaerulata* Parker and Jones

Baculogypsina SACCO, Bull. Soc. Belge Géol., vol. 7, 1893, p. 206.
Orbitolina PARKER and JONES, 1860 (not D'ORBIGNY).
Tinoporus of authors (not MONTFORT).

Test in the early stages like *Calcarina*, very early developing four or more large spines which increase in size independent 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.

Genus ARNAUDIELLA H. Douvillé, 1907

Plate 55, figures 10, 11

Genoholotype, *Arnaudiella grossouvrei* H. Douvillé

Arnaudiella H. DOUVILLÉ, Bull. Soc. Géol. France, ser. 4, vol. 6, 1907, p. 599.

Test lenticular, the early chambers involute, later ones compressed and somewhat evolute, supplementary thin-walled chambers developed along the spiral; wall calcareous, perforate, with pillars.

Eocene.

Hofker, 1927, has suggested the placing of *Arnaudiella* in the Calcarinidae. A study of the types in Paris through the kindness of Dr. Douvillé has made me feel that this may be one solution of the vacuole-like openings in the test although otherwise the genus seems related to the Camerinidae.

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. CYMBALOPORETTIDAE

Test in the early stages trochoid, close to *Discorbis*, in the later development the chambers generally in annular series about the periphery; wall calcareous, perforate; apertures numerous, circular pores in the adult, variously arranged; in *Tretomphalus* pelagic in the adult.

Genus CYMBALOPORETTA Cushman, 1928

Plate 43, figure 1; plate 44, figure 6

Genoholotype, *Rosalina squammosa* d'Orbigny

Cymbaloporetta CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 4, 1928, p. 7.

Rotalia (part) D'ORBIGNY.

Rosalina (part) of authors (not D'ORBIGNY).

Cymbalopora of authors (not HAGENOW).

Test conical, the early chambers trochoid, later ones in annular series separated somewhat from one another along the periphery, with depressions between radiating from the central umbilical area, the next series of chambers placed in these depressions and filling them; wall calcareous, coarsely perforate; aperture in the adult consisting of fine rounded pores along the ventral sides of the chamber.

Cretaceous (?) to Recent.

EXPLANATION OF PLATE 43

Cymbaloporettidae, Cassidulinidae

Fig.

1. *Cymbaloporetta squammosa* (d'Orbigny). × 35. (After H. B. Brady).

2–4. *Cymbaloporella tabellaeformis* (H. B. Brady). × 28. (After type figures). Fig. 2, Dorsal view. Fig. 3, Peripheral view. Fig. 4, Ventral view.

5, 6. *Halkyardia minima* (Liebus). × 25. (After Halkyard). Fig. 6, Section.

7–10. *Tretomphalus bulloides* (d'Orbigny). Figs. 7–9, (After H. B. Brady). × 40. Fig. 7, Dorsal view. Fig. 8, Ventral view. Fig. 9, Peripheral view. Fig. 10, (After Earland), showing inner "float" chamber. × 40.

11. *Ceratobulimina pacifica* Cushman and Harris. × 40. (After H. B. Brady).

12, 13. *Pulvinulinella pacifica* Cushman. × 35. (After type figures). Fig. 12, Dorsal view. Fig. 13, Peripheral view.

14–16. *Cassidulina laevigata* d'Orbigny. Figs. 14, 15 (After type figures). Fig. 14, Side view. Fig. 15, Peripheral view. Fig. 16 (After H. B. Brady). × 50.

17–19. *Cassidulinoides parkeriana* (H. B. Brady). × 50. (After type figures).

20. *Orthoplecta clavata* H. B. Brady. × 65. (After type figure).

21–23. *Ehrenbergina bradyi* Cushman. (After type figures). Fig. 21, Ventral view. × 40. Fig. 22, Dorsal view. × 40. Fig. 23, Apertural view. × 50.

(In all figures: *a*, dorsal view; *b*, ventral view; *c*, peripheral view).

PLATE 43

Genus CYMBALOPORELLA Cushman, 1927

Plate 43, figures 2-4; plate 44, figure 7

Genoholotype, *Cymbalopora tabellaeformis* H. B. Brady

Cymbaloporella CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 3, 1927, p. 81.

Cymbalopora (part) of authors.

Test compressed, the early chambers trochoid, later ones in annular series, those of each series somewhat alternating; wall calcareous, coarsely perforate; apertures in the adult consisting of a vertical series of small circular openings on the sides of the peripheral face of each chamber.

Late Tertiary and Recent.

Genus HALKYARDIA Heron-Allen and Earland, 1919

Plate 43, figures 5, 6; plate 44, figure 8

Genotype, by designation, *Cymbalopora radiata*, var. *minima* Liebus

Halkyardia HERON-ALLEN and EARLAND, Mem. Proc. Manchester Lit. Phil. Soc., vol. 62, 1917-18 (1919), p. 107.

Cymbalopora LIEBUS, 1911 (not HAGENOW).

Test biconvex, early chambers trochoid, later ones in annular series extending ventrally to the umbilical area, the dorsal side of earlier chambers somewhat hidden by a later covering of shell material, umbilical area filled by shell material with fine tubules, the exterior standing out as a rounded boss.

Eocene.

Genus TRETOMPHALUS Moebius, 1880

Plate 43, figures 7-10; plate 44, figure 9

Genoholotype, *Rosalina bulloides* d'Orbigny

Tretomphalus MOEBIUS, Foram. Insel Mauritius, 1880, p. 98.

Rosalina (part) D'ORBIGNY, 1839.

Cymbalopora (part) of authors (not HAGENOW).

Test free, early stages *Discorbis*-like in a flattened trochoid arrangement, later in some forms like *Cymbalopora* with alternating series of annular chambers; wall calcareous, perforate; in the adult developing a large semiglobular "float chamber", an interior, entirely globular or lobed chamber with a valve-like opening inside the outer wall which is provided with numerous large rounded pores on the outer face, the test at this stage becoming pelagic.

Recent.

This family evidently developed from a form close to *Discorbis* and has adopted the alternating annular series of chambers about the periphery with numerous apertures. In *Tretomphalus*, there is a very interesting adult development fitting the test for the pelagic life of the animal at this stage. See Earland, On *Cymbalopora bulloides* (d'Orbigny) and its internal structures, (Journ. Quekett Micr. Club, ser. 2, vol. 8, No. 51, 1902, pp. 309-322, pl. 16).

FAMILY 37. CASSIDULINIDAE

Test at least in the early stages, trochoid, later chambers in some genera alternating on the dorsal and ventral surfaces of the test or even uncoiling; wall calcareous, perforate; aperture in the early stages of the simpler genera at the margin of the ventral face of the chamber but projecting into the apertural face in a direction gradually becoming parallel to the periphery, elongate.

KEY TO THE GENERA

I. Test trochoid throughout.
   A. Aperture opening into the umbilicus, covered by a thin plate. *Ceratobulimina.*
   B. Aperture not opening into the umbilicus, not covered by a plate, nearly in the plane of coiling.................. *Pulvinulinella.*

II. Test biserial, at least in the early stages.
   A. Close coiled throughout. .... *Cassidulina.*
   B. Uncoiling in the adult
      1. Not compressed, chambers irregular, sutures not depressed. *Orthoplecta.*
      2. Rounded or compressed.
         a. Chambers rounded in section, sutures depressed, test not spinose. .... *Cassidulinoides.*
         b. Chambers triangular or rhomboid in section, sutures depressed, test usually spinose............ *Ehrenbergina.*

Subfamily 1. Ceratobulimininae

Test rotaliform throughout.

Genus CERATOBULIMINA Toula, 1920

Plate 43, figure 11; plate 46, figure 1

Genoholotype, *Rotalina contraria* Reuss

Ceratobulimina TOULA, Jahrb. k. k. Geol. Reichs., vol. 64, 1920, p. 665.
Rotalina (part) REUSS, 1851 (not D'ORBIGNY).
Cassidulina (part) H. B. BRADY, 1881 (not D'ORBIGNY).
Bulimina (part) of authors (not D'ORBIGNY).
Buliminella (part) CUSHMAN, 1911.
Pulvinulina (part) RZEHAK, 1888 (not PARKER and JONES).
Rotalia (part) PLUMMER, 1927 (not LAMARCK).

Test rotaliform, all chambers visible from the dorsal side, only those of the last-formed whorl visible from the ventral side, close coiled; chambers numerous, distinct; wall calcareous, perforate, added to as growth progresses, laminated, the entire exterior polished; ventral side of the test with the umbilicus open, the aperture extending into the ventral side of the last-formed chamber and in perfect adult specimens the aperture covered by a thin convex plate merged with the chamber wall above the aperture in a semicircular line, the lower end thin, lip-like.

Upper Cretaceous to Recent.

EXPLANATION OF PLATE 44

CALCARINIDAE, AMPHISTEGINIDAE, CYMBALOPORETTIDAE

FIG.

1. *Calcarina spengleri* (Linné). (After Carpenter). *a*, dorsal view; *b*, ventral view; *c*, edge view.
2. *Siderolites tetraëdra* (Gümbel). (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. *Cymbaloporetta squammosa* (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.
9. *Tretomphalus bulloides* (d'Orbigny). (After H. B. Brady). *a*, dorsal view; *b*, side view.

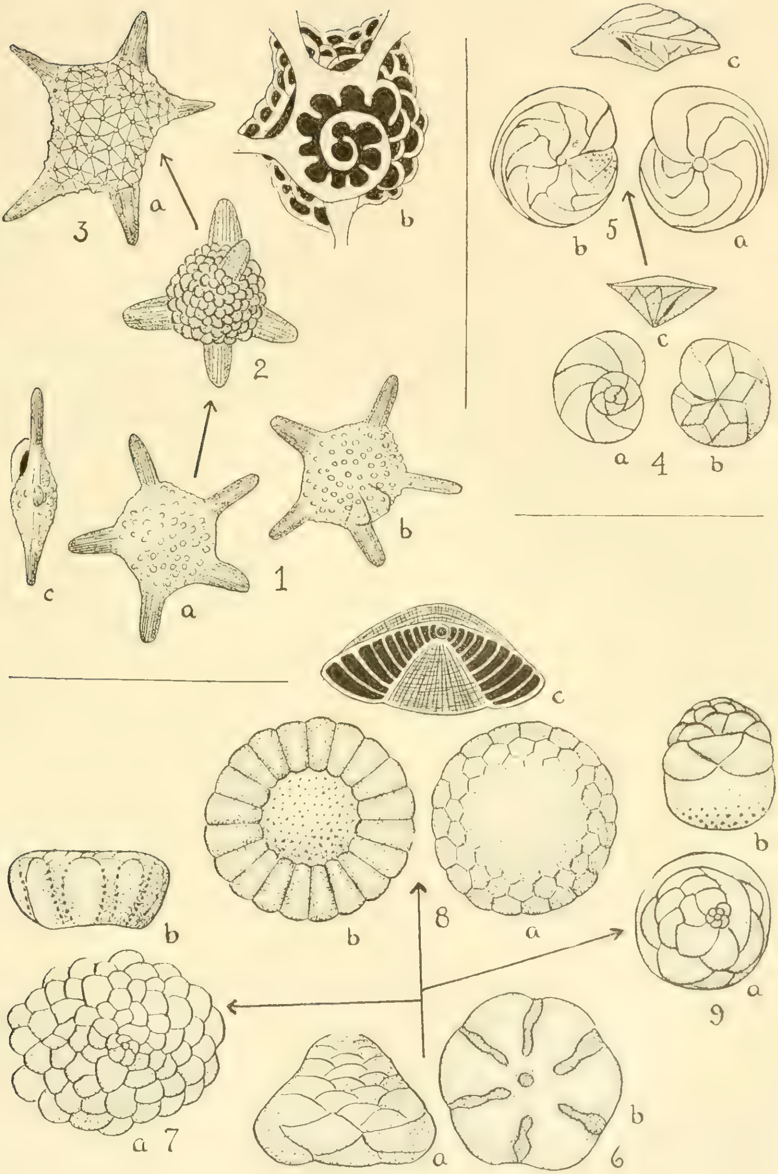

PLATE 44

See Cushman and Harris, Some Notes on the Genus *Ceratobulimina* (Contr. Cushman Lab. Foram. Res., vol. 3, 1927, pp. 171-179, pls. 29, 30).

Genus PULVINULINELLA Cushman, 1926

Plate 43, figures 12, 13; plate 46, figure 2

Genoholotype, *Pulvinulinella subperuviana* Cushman

Pulvinulinella CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 2, 1926, p. 62.
Rosalina (part) of authors.
Truncatulina (part) of authors.
Planorbulina (part) PARKER and JONES, 1865.
Anomalina (part) SCHWAGER, 1866 (not D'ORBIGNY).

Test trochoid, close coiled, all the chambers visible from the dorsal side, only those of the last-formed coil from the ventral side, very slightly if at all umbilicate; chambers numerous and distinct; sutures on the dorsal side oblique, on the ventral side nearly radial; wall calcareous, perforate; aperture on the ventral side of the peripheral face, elongate, somewhat loop-shaped, nearly parallel to the plane of coiling, sometimes with a slight tooth-like projection of the margin on one side.

Tertiary and Recent.

Subfamily 2. Cassidulininae

Test with the chambers alternating on the two sides of the plane of coiling.

Genus CASSIDULINA d'Orbigny, 1826

Plate 43, figures 14-16; plate 46, figure 3

Genoholotype, *Cassidulina laevigata* d'Orbigny

Cassidulina D'ORBIGNY, Ann. Sci. Nat., vol. 7, 1826, p. 282.
Entrochus EHRENBERG, Abhandl. k. preuss. Akad. Wiss. Berlin, 1841, p. 408 (genoholotype, *Entrochus septatus* EHRENBERG).
Selenostomum EHRENBERG, Monatsber. k. preuss. Akad. Wiss. Berlin, 1858, p. 12 (genotype, by designation, *Selenostomum aegaeum* EHRENBERG).
Burseolina SEGUENZA, *fide* H. B. BRADY, Atti R. Accad. Nuovi Lincei, ser. 3, vol. 6, 1880, p. 138 (genoholotype, *Burseolina calabra* SEGUENZA).

Test close coiled, lenticular or subglobular, the chambers alternating on the two sides of the periphery; wall calcareous, perforate; aperture elongate, close to the peripheral plane.

Tertiary and Recent.

See Cushman, Notes on the Genus *Cassidulina* (Contr. Cushman Lab. Foram. Res., vol. 1, 1925, pp. 51-60, pls. 8, 9).

Genus CASSIDULINOIDES Cushman, 1927

Plate 43, figures 17-19; plate 46, figure 4

Genoholotype, *Cassidulina parkeriana* H. B. Brady

Cassidulinoides CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 3, 1927, p. 84.

Cassidulina (part) of authors.

Test in the early stages like *Cassidulina*, but in the adult becoming uncoiled in a series of alternating chambers; aperture in the young like *Cassidulina*, later becoming terminal.

Miocene to Recent.

Genus ORTHOPLECTA H. B. Brady, 1884

Plate 43, figure 20; plate 46, figure 5

Genoholotype, *Cassidulina (Orthoplecta) clavata* H. B. Brady

Orthoplecta H. B. BRADY, Rep. Voy. *Challenger*, Zoology, vol. 9, 1884, p. 432.

Test very elongate, subcylindrical; chambers in an irregular biserial arrangement in the adult, those of the young appearing more as in *Cassidulina;* wall calcareous, perforate; aperture nearly terminal.

Recent.

Subfamily 3. Ehrenbergininae

Test in the early stages as in *Cassidulina*, but the chambers soon becoming 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 EHRENBERGINA Reuss, 1850

Plate 43, figures 21-23; plate 46, figure 6

Genoholotype, *Ehrenbergina serrata* Reuss

Ehrenbergina REUSS, Denkschr. k. Akad. Wiss. Wien, vol. 1, 1850, p. 377.
Cassidulina (part) D'ORBIGNY, 1839.

Test with the young, at least in the microspheric form, compressed, planispiral, in the adult with the test compressed at right angles to that of the early coiling and becoming uncoiled, developing a dorsal side which is flattened or slightly convex and a ventral which is thickest near the median line; aperture elongate, on the ventral side near the periphery.

Eocene to Recent.

See Cushman, Foraminifera of the Genus *Ehrenbergina* and its Species (Proc. U. S. Nat. Mus., vol. 70, Art. 16, 1927, pp. 1-8, pls. 1, 2).

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 chamber 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 of the simpler genera typically trochoid, the chambers all visible from the dorsal side, only those of the last-formed chamber visible from the ventral side, the chambers in later development variously arranged, typically planispiral and involute so that the early stages are completely covered; wall calcareous, perforate; aperture typically on the ventral side, at least in the early stages, in the planispiral forms becoming median.

KEY TO THE GENERA

I. Test trochoid throughout, three chambers to a whorl.....*Allomorphina.*
II. Test trochoid in the young, later planispiral.
  A. Two chambers in each coil.
    1. Aperture at the side of the test.
      a. Aperture narrow. ....*Chilostomella.*
      b. Aperture rounded. ....*Chilostomelloides.*
    2. Aperture terminal. ....*Seabrookia.*
  B. More than two chambers in each coil.
    1. Chambers high.
      a. Aperture simple, narrow, low............*Allomorphinella.*
      b. Aperture fimbriate. ....*Chilostomellina.*
    2. Chambers low.
      a. Aperture broad, low, chambers regular.........*Pullenia.*
      b. Aperture narrow, semielliptical, chambers irregularly involute. ....*Sphaeroidina.*

Subfamily 1. Allomorphininae

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

Genus ALLOMORPHINA Reuss, 1850

Plate 45, figures 1, 2; plate 46, figure 7

Genoholotype, *Allomorphina trigona* Reuss

Allomorphina Reuss, Denkschr. k. Akad. Wiss. Wien, vol. 1, 1850, p. 380.

Test trochoid, in the adult with usually three chambers to a coil, the chambers inflated and enlarging rapidly as added, often very involute; wall calcareous, perforate; aperture, an elongate, arched opening below the border of the last-formed chamber on the ventral side, sometimes with a slight lip.

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, lateral or terminal.

Genus CHILOSTOMELLA Reuss, 1850

Plate 45, figures 3-7; plate 46, figure 8

Genoholotype, *Chilostomella ovoidea* Reuss

Chilostomella Reuss, Denkschr. k. Akad. Wiss. Wien, vol. 1, 1850, p. 379.

Test fusiform, ovoid, or subcylindrical, in the early stages, especially of the microspheric form, with the chambers as in *Allomorphina*, but in the adult two chambers completing a coil, each chamber making a half coil of 180° and embracing so that but a small part of the base of the preceding chamber is visible

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EXPLANATION OF PLATE 45

Chilostomellidae, Globigerinidae

Fig.

1, 2. *Allomorphina trigona* Reuss. × 40. (After H. B. Brady). Fig. 1, Ventral view. Fig. 2, Dorsal view.

