TREATISE ON
INVERTEBRATE PALEONTOLOGY

Prepared under the Guidance of the
Joint Committee on Invertebrate Paleontology

Paleontological Society | *Society of Economic Paleontologists and Mineralogists* | *Palaeontographical Society*

Directed and Edited by

RAYMOND C. MOORE

Part D
PROTISTA 3
Protozoa (Chiefly Radiolaria and Tintinnina)

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JOINT COMMITTEE ON INVERTEBRATE PALEONTOLOGY

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PARTS

The indicated Parts (excepting the first and last) are to be published at whatever time each is ready. All may be assembled ultimately in bound volumes. The list of contributing authors is subject to change.

A—INTRODUCTION. **B**—PROTISTA 1 (chrysomonads, silicoflagellates, coccolithophorids, diatoms, xanthomonads, dinoflagellates, euglenids). **C**—PROTISTA 2 (foraminifers, testaceans). **D**—PROTISTA 3 (radiolarians, tintinnines). **E**—PORIFERA (sponges, archaeocyathids). **F**—COELENTERATA (hydrozoans, scyphozoans, anthozoans). **G**—BRYOZOA. **H**—BRACHIOPODA. **I**—MOLLUSCA 1 (chitons, scaphopods, gastropods). **J**—MOLLUSCA 2 (gastropods). **K**—MOLLUSCA 3 (nautiloid cephalopods). **L**—MOLLUSCA 4 (ammonoid cephalopods). **M**—MOLLUSCA 5 (dibranchiate cephalopods). **N**—MOLLUSCA 6 (pelecypods). **O**—ARTHROPODA 1 (trilobitomorphs). **P**—ARTHROPODA 2 (chelicerates). **Q**—ARTHROPODA 3 (ostracodes). **R**—ARTHROPODA 4 (branchiopods, cirripeds, malacostracans, myriapods, insects). **S**—ECHINODERMATA 1 (cystoids, blastoids, carpoids, eocrinoids, paracrinoids, edrioasteroids, haplozoans). **T**—ECHINODERMATA 2 (crinoids). **U**—ECHINODERMATA 3 (asterozoans, echinozoans). **V**—GRAPTOLITHINA. **W**—MISCELLANEA (worms, conodonts, conulariids, problematical fossils). **X**—ADDENDA (index).

Part G, Bryozoa (p. i-xiii, 1-253, about 2,000 individual figures, cloth-bound) was published in December, 1953. Copies are available on orders sent to the Geological Society of America (419 West 117th Street, New York) with payment of three dollars ($3.00) in U.S. currency for each copy. This price includes cost of wrapping and shipping to any address in the world.

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EDITORIAL PREFACE

The aim of the *Treatise on Invertebrate Paleontology,* as originally conceived and consistently pursued, is to present the most comprehensive and authoritative, yet compact statement of knowledge concerning invertebrate fossil groups that can be formulated by collaboration of competent specialists in seeking to organize what has been learned of this subject up to the mid-point of the present century. Such work has value in providing a most useful summary of the collective results of multitudinous investigations and thus should constitute an indispensable text and reference book for all persons who wish to know about remains of invertebrate organisms preserved in rocks of the earth's crust. This applies to neozoologists as well as paleozoologists and to beginners in study of fossils as well as to thoroughly trained, long-experienced professional workers, including teachers, stratigraphical geologists, and individuals engaged in research on fossil invertebrates. The making of a reasonably complete inventory of present knowledge of invertebrate paleontology may be expected to yield needed foundation for future research and it is hoped that the *Treatise* will serve this end.

The *Treatise* is divided into parts which bear index letters, each except the initial and concluding ones being defined to include designated groups of invertebrates. The chief purpose of this arrangement is to provide for independence of the several parts as regards date of publication, because it is judged desirable to print and distribute each segment as soon as possible after it is ready for press. Pages in each part will bear the assigned index letter joined with numbers beginning with 1 and running consecutively to the end of the part. When the parts ultimately are assembled into volumes, no renumbering of pages and figures is required.

The outline of subjects to be treated in connection with each large group of invertebrates includes (1) description of morphological features, with special reference to hard parts, (2) ontogeny, (3) classification, (4) geological distribution, (5) evolutionary trends and phylogeny, and (6) systematic description of genera, subgenera, and higher taxonomic units. In general, paleoecological aspects of study are omitted or little emphasized because comprehensive treatment of this subject is being undertaken in a separate work, prepared under auspices of a committee of the United States National Research Council. A selected list of references is furnished in each part of the *Treatise.*

Features of style in the taxonomic portions of this work have been fixed by the Editor with aid furnished by advice from the Joint Committee on Invertebrate Paleontology representing the societies which have undertaken to sponsor the *Treatise.* It is the Editor's responsibility to consult with authors and co-ordinate their work, seeing that manuscript properly incorporates features of adopted style. Especially he has been called on to formulate policies in respect to many questions of nomenclature and procedure. The subject of family and subfamily names is reviewed briefly in a following section of this preface, and features of *Treatise* style in generic descriptions are explained.