3–7. *Chilostomella oolina* Schwager. × 35. (After H. B. Brady). Fig. 3, Ventral view. Fig. 4, Apertural view. Fig. 5, Dorsal view. Fig. 6, Side view by transmitted light. Fig. 7, Partially broken specimen.

8–11. *Chilostomelloides oviformis* (Sherborn and Chapman). × 12. (After type figures). Figs. 8, 9, Side views. Figs. 10, 11, Apertures.

12, 13. *Seabrookia pellucida* H. B. Brady. × 135. (After type figures). Fig. 12, *a*, ventral view; *b*, apertural view. Fig. 13, By transmitted light.

14. *Allomorphinella contraria* (Reuss). (After type figure). *a*, side view; *b*, ventral view; *c*, apertural view.

15. *Chilostomellina fimbriata* Cushman. (After type figure). *a*, dorsal view; *b*, ventral view; *c*, end view.

16. *Pullenia quinqueloba* Reuss. × 35. (After H. B. Brady). *a*, side view; *b*, apertural view.

17. *Sphaeroidina bulloides* d'Orbigny. (After d'Orbigny's Model). *a*, side view; *b*, apertural view.

18, 19. *Globigerina bulloides* d'Orbigny. (After d'Orbigny's Models). Fig. 17, Young. Fig. 18, Adult. *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

20. *Globigerina inflata* d'Orbigny. × 35. (After H. B. Brady). *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

21. *Globigerinoides rubra* (d'Orbigny). × 35. (After H. B. Brady). *a*, dorsal view; *b*, ventral view; *c*, side view.

22. *Globigerinoides conglobata* (H. B. Brady). × 35. (After H. B. Brady). Dorsal view.

23. *Globigerinoides sacculifera* (H. B. Brady). × 35. (After H. B. Brady). Dorsal view.

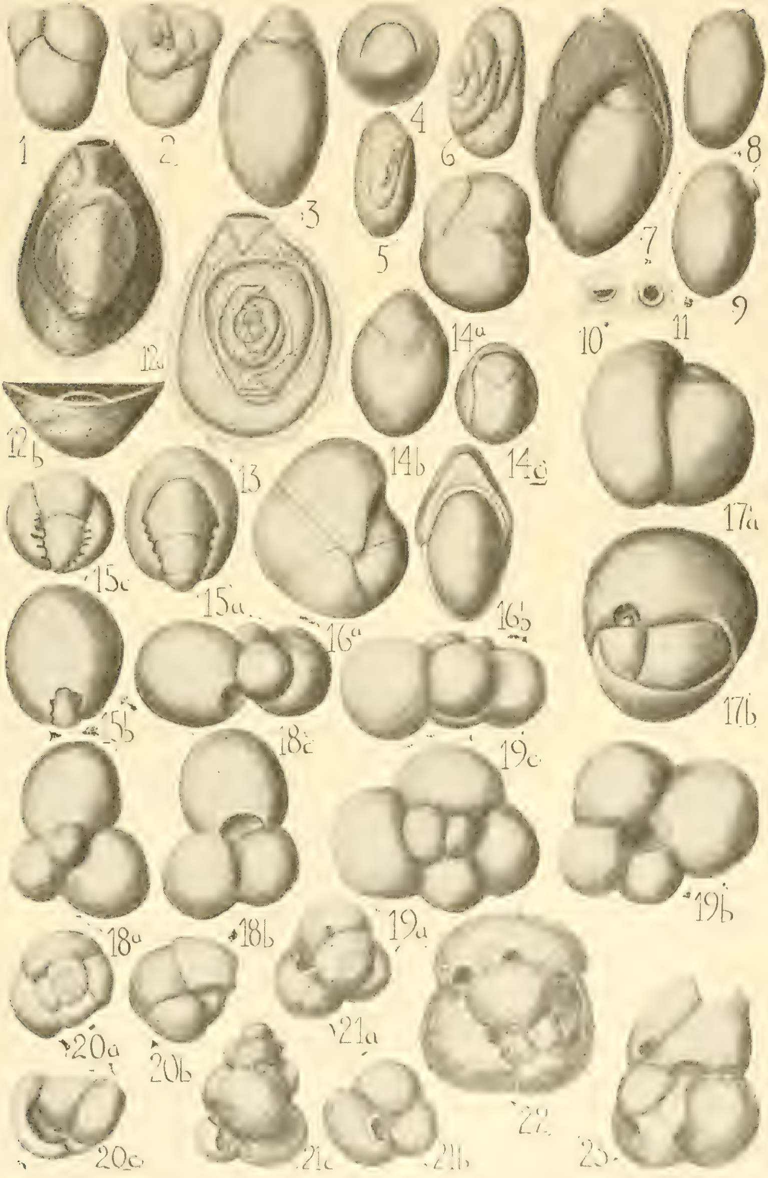
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PLATE 45

from the ventral side; wall calcareous, perforate; aperture, a narrow curved opening at the inner margin of the ventral face of the last-formed chamber, often with a slightly upturned lip.

Upper Cretaceous to Recent.

See Cushman, The Genus *Chilostomella* and Related Genera (Contr. Cushman Lab. Foram. Res., vol. 1, 1926, pp. 73-80, pl. 11).

Genus CHILOSTOMELLOIDES Cushman, 1926

Plate 45, figures 8-11; plate 46, figure 9

Genoholotype, *Lagena (Obliquina) oviformis* Sherborn and Chapman

Chilostomelloides CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 1, 1926, p. 77.

Lagena (Obliquina) SHERBORN and CHAPMAN, 1886 (not SEGUENZA).

Chilostomella (part) of authors.

Test similar in general structure to *Chilostomella*, but the aperture rounded and somewhat offset from the general contour of the test, with a slight neck in some species and a slightly developed lip.

Upper Cretaceous and Lower Eocene.

Subfamily 3. Seabrookiinae

Test with two chambers forming a coil but entirely embracing on the ventral side, the aperture elliptical and terminal.

Genus SEABROOKIA H. B. Brady, 1890

Plate 45, figures 12, 13; plate 46, figure 10

Genoholotype, *Seabrookia pellucida* H. B. Brady

Seabrookia H. B. BRADY, Journ. Roy. Micr. Soc., 1890, p. 570.

Cerviciferina GODDARD and JENSEN, Proc. Linn. Soc. N. S. Wales, vol. 32, 1907, p. 304 (genoholotype, *Cerviciferina hilli* GODDARD and JENSEN).

Test essentially trochoid, the earliest stages as in *Allomorphina*, three chambers making up a whorl, in the adult two chambers involute, the last-formed one making up nearly the whole surface of the test on the ventral side; wall calcareous, thin, perforate; aperture elliptical at the periphery of the more acute end of the chamber.

Recent.

Subfamily 4. Allomorphinellinae

Test with the later chambers planispiral, involute, chambers increasing rapidly in size as added; apertures becoming median.

Genus ALLOMORPHINELLA Cushman, 1927

Plate 45, figure 14; plate 46, figure 11

Genoholotype, *Allomorphina contraria* Reuss

Allomorphinella CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 3, 1927, p. 86.

Allomorphina (part) of authors.

Test with the adult chambers in a planispiral coil, the chambers involute, rapidly increasing in size as added, and embracing; wall calcareous, perforate; aperture elongate, narrow, at the periphery of the chamber at the median line.

Upper Cretaceous.

Genus CHILOSTOMELLINA Cushman, 1926

Plate 45, figure 15; plate 46, figure 12

Genoholotype, *Chilostomellina fimbriata* Cushman

Chilostomellina CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 1, 1926, p. 78.

Test composed of a few inflated chambers, the last-formed one almost completely enveloping the preceding ones, and the chambers rapidly increasing in size as added; wall calcareous, thin, finely perforate; aperture small, crescentiform, the sides of the chamber with a series of reëntrants at each side.

Recent.

Genus PULLENIA Parker and Jones, 1862

Plate 45, figure 16; plate 46, figure 13

Genotype, by designation, *Nonionina sphaeroides* d'Orbigny

Pullenia PARKER and JONES, in CARPENTER, PARKER and JONES, Introd. Foram., 1862, p. 184.

Nonionina (part) D'ORBIGNY, 1826.

Test in the adult planispiral, close coiled, chambers completely involute, a few making up the coil; wall calcareous, perforate; aperture, an elongate crescentic opening at the inner margin of the last-formed chamber.

Cretaceous to Recent.

Subfamily 5. Sphaeroidininae

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

Genus SPHAEROIDINA d'Orbigny, 1826

Plate 45, figure 17; plate 46, figure 14

Genoholotype, *Sphaeroidina bulloides* d'Orbigny

Sphaeroidina D'ORBIGNY, Ann. Sci. Nat., vol. 7, 1826, p. 267.
Sexloculina CZJZEK, Haidinger's Nat. Abhandl., vol. 2, 1848, p. 149 (genoholotype, *Sexloculina haueri* CZJZEK).
Bolbodium EHRENBERG, Monatsber. k. preuss. Akad. Wiss. Berlin, 1872, p. 281 (genoholotype, *Bolbodium sphaerula* EHRENBERG).

EXPLANATION OF PLATE 46

CASSIDULINIDAE, CHILOSTOMELLIDAE

FIG.
1. *Ceratobulimina pacifica* Cushman and Harris. (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.

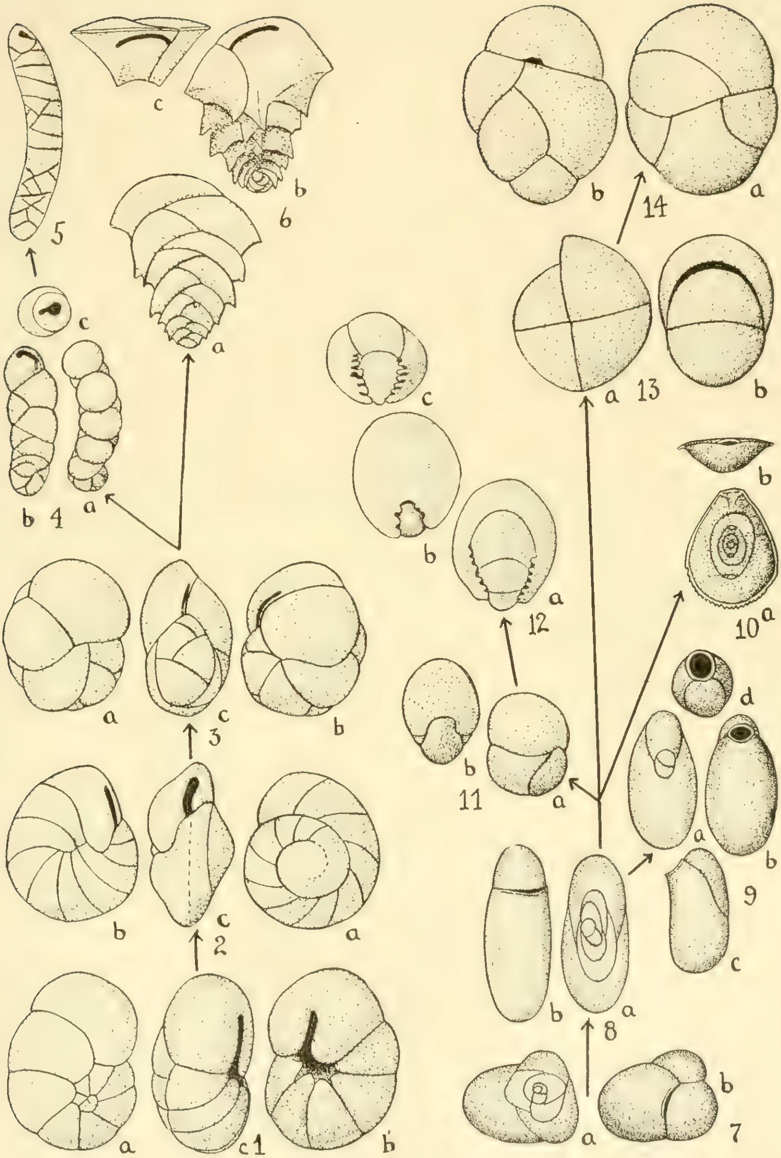

PLATE 46

Test in the earliest stages generally planispiral, later chambers irregularly embracing; wall calcareous, perforate; aperture in the young, a crescent-shaped opening, in the adult, rounded, with a flat, rounded, tooth-like projection.

Cretaceous to Recent.

The genera included in this family show a regular progression from the more primitive *Allomorphina,* which is trochoid and allied to the Rotaliidae, to the specialized *Seabrookia.* The planispiral forms connect with the irregularly involute *Sphaeroidina* which has a *Pullenia*-like young. Some of the genera on account of the rounded form have been placed in the Globigerinidae but they have no trace of the spinose or cancellated test, or the coarse wall 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.

KEY TO THE GENERA

I. Test trochoid throughout.
- A. Not involute.
  - 1. Aperture single, ventral. .... *Globigerina.*
  - 2. Apertures several.
    - a. Apertures small, all along the sutures......... *Candeina.*
    - b. Apertures large, one umbilicate, others along the suture. *Globigerinoides.*
- B. Involute.
  - 1. Aperture not in a deep depression.............. *Pulleniatina.*
  - 2. Aperture in a deep depression............... *Sphaeroidinella.*

II. Test not trochoid throughout.
- A. Test in the adult planispiral.
  - 1. Wall cancellated, spines fine and numerous..... *Globigerinella.*
  - 2. Wall rather smooth, spines coarse, flat, few....... *Hastigerina.*
- B. Test in the adult irregularly spiral, spines at the ends of the chambers. .... *Hastigerinella.*
- C. Test in the adult with the last chamber spherical and completely enclosing the earlier ones........................... *Orbulina.*

Subfamily 1. Globigerininae

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

Genus GLOBIGERINA d'Orbigny, 1826

Plate 45, figures 18-20; plate 47, figures 1-3; plate 48, figure 1

Genotype, by designation, *Globigerina bulloides* d'Orbigny

Globigerina D'ORBIGNY, Ann. Sci. Nat., vol. 7, 1826, p. 277.
Rotalia (part) of authors.
Rhynchospira EHRENBERG, Bericht. k. preuss. Akad. Wiss. Berlin, 1845, p. 358 (genoholotype, *Rhynchospira indica* EHRENBERG).
Phanerostomum (part) EHRENBERG, 1854.
Ptygostomum (part) EHRENBERG, 1854.
Planulina (part) EHRENBERG, 1854 (not D'ORBIGNY).
Pylodexia EHRENBERG, Monatsber. k. preuss. Akad. Wiss. Berlin, 1858, p. 27 (genotype, by designation, *Pylodexia tetratrias* EHRENBERG).

Test trochoid throughout, umbilicate, chambers in the young especially of the microspheric form in a flattened trochoid form like *Discorbis* usually smooth and the wall thin, later chambers globular; wall thick and cancellated, in well preserved, especially pelagic specimens, clothed with long slender spines coming from the angles of the cancellated surface areas, the base of such areas with the pores of the wall, calcareous; aperture large, opening into the umbilicus.

Cretaceous to Recent.

Genus GLOBIGERINOIDES Cushman, 1927

Plate 45, figures 21-23; plate 48, figure 6

Genoholotype, *Globigerina rubra* d'Orbigny

Globigerinoides CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 3, 1927, p. 87.
Globigerina (part) of authors.

Test usually trochoid throughout; aperture as in *Globigerina* with numerous large, supplementary apertures around the margin of the chamber, opening into the chamber and some of them into the umbilical area, surface in the well preserved specimens clothed with fine spines.

Tertiary and Recent.

Genus GLOBIGERINELLA Cushman, 1927

Plate 47, figures 4, 5; plate 48, figure 7

Genoholotype, *Globigerina aequilateralis* H. B. Brady

Globigerinella CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 3, 1927, p. 87.

Test trochoid in the young, at least in the microspheric form, later becoming planispiral; aperture single, large, opening into the umbilicus in the young, in the adult median; fine spines covering the test in well preserved specimens.

Cretaceous to Recent.

EXPLANATION OF PLATE 47

GLOBIGERINIDAE

FIG.

1–3. *Globigerina triloba* Reuss. (After Rhumbler). Fig. 1, Dorsal view, showing *Discorbis*-like young of microspheric form. Fig. 2, Side view. Fig. 3, Side view of *Discorbis*-like young stage, smooth, without spines.

4, 5. *Globigerinella aequilateralis* (H. B. Brady). Fig. 4 (After H. B. Brady). × 35. *a*, side view; *b*, peripheral view. Fig. 5 (After Rhumbler). Showing smooth, trochoid young.

6, 7. *Hastigerina pelagica* (d'Orbigny). × 35. (After H. B. Brady). Fig. 6, Peripheral view. Fig. 7, Side view.

8. *Hastigerinella digitata* (Rhumbler). (After type figure). *a*, dorsal view; *b*, ventral view.

9, 10. *Orbulina universa* d'Orbigny. (After Rhumbler). Fig. 9, Early stage showing *Discorbis*-like young. Fig. 10, Adult globular chamber with *Globigerina* stage inside.

11–13. *Pulleniatina obliquiloculata* (Parker and Jones). Figs. 11, 12 (After H. B. Brady). Fig. 11, Section showing early *Globigerina* stage. Fig. 12, Exterior. Fig. 13 (After Rhumbler), Viewed by transmitted light showing early included *Globigerina* stage.

14–17. *Sphaeroidinella dehiscens* (Parker and Jones). Figs. 14–16 (After H. B. Brady). Figs. 14, 15, Exteriors. × 35. Fig. 16, Section through test. Fig. 17 (After Rhumbler), *a*, vertical section of wall; *b*, outer surface.

18–21. *Candeina nitida* d'Orbigny. × 35. (After H. B. Brady). Fig. 18, Dorsal view. Figs. 19, 20, Side views. Fig. 21, Ventral view.

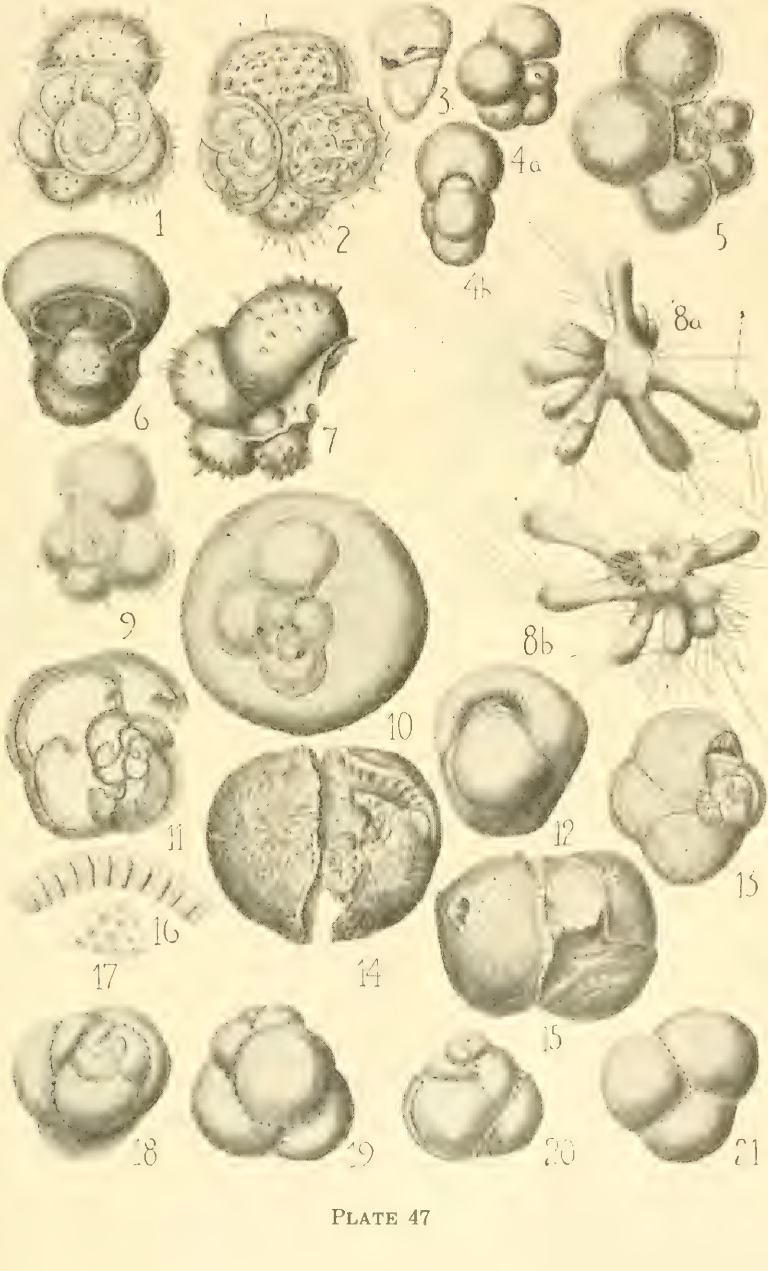

PLATE 47

Genus HASTIGERINA Wyville Thomson, 1876

Plate 47, figures 6, 7; plate 48, figure 8

Genoholotype, *Hastigerina murrayi* Wyville Thomson = *Nonionina pelagica* d'Orbigny, 1839

Hastigerina WYVILLE THOMSON, Proc. Roy. Soc., vol. 24, 1876, p. 534.
Nonionina (part) of authors.
Lituola (part) JONES and PARKER, 1860 (not LAMARCK).
Globigerina (part) PARKER and JONES, 1865 (not D'ORBIGNY).

Test with the early chambers trochoid, later ones planispiral, involute; wall calcareous, perforate, 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, 1927

Plate 47, figure 8; plate 48, figure 9

Genoholotype, *Hastigerina digitata* Rhumbler

Hastigerinella CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 3, 1927, p. 87.
Hastigerina (part) RHUMBLER, 1911.

Test similar to *Hastigerina* in the young, in the adult the chambers elongate, club-shaped, the spines limited to the outer ends of the chambers.

Late Tertiary and Recent.

Subfamily 2. Orbulininae

Test in the early stages trochoid 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, occasionally large openings which are apparently accidental; exterior with fine spines.

Genus ORBULINA d'Orbigny, 1826

Plate 47, figures 9, 10; plate 48, figure 4

Genoholotype, *Orbulina universa* d'Orbigny

Orbulina D'ORBIGNY, in DE LA SAGRA, His. Fis. Pol. Nat. Cuba, 1839, vol. 2, pt. 2, "Foraminifères", p. 3.
Globigerina (part) of authors.

Test in the early stages like *Globigerina*, later developing a globular chamber entirely enclosing the earlier ones, which may be later resorbed; wall calcareous, often of several layers, with perforations of various sizes, no general aperture, exterior with fine elongate spines.

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

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

Genus PULLENIATINA Cushman, 1927

Plate 47, figures 11-13; plate 48, figure 5

Genoholotype, *Pullenia obliquiloculata* Parker and Jones

Pulleniatina CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 3, 1927, p. 90.

Pullenia (part) of authors.

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, the chambers involute, the last three or four forming the outer surface of the test, without spines in the adult; aperture elongate, arched, at the base of the chamber.

Late Tertiary and Recent.

Genus SPHAEROIDINELLA Cushman, 1927

Plate 47, figures 14-17; plate 48, figure 2

Genoholotype, *Sphaeroidina dehiscens* Parker and Jones

Sphaeroidinella CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 3, 1927, p. 90.

Sphaeroidina (part) of authors.

Globigerina (part) SCHWAGER, 1866 (not D'ORBIGNY).

Test in the early stages trochoid and like *Globigerina* with coarsely cancellated surface and 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 and without spines; aperture in the deep cavity between the chambers.

Pliocene to Recent.

EXPLANATION OF PLATE 48

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 obliquiloculata* (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* (d'Orbigny). (After H. B. Brady).
9. *Hastigerinella digitata* (Rhumbler). (After Rhumbler—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.

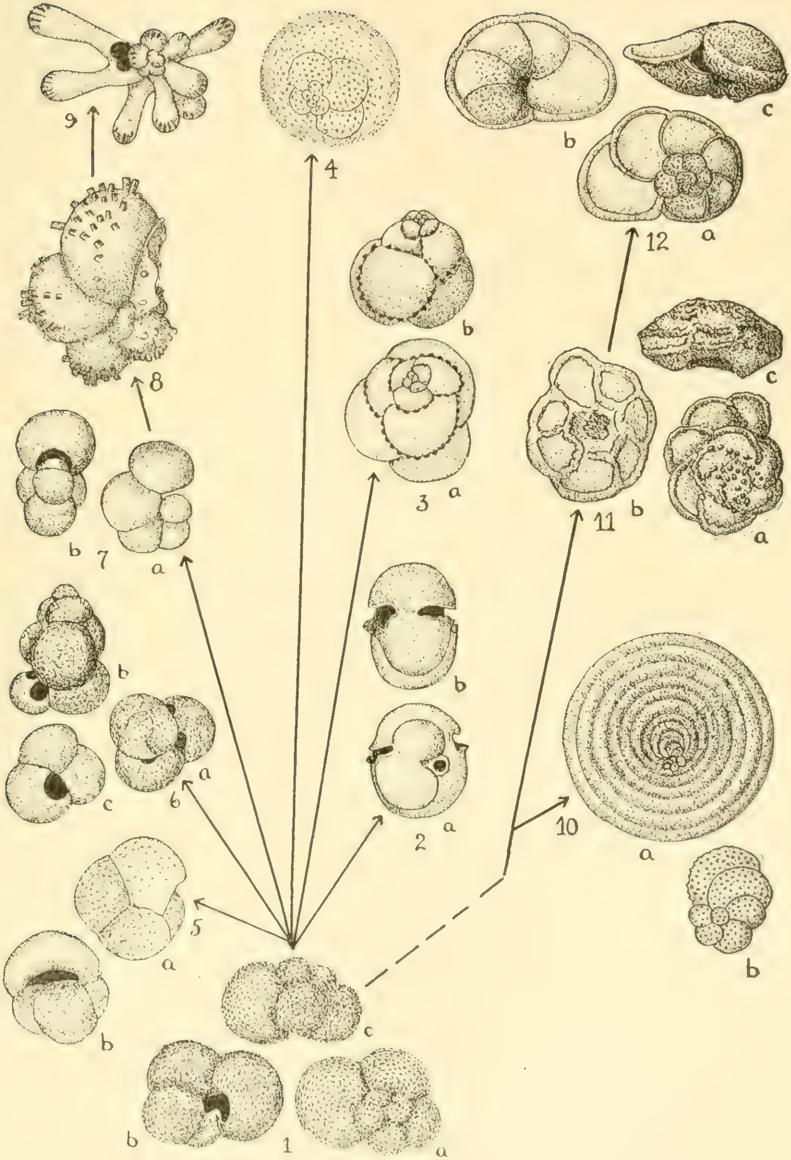

PLATE 48

Subfamily 4. Candeininae

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

Genus CANDEINA d'Orbigny, 1839

Plate 47, figures 18-21; plate 48, figure 3

Genoholotype, *Candeina nitida* d'Orbigny

Candeina d'Orbigny, in De la Sagra, Hist. Fis. Pol. Nat. Cuba, 1839, "Foraminifères", p. 107.

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

Late Tertiary 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 a rough, cancellated exterior and often spinose, in the adult resuming the ancestral rotalid form or becoming annular, but often retaining the rough, spinose surface; aperture typically opening into the umbilical area, the older species often retaining the protecting covering above the umbilical area, and traces of it appear in the living forms; largely pelagic.

KEY TO THE GENERA

I. Test trochoid throughout.
- A. Periphery truncate, usually with a double keel.....*Globotruncana*.
- B. Periphery acute or rounded, with a single keel.......*Globorotalia*.

II. Test becoming annular.
- A. A single layer of chambers........................*Cycloloculina*.
- B. Chamberlets on the flattened surface...............*Sherbornina*.

Genus GLOBOTRUNCANA Cushman, 1927

Plate 48, figure 11; plate 49, figures 1, 2

Genoholotype, *Pulvinulina arca* Cushman

Globotruncana CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 3, 1927, p. 91.
Rosalina (part) of authors.
Discorbina (part) of authors.
Globigerina (part) of authors.
Rotalia (part) of authors.
Pulvinulina (part) of authors.

Test trochoid in the young the chambers usually globose, rough and cancellated, 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, often in well preserved specimens with a thin plate-like structure over the umbilical area; apparently pelagic in part.

Upper Cretaceous to Recent.

Genus GLOBOROTALIA Cushman, 1927

Plate 48, figure 12; plate 49, figures 3, 4

Genoholotype, *Pulvinulina menardii*, var. *tumida* H. B. Brady

Globorotalia CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 3, 1927, p. 91.
Rotalia (part) of authors.
Rotalina (part) of authors.
Planulina (part) of authors.
Pulvinulina (part) of authors.

Test trochoid, the earliest chambers often like *Globigerina*, with a rough cancellated exterior, biconvex, on the dorsal side more or less flattened with the ventral side strongly convex; wall calcareous, perforate, frequently spinose in whole or in restricted areas; aperture large, opening into the umbilicus which is either open or partially covered by a lip.

Upper Cretaceous to Recent.

EXPLANATION OF PLATE 49

GLOBOROTALIIDAE, ANOMALINIDAE

FIG.

1. *Globotruncana arca* (Cushman). × 40. (After type figure).
2. *Globotruncana marginata* (Reuss). × 65. (After Heron-Allen and Earland).
3. *Globorotalia tumida* (H. B. Brady). × 25. (After type figure).
4. *Globorotalia fimbriata* (H. B. Brady). × 25. (After type figure).

5–8. *Cycloloculina annulata* Heron-Allen and Earland. (After type figures). Fig. 5, Adult. × 32. Fig. 6, Detail of surface and spines. × 95. Fig. 7, Early chambers. × 32. Fig. 8, Early stages to the first annular chambers. × 40.

9, 10, *Sherbornina atkinsoni* Chapman. (After type figures). Fig. 9, Surface view. × 14. Fig. 10, Portion of median section. × 16.

11. *Anomalina punctulata* d'Orbigny. (After type figures).
12. *Anomalina grosserugosa* Gümbel. × 28. (After H. B. Brady).
13. *Planulina ariminensis* d'Orbigny. (After type figures).
14. *Planulina ornata* (d'Orbigny). × 35.

15–18. *Laticarinina pauperata* (Parker and Jones). Fig. 15 (After type figure). × 20. Fig. 16 (After Flint). × 10. Fig. 17, From side. Fig. 18, From periphery.

(In all figures: *a*, dorsal view; *b*, ventral view; *c*, peripheral view).

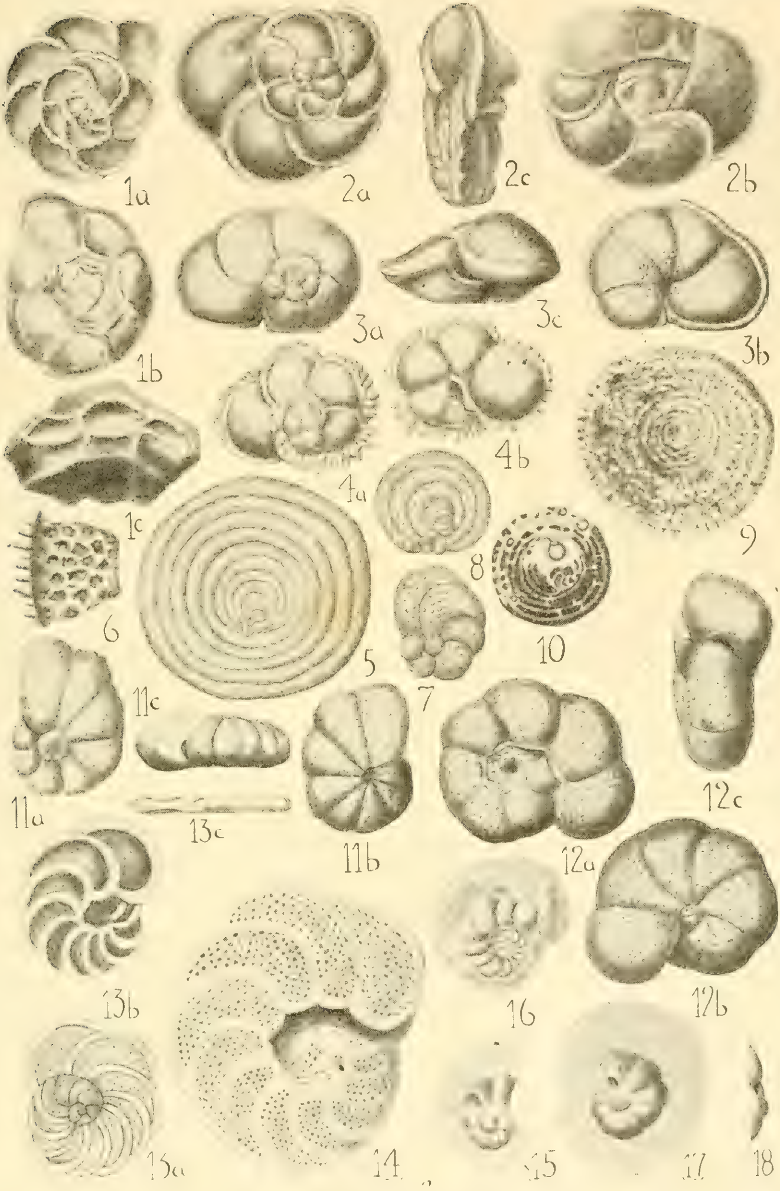
1a
2a
2c
2b
1b
3a
3c
3b
4a
4b
1c
9
6
8
5
10
7
11c
12c
11a
13c
11b
12a
13b
16
12b
13a
14
15
17
18

Plate 49

Genus CYCLOLOCULINA Heron-Allen and Earland, 1908

Plate 48, figure 10; plate 49, figures 5-8

Genotype, by designation, *Cycloloculina annulata* Heron-Allen and Earland

Cycloloculina HERON-ALLEN and EARLAND, Journ. Roy. Micr. Soc., 1908, p. 533.

Test with the early chambers in a low trochoid spire, the chambers globular, then becoming elongate, the periphery somewhat spinose, with short conical spines, later chambers still more elongate finally becoming annular; wall calcareous, coarsely perforate; no general aperture, the large coarse perforations serving as apertures.

Eocene.

Genus SHERBORNINA Chapman, 1922

Plate 49, figures 9, 10

Genoholotype, *Sherbornina atkinsoni* Chapman

Sherbornina CHAPMAN, Journ. Linn. Soc. Zool., vol. 34, 1922, p. 501.

"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 tubuli." (Chapman).

Miocene. Tasmania.

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 show 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 free, or attached by the dorsal surface which is typically flattened or concave; chambers arranged in a trochoid manner, at least in the early stages, only those of the last-formed chamber visible from the ventral side; wall calcareous, coarsely perforate; aperture in the adult either at the periphery or with an extension on the dorsal side.

KEY TO THE GENERA

I. Test nearly symmetrical.
  A. Test more or less involute.
    1. Aperture usually median in the adult, at the base of the chamber. . . . . *Anomalina*.
    2. A supplementary aperture on the peripheral margin. *Anomalinella*.
  B. Test little if at all involute, much compressed.
    1. Without a broad keel. . . . . *Planulina*.
    2. With a broad, thin keel. . . . . *Laticarinina*.

II. Test strongly plano-convex.
  A. Aperture narrow, along the periphery and inner dorsal edge of the chamber. . . . . *Cibicides*.
  B. Aperture with a neck and lip.
    1. Irregularly spreading. . . . . *Cibicidella*.
    2. Irregularly linear. . . . . *Webbina*.
  C. Aperture of several small openings. . . . . *Cyclocibicides*.

Subfamily 1. Anomalininae

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

Genus ANOMALINA d'Orbigny, 1826

Plate 49, figures 11, 12; plate 51, figure 1

Genotype, by designation, *Anomalina punctulata* d'Orbigny

Anomalina D'ORBIGNY, Ann. Sci. Nat., vol. 7, 1826, p. 282.
Aspidospira EHRENBERG, Bericht. k. preuss. Akad. Wiss. Berlin, 1844, p. 75 (genotype, by designation, *Aspidospira saxipara* EHRENBERG).

Porospira EHRENBERG, l. c., p. 75 (genotype, by designation, *Porospira comes* EHRENBERG).
Rosalina (part) of authors.
Rotalia (part) of authors.
Discorbina (part) of authors.
Planorbulina (part) of authors.
Truncatulina (part) of authors.

Test in the young, trochoid, in the adult often nearly involute on the dorsal as well as on the ventral side, the chambers added nearly in a planispiral manner, the inner coils of the dorsal side often appearing as a central raised boss; wall calcareous, perforate; aperture in the young on the ventral side, in the adult becoming peripheral at the base of the last-formed chamber in the median line, sometimes with a boss of clear material over the umbilical region.

Lower Cretaceous to Recent.

EXPLANATION OF PLATE 50

ANOMALINIDAE, PLANORBULINIDAE

FIG.

1. *Anomalinella rostrata* (H. B. Brady). × 35. (After type figure).
2. *Cibicides refulgens* Montfort. × 20. (After H. B. Brady).
3. *Cibicides lobatulus* (Walker and Jacob). × 40. (After H. B. Brady).
4. *Cyclocibicides vermiculatus* (d'Orbigny). × 20. (After H. B. Brady).

5–7. *Cibicidella variabilis* (d'Orbigny). Fig. 5 (After type figure). Figs. 6, 7 (After Sidebottom). × 16.

8. *Webbina rugosa* d'Orbigny. (After type figure).

9, 10. *Planorbulina mediterranensis* d'Orbigny. Fig. 9 (After type figure). Fig. 10 (After H. B. Brady), Dorsal side. × 28.

11. *Planorbulinella larvata* (Parker and Jones). × 10. (After type figure). *a*, dorsal view; *b*, peripheral view.
12. *Planorbulinoides retinaculata* (Parker and Jones). × 10. (After type figure).