A generous grant of $25,000 has been made by the Geological Society of America for the purpose of preparing *Treatise* illustrations. Administration of expenditures has been in charge of the Editor and most of the work by photographers and artists has been done under his direction at the University of Kansas, but sizable parts of this program have also been carried forward in Washington and London.

FAMILIAL NAMES

Any formally designated assemblage of genera having indicated rank below that of a suborder (or exceptionally, a sub-subordinal category such as "division" introduced above superfamily) is recognized as one of the family-group types of taxonomic units (taxa; singular, taxon) (Copenhagen Decisions on Zoological Nomenclature, 1953). These assemblages may include, in order of increasing comprehensiveness, subtribe, tribe, supertribe, subfamily, family, and superfamily; in addition, CAMPBELL in this volume recognizes a taxon called subsuperfamily, which is intermediate between family and superfamily.

Many problems are encountered in the nomenclature of family-group taxa and correct definition of the authorship and date of original publication of family-group names. This depends partly on acceptance of the co-ordinate status of all family-group taxa as regards nomenclature and partly on adoption of priority of publication as the main determinant for fixation of family-group names. Stability and uniformity of nomenclature are important objectives, and in a work like the *Treatise* it is very desirable to furnish information as completely and compactly as possible on the manner in which each accepted family-group name is derived. Rules adopted as guides in preparing systematic portions of *Treatise* text include the following provisions concerning familial names.

(1) Family and subfamily names are formed by adding the prescribed endings -idae and -inae, respectively, to the stem of the generic name chosen as nomenclatorial type of the assemblage. This accords with stipulations given in Article 4 of the International Rules of Zoological Nomenclature. No restriction is imposed on an author in choosing the type genus of a new family or subfamily, but a subfamily that includes the type genus of the family to which it belongs (nominotypical subfamily) must be named after such genus. The type genus of a family or subfamily need not be the first-published among those included, but once fixed by publication, it cannot be replaced by another genus in the assemblage unless the type genus in question is transferred to a family or subfamily having an earlier chosen different type genus.

(2) Family-group names are co-ordinate, which signifies that a name published with the ending -idae may be changed to -inae or vice versa without change in citation of author and date from those of the original publication. Family-group taxa of other ranks are treated likewise.

(3) The first-published name of any family-group assemblage shall be accepted unless it is unavailable, as in case of names based on junior homonyms or objective synonyms or on invalid emendations of generic names, and unless the name conflicts with requirements stated in paragraph 4.

(4) If a family is divided into subfamilies or a subfamily into tribes, the name of no such subfamily or tribe can antedate the family name. Every family divided into subfamilies must have a nominotypical *(sensu stricto)* subfamily, which has as its type genus the same one which serves as type of the family, and because the name of the family is based on the generic name which (among all included in the assemblage) was first published as type of a familial category, this applies also to the nominotypical subfamily. The same principle applies to subfamilies divided into tribes.

The author and date of the nominotypical subfamily invariably are identical with those of the family (and tribe with subfamily and family), without reference to whether the author of the family or some subsequent author introduced subdivisions. Thus, the family Astrocoeniidae KOBY, 1890, contains the subfamilies Astrocoeniinae KOBY, 1890 (not Astrocoeniinae FELIX, 1898), and Pinacophyllinae VAUGHN & WELLS, 1943; KOBY did not subdivide the family. Just as the nominotypical subgenus of a genus must be ascribed to the author who erected the genus and must bear the same date, so a nominotypical subfamily cannot be attributed to an author other than the one who first selected the genus that serves the family and nominotypical subfamily as type and it cannot bear a date subsequent to that of erecting the family.

(5) Change from the originally published form of family and subfamily names is required (a) if the taxonomic rank assigned to the assemblage is altered, (b) if the stem of the nominotypical generic name is incorrectly distinguished, or (c) if the name of the type genus is changed.

(6) Changes of the sort specified in 5a and 5b do not call for change in citing author and date of family or subfamily assemblages, for these remain as in the original publication. Yet it is desirable to know exactly how an originally published familial or subfamilial name has been modified, and for completeness of information, when and by whom. Such documentation aids understanding of adopted nomenclature and facilitates work of any student concerned with research on a group of invertebrates. It is appropriate for the *Treatise* to supply records of this sort, as illustrated by the following examples. (a) NICHOLSON in 1889 proposed a family of rugose corals called Streptelasmidae, based on the genus *Streptelasma,* whereas the cor-

rect name, first published by WEDEKIND in 1927, is Streptelasmatidae. This seems like a minor sort of emendation but it is needful. The *Treatise* form of citation is "Family Streptelasmatidae NICHOLSON, in NICHOLSON & LYDEKKER, 1889 [as Streptelasmidae; emend. WEDEKIND, 1927]." (b) BASSLER in 1935 defined a subfamily of bryozoans named Exochellinae which in *Treatise* Part G he recognized as an independent family. This is indicated by the entry "Family Exochellidae BASSLER, 1935 [as Exochellinae; emend. BASSLER, 1953]."