(Except where noted, *a*, dorsal view; *b*, ventral view; *c*, peripheral view).

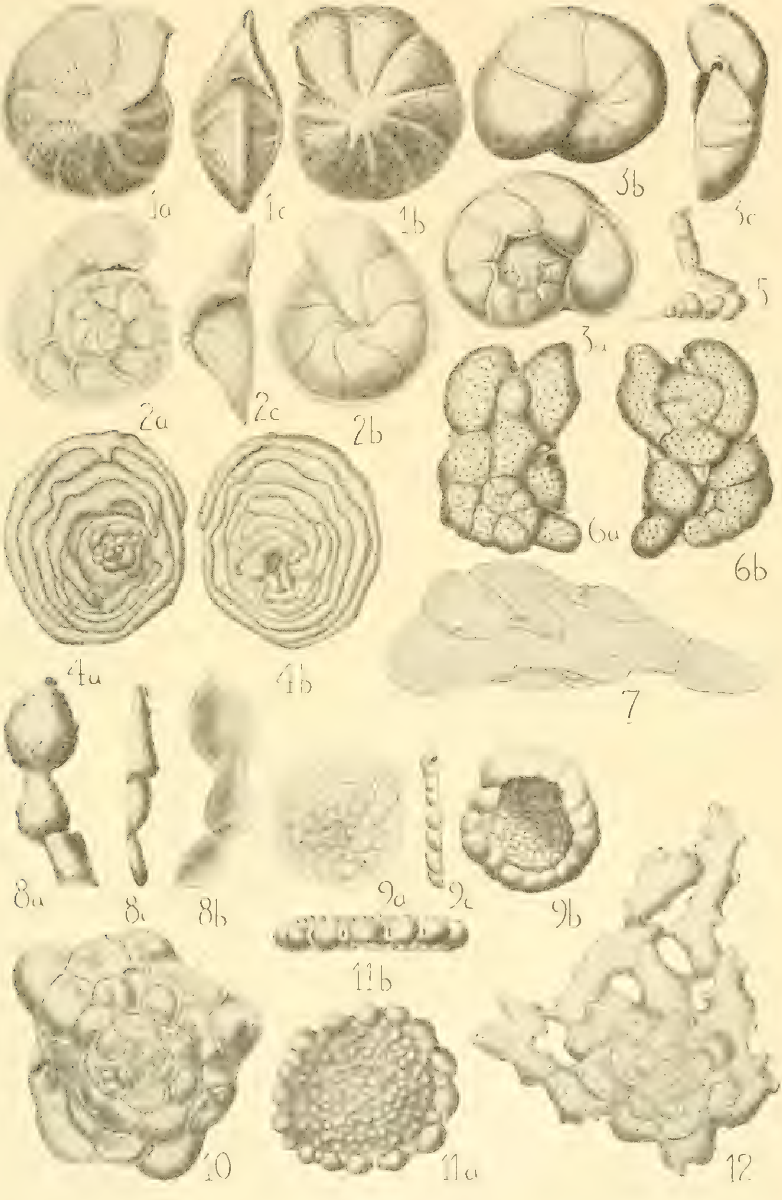
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PLATE 50

Genus PLANULINA d'Orbigny, 1826

Plate 49, figures 13, 14; plate 51, figure 2

Genotype, by designation, *Planulina ariminensis* d'Orbigny

Planulina d'Orbigny, Ann. Sci. Nat., vol. 7, 1826, p. 280.
Anomalina (part) of authors.
Truncatulina (part) of authors.

Test in the young trochoid, in the adult very much compressed, evolute, the earlier chambers visible from both sides of the test in the megalospheric form, in the microspheric form with the central area raised on the dorsal side; wall calcareous, coarsely perforate; aperture at the base of the chamber at the median line.

Cretaceous to Recent.

Genus LATICARININA Galloway and Wissler

Plate 49, figures 15-18; plate 51, figure 3

Genoholotype, *Pulvinulina repanda*, var. *menardii*, subvar. *pauperata* Parker and Jones

Laticarinina Galloway and Wissler, Journ. Pal., vol. 1, 1927-28 (1928), p. 192.

EXPLANATION OF PLATE 51

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. *Laticarinina 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 mediterranensis* 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.

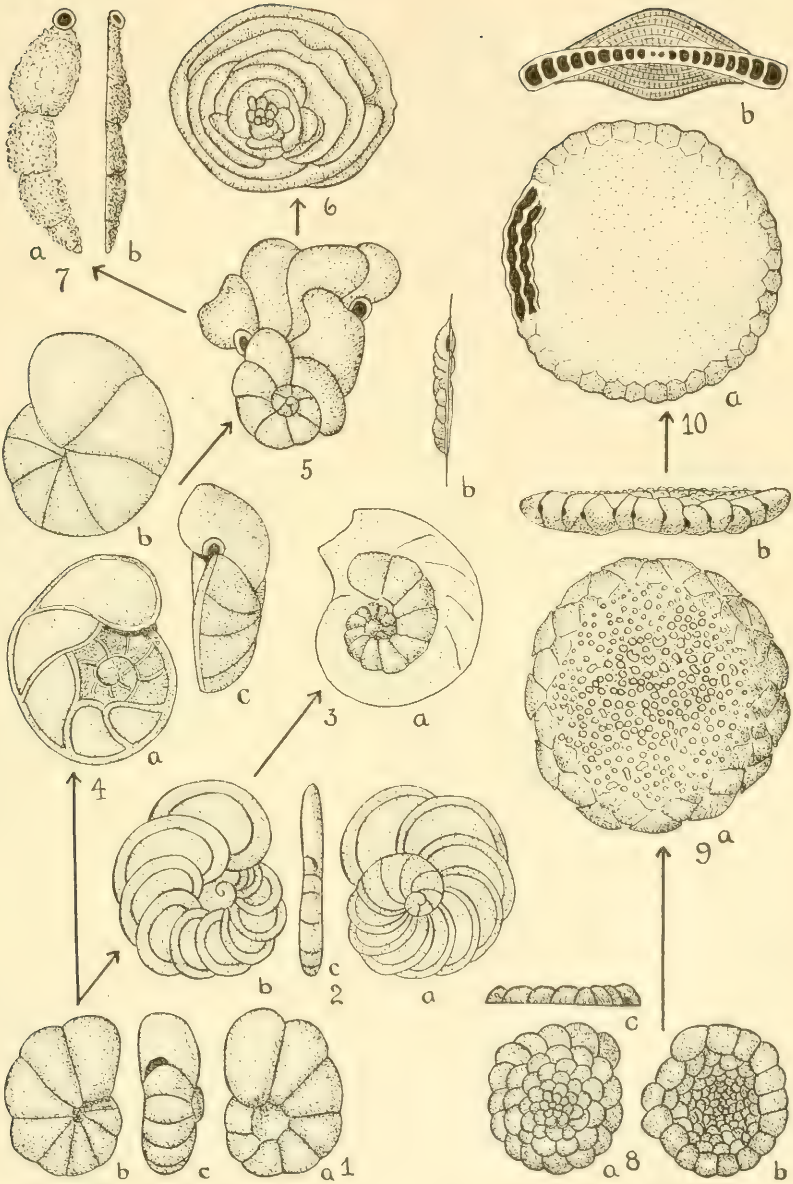

PLATE 51

Pulvinulina (part) of authors.
Pellatispira Cushman, 1927 (not Boussac).
Carinina Galloway and Wissler, 1927 (not Rubrecht).

Test typically plano-convex, the dorsal side flattened, ventral side convex, in the early stages especially of the microspheric form trochoid, the aperture on the periphery or even on the ventral side as in *Cibicides*, later on the margin on the dorsal side, a low, elongate opening at the base of the chamber, a wide flange of clear material separating the later coils and forming a carina about the periphery.

Eocene to Recent.

EXPLANATION OF PLATE 52

Planorbulinidae, Rupertiidae, Homotremidae

Fig.

1–4. *Linderina brugesi* Schlumberger. (After type figures). Fig. 1, Exterior. × 28. Fig. 2, Vertical section. × 25. Fig. 3, Details of vertical section. × 65. Fig. 4, Portion of horizontal section. × 65.

5. *Gypsina vesicularis* (Parker and Jones). × 20. (After H. B. Brady).

6–9. *Acervulina inhaerens* Schultze. Fig. 6 (After type figure). × 50. Figs. 7–9 (After H. B. Brady). × 25.

10–13. *Rupertia stabilis* Wallich. × 28. (After H. B. Brady). Fig. 10, Young stage. Fig. 11, Adult. Fig. 12, Longitudinal section. Fig. 13, Transverse section.

14. *Carpenteria monticularis* Carter. × 8. (After H. B. Brady). Young specimen.

15. *Carpenteria utricularis* Carter. × 10. (After H. B. Brady). Young specimen.

16. *Carpenteria monticularis* Carter. × 20. (After H. B. Brady). *a*, peripheral view; *b*, ventral view.

17. *Carpenteria proteiformis* Goës. × 10.

18–20. *Eorupertia boninensis* (Yabe and Hanzawa). (After type figures). Fig. 18, Exterior. × 8. Fig. 19, Longitudinal section. × 12. Fig. 20, Transverse section. × 12.

21–24. *Polytrema miniaceum* (Pallas). Fig. 21 (After Hickson). × 3. Fig. 22 (After Heron-Allen and Earland). Ventral view, showing very young coiled stage. Figs. 23, 24 (After Hickson). Fig. 23, Surface view. × 35. Fig. 24, Section. × 65.

25–27. *Homotrema rubrum* (Lamarck). (After Hickson). Fig. 25, Exterior. × 3. Fig. 26, Surface. × 35. Fig. 27, Section. × 65.

28–30. *Sporadotrema cylindricum* (Carter). (After Hickson). Fig. 28, Exterior. × 1½. Fig. 29, Surface. × 35. Fig. 30, Section. × 65.

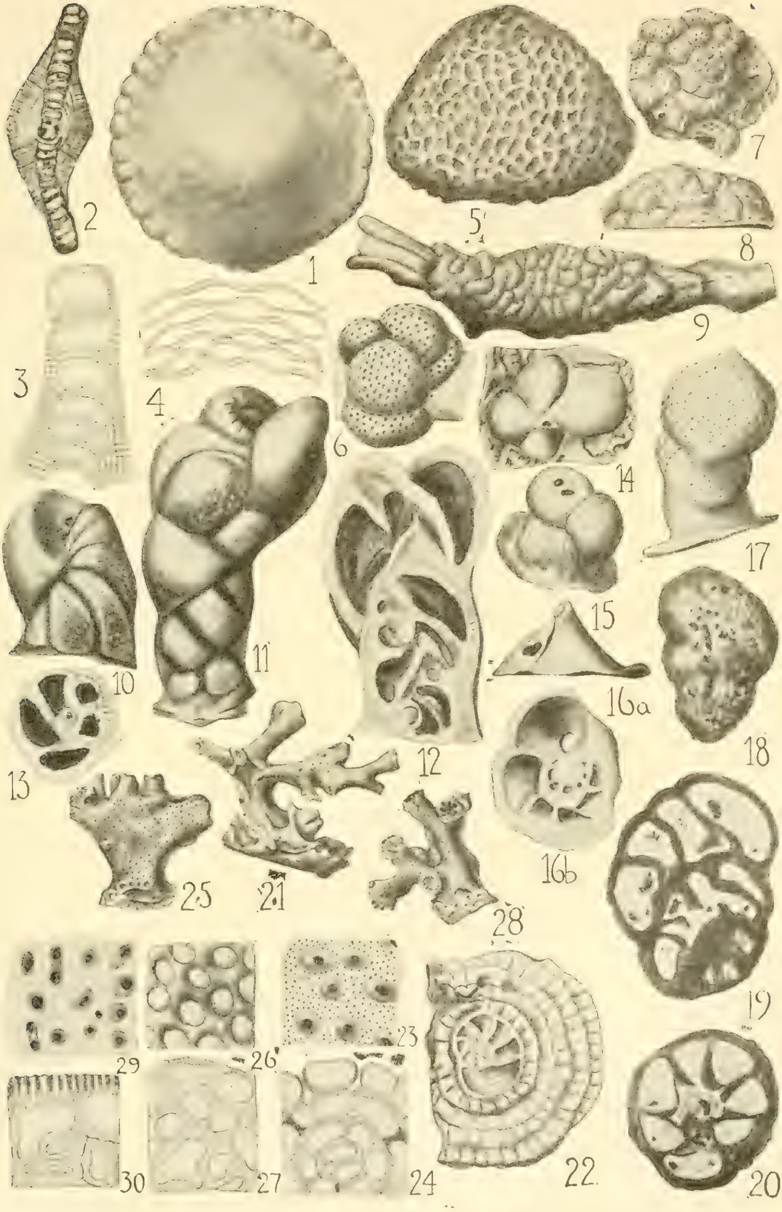
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PLATE 52

Genus ANOMALINELLA Cushman, 1927

Plate 50, figure 1

Genoholotype, *Truncatulina rostrata* H. B. Brady

Anomalinella CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 3, 1927, p. 93.

Truncatulina (part) of authors.

Test in the early stages trochoid, in the adult nearly planispiral and with the chambers almost entirely involute; wall calcareous, coarsely perforate; aperture on the ventral margin of the last-formed chamber between the periphery and the umbilical area with a supplementary aperture just below the peripheral margin, elongate and parallel to the axis of coiling.

Miocene (?) to 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

Plate 50, figures 2, 3; plate 51, figure 4

Genoholotype, *Cibicides refulgens* Montfort

Cibicides MONTFORT, Conch. Syst., vol. 1, 1808, p. 123.

Storilus MONTFORT (?), l. c., p. 131 (genoholotype, *Storilus radiatus* MONTFORT).

Polyxenes MONTFORT (?), l. c., p. 139 (genoholotype, *Polyxenes cribratus* MONTFORT=*Nautilus farctus* FICHTEL and MOLL).

Nautilus (part) of authors.

Truncatulina D'ORBIGNY, Ann. Sci. Nat., vol. 7, 1826, p. 279 (genotype, by designation, *Cibicides refulgens* MONTFORT).

Lobatula FLEMING, Hist. Brit. Anim., 1828, p. 232 (genoholotype, *Lobatula vulgaris* FLEMING).

Rosalina and *Rotalina* (part) of authors.

Aristeropora EHRENBERG, Monatsber. k. preuss. Akad. Wiss. Berlin, 1858, p. 11 (genotype, by designation, *Aristeropora graeca* EHRENBERG).

Heterolepa FRANZENAU, Természetrajzi Füsetek, vol. 8, 1884, p. 181 (genotype, by designation, *Rotalina dutemplei* D'ORBIGNY).

Pseudotruncatulina ANDREAE, Abhandl. geol. Special karte Elsass-Lothr., vol. 2, pt. 3, 1884, p. 213 (genoholotype, *Rotalina dutemplei* D'ORBIGNY).

Test plano-convex, usually attached to various objects by the flattened dorsal side, trochoid; wall calcareous, coarsely perforate; aperture peripheral, at the base of the chamber, sometimes extending ventrally, but typically with a long slit-like extension between the inner margin of the chamber on the dorsal side and the previous whorl nearly or fully the length of the chamber.

Cretaceous to Recent.

Genus CYCLOCIBICIDES Cushman, 1927

Plate 50, figure 4; plate 51, figure 6

Genoholotype, *Planorbulina vermiculata* d'Orbigny

Cyclocibicides CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 3, 1927, p. 93.
Planorbulina (part) of authors.
Rotalia JONES and PARKER, 1860 (not LAMARCK).
Pulvinulina (part) of authors.
Planopulvinulina (part) SCHUBERT, Pal. Zeitschr., vol. 3, 1920, p. 153.

Test attached, in the early stages similar to *Cibicides*, the chambers elongating in later growth and becoming nearly or completely annular; wall calcareous, coarsely perforate; aperture in the early stages as in *Cibicides*, in the adult formed by the numerous large pores scattered over the surface.

Recent.

Genus CIBICIDELLA Cushman, 1927

Plate 50, figures 5-7; plate 51, figure 5

Genoholotype, *Truncatulina variabilis* d'Orbigny

Cibicidella CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 3, 1927, p. 93.
Truncatulina (part) of authors.
Planorbulina (part) EGGER, 1857 (not D'ORBIGNY).

Test attached by the flattened dorsal side, in the early stages similar to *Cibicides*, later chambers irregularly disposed; wall calcareous, coarsely perforate; aperture in the early stages as in *Cibicides*, in the adult, rounded, on the dorsal side with a short neck and distinct lip.

Recent.

Genus WEBBINA d'Orbigny, 1839

Plate 50, figure 8; plate 51, figure 7

Genoholotype, *Webbina rugosa* d'Orbigny

Webbina D'ORBIGNY, in BAKER, WEBB and BERTHELOT, Hist. Nat. Iles Canaries, 1839, vol. 2, pt. 2, "Foraminifères", p. 125.

Webbum RHUMBLER, Foram. Plankton Exped., pt. 2, 1913, p. 445 (genotype, by designation, *Webbina rugosa* D'ORBIGNY).

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.

The genus *Placopsum* Rhumbler, 1913, may belong close to *Webbina*, but until the types may be restudied to determine more of the structure, it may be simply noted here. Rhumbler places these Jurassic forms close to *Webbina*. The genotype is desig-

EXPLANATION OF PLATE 53

FIG.

1, 2. *Ruditaxis rudis* (H. B. Brady). × 35. (After type figures). Fig. 1, *a*, dorsal view; *b*, ventral view; *c*, peripheral view. Fig. 2, Section showing labyrinthic interior.

3, 4. *Globivalvulina bulloides* (H. B. Brady). (After type figures). Fig. 3, *a*, dorsal view; *b*, ventral view; *c*, peripheral view. × 35. Fig. 4, Section. × 65.

5–7. *Hemigordius schlumbergeri* (Howchin). (After type figures). Fig. 5, Exterior. Fig. 6, Transverse section. Fig. 7, Longitudinal section.

8. *Schlumbergerina areniphora* Munier-Chalmas. (After type figure).

9, 10. *Schlumbergerina alveoliniformis* (H. B. Brady). × 15. (After H. B. Brady). Fig. 9, Side view. Fig. 10, Apertural view.

11–13. *Silvestria bradyi* (Millett). × 35. (After type figures). Exteriors.

14. *Flintia robusta* (H. B. Brady). × 13. (After type figure). *a*, side view; *b*, apertural view.

15. *Patellinella inconspicua* (H. B. Brady). × 50. (After type figure). *a*, dorsal view; *b*, ventral view; *c*, side view.

16, 17. *Cornuspirella diffusa* (Heron-Allen and Earland). × 13. (After type figures). Fig. 16, Showing central coiled portion and some of the peripheral extensions. Fig. 17, A more expanded peripheral portion.

18. *Planopulvinulina dispansa* (H. B. Brady). × 10. (After type figure). *a*, dorsal view; *b*, ventral view.


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18a
18b

PLATE 53

nated as *Webbina breoni* Terquem and Piet, (Mem. Acad. Imp. Metz, vol. 42, 1862, p. 458, pl. 6, figs. 18*a-h*).