(7) A statement given under this number in the Editorial Preface of *Treatise* Part G (Bryozoa) (1953) refers to change of familial names based on change in the name of the type genus, pointing out that the familial name is not replaced by one based on some other genus but is altered to accord with revision of the nominotypical genus. Recommendation approved by the International Zoological Congress at Copenhagen in 1953 calls for restriction of such familial name changes to those which are found to be based on junior homonyms. It is proposed that the new Rules shall provide for retention of familial names having priority over others if the nominotypical genus proves to be an objective junior synonym and likewise if it is judged to be a subjective junior synonym. In the interest of stability of nomenclature, it is appropriate to accept priority of publication as ground for sustaining a familial name based on a junior subjective synonym, for opinions of different workers as to the synonymy of generic names founded on different type species may not agree and opinions of the same worker at different times also may change. This does not pertain to objective synonyms, however, and accordingly *Treatise* authors who conclude that stability of nomenclature is served by adopting familial names (particularly long-used ones) based on senior objective synonyms are encouraged to recognize such names rather than an older familial name based on a junior objective synonym.

An example of alteration of a familial name which is required by discovery that the originally designated nominotypical genus is a junior homonym is replacement of Electrinidae by Electridae as applied to an assemblage of cheilostome bryozoans. Here a junior homonym *(Electrina)* yields to a senior subjective synonym *(Electra)* as name giver to the family. The form of *Treatise* reference is "Family Electridae LAGAAIJ, 1952 [*pro* Electrinidae D'ORBIGNY, 1851, *ex Electrina* D'ORBIGNY, 1851 (*non* BAIRD, 1850) (= *Electra* LAMOUROUX 1816)]." The citation of a widely accepted family name for corals that involves objective synonyms is "Family Heliolitidae LINDSTRÖM, 1876 [*pro* Palaeoporidae M'COY, 1851, *ex Palaeopora* M'COY, 1849 (=*Heliolites* DANA, 1846, obj.)]; *pro* Heliolithidae LINDSTRÖM, 1873, *ex Heliolithes* LINDSTRÖM, 1873 (=*Heliolites* DANA, 1846, obj.)]."

(8) Names not available for family-group assemblages include (a) vernacular designations, such as membranipores (English), Pisokrinoiden (German), and Aulacocératidés or Syringoporiens (French); (b) terms not founded on generic names, as for example "Hastatide STOLLEY, 1919," for which no corresponding generic name exists (derivation presumably based on the "section" of the broad genus *Belemnites* called Hastati, after the species *Hibolites hastatus*); (c) names not originally of suprageneric rank, as terms derived from trivial names of species; (d) names formed from the stem of generic or subgeneric names which are junior homonyms or synonyms; (e) names based on a type other than that having priority of designation among all genera and subgenera included in the assemblage; and (f) names based on invalid emendations of generic or subgeneric names, as for example "Family Zitteloceratidae," based on invalid emendation of *Zittelloceras* HYATT to *Zitteloceras* (even though this genus patently was named for ZITTEL). Present International Rules do not contain some of these stipulations.

STYLE IN GENERIC DESCRIPTIONS

DEFINITION OF NAMES

Most generic names are distinct from all others and are indicated without ambiguity by citing their originally published spelling accompanied by name of the author and date of first publication. If the same generic name has been applied to 2 or more distinct taxonomic units, however, it is necessary to differentiate such homonyms, and this calls for distinction between junior homonyms and senior homonyms. Because a junior homonym is invalid, it must be replaced by some other name. For example, *Callopora* HALL, 1851, introduced for Paleozoic trepostome bryozoans, is invalid because GRAY in 1848 published the same name for Cretaceous-to-Recent cheilostome bryozoans, and BASSLER in 1911 introduced the new name *Hallopora* to replace HALL's homonym. The *Treatise* style of entry is: "*Hallopora* BASSLER, 1911 [*pro Callopora* HALL, 1851 (*non* GRAY, 1848)]." A senior homonym is valid, and in so far as the *Treatise* is concerned, such names are handled according to whether the junior homonym belongs to the same major taxonomic division (class or phylum) as the senior homonym or to some other; in the former instance, the author and date of the junior homonym are cited as "*Diplophyllum* HALL, 1851 [*non* SOSHKINA, 1939]"), but in the latter no mention of the existence of a junior homonym is made.

CITATION OF TYPE SPECIES

The name of the type species of each genus and subgenus is given next following the generic name with its accompanying author and date, or after entries needed for definition of the name if it is involved in homonymy. The originally published combination of generic and trivial names for this species is cited, accompanied by an asterisk (*), with notation of the author and date of original publication. An exception in this procedure is made, however, if the species was first published in the same paper and by the same author as that containing definition of the genus which it serves as type; in such case, the initial letter of the generic name followed by the trivial name is given without repeating the name of the author and date, for this saves needed space. Examples of these 2 sorts of citations are as follows: "*Diplotrypa* NICHOLSON, 1879 [**Favosites petropolitanus* PANDER, 1830]" and "*Chainodictyon* FOERSTE, 1887 [**C. laxum*]." If the cited type species is a junior synonym of some other species, the name of this latter also is given, as "*Acervularia* SCHWEIGER, 1819 [**A. baltica* (=**Madrepora ananas* LINNÉ, 1758)]."

It is judged desirable to record the manner of establishing the type species, whether by original designation of by subsequent designation, but various modes of original designation are not distinguished. According to convention adopted in the *Treatise,* absence of any indication as to manner of fixing the type species is to be understood as signifying original designation. If the type species has been fixed by subsequent designation, this is indicated by the letters "SD" followed by the name of the author and date of such subsequent designation. An example is "*Hexagonaria* GÜRICH, 1896 [**Cyathophyllum hexagonum* GOLDFUSS, 1826; SD LANG, SMITH, & THOMAS, 1940]."

SYNONYMS

Citation of synonyms is given next following record of the type species and if 2 or more synonyms of differing date are recognized, these are arranged in chronological order. Objective synonyms are indicated by accompanying designation "(obj.)," others being understood to constitute subjective synonyms. Examples showing *Treatise* style in listing synonyms are "*Calapoecia* BILLINGS, 1865 [**C. anticostiensis;* SD LINDSTRÖM, 1833] [=*Columnopora* NICHOLSON, 1874; *Houghtonia* ROMINGER, 1876]" and "*Staurocyclia* HAECKEL, 1882 [**S. cruciata* HKL., 1887] [=*Coccostaurus* HKL., 1882 (obj.); *Phacostaurus* HKL., 1887 (obj.)]." A synonym which is also a homonym is recorded in the following: "*Lyopora* NICHOLSON & ETHERIDGE, 1878 [**Palaeopora? favosa* M'COY, 1850] [=*Liopora* LANG, SMITH, & THOMAS, 1940 (*non* GIRTY, 1915)]."

ABBREVIATIONS

Some authors' names and most stratigraphic and geographic names are abbreviated in order to save space. General principles for guidance in determining what names should be abbreviated are frequency of repetition, length of name, and avoidance of ambiguity. Abbreviations used in this division of the *Treatise* are explained in the following alphabetically arranged list.

Abbreviations of Stratigraphic and Place Names and Words Used in Bibliographical Citations

Accad., Accademia
Am., America
Austral., Australia
Bd., Band
Belg., Belgium
Berrias., Berriasian
Bull., Bulletin
C., Central
Calif., California
Cam., Cambrian
Carb., Carboniferous
Circumtrop., Circumtropical
Comm., Committee
Comp., Comparative
Cosmop., Cosmopolitan
Cret., Cretaceous
Dept., Department
Dev., Devonian
E., East
emend., emended by
Eng., England
Eoc., Eocene
Eur., Europe
fasc., fascicle
fig., figure, -s
Fr., France
Geol., Geological, Geology
géol., géologique
Ger., Germany
illus., illustrated
Imp., Imperial
Inst., Institute
ital., italiana
Jour., Journal
Jur., Jurassic
L., Lower
M., Middle
Medd., Meddeelingen
Mio., Miocene
Mts., Mountains
Mus., Museum
N., North
N.Am., North America
Natl., National
Naturw., Naturwissenschaften
Neocom., Neocomian
N.Y., New York
obj., objective
Oceanogr., Oceanographic
Ord., Ordovician
p., page, -s
Palaeontogr., Palaeontographica
Paleoc., Paleocene
Paleont., Paleontology
Perm., Permian
pl., plate, -s
Plio., Pliocene
Pub., Publication
Rec., Recent
Rept., Report
Riv.. Rivista
Roy., Royal
Russ., Russia
S., South
Sci., Science
Scot., Scotland
SD, subsequent designation
ser., serial
Sil., Silurian
Soc., Society, Société
Switz., Switzerland
t., tome
Tech., Technology
Tithon., Tithonian
Trias., Triassic
Trop., Tropical
U., Upper
Univ., Université, University
Va., Virginia
Valang., Valanginian
vol., volume, -s
Zeitschr., Zeitschrift
Zool., Zoology, Zoological

Abbreviations of Authors' Names

C.-Cl., Campell, A. S., & Clark, B. L.
Cl.-C., Clark, B. L., & Campbell, A. S.
Ehr., Ehrenberg, C. G.
Hkl., Haeckel, Ernst
Jörg., Jörgensen, E.
K.-C., Kofoid, C. A., & Campbell, A. S.
Pop., Popofsky, A.
Rued.-W., Ruedemann, Rudolf, & Wilson, T. Y.
Schew., Schewiakoff, W.
Squin., Squinabol, Senofonte
Vinassa, Vinassa de Regny, P. E.