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 plano-convex 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 early stages, coiled, attached by the dorsal surface, chambers in a spiral arrangement, apertures single, later with the chambers added in annular series, the apertures usually two to a chamber, the test free and becoming bilaterally symmetrical, not developing pillars.

KEY TO THE GENERA

I. Test plano-convex or globular, not bilaterally symmetrical.
  A. Chambers definitely in one plane.
    1. Chambers closely grouped. .... *Planorbulina*.
    2. Later chambers forming a reticulate network. *Planorbulinoides*.
  B. Chambers piled up irregularly or in a spherical mass.
    1. Chambers few, hemispherical, test compressed and attached. *Acervulina*.
    2. Chambers numerous, compressed, test globular, free. *Gypsina*.

II. Test bilaterally symmetrical.
  A. Sides papillate but not greatly thickened......... *Planorbulinella*.
  B. Sides with a very thick secondary mass................ *Linderina*.

Genus PLANORBULINA d'Orbigny, 1826

Plate 50, figures 9, 10; plate 51, figure 8

Genotype, by designation, *Planorbulina mediterraneansis* d'Orbigny

Planorbulina D'ORBIGNY, Ann. Sci. Nat., vol. 7, 1826, p. 280.

Asterodiscus EHRENBERG, Abhandl. k. Akad. Wiss. Berlin, 1838, p. 130 (genoholotype, *Asterodiscus forskalii* EHRENBERG).
Spirobotrys EHRENBERG, Bericht. k. preuss. Akad. Wiss. Berlin, 1844, p. 247 (genoholotype, *Spirobotrys aegaea* EHRENBERG).
Soldanina COSTA, Atti Accad. Pont., vol. 7, fasc. 2, 1856, p. 246 (genoholotype, *Soldanina exagona* COSTA).

Test in the young, coiled, attached by the dorsal surface, very earliest chambers slightly trochoid, closely spiral, later in an irregular series of a single layer about the periphery; wall calcareous, coarsely perforate; apertures in the early stages one to each chamber, near the periphery or in the irregular chambers sometimes multiple.

Tertiary and Recent.

Genus PLANORBULINOIDES Cushman, 1928

Plate 50, figure 12

Genoholotype, *Planorbulina retinaculata* Parker and Jones

Planorbulinoides CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 4, 1928, p. 6.
Planorbulina (part) PARKER and JONES, 1865.

Test attached, in the early stages similar to *Planorbulina* but the later chambers spreading, becoming elongate and more or less separated to form a network; apertures in the early stages as in *Planorbulina*, later several on the sides of the chambers, with very short necks.

Recent.

Genus PLANORBULINELLA Cushman, 1927

Plate 50, figure 11; plate 51, figure 9

Genoholotype, *Planorbulina larvata* Parker and Jones

Planorbulinella CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 3, 1927, p. 96.
Planorbulina (part) of authors.

Test in the adult nearly bilaterally symmetrical, in the young attached and like *Planorbulina*, soon having the chambers developed about the periphery in annular series, the chambers of each series alternating with those of the adjacent ones; wall calcareous, coarsely perforate; apertures in the adult two, one at each side of the chamber in the median line.

Tertiary and Recent.

Genus LINDERINA Schlumberger, 1893

Plate 51, figure 10; plate 52, figures 1-4

Genoholotype, *Linderina brugesi* Schlumberger

Linderina SCHLUMBERGER, Bull. Soc. Géol. France, ser. 3, vol. 21, 1893, p. 120.

Test similar to *Planorbulinella* with annular series of chambers, but developing a thick layer of clear shell material over the central portion of the test on the two flattened sides; wall calcareous, coarsely perforate; apertures in the adult formed by the coarse perforations of the peripheral border.

Upper Eocene.

Genus ACERVULINA Schultze, 1854

Plate 52, figures 6-9

Genotype, by designation, *Acervulina inhaerens* Schultze

Acervulina SCHULTZE, Organ. Polythal., 1854, p. 67.

Test attached by the dorsal side, at least in the early stages, if attached to a small object often entirely covering it and then covering its own early chambers, earliest chambers coiled; wall

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EXPLANATION OF PLATE 54

FIG.

1–3. *Ptychomiliola separans* (H. B. Brady). × 12. (After type figures). *b*, Specimen showing aperture.

4. *Pleurostomellina barroisi* (Berthelin). × 120. (After type figures). *a*, front view; *b*, side view.

5. *Orbignyna ovata* Hagenow. (After type figures). *a*, apertural view; *b*, side view; *c*, peripheral view.

6. *Neobulimina canadensis* Cushman and Wickenden. × 125. (After type figures). *a*, front view; *b*, side view; *c*, apertural view.

7, 8. *Flabellammina alexanderi* Cushman. × 35. (After type figures). *b*, apertural view.

9. *Epistomella rimosa* (Parker and Jones). × 15. (After type figure). *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

10, 11. *Neocribrella globigerinoides* (Parker and Jones). × 15. (After type figures). 10 *a*, 11, showing apertures.

12, 13. *Cornuspiroides striolata* (H. B. Brady). Fig. 12, (After Heron-Allen and Earland), × 2. Fig. 13, (After type figure), *b*, peripheral view. × 3.

14. *Lunucammina permiana* Spandel. × 35. (After type figures). *a*, *b*, from opposite sides; *c*, peripheral view; *d*, end view.

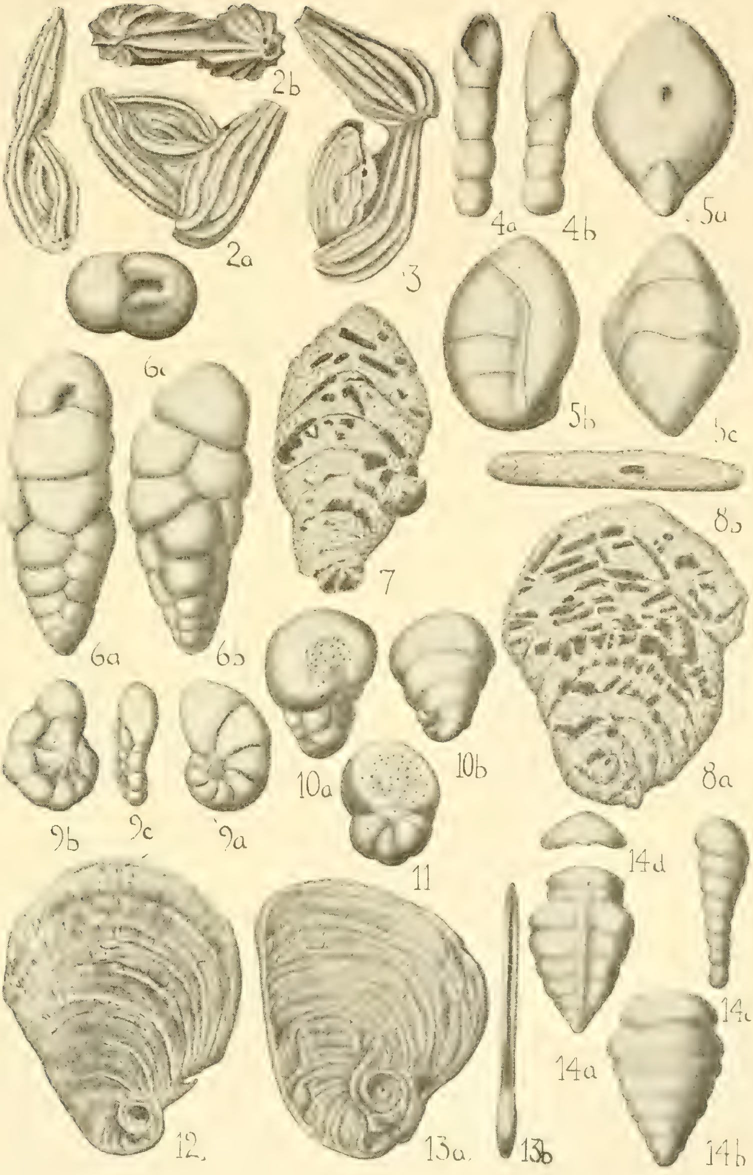
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PLATE 54

calcareous, coarsely perforate; apertures formed by the coarse perforations of the test.

Late Tertiary and Recent.

Genus GYPSINA Carter, 1877

Plate 52, figure 5

Genotype, by designation, *Orbitolina vesicularis* Parker and Jones

Gypsina Carter, Ann. Mag. Nat. Hist., ser. 4, vol. 20, 1877, p. 173.
Orbitolina (part) of authors.
Tinoporus (part) of authors.
Ceriopora (part) of authors.

Test, a generally spherical mass of compressed chambers, sometimes arranged in more or less radial rows; apertures formed by the coarse pores of the wall.

Cretaceous to 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. In such forms as *Planorbulinella* and *Linderina,* the early stages are seen toward the development of the complex forms of the Orbitoididae.

FAMILY 43. RUPERTIIDAE

Test in the early stages, 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

Plate 52, figures 10-13

Genoholotype, *Rupertia stabilis* Wallich

Rupertia Wallich, Ann. Mag. Nat. Hist., ser. 4, vol. 19, 1877, p. 502.

Test attached, in the young, trochoid, the chambers later extending upward from the base of attachment still keeping a loose spiral; wall calcareous, thick, coarsely perforate; aperture in the early stages narrow, at the base of the chamber, in later development becoming much more open, rounded and with a thickened, rounded lip.

Recent.

Genus CARPENTERIA Gray, 1858

Plate 52, figures 14-17

Genoholotype, *Carpenteria balaniformis* Gray

Carpenteria Gray, Proc. Zool. Soc. London, vol. 26, 1858, p. 269.
Dujardinia Gray, l. c., p. 270 (genoholotype, *Dujardinia mediterranea* Gray).
Polytrema (part) Carter, 1876 (not Risso).

Test attached, early chambers trochoid, later spreading out over the surface of attachment but with the inner ends piled up in a loose spire or the whole test becoming subcylindrical, the chambers loosely spiral or even uniserial; wall calcareous, coarsely perforate; aperture in the young narrow, in the older stages somewhat rounded at the end of a tubular projection, and in the uniserial forms sometimes with a tubular neck.

Cretaceous to Recent.

Genus EORUPERTIA Yabe and Hanzawa, 1927

Plate 52, figures 18-20

Genoholotype, *Uhligina boninensis* Yabe and Hanzawa

Eorupertia Yabe and Hanzawa, in Cushman, Contr. Cushman Lab. Foram. Res., vol. 3, 1927, p. 97.
Uhligina Yabe and Hanzawa, Japanese Journ. Geol. Geog., vol. 1, 1922, p. 71 (genoholotype, *Uhligina boninensis* Yabe and Hanzawa) (not *Uhligina* Schubert).

Test with the early stages coiled, later in a subcyclindrical form, the chambers in an elongate spiral about a hollow center; wall calcareous, coarsely perforate, developing canals and pillars; aperture not well distinguished.

Eocene. Japan.

The genera of this family are all attached forms growing upward from the base, coarsely perforate and with the aperture tending to become terminal. Rzehak has considered that *Karreria* Rzehak, 1895 and *Semseya* Franzenau, 1893, should be grouped near *Carpenteria*, but without seeing the types it is very difficult to place these.

FAMILY 44. HOMOTREMIDAE

Test in the early stages trochoid, attached by the dorsal surface, later becoming irregular and growing upward from the area of attachment into a more or less branched mass, all trace of the early arrangement being lost; wall calcareous, coarsely perforate; apertures large, open or covered by a perforated plate; a reddish or orange color strongly developed.

Genus HOMOTREMA Hickson, 1911

Plate 52, figures 25-27

Genoholotype, *Millepora rubra* Lamarck

Homotrema HICKSON, Trans. Linn. Soc. Zool., vol. 14, 1911, p. 445.
Millepora LAMARCK, 1816 (not LINNÉ).
Polytrema (part) of authors (not RISSO).

Test attached, the early stages coiled, later extending up in an irregular mass with short stout projecting portions; wall cal-

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EXPLANATION OF PLATE 55

FIG.

1, 2. *Cornuspiramia antillarum* (Cushman). (After type figures). Fig. 1, Exterior. Fig. 2, Ventral view of young specimen showing structure.

3–5. *Tubulogenerina mooraboolensis* (Cushman). × 75. (After Heron-Allen and Earland). Fig. 3, Front view showing aperture and tubular spines. Fig. 4, Diagrammatic longitudinal section. Fig. 5, Diagrammatic horizontal section.

6. *Dictyopsella chalmasi* Schlumberger. × 10. (After type figure).

7, 8. *Dictyopsella kiliani* Schlumberger. (After type figures). Fig. 7, Exterior. × 12. Fig. 8, Longitudinal section. × 15.

9. *Flabellina rugosa* d'Orbigny. (After type figure).

10, 11. *Arnaudiella grossouvrei* H. Douvillé. (After H. Douvillé). Fig. 10, Transverse section. × 10. Fig. 11, Detail of section showing pillars and vacuolar structure.

12–14. *Pellatispira douvillei* Boussac. (After type figures). Fig. 12, Equatorial section. × 7. Fig. 13, Transverse section. × 7. Fig. 14, Exterior. × 4.

15. *Pellatispira madaraszi* (Hantken). × 4. (After Boussac).

16. *Heterostegina*. Schematic figure showing structure. (After Van der Vlerk and Umbgrove).

17. *Cycloclypeus*. Schematic figure showing structure. (After Van der Vlerk and Umbgrove).

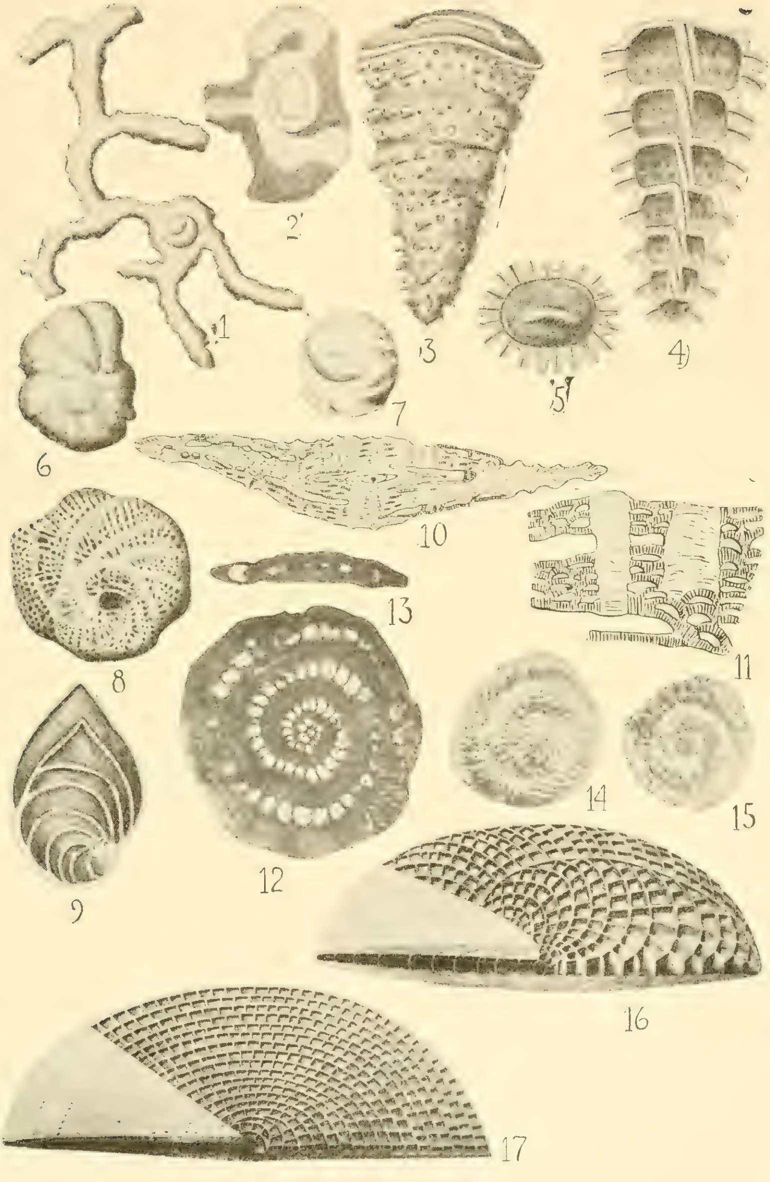


PLATE 55

careous, the surface solid with large scattered foramina covered by a finely perforated plate; color dark red.

Recent.

Genus SPORADOTREMA Hickson, 1911

Plate 52, figures 28-30

Genoholotype, *Polytrema cylindricum* Carter

Sporadotrema Hickson, Trans. Linn. Soc. Zool., vol. 14, 1911, p. 447.
Polytrema Carter, 1880 (not Risso).

Test attached, the early stages coiled, later extending outward and upward into short stout branches, numerous chambers apparent about the outer end; wall calcareous, the surface solid with scattered foramina, open, not covered by a plate; color orange or red.

Recent.

Genus POLYTREMA Risso, 1826

Plate 52, figures 21-24

Genoholotype, *Polytrema corallina* Risso = *Millepora miniacea* Pallas
Polytrema Risso, Hist. Nat. Europe Mérid., vol. 5, 1826, p. 340.
Millepora (part) of authors.
Pustularia Gray, Proc. Zool. Soc. London, vol. 26, 1858, p. 271 (genoholotype, *Pustularia rosea* Gray).

Test attached, in the early stages coiled, later with the small chambers piled up in an irregular branching mass with slender projections; wall calcareous, perforate, the surface finely perforate with larger open foramina; color light red.

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

By T. Wayland Vaughan

Synopsis of the Family

The following synopsis of the Orbitoididae is frankly imperfect and unsatisfactory, notwithstanding the large amount of research that has been bestowed upon the family. The principal workers have been Gümbel, Charles Schlumberger, Verbeek, P. Lemoine and R. Douvillé, and H. Douvillé. Publications by most of these authors are listed in the references under the genera and subgenera of the family, and from those citations most of the important literature can be found. A number of Italians, especially A. Silvestri, have made important investigations. Recently L. Rutten, A. Tobler, F. Chapman, J. H. Umbgrove, I. M. van der Vlerk, and H. Yabe have published many papers on the East Indies, other Pacific Islands, Australia, and Japan. W. L. F. Nuttall is the author of a series of valuable articles and memoirs on the orbitoids of India. The American species have received much attention from J. A. Cushman and myself, and several others have published one or more articles each. The most comprehensive work is that of H. Douvillé, who has recently published a general review of the group. In 1924, I published a summary of what was then known of the American species, a work which was confessedly tentative, incomplete, and in a number of respects crude. The literature is very large and it cannot be reviewed here.