REFERENCES TO LITERATURE

Each part of the *Treatise* is accompanied by a selected list of references to paleontological literature consisting primarily of recent and comprehensive monographs available but also including some older works recognized as outstanding in importance. The purpose of giving these references is to aid users of the *Treatise* in finding detailed descriptions and illustrations of morphological features of fossil groups, discussions of classifications and distribution, and especially citations of more or less voluminous literature. Generally speaking, publications listed in the *Treatise* are not original sources of information concerning taxonomic units of various rank but they tell the student where he may find them; otherwise it is necessary to turn to such aids as the *Zoological Record* or NEAVE's *Nomenclator Zoologicus*. References given in the *Treatise* are arranged alphabetically by authors and accompanied by index numbers which serve the purpose of permitting citation most concisely in various parts of the text; these citations of listed papers are inclosed invariably in parentheses and are distinguishable from dates because the index numbers comprise no more than 3 digits. Ordinarily, index numbers for literature references are given at the end of generic or family diagnoses.

SOURCES OF ILLUSTRATIONS

At the end of figure captions an index number is given to supply record of the author of illustrations used in the *Treatise*, reference being made to an alphabetically arranged list of authors' names which follows. Index numbers printed in lightface roman type denote reproduction of original illustrations in modified form, as in redrawing (in the manner commonly recorded by the examples "after SCHUCHERT"), whereas facsimile copies without any change other than alteration of scale are indicated by numbers in italic type (for example, signifying "from SCHUCHERT").

RAYMOND C. MOORE

PART D

PROTISTA 3

(CHIEFLY RADIOLARIANS AND TINTINNINES)

By Arthur Shackleton Campbell and Raymond C. Moore

CONTENTS

INTRODUCTION

By RAYMOND C. MOORE

The subdivision of protistan organisms which has been effected by allocation of respective groups to Parts B, C, and D of the *Treatise* seems to be unnatural in that several assemblages ranked as phyla are brought together in Protista Section 1 (Part B), whereas only the class Rhizopoda of the subphylum Sarcodina, taking care of a segment of the protozoans, is assigned to Protista Section 2 (Part C), and the remainder of protozoans is covered in this division (Part D). Thus Protista Section 3 deals with the class Actinopoda of the Sarcodina and the subphyla Sporozoa and Ciliophora of the Protozoa. This arrangement is explained by the distribution of various taxonomic groups which are either important or very unimportant to paleontology as one consideration, and by readiness of materials for publication as another. One of the first-completed contributions to the *Treatise* was the comprehensive description of radiolarians prepared by Dr. ARTHUR S. CAMPBELL, and priority achieved by his industry is a factor in shaping Part D for publication in advance of others. Dr. CAMPBELL has submitted a complete survey of the suborder Tintinnina also, including the only known fossils among the host of ciliate protozoans. Because groups like the Heliozoa, which are unimportant as fossils, are given very brief attention and others are little more than mentioned, this volume is devoted essentially to the radiolarians and tintinnines.

ACTINOPODA

By RAYMOND C. MOORE

GENERAL CHARACTERS

The actinopod protozoans comprise a host of forms which are characterized by very fine radially disposed protoplasmic extensions from the generally spheroidal main body. These extensions consist of somewhat stiffened long axopods (axopodia), unbranched or rarely branching unstiffened slender filopods (filopodia), and, in a few types, anastomosing rhizopods (rhizopodia) that may form a delicate network. Combinations of these types may appear, and even blunt lobose pseudopods (pseudopodia) may be developed temporarily in some species. On the whole, common presence of axopods or filopods distinguishes the group.

A delicate but firmly constructed skeleton composed of silica occurs in a majority of the actinopods (most radiolarians), but one important assemblage (acantharine radiolarians) has a complexly built test of strontium sulfate (Fig. 1). A few forms (some heliozoans) have a netlike exoskeleton of chitinoid nature, more or less impregnated by silica, and several heliozoan genera possess hard parts consisting of siliceous spicules, scalelike plates, and spines which are not firmly joined together. A few encase the body in a covering of diatom tests, mineral grains, and other foreign particles which are loosely embedded in gelatinous or mucilaginous substance surrounding the body. Finally, there are naked actinopods; these are uncommon in the assemblage of radiolarians but relatively numerous among the heliozoans.

The form of the main body is generally subspherical and almost invariably a thick or thin outer zone of ectoplasm can be differentiated from the fine granular, more compact endoplasm of the body interior. A nucleus is located within the endoplasm, most commonly at the center of the spheroid body, but in some excentrically. Some actinopods are multinucleate. Among radiolarians, the protoplasm may be concealed almost entirely by surrounding skeletal structures of complex nature (Fig. 2).

Actinopods are almost exclusively free-swimming or floating organisms that predominantly live in oceanic waters, but all heliozoans except a few are confined to fresh-water bodies. Some forms grow in fixed location, attached by a slender stalk. Colonial actinopods are included both among radiolarians and heliozoans, but they are exceptions to the rule. Uncommonly, actinopods are found to occur in moist soil. All kinds depend on other microorganisms for food.