The family Orbitoididae will be defined as follows:

Test thin or inflated, round lenticular, selliform, or stellate, with a layer of equatorial chambers, which in the megalospheric generation begins growth from a multilocular embryonic apparatus. Chamber walls perforate, usually also communication between chambers through openings for the passage of protoplasmic stolons. *There is no canal system.*

Subfamilies:

Orbitoidinae, growth cyclical, except in very early stages in which there may be, particularly in the microspheric generation, an initial spiral. Well developed lateral chambers on each side of the equatorial layer.

Miogypsininae, early stages distinctly spiral, later growth spiral, which ultimately may become cyclical, or the growth may be largely on only a segment of the periphery producing a test triangular in plan with the embryonic chambers at or near the apex. Lateral chambers well developed.

Omphalocyclinae, growth cyclical, initially spiral in the microspheric form. Without definitely differentiated lateral chambers; initial chambers, beyond the embryonic, in a single or double layer. If the layer is single it may bifurcate and a third layer may be intercalated between the two previously formed; if it is double there may be direct intercalation of the third layer.

The features of the embryonic chambers of the megalospheric forms are used in defining genera and subgenera, although they are subject to considerable variations. Details will be found in the subsequent descriptions.

There are two hypotheses regarding the origin of the Orbitoididae. According to H. Douvillé the family is derived from *Arnaudiella* or some similar parent and is, therefore, ancestrally related to *Camerina*. Hofker, however, is of the opinion that the family is derived from ancestors related to his Tinoporidae (Hofker, J., The Foraminifera of the Siboga Expedition, pt. 1, 1927, pp. 4-6), because of general similarity of structure, including the absence of any canal system. I have restudied many thin sections of orbitoids with Hofker's suggestion in mind, and in essentials I am inclined to agree with him. In some of the sections that I have examined there are passages connecting the equatorial with the lateral chambers, similar to the passages between the lateral chambers, as they were figured by Carpenter (Carpenter, W. B., Introduction to the Study of the Foraminifera, pl. 20, fig. 6). These observations are at variance with Hofker's statement that the median chambers communicate with the lateral only by means of pores. I agree with H. Douvillé in his opinion that *Omphalocyclus* is a close relative to the orbitoids. *Miogypsina* and *Helicolepidina* are also closely akin to the orbitoids. They both lack any canal system and their general structural features are similar to those of the orbitoids. It is probable that *Miogypsina* is derived from *Helicolepidina*. My previous expressed opinion of the similarity of *Helicolepidina* to *Spiroclypeus*, a modified *Heterostegina*, I now regard as erroneous.

Not all the nomenclature that follows can be regarded as firmly established. No decision has been reached regarding the disposition of *Hymenocyclus* Bronn, 1851-52. Perhaps this name should be substituted for one of those here used.

Subfamily Orbitoidinae

Genus ORBITOIDES d'Orbigny, 1847

Plate 57, figure 4; plate 58, figures 1-6

Genolectotype, *Orbitoides media* (d'Archiac)

Orbitoides D'ORBIGNY, Quart. Jour. Geol. Soc. London, vol. 4, 1847, p. 11; Cours Element. Pal., vol. 2, 1850, p. 193, fig. 316.

Orbitella H. DOUVILLÉ, C. R. Acad. Sci., vol. 161, 1915, p. 666, figs. 5, 6; Bull. Soc. Géol. France, 4th ser., vol. 20, 1921, p. 214.

Test lenticular, more or less compressed, surface ornamented with vermicular pillars or radiating costae. Embryonic chambers enveloped in a thick shell, at first quadrilocular, later becoming bilocular, by atrophy and fusion of three of the initial chambers, and the production of a smaller embraced by a larger chamber. Equatorial chambers with a curved outer wall and inwardly converging lateral walls, radial diameter shorter than the transverse. Communication between the chambers by a few round lateral apertures.

Upper Cretaceous.

It is probable that *Silvestrina* Prever (Riv. ital. Paeontol., vol. 10, 1904, p. 122, pl. 6, figs. 2, 3), 1904, is a synonym of *Orbitoides*.

Genus SIMPLORBITES de Gregorio, 1882

Plate 58, figure 7

Genoholotype, *Nummulites papyracea* Boubée, 1832=*Orbitolites gensacicus* Leymerie, 1851

Simplorbites DE GREGORIO, Fossili dei Dintorno di Pachino, 1882, p. 10, pl. 6, figs. 21-28, 30.

Simplorbites H. DOUVILLÉ, C. R. Acad. Sci., vol. 161, 1915, p. 667, figs. 13-15; Bull. Soc. Géol. France, 4th ser., vol. 20, 1921, p. 217, figs. 19-21.

Test inflated or compressed lenticular. Surface ornamented with compressed vermicular or radiately elongate pillars similar to those of *Orbitoides*. Embryonic apparatus large, exceeding 2 mm. in diameter, roughly ovoid in form, and enclosed in a thick, porous shell, within which there are many chambers, piled one on another without any definite order. Otherwise the genus resembles *Orbitoides*, to which it is similar in its equatorial and lateral chambers and its pillars.

Maestrichtian.

H. Douvillé thinks that *Simplorbites* may not be a valid genus, and that the peculiar embryonic chambers may be due to "gigantisme" in specimens actually referable to *Orbitoides apiculatus*. If this opinion should be correct, the species would be *O. gensacicus* (Leymerie), 1851, and not *O. apiculatus* Schlumberger, 1901.

Genus LEPIDORBITOIDES Silvestri, 1907

Plate 56, figures 9, 10; plate 58, figures 8-10

Genoholotype, *Orbitolites socialis* Leymerie

Lepidorbitoides SILVESTRI, Atti Acad. Nuovi Lincei, an. 61, 1908, p. 23 (15 Dec., 1907).

Lepidorbitoides H. DOUVILLÉ, Bull. Soc. Géol. France, 4th ser., vol. 20, 1920, p. 220, figs. 22-24.

EXPLANATION OF PLATE 56

FIG.

1. *Discocyclina (Asterocyclina) georgiana* (Cushman). × 6. Exterior.
2. *Discocyclina (Discocyclina) floridana* (Cushman). × 6. Exterior.
3. *Miogypsina*. Diagrammatic figure to show structure. (After Van der Vlerk and Umbgrove).

4–6. *Omphalocyclus macroporus* (Lamarck). × 2. (After H. Douvillé). Fig. 4, Horizontal weathered section. Figs. 5, 6, Peripheral views.

7. *Discocyclina*. Diagrammatic figure to show structure. (After Van der Vlerk and Umbgrove).
8. *Miogypsina cushmani* Vaughan. × 16. (After Vaughan). Horizontal section to show embryonic and meridional chambers.

9, 10. *Lepidorbitoides socialis* (Leymerie). × 80. (After H. Douvillé). Fig. 9, Portion of vertical section. Fig. 10, Portion of horizontal section.

11. *Lepidocyclina*. Diagrammatic figure to show structure. (After Van der Vlerk and Umbgrove).

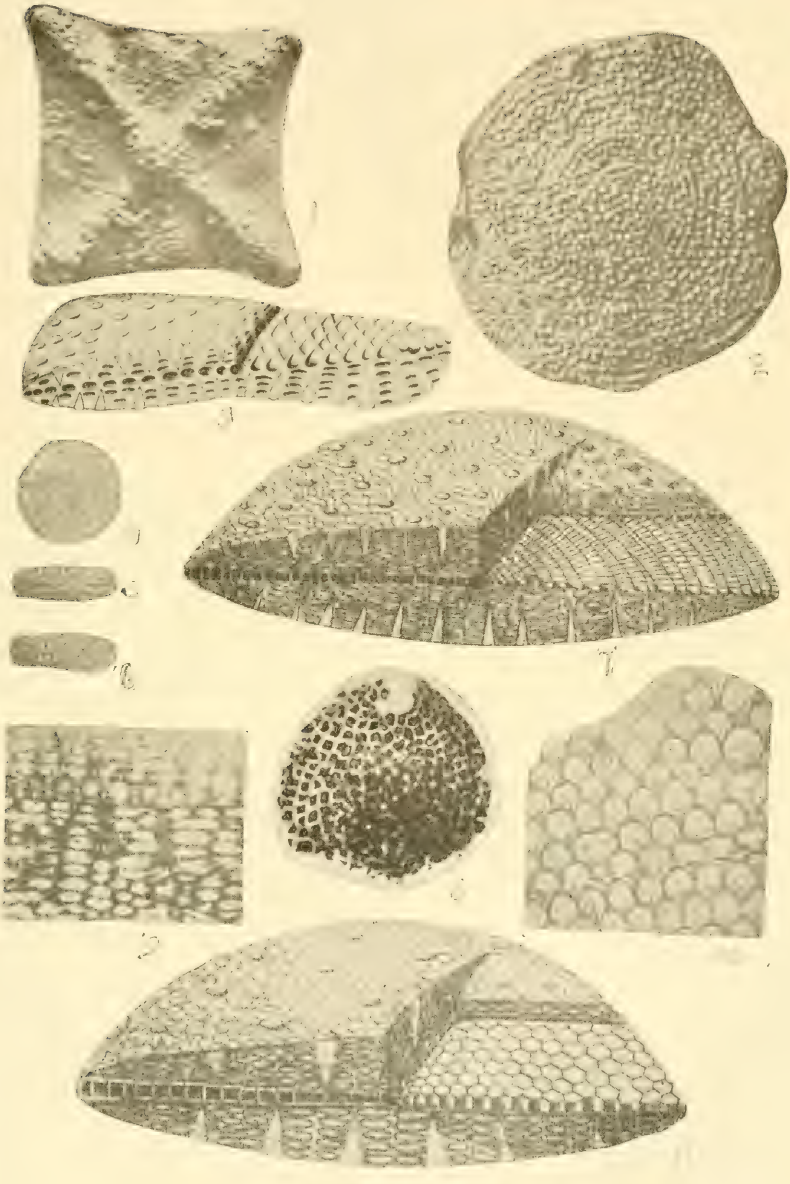


PLATE 56

Test lenticular, surface papillate. Embryonic chambers bilocular, one much larger than the other and partly embracing it. Equatorial chambers somewhat elongate radially, outer wall curved, in the adult their sides touch and they become hexagonal in form. The communications between the chambers are by cribriform perforations, about 1.5 μ in diameter, over the entire anterior chamber wall, similar to the perforations of the chamber roofs. Pillars between the lateral chambers of pyramidal or conical form, terminating on the surface in granules or rounded pustules.

CLYPEORBIS 1915

Genus ~~PSEUDORBITOIDES~~ H. Douvillé, ~~1922~~

Plate 58, figures 11-15

Genoholotype, *Orbitoides mamillata* Schlumberger

Clypeorbis H. Douvillé, C. R. Acad. Sci., vol. 161, 1915, p. 669, figs. 18-20; Bull. Soc. Géol. France, 4th ser., vol. 20, 1920, p. 227, figs. 29-34.

Test asymetrically lenticular or low conical with a rounded apex. Surface papillate similar to that of *Lepidorbitoides*. Embryonic chambers composed of an initial spheroidal chamber, below which are developed 3 or 4 chambers arranged as a rosette. The embryonic chambers actually form a conical spiral which appears in the arrangement of the early lateral chambers. The equatorial chambers have convex outer walls and form a network of hexagonal pattern. The chambers are radially shortened, are arranged along radial lines, and increase in number by bifurcation of or intercalation between older linear series. Communication between chambers by minute perforations of the same kind as those in roofs of the chambers, therein resembling *Lepidorbitoides*. The anterior chamber wall appears to be a direct continuation of the chamber roof with the maintenance of the same porous texture.

Maestrichtian.

Genus PSEUDORBITOIDES H. Douvillé, 1923

Plate 58, figures 16, 17

Genoholotype, *Pseudorbitoides trechmanni* H. Douvillé

Pseudorbitoides H. Douvillé, C. R. Soc. Géol. France, 1922, p. 203; Bull. Soc. Géol. France, 4th ser., vol. 23, 1923, p. 369, figs. 1,2.

Test lenticular, rather small. Embryonic chambers in a distinct spiral. Equatorial chambers in a single layer near the center, forming several layers near the periphery, those in the same ring often slightly separated and arranged along radial lines.

Upper Cretaceous of Jamaica.

Genus DISCOCYCLINA Gümbel, 1868

Plate 56, figures 1, 2, 7; plate 58, figures 18-22

Genolectotype, *Orbitulites pratti* Michelin.

Discocyclina GÜMBEL, Abhandl. k. bay. Akad. Wiss., vol. 10, 1868, p. 109.

Rhipidocyclina GÜMBEL, Ibid., 1868, p. 110.

Orthophragmina MUNIER-CHALMAS (pars), Étude du Tithon. du Cret. et du Tert. du Vicentin, 1891, p. 18.

Discocyclina H. DOUVILLÉ, Bull. Soc. Géol. France, 4th ser., vol. 22, 1922, p. 64, numerous figs. in text and on plates.

Pseudophragmina H. DOUVILLÉ, Bull. Soc. Géol. France, 4th ser., vol. 23, 1923, p. 373, pl. 13, figs. 1-3.

Test discoid, lenticular, thin or inflated, selliform, or stellate. Surface granulate. Embryonic apparatus consists of a smaller subglobular chamber partly embraced by a larger chamber. Equatorial chambers of rectangular shape, usually radially elongate, arranged in more or less definite concentric rings, the radial walls of chambers of contiguous rings alternating in position or aligned. Chambers of one ring communicate with the chambers of adjacent rings by a row of lateral small apertures 5 to 7 μ in diameter, usually 2 to 4 in each row; the perforations in the chamber roofs are very small, cribriform. Lateral chambers greatly developed, usually composing most of the test. Pillars usually well developed and terminate on the surface in papillae or granulations of distinctive character of much value in recognizing species.

Danian to uppermost Eocene.

H. Douvillé (*op. sup. cit.*) proposed the genus name *Pseudophragmina* for *Orthophragmina floridana* Cushman as the genoholotype and gave as its distinguishing features, first, the degeneration of the radial chamber walls so that they do not join the inner wall of the ring of chambers next beyond and in places are represented by rows of granules; second, the radial chamber-walls of one ring do not regularly alternate with those of adjacent rings. I have had many specimens of *Discocyclina* *floridana* prepared to show the embryonic and equatorial chambers. The embryonic chambers are typically reniform. The degree of degeneration of the radial chamber-walls varies and is not of generic significance. There is variation in the relation of the chamber walls of adjacent rings, they may alternate or they may be in alignment. I examined many specimens and figures of *Discocyclina* with reference to this feature. Even the original figures of Gümbel (*op. sup. cit.*) show variation. This feature does not furnish characters of even specific value. Therefore, in my opinion, *Pseudophragmina* is a synonym of *Discocyclina*. The species I described as *Orbitoclypeus* (?) *cristensis*, (Bull. Geol. Soc. Amer., vol. 35, 1924, p. 814, pl. 36, fig. 8), I now consider to belong to *Discocyclina*. The receipt of additional specimens has made possible the examination of the embryonic chambers, which, although they are somewhat different from those of *Discocyclina* that I have previously examined, do not appear sufficiently different to warrant reference to another genus. *Orbitoclypeus* according to Silvestri represents the last evolutionary phase of *Spiroclypeus* (Boll. Soc. geol. Ital., vol. 26, 1907, p. 59.)

EXPLANATION OF PLATE 57

Fig.

1. *Lepidocyclina (Lepidocyclina) mortoni* Cushman. × 80. (After Vaughan). Part of horizontal section to show perforations in the chamber roofs and floors and details of the chamber walls.
2. *Miogypsina cushmani* Vaughan. × 80. (After Vaughan). Part of a horizontal section to show perforations in the roofs and floors of the chambers and details of the chamber walls.
3. *Lepidocyclina (Polylepidina) proteiformis* Vaughan. × 16. (After Vaughan). Section in median plane of megalospheric specimen.
4. *Orbitoides media* (d'Archaic). × 16. (After Vaughan). Showing quadrilocular embryonic apparatus surrounded by a common thick wall.
5. *Lepidocyclina (Nephrolepidina) undosa* Cushman. × 16. (After Vaughan). Horizontal section through embryonic and meridional chambers.
6. *Lepidocyclina (Lepidocyclina) parvula* Cushman. × 8. Vertical section.
7. *Lepidocyclina (Eulepidina) favosa* Cushman. × 16. (After Vaughan). Horizontal section through embryonic and meridional chambers.

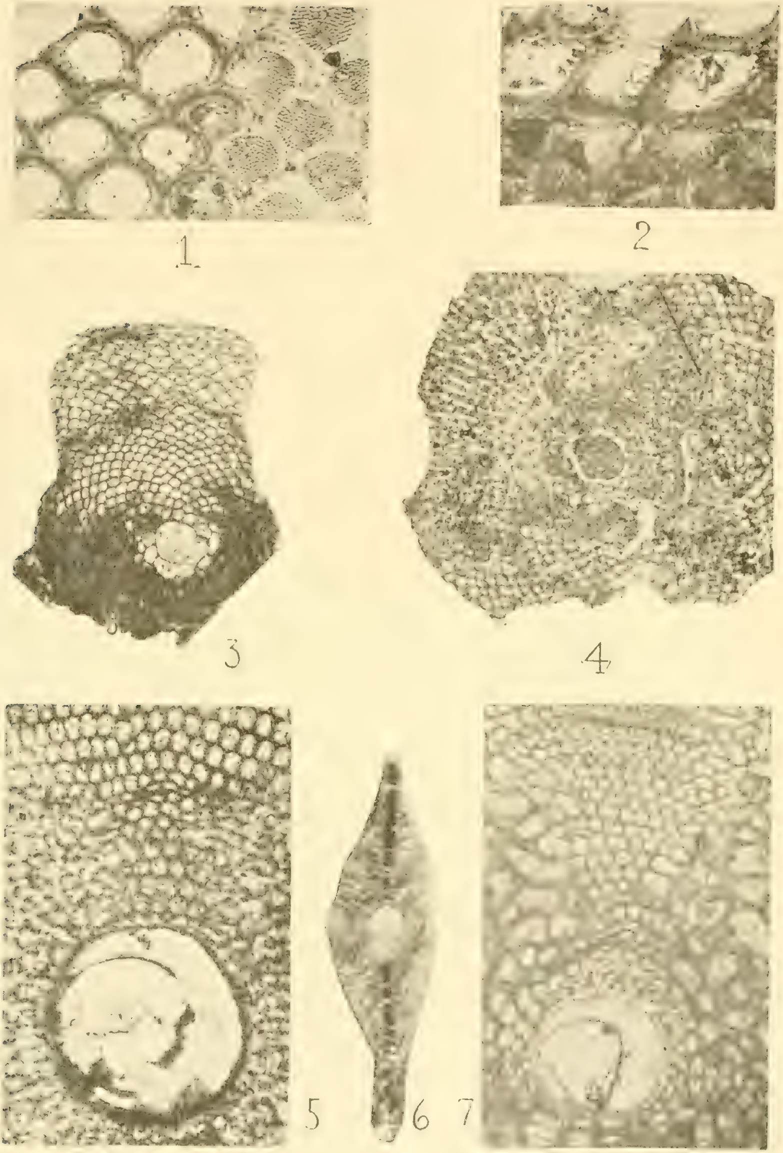


PLATE 57

Subgenus DISCOCYCLINA Gümbel, 1868

Genolectotype, *Orbitulites pratti* Michelin

Test discoid, flat or inflated, peripheral plan circular, surface without radial ridges.

Danian to uppermost Eocene.

Subgenus AKTINOCYCLINA Gümbel, 1868

Genolectotype, *Orbitulites radians* d'Archiac

Aktinocyclina GÜMBEL, Abhandl. k. bay. Akad. Wiss., vol. 10, 1868, p. 110, many figs.

Orthophragmina MUNIER-CHALMAS (pars), *(op. sup. cit.)*, 1891.

Actinocyclina H. DOUVILLÉ, Bull. Soc. Géol. France, 4th ser., vol. 22, 1922, p. 79, pl. 5, figs. 3-8.

Similar to *Discocyclina* except that there are on the surface of the test elevated rays which, however, do not terminate in protuberant angles on the margin of the test, as is the case in *Asterocyclina*. Gümbel says of the test "kreisrund".

Middle and upper Eocene.

The subgenus is represented in both Europe and America. Recently specimens, not yet described in print, have been collected in the upper Eocene Ocala limestone near Bainbridge, Georgia.

Subgenus ASTEROCYCLINA Gümbel, 1868

Genolectotype, *Calcarina* (?) *stellata* d'Archiac

Asteriacites SCHLOTHEIM, Die Petrefactenkunde, Nachtrag, 1822, p. 71, pl. 12, fig. 6 (not of SCHLOTHEIM of earlier date, *teste* HODSON).

Cisseis R. J. L. GUPPY, Quart. Jour. Geol. Soc. London, vol. 22, 1866, p. 584, pl. 26, figs. 19*a*, *b* (not LAPORTE and GORG, 1839).

Asterodiscus SCHAFHÄUTL, Sud-Bayern Leth. Geognos., 1863, p. 130 (not EHRENBERG, 1838).

Asterocyclina GÜMBEL, Abhandl. k. bay. Akad. Wiss., vol. 10, 1868, p. 689, many figs.

Orthophragmina MUNIER-CHALMAS (pars), *(op. sup. cit.)*, 1891.

Asterodiscus H. DOUVILLÉ, Bull. Soc. Géol. France, 4th ser., vol. 22, 1922, p. 60 (figs. 13, 14), 76.

Asteriacites VAUGHAN, Bull. Geol. Soc. Amer., vol. 35, 1924, pp. 790, 793.

Asterocyclina VAUGHAN, Jour. Paleontol., vol. 1, 1928, p. 285.

The only essential difference between *Discocyclina* and *Asterocyclina* consists of difference in form. *Asterocyclina* is radiate, the number of arms ranging from 5 to more than 12. The test is correspondingly quadrangular or many rayed. The ends of the rays determine the shape of the test as seen in plan and project beyond the margin of the interradial part of the test. The initial embryonic chambers are reniform as in *Discocyclina*. This is true of the species figured by H. Douvillé and of all the American species of which I have examined the embryonic chambers.

Middle and upper Eocene.

Genus LEPIDOCYCLINA Gümbel, 1868

Plate 56, figure 11; plate 57, figures 1, 3, 5-7; plate 59, figures 1-11

Genolectotype, *Nummulites mantelli* Morton

Lepidocyclina GÜMBEL, Abhandl. k. bay. Akad. Wiss., vol. 10, 1868, p. 689.

Lepidocyclina P. LEMOINE and R. DOUVILLÉ, Mém. Soc. Géol. France, Mém. no. 32, 1904, 41 pp., 3 pls.

Lepidocyclina CUSHMAN, U. S. Geol. Survey Prof. Paper no. 125, 1920, pp. 55-105, pls. 12-35.

Lepidocyclina H. DOUVILLÉ, Mém. Soc. Géol. France, n. ser., vol. 1, Mém. no. 2, 1924, pp. 1-49, pls. 5, 6, 48 text figs.; Ibid, vol. 2, Mém. no. 2, 1925, pp. 51-123, pls. 3, 4, text figs. 49-83.

Lepidocyclina VAUGHAN, Bull. Geol. Soc. Amer., vol. 35, 1924, pp. 794-802, 807-812, pl. 30, figs. 1-3, pls. 31-35, pl. 36, figs. 1-3; Proc. Acad. Nat. Sci. Phila., vol. 79, 1928, p. 299, pl. 23, figs. 1*a*, 1*b*, 2.

Test flat to inflated, lenticular, circular, selliform, or stellate. Surface glabrous or papillate, with or without costae or radial ridges. Embryonic chambers normally of one of five types: (a) Several large chambers, as many as 4 or 5, 2 or more of which are subequal in size. (b) One large chamber with several smaller chambers around its periphery. (c) Two equal or subequal chambers, adjacent to which there are smaller accessory chambers, intermediate in size between the embryonic and the normal equatorial chambers. (d) Two unequal embryonic chambers, the larger of which partly embraces the smaller. (e) Two unequal chambers, the larger of which extends entirely around the smaller except at the place of attachment of the smaller to the inside of the wall of the larger. Chamber walls pierced by cribriform perforations. Equatorial chambers in concentric rings, which are modified in the species with stellate tests. The chambers in one ring usually alternate in position with those in adjacent rings in such a way as to produce intersecting, outwardly convex curves. According to their shape as seen in plan, the following types are recognized: (a) Outer walls convex, side walls converge to a point or the inner boundary may be formed by the outer wall of a chamber of an inner ring; the transverse or the radial diameter may be the longer. (b) Type (a) grades into rhomboid or diamond-shaped chambers; the radial or transverse diagonal may be the longer. (c) Spatulate chambers, which have an elongate pointed inner end, more or less parallel sides, and either a curved or an angular outer end; radially elongate or short. (d) Hexagonal chambers, elongate or short. Although for species or even for subgenera, the types of chambers may be characteristic, there is variation, and there is intergradation between the different types. Types (a) and (b) are very

EXPLANATION OF PLATE 58

FIG.

1–5. *Orbitoides apiculata* Schlumberger. × 16. (After H. Douvillé). Early stages of megalospheric individuals showing various divisions of the chambers.

6. *Orbitoides media* (d'Archiac). × 24. (After H. Douvillé). Portion of vertical section showing median chambers and openings.

7. *Simplorbites gensacicus* (Leymerie). × 16. (After H. Douvillé). Horizontal section of early chambers of megalospheric specimen.

8–10. *Lepidorbitoides socialis* (Leymerie). Fig. 8, Central chambers of horizontal section of microspheric form. × 40. Fig. 9, Central chambers of horizontal section of megalospheric form. × 16. Fig. 10, Horizontal section of outer median chambers. × 16.

11–15. *Clypeorbis mamillata* (Schlumberger). × 16. (After H. Douvillé). Figs. 11–13, Horizontal sections of the early chambers at different levels. Fig. 14, Vertical section. Fig. 15, Horizontal section showing pillars.

16, 17. *Pseudorbitoides trechmanni* H. Douvillé. (After H. Douvillé). Fig. 16, Horizontal section of early chambers. × 32. Fig. 17, Portion of vertical section. × 16.

18. *Discocyclina*. Diagrammatic horizontal section. (After Van der Vlerk and Umbgrove).

19. *Discocyclina (Asterocyclina) stella* Gümbel. × 24. (After H. Douvillé). Portion of horizontal section.

20. *Discocyclina (Discocyclina) nummulitica* Gümbel. × 16. (After H. Douvillé). Section showing pillars and lateral chambers.

21. *Discocyclina (Discocyclina) archiaci* (Schlumberger). × 16. (After H. Douvillé). Horizontal section of early chambers.

22. *Discocyclina (Discocyclina) sennesi* H. Douvillé. × 16. (After H. Douvillé). Horizontal section of early chambers.

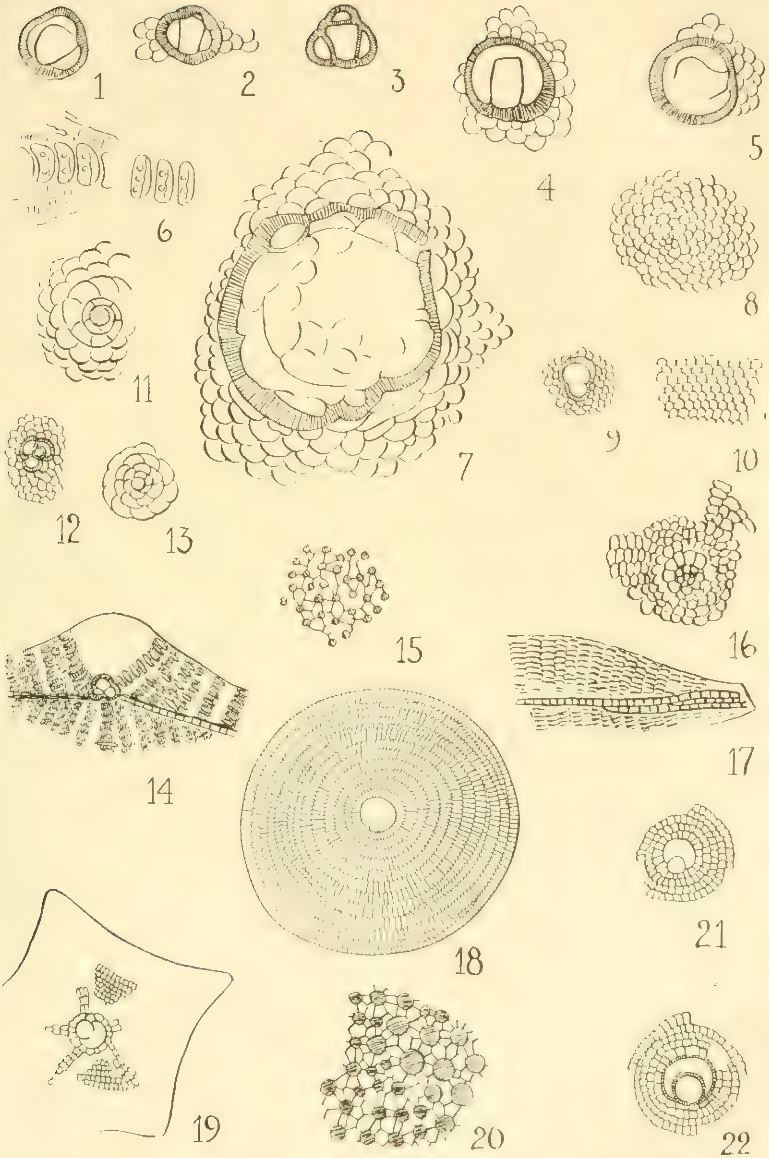


PLATE 58

similar to the equatorial chambers of *Orbitoides*. The equatorial chambers communicate with the chambers of the same ring and with those of the adjacent rings through apertures at the chamber corners by means of stolons. The roofs of the chambers are minutely cribriform. Lateral chambers well developed, their roofs minutely perforate, communication also through apertures at the chamber ends. Pillars and papillae or pustules variable in development. They may have their origin at the surface of the equatorial chamber or between the ends of the lateral chambers.

Upper Eocene to lower Miocene.

The apertures and perforations of *Lepidocyclina* have not been studied with nearly sufficient thoroughness. Sections of *Lepidocyclina* in the equatorial plane show that the inner ends of the side walls of chambers in the same ring do not in every instance reach the outer wall of the ring against which they abut, and there may be similar openings between the chambers of one ring and those in the next beyond. These openings represent passages that lead from one chamber to another in the same ring and from the chambers in one ring to those of the next outer ring. In a vertical section of a well preserved specimen, the surfaces of the radial chamber walls can be examined and end views of the apertures obtained. They may also be seen on the edges of some specimens by looking along a line perpendicular to the periphery. These openings or passages are different from the minute cribriform perforations. Hofker called the larger openings "foramina", and the cribriform perforations "pores", a nomenclature of more than doubtful validity (see Century Dictionary, under foraminifera). I shall for present purposes call the larger openings, apertures or passages; and the smaller ones, cribriform perforations.

In many, if not most species of *Lepidocyclina*, the equatorial chambers communicate with the lateral chambers only by means of cribriform perforations in the chamber roofs. Those in *L. mortoni* Cushman are from 1 to 1.5 μ in diameter. In some species the roof of the equatorial chamber appears to bend downward and form the front or external wall of the chamber. Where this occurs there may be a passage leading from the equatorial layer to the adjacent lateral layer. This seems to be the case in *L. r. douvilléi* Lisson and *L. gigas* Cushman.

The passages between chambers in the equatorial layer vary in the number in a row and the size from species to species. The largest that I have studied are in *L.* (*Polylepidina*) *chiapasensis* Vaughan, in which they are from 30 to 38 μ in diameter, and there are three in a row in a chamber 210 μ high. These passages are of the same size as those of *Orbitoides* sp. cf. *O. media* from India. The next in size are the apertures of *L.* (*Polylepidina*) *proteiformis* Vaughan, in which they are 23 to 30 μ in diameter, one in a chamber 110 μ tall, and 2 in a row in a chamber 160 μ tall. In the size of the passages, as well as in the form of the chambers, *Polylepidina* is very similar to *Orbitoides*. The size of the apertures grades to smaller sizes. In *L. miraflorensis* they are only about 10 μ in diameter and there are about 6 in a row in a chamber 120 μ high.

In most of the species of *Lepidocyclina* that I have examined, vertical sections of the equatorial layer show pectinate processes on the distal side of the outer chamber walls, and they may be seen on the broken edges of some specimens as ridges transverse to the outer faces of the chamber and parallel to the equatorial plane. Do these processes bear any relation to the passages between chambers or to the cribriform perforations? In some species it seems clear that they do not, but this is not established for other species. In *L. gigas* Cushman, processes become more or less incorporated in the chamber roofs, which seem to bend downward and form the outer chamber walls, and in places there also seem to be passages from the equatorial to the adjacent lateral chambers.

Is the communication between the equatorial chambers only by means of stoloniferous passages? In some species no other communication could be found, *L. mortoni* Cushman and *L. supera* (Conrad) for example. In other species, however, it appears that both means of communication may be present in the same species, but it is not yet established that such is really the case. Doubt regarding many of the structural features of specimens is due to changes that have resulted from fossilization. Some features may become concealed, while deceptive appearances may be produced.

This statement is made to indicate certain features of the orbitoids on which much more research is needed.

Subgenus POLYLEPIDINA Vaughan, 1924

Genoholotype, *Lepidocyclina (Polylepidina) chiapasensis* Vaughan

Polylepidina VAUGHAN, Bull. Geol. Soc. Amer., vol. 35, 1924, p. 807, pl. 30, figs. 1-3, text-figs. 4*a-e*.

Embryonic chambers 4 to 5 in number, of which one or two may be somewhat larger than the others. There may be two subequal chambers somewhat larger than two other subequal chambers, and four chambers so arranged as to form a cross. The chambers tend to grade on one hand into *Pliolepidina* and on the other into *Lepidocyclina*. *Polylepidina* in its embryonic features appears to be very primitive. Equatorial chambers with curved outer walls, sides converging to a truncate or to a pointed inner end, radial diameter shorter than the transverse. Each chamber in the type species communicates by openings with two chambers of the next inner and two of the next outer rings. The number of the apertures in a chamber wall ranges from 1 to 3, they occur in the corners of the chambers, and are from 23 to 38 μ in diameter. The equatorial chambers in their form and the apertures resemble rather closely those of *Orbitoides*. Pillars and surface papillae present.

Upper Eocene of southern Mexico.

Subgenus PLIOLEPIDINA H. Douvillé, 1915

Genoholotype, *Lepidocyclina (Pliolepidina) tobleri* H. Douvillé

Pliolepidina H. DOUVILLÉ, C. R. Acad. Sci., vol. 161, 1915, p. 727; Mém. Soc. Géol. France, 2d ser., vol. 1, Mém. no. 2, 1924, pp. 11, 43, text-figs. 34, 35.

Pliolepidina VAUGHAN, Bull. Geol. Soc. Amer., vol. 35, p. 796, pl. 33, figs. 1, 2.

Embryonic apparatus composed of a larger chamber with several smaller chambers around its periphery. Equatorial chambers with curved outer walls and converging sides and diamond-shaped, both forms in the same specimen.

Upper Eocene, Island of Trinidad, Panama, southern Mexico, East Indies.

Professor Douvillé suggests that the specimens he placed in this subgenus might be teratologic, but it appears to me to be a valid subgenus. I am inclined to consider both *Polylepidina* and *Pliolepidina* as more primitive forms than *Lepidocyclina* s. s.

Multicyclina proposed by Cushman (U. S. Nat. Mus. Bull. 103, 1919, p. 96, pl. 41, figs. 2-4) as a subgenus of *Lepidocyclina*, with *Lepidocyclina duplicata* Cushman as the holotype, was based on microspheric individuals of a species, the megalospheric individuals of which have pliolepidine embryonic chambers.

Subgenus LEPIDOCYCLINA Gümbel, 1868

Holotype, *Lepidocyclina mantelli* (Morton) Gümbel

Isolepidina H. DOUVILLÉ, C. R. Acad. Sci., vol. 161, 1915, p. 724; Mém. Soc. Géol. France, n. s., vol. 1, Mém. no. 2, 1924, pp. 11, 34 *et seq.*

Embryonic chambers bilocular, equal or subequal in size, separated by a straight wall. Equatorial chambers of all the kinds enumerated in stating the characters of the genus. Lateral chambers and pillars of different kinds.

Upper Eocene to upper Oligocene and perhaps lower Miocene.

Subgenus NEPHROLEPIDINA H. Douvillé, 1911

Genoholotype, *Lepidocyclina marginata* (Michelotti)

Nephrolepidina H. DOUVILLÉ, Philippine Jour. Sci., vol. 6, 1911, p. 59; Samml. Geol. Reichsmus., Leiden, ser. 2, vol. 8, 1912, pp. 269, 270; C. R. Acad. Sci., vol. 161, 1915, p. 727; Mém. Soc. Géol. France, n. s., vol. 1, Mém. no. 2, 1924, pp. 11, 46 *et seq.; Ibid.*, vol. 2, Mém. no. 2, pp. 73 *et seq.*, 113 *et seq.*

Amphilepidina H. DOUVILLÉ, C. R. Acad. Sci., vol. 175, 1922, p. 553; Mém. Soc. Géol. France, n. s., vol. 1, Mém. no. 2, 1924, pp. 11, 44 *et seq.; ibid.*, vol. 2, Mém. no. 2, 1925, p. 100 *et seq.*

Embryonic chambers bilocular, reniform, a smaller partly embraced by a larger chamber. Equatorial chambers spatulate, with curved outer wall, or the distal end of the chamber is angular. Pillars and papillae present.

Upper Eocene to lower Miocene.