CLASSIFICATION

Divergent interpretation of the taxonomic significance of many morphological features observed in actinopod types of protozoans, as well as incompleteness of knowledge, explains a considerable variation in classifying these protistans both in the past and at present. EHRENBERG (1838) first distinguished typical representatives of the great assemblage now called Radiolaria (MÜLLER, 1858), using for them the name "Polycystina." Although preference for this designation could be expressed on the ground of priority, a universal long-prevailing disuse of EHRENBERG's term strongly favors continuation of practice that allows it to stay buried. HAECKEL, in 1866, recognized under the name of Heliozoa a group that somewhat resembles the radiolarians in appearance; they lack skeletal structures of comparable sort, however, and are adapted to life in fresh waters rather than a marine environment. HAECKEL also made extensive investigations of the Radiolaria and was first (1862) to distinguish among them a major group which he named Acantharia. These differ from other radiolarians in arrangement of the skeletal structures, which conform to the so-called Müllerian law, and in their composition of strontium sulfate instead of silica (Fig. 1). Subsequently, the main divisions of siliceous-shelled Radiolaria were established by EHRENBERG (1875), who defined the Nassellaria and Spumellaria (Fig. 2), and by HAECKEL (1879), who differentiated the Phaeodaria. These divisions are mainly based on the nature of perforations in the central capsule.

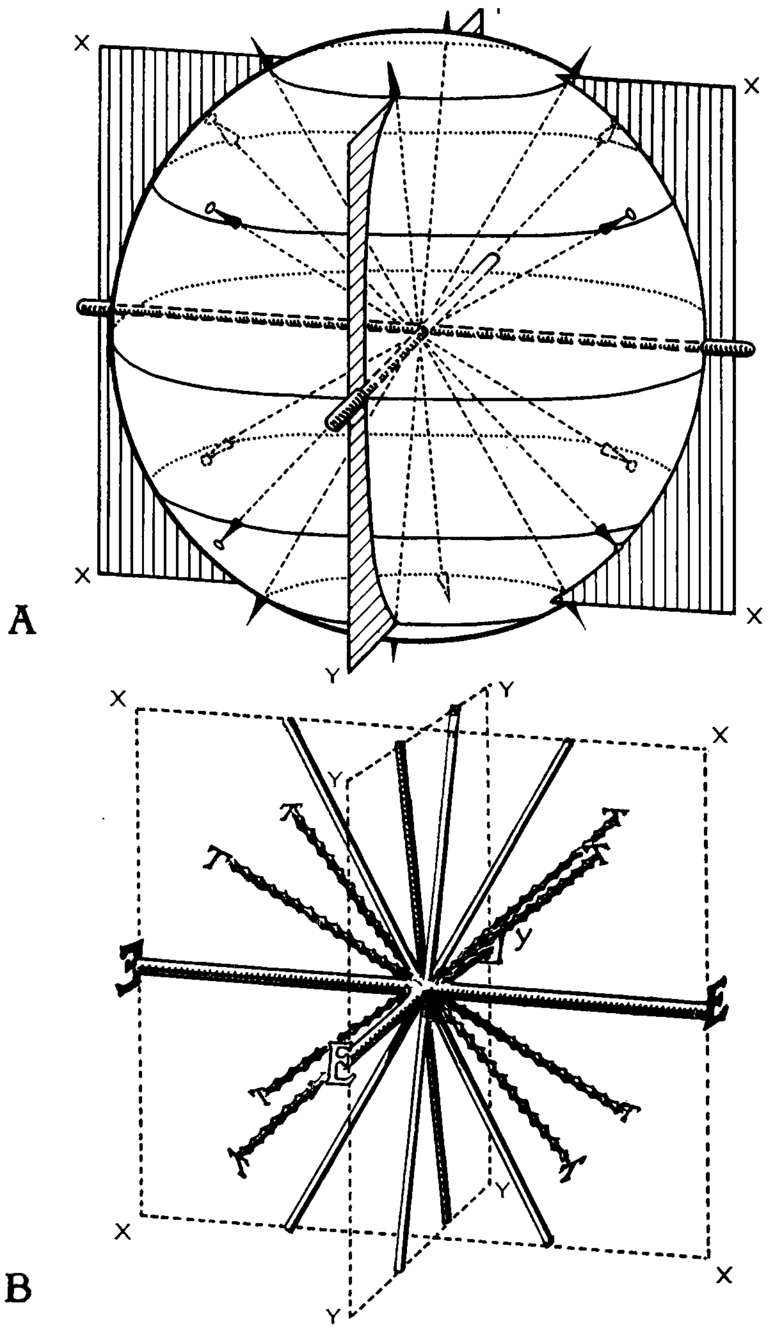

FIG. 1. Arrangement of skeletal spines in acantharine radiolarians, conforming to the so-called Müllerian law. *A,* Spheroidal diagram showing oblique view of equatorial plane and 2 meridional planes (X-X, Y-Y), each intersecting the others at right angles. Junctions of the equatorial plane with meridional ones define the positions of 4 **equatorial spines,** whereas 8 **polar spines** are located in the meridional planes at angles diverging 60 degrees from the equatorial plane. Diverging at an angle of 30 degrees from the equatorial plane, 8 **tropical spines** are located halfway between the polar meridional planes. *B,* Same spine system with spheroid omitted, equatorial spines diagrammatically distinguished by greater thickness and letter "E" at tip, polar spines by smooth slender form, and tropical spines by their crenulate surface and terminal letter "T."

A most common arrangement of protozoan groups given in standard textbooks such as those by Hyman (*Invertebrates, Protozoa through Ctenophora,* McGraw-Hill, New York, 1940), Storer (*General Zoology,* McGraw-Hill, New York, 1943), Borradaile *et al.* (*Invertebrates,* University Press, Cambridge, 1948), and many others defines a class called Sarcodina or Rhizopoda, which is divided into orders named Amoebida (or Lobosa), Foraminifera, Heliozoa, Radiolaria, and Mycetozoa. Calkins (1909) united the Heliozoa and Radiolaria in a subclass that he named Actinopoda. This arrangement is recognized in standard works on protozoology (Minchin, *Study of the Protozoa,* Arnold, London, 1912; Kudo, *Protozoology,* Thomas, Springfield, Ill., 1947; Jahn & Jahn, *How to know the Protozoa,* Brown, Dubuque, 1949; Hall, *Protozoology,* Prentice-Hall, New York, 1953; and others). Recently published comprehensive French works (Grassé *et al., Traité de Zoologie,* Masson, Paris, 1952; Deflandre, in Piveteau, *Traité de Paléontologie,* Masson, Paris, 1952) elevate the assemblage of actinopods to the rank of a subphylum, correlative with Rhizopoda, and among living Actinopoda three classes are defined as Heliozoa, Acantharia, and Radiolaria. The correspondence in characters which supports setting protozoans classed as actinopods apart from others is recognized in the present *Treatise,* and likewise the distinctions which give basis for defining major subdivisions, but classification here adopted is somewhat more conservative in its assignment of lower taxonomic rank to all groups and in retaining Haeckel's Acantharia within the span of the radiolarians. This arrangement best reflects a consensus of judgment by specialists.

For the purpose of furnishing in proper sequence appropriate headings and diagnoses which comprise parts of the text devoted to systematic descriptions, the following characterization of the Actinopoda is introduced. References are given at the end of the section on Heliozoa.

Class ACTINOPODA Calkins, 1909

Rhizopod protozoans of typically spherical form characterized by radially pro-

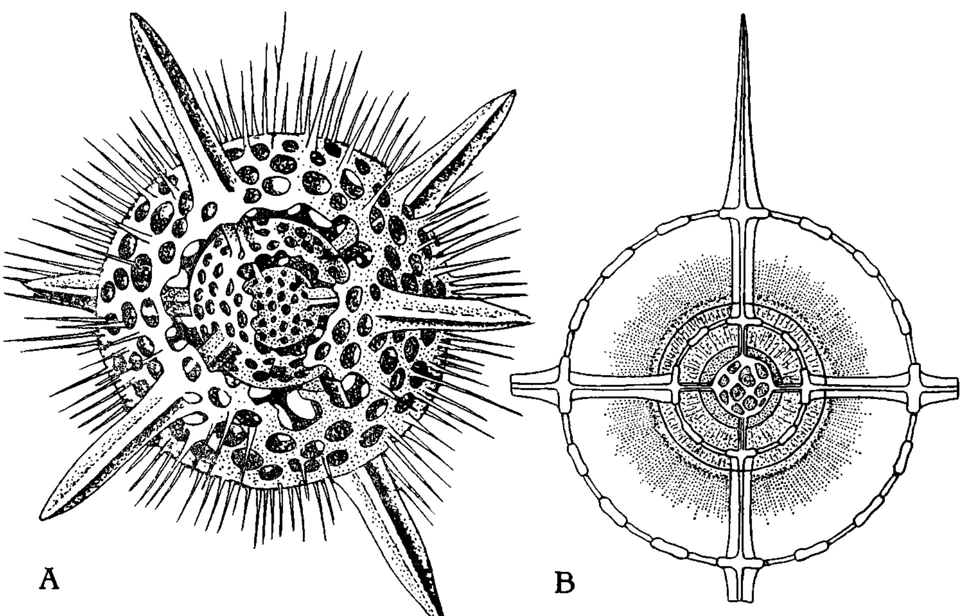

Fig. 2. Siliceous skeleton of a spumelline radiolarian *(Actinomma asteracanthion)* showing large, regularly disposed principal spines that are continuous inward through successive spherical lattice shells so as to form radial beams; very numerous slender by-spines occur also, radiating outward. *A,* View of specimen with parts of the lattice shells broken away in order to reveal interior construction. *B,* Cross section showing relation of skeleton to soft parts (enlarged, *after Bütschli*).