After establishing the subgeneric name *Nephrolepidina*, Professor Douvillé proposed the subgeneric designation *Amphilepidina* for those species of *Lepidocyclina* that have reniform embryonic chambers and spatulate equatorial chambers, and in 1925 stated that *L. sumatrensis* may be considered the type. The application of a similar procedure to *Lepidocyclina* s. s. would divide it into two or more subgenera. Furthermore, according to Professor Douvillé's own figures (see 1924, p. 46, figs. 40-41) equatorial chambers with both curved and angular outer walls occur in the same specimen. For this and other reasons it is my opinion that there is no need for *Amphilepidina*.

There are several stellate species of *Nephrolepidina*. Among them there are *Lepidocyclina radiata* Martin and *L. martini* Schlumberger in the lower Miocene of Java, and a new species from Cuba, which I have described and figured but have not yet published.

Subgenus EULEPIDINA H. Douvillé, 1911

Holotype, *Lepidocyclina dilatata* (Michelotti)

Eulepidina H. DOUVILLÉ, Philippine Jour. Sci., vol. 6, 1911, p. 59; Samml. Geol. Reichsmus. Leiden, vol. 2, 1912, pp. 268, 269; C. R. Acad. Sci., vol. 161, 1915, p. 726; Mém. Soc. Géol. France, vol. 1, Mém. no. 2, 1924, pp. 11, 48, 49; *Ibid.*, vol. 2, Mém. no. 2, 1925, pp. 66 *et. seq.*, 96 *et. seq.*

EXPLANATION OF PLATE 59

FIG.

1. *Lepidocyclina (Polylepidina) chiapasensis* Vaughan. × 16. (After Vaughan). Early chambers in oblique section.

2–4. *Lepidocyclina (Pliolepidina) tobleri* H. Douvillé. × 24. (After H. Douvillé). Fig. 2, Horizontal section of early megalospheric chambers. Figs. 3, 4, Vertical sections of early megalospheric chambers.

5. *Lepidocyclina (Lepidocyclina) ocalana* Cushman. × 16. (After H. Douvillé). Horizontal section of early chambers of megalospheric form.

6. *Lepidocyclina (Nephrolepidina)*. Diagrammatic horizontal section. (After Van der Vlerk and Umbgrove).

7. *Lepidocyclina (Nephrolepidina) chaperi* Lemoine and R. Douvillé. × 16. (After H. Douvillé). Early chambers of horizontal section of megalospheric form.

8–10. *Lepidocyclina (Eulepidina)* sp.? × 16. (After H. Douvillé). Fig. 8, Horizontal section of early chambers of megalospheric form. Figs. 9, 10, Vertical sections of same.

11. *Lepidocyclina (Eulepidina) dilatata* (Michelotti). × 16. (After H. Douvillé). Horizontal section of early chambers of megalospheric form.

12. *Miogypsina*. Diagrammatic horizontal section. (After Van der Vlerk and Umbgrove).

13, 14. *Helicolepidina spiralis* Tobler. × 24. (After H. Douvillé). Fig. 13, Horizontal section of early chambers of megalospheric form. Fig. 14, Portion of vertical section.

15, 16. *Omphalocyclus macroporus* (Lamarck). (After H. Douvillé). Fig. 15, Vertical section. × 8. Fig. 16, Horizontal section. × 16.

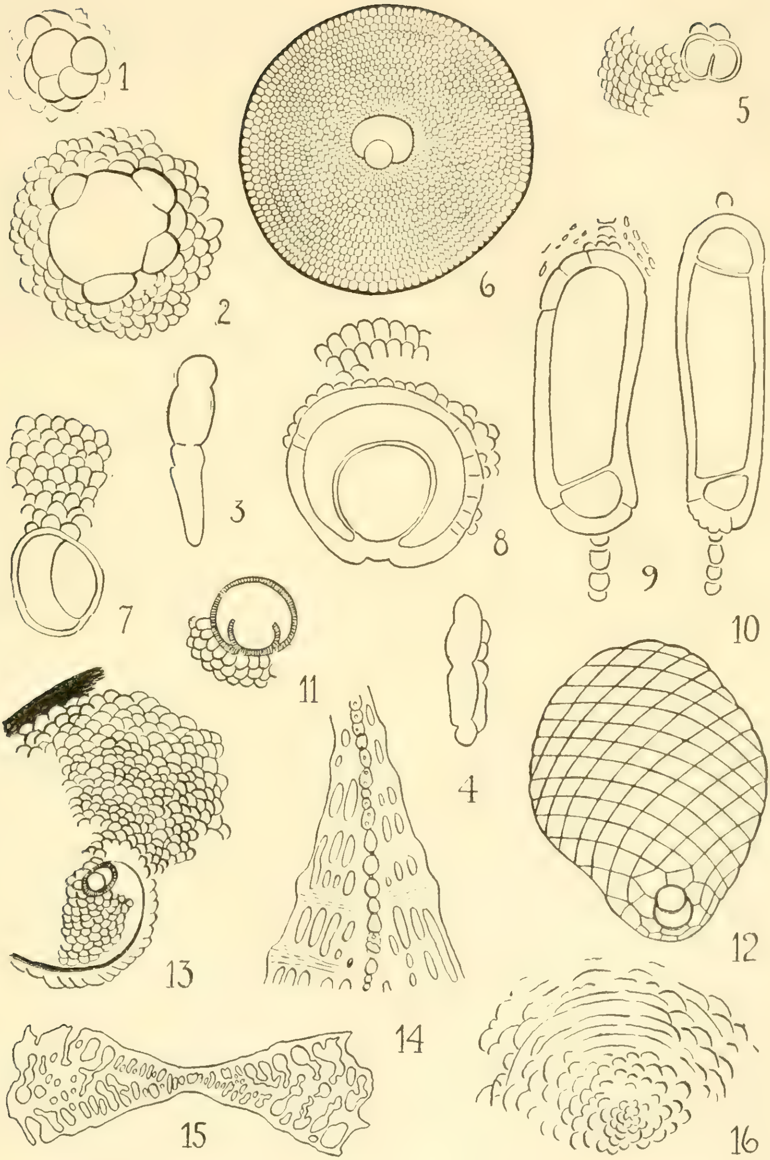


PLATE 59

Embryonic chambers bilocular, a larger chamber completely surrounds a smaller one, except at the place where the smaller is attached to the inside of the wall of the larger. The equatorial chambers are spatulate, the outer wall curved or angular. The radial diameter may be relatively long or rather short.

Middle Oligocene to Miocene.

Nephrolepidina and *Eulepidina* intergrade.

Subfamily Miogypsininae

Genus MIOGYPSINA Sacco, 1893

Plate 56, figures 3, 8; plate 57, figure 2; plate 59, figure 12

Genoholotype, *Nummulites globulina* Michelotti

Miogypsina Sacco, Bull. Soc. belge Géol., vol. 7, 1893, p. 205.

Heterosteginoides Cushman, U. S. Nat. Mus. Bull. 103, 1919, p. 97, pl. 43, figs. 1-8.

Test compressed, usually subtrigonal in plan, surface papillate. Embryonic apparatus excentric in position, in some species apical or subapical, composed of two equal or subequal chambers, around which there are several chambers whose features are intermediate in character between those of the embryonic and those of the usual equatorial chambers. The early chambers may be distinctly spiral in arrangement, later growth mostly on only a segment of the periphery and thereby producing a triangular outline. Equatorial chambers rhomboid or elongate hexagonal, roofs and lateral walls pierced by cribriform perforations. Lateral chambers present, irregular in development. Pillars developed, terminating in surface papillae.

Oligocene to Miocene.

Genus HELICOLEPIDINA Tobler, 1922

Plate 59, figures 13, 14

Genoholotype, *Helicolepidina spiralis* Tobler

Helicolepidina Tobler, Ecologae geol. Helvetiae, vol. 17, 1922, pp. 380-384, 3 text figs.

Helicolepidina H. Douvillé, Ibid., vol. 17, 1923, pp. 566-569, 2 text figs.

Test rather small, maximum known diameter about 4 mm., lenticular, slightly asymmetrical with reference to the equatorial plane; central part arched, sloping to a rather sharp edge. Surface papillate. Embryonic chambers bilocular, one somewhat larger than the other, separated by a straight or slightly curved wall, the smaller chamber may be deformed to the contour of the larger, walls pierced by minute cribriform perforations. Equatorial chambers of two kinds: (a) A spiral of a single row of larger chambers which extend through a little more than a complete whorl. The walls of these chambers slope in a curve from their anterior inner ends backward to their posterior outer ends. Outside this row there is a row of smaller spiral chambers. (b) Smaller chambers which occupy most of the equatorial plane. In larger specimens the growth may become cyclical. The arrangement of the chambers is somewhat irregular with a tendency toward occurrence along radial lines. The outer wall curved; in the proximal corners of the chambers openings for communication with adjacent chambers, similar to those in *Lepidocyclina*. In addition to these larger openings, there appear to be minute cribriform perforations. Roofs cribriform perforate. Lateral chambers irregular but well developed, floor and roofs with cribriform perforations, communications also by passages for protoplasmic stolons. Pillars present.

Upper Eocene of the Caribbean region and Peru.

Subfamily Omphalocyclinae

Genus OMPHALOCYCLUS Bronn, 1852

Plate 56, figures 4-6; plate 59, figures 15, 16

Genoholotype, *Orbulites macroporus* Lamarck, 1816

Omphalocyclus BRONN, Lethaea geognost., ed. 3, vol. 2, 1851-52, p. 95.

Omphalocyclus H. DOUVILLÉ, Soc. Géol. France, 4th ser., vol. 20, 1921, p. 228, pl. 8, figs. 5-14, text figs. 35-37.

Sporadotrema HOFKER, Naturhist. Maanbl. Limburg, Jahrg. 15, 1926, p. 62, pl. on p. 64, 19 figs. (not HICKSON, 1911).

Test biconcave lenticular. Embryonic chambers quadrilocular. In the central part of the test there is a single layer of chambers[1], which as growth progresses becomes double, or a

[1] An enlarged photograph of a specimen from 50 mi. n. e. of Sibi, Baluchistan, before me as I write this note, shows two layers of chambers immediately adjacent to the embryonic chambers on each side of them. The two layers extend for seven chambers from the embryonic chambers, and from there outward there is an intermediate layer of chambers.

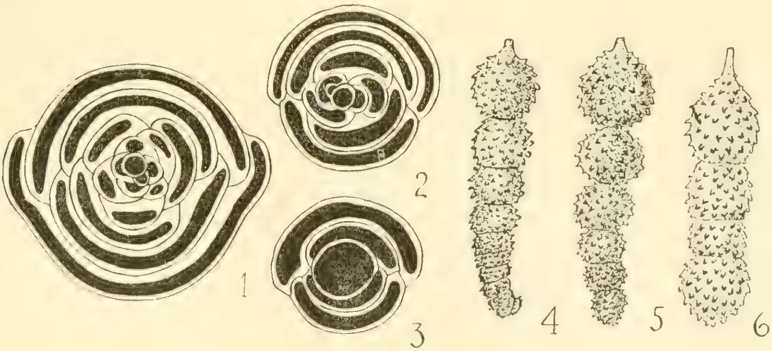
double layer of chambers, and later a median layer is intercalated between the chambers of the lateral layers. The median layer is composed of concentric rings of chambers, the chambers of one ring alternating in position with those of adjacent rings. The outer walls of the chambers are only slightly curved or are nearly straight. The median chambers communicate with the lateral chambers through apertures in the floors of the latter and those in the periphery open to the outside through marginal apertures which rather regularly alternate in position and are arranged in one, two, three, or four rows. Both the roofs and sides of the chambers are pierced by very fine perforations similar to those of the more typical orbitoids. The superficial or lateral chambers are arranged in concentric rings, with those of each ring alternating in position with those of adjacent rings. Each chamber communicates with two chambers of both the preceding and the succeeding ring. There are also cribriform perforations. On the outer surface a network of lozenge-shaped meshes is produced by the immediately underlying layer. Pillars, which may be lamellate, may be formed and produce wavy radiating costae.

Maestrichtian.

CHAPTER X

TRIMORPHISM

This work would be incomplete without a short discussion of the phenomena to which the name Trimorphism has been given by Hofker. The microspheric and megalospheric forms have already been discussed in some detail. There may be more than one development of the megalospheric form between two generations of microspheric ones. The size of the megalospheric proloculum in these intermediate generations is not constant, and the resulting test lacks some of the early stages. With the largest megalospheric proloculum, the adult characters are taken on almost at once. With the smaller megalospheric proloculum,



Figs. 1—3. *Idalina antiqua* (d'Orbigny). (After Munier Chalmas and Schlumberger). Fig. 1. Section of microspheric specimen with quinqueloculine early stage followed by triloculine and biloculine stages. Fig. 2. Section of megalospheric specimen with triloculine early stage followed by a biloculine stage, the quinqueloculine stage skipped. Fig. 3. Section of a megalospheric specimen with the biloculine stage following the proloculum, the triloculine and quinqueloculine stages skipped. Figs. 4—6, after d'Orbigny. Fig. 4. Microspheric form "*Marginulina hirsuta* d'Orbigny." Fig. 5. Megalospheric form "*Dentalina floscula* d'Orbigny" Fig. 6. Megalospheric form "*Nodosaria aculeata* d'Orbigny."

some of the early stages skipped in the preceding are now present. With the microspheric proloculum, the greatest number of early stages are present.

The problem involved would not be so perplexing nor so troublesome did it not involve our nomenclature. In the figure are shown three forms from the Miocene of the Vienna Basin. The first of these was named by d'Orbigny "*Nodosaria aculeata*". It has a very large proloculum, even larger than the succeeding chamber. There are but four chambers in the test arranged in a straight line and would be called *Nodosaria* with little question. The second was named "*Dentalina floscula*" by d'Orbigny. It has a smaller megalospheric proloculum, six chambers in gradually increasing size and the axis of the test is curved. The third was named "*Marginulina hirsuta*" by d'Orbigny. It has a microspheric proloculum, nine chambers or more, the early ones somewhat compressed, but the final ones exactly like those in the other two forms. The ornamentation in the adult of all three is the same. All three forms occur together, and it is evident from a study of a suite of specimens from the type locality that all three forms belong to a single species. The microspheric form is the only one that has the full characters. The three forms may be graphically represented using P for the proloculum, M for the *Marginulina* stage, D for the *Dentalina* stage, and N for the *Nodosaria* stage as follows:

P+M+D+N	for the microspheric form.
P+D+N	for that with a smaller megalospheric form.
P+N	for that with a larger megalospheric form.

It becomes difficult to name such forms. There are three generic names involved as well as three specific ones. The specific names can be disposed of on the basis of the usual application of the Rules of Nomenclature the first described, one holding its specific name and dropping the other two. With the generic names the difficulty is increased. As the microspheric form is the only one that shows the full characters, it would seem best to call all the specimens *Marginulina aculeata* (d'Orbigny), and consider the two megalospheric forms and others of the same sort as specimens with incomplete stages. It is obvious that this could be done only with the knowledge of all the forms of the species.

Another example may be seen in *Idalina antiqua* (d'Orbigny). In the section of a specimen with a microspheric proloculum, there are 15 chambers developed after the proloculum. The early chambers I-VIII are quinqueloculine, IX-XII triloculine, and the remainder biloculine, the normal sequence in microspheric forms of this group. Fig. 2 is a section of a specimen with a small megalospheric proloculum and having but 9 chambers after the proloculum. There is no truly quinqueloculine stage, chambers I-VI showing the triloculine stage and the remainder biloculine. In the figure is a section of a specimen with a very large megalospheric proloculum and with but 4 chambers after it, all of them biloculine. If this were not an involute species covering the early stages an exactly parallel case would obtain to that previously given. Graphically the stages may be represented as follows:

P+Q+T+B	for the microspheric form.
P+T+B	for that with a smaller megalospheric proloculum.
P+B	for that with a larger megalospheric proloculum.

Hofker in his work on the Foraminifera of the Siboga Expedition gives many examples along this same line, and they are well known to all students who have worked with many forms. There are many species of *Quinqueloculina* in which the microspheric and megalospheric forms are known and in which no development goes beyond the quinqueloculine stage. *Quinqueloculina* then is a good genus for such forms. There are many species of *Triloculina* in which the microspheric form has a quinqueloculine young and the larger megalospheric forms do not go beyond a triloculine stage. For all such forms, *Triloculina* becomes a good genus. *Biloculina* may have all three forms: the microspheric quinqueloculine, then triloculine, and finally biloculine; the form with the smaller megalospheric proloculum triloculine then biloculine and lastly individuals with a very large megalospheric proloculum that become at once biloculine. For all these, *Pyrgo* (*Biloculina*) becomes a perfectly good genus.

So in the case of other groups if all three forms seem to show different generic characters, there is difficulty, but if one generic character is involved, the generic problem is not difficult. It may be shown that when all three forms occur without the addition of a new character, a primitive form is under observation. In the microspheric form which shows several stages, it may be safely assumed that they are taken on in the order in which they once developed, and that they represent more primitive genera which are already known or are to be looked for in either the recent or fossil series. A classification built on this basis, as is the one here, must be close to the truth of the actual development of the different groups.

A closer understanding of the results of the trimorphism must lead to a simplification of our treatment of species. It is very evident that it is unsafe to describe a species entirely from the megalospheric form even though that may be the more common one. Sections should be obtained, if necessary to know whether the worker is dealing with a microspheric or a megalospheric form that he may search his material for the microspheric form if he does not have it. It will undoubtedly be possible to unite species under a single name where they now may be placed as different species and under different genera. This task of simplification and grouping together of forms does not mean that there are not very many species and genera of the foraminifera, but that the known facts of development have not been taken into account in naming forms or in grouping them.

CHAPTER XI

BIBLIOGRAPHY

As there are to date between 4,000 and 5,000 papers dealing partially or exclusively with foraminifera, the preparation of a condensed bibliography covering all the phases of the work is a considerable task. The bibliography as originally projected for this volume has twice been cut down, and the present list is the result. Many of the shorter works or those dealing with special groups like the "Nummulites" have been left out. Papers without illustrations have for the most part also been left out unless they have particular features as to region or special subject matter. Many of the newer workers on the foraminifera do not easily read other languages than their own, yet many of the most important papers on the foraminifera are published in languages other than English. The figures however, with the generic and specific names in Latin, are the same in all languages, and for this reason the more important works are here given regardless of the original language. Some reading knowledge of French, German, and Italian is essential to one who is to do any serious research work on the foraminifera. The American foraminifera are in many formations, especially the Cretaceous, so closely identical with the European that a careful study of the European literature is an absolute necessity as is also a study of European material.

The works will be found under various headings, the Recent, Tertiary, Cretaceous, Jurassic, Triassic, and Palaeozoic with the papers grouped roughly by geographic divisions where there are many. Papers are arranged alphabetically by authors under these headings. The later papers on Classification, Structure, &c., are arranged by authors. It has been necessary to place papers under one or another heading whereas it would have been useful to have it under several headings, but space has had to be considered and a paper is placed under the heading where it seems most appropriate. References are given to the best known bibliographies which with the Zoological Record will give the titles of practically all papers published on the foraminifera. It is hoped that this condensed list will furnish the worker with at least a clue to the more important papers.

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