duced, generally long, fine pseudopodia which in many members of the group are unbranched stiffened axopodia but in others consist of threadlike filopodia or bifurcate and join together so as to make a delicate network; a delicate, complexly built, firm siliceous skeleton distinguishes a majority, in others the test is composed of strontium sulfate or, in a few of a chitinoid substance, and in still others there are loose siliceous hard parts surrounding the body; some types are naked. Protoplasm of the cell is mostly divisible into clearly differentiated ectoplasm and endoplasm, the latter containing a nucleus or nuclei. Predominantly marine but some groups live almost exclusively in fresh waters; typically live as solitary individuals but some are colonial. *Cam.-Rec.*

HELIOZOA

By Raymond C. Moore

The Heliozoa derive their name from resemblance that is shown by a majority of them to the spheroidal body of the sun surrounded on all sides by outward streaming rays. The body comprises the main mass of protoplasm, and the rays are threadlike or fine rodlike pseudopodial extensions. Many heliozoans lack hard parts, but others secrete a reticulate chitinoid skeleton partly impregnated by silica or build protection around the body consisting of loose siliceous spicules, scalelike plates, and spines; some utilize foreign material such as sand particles and diatom shells for a covering. Except for a few species found in brackish or marine environments, the Heliozoa are fresh-water protistans.

MORPHOLOGICAL FEATURES

The soft body of nearly all heliozoans is divisible clearly into an outer part called **ectoplasm,** which has a hyaline appearance, and an inner part of finely granular or alveolar nature termed **endoplasm.** The ectoplasm generally contains numerous vacuoles, among which one or more relatively large ones (contractile vacuoles) are concerned primarily with nourishment, enveloping captured prey, carrying on functions of digestion, and ultimately discharging waste products; another kind of vacuoles, commonly numerous, pulsates rhythmically, serving probably for control of osmotic pressure in the cell. The endoplasm contains many variously colored granules which are mostly stored food of different sorts, and without exception it includes a relatively large nucleus or several of them. The nuclear bodies are typically spheroidal. In heliozoans having only a single nucleus, its location generally is at the center of the cell, but in some species a highly refractive clear body (centroplast) occurs in this position and the nucleus is excentric.

The pseudopods of organisms classed as Heliozoa consist typically of **axopods,** which are relatively long, straight, unbranched protoplasmic extensions that are strengthened by an axial rod of fibrils (Fig. 3). They are by no means stiff and rigid, however. Commonly, the axial rod (axoneme) extends inward through the ectoplasm and endoplasm to the border of the nucleus or to a centroplast. A flow of protoplasmic granules along borders of the axoneme is typical. The outer part of the axopods may be reduced by absorption. Some heliozoans possess threadlike filopods, distinguished by lack of a supporting axial element, and a few exhibit branched or even reticulate pseudopodial extensions. The group of helioflagellids, which are included questionably in the Heliozoa, possess flagella as well as axopods. The pseudopods function in capturing small organisms used as food and there is evidence that they may act in manner serving to numb their prey as by emission of a poison.

Except for some forms (Desmothoraca, Helioflagellida) which are rather doubtfully included among heliozoans, as suggested by the term "pseudoheliozoans" often applied to them, members of this subclass possess no firmly knit skeleton. In this respect, they differ from most Radiolaria. Some heliozoans are naked, but many secrete a protective covering of siliceous spines or thin plates or both; and these discrete hard parts are embedded in gelatinous or mucilaginous substance of the outer ectoplasm. They may extend outward around basal parts of the axopodia. A few species that secrete no skeletal elements of their own utilize foreign particles of various sorts as a partial or complete armor. Although the siliceous scales and spines of Heliozoa may be preserved as fossils, they are almost invariably so scattered that associations belonging to an individual organism are rarely or never discovered. Therefore, identification of species based on study of preserved skeletal parts is possible only in case of distinctive peculiarities of isolated parts. Even so, it may be possible to recognize the heliozoan nature of the fossils.

Reproduction of the heliozoans is by binary fission or budding, and if buds remain attached to the parent, colonies may be produced.

OCCURRENCE

Nearly all Heliozoa are solitary vagile individuals that live in fresh-water environments, especially in lakes, ponds, and swamps. A few are marine. Some kinds grow attached to algae or an inorganic substratum, fixed by a slender stalk.

Probably the fossilized remains of Heliozoa are widely distributed both stratigraphically and geographically but they are now virtually unknown. Pleistocene heliozoans have been reported from lake and peat deposits in northern Germany and Sweden. An alleged occurrence of heliozoan remains in Oligocene strata of France is based on misidentification of poorly preserved diatoms, according to DEFLANDRE (1952).

SYSTEMATIC DESCRIPTIONS

Subclass HELIOZOA Haeckel, 1866

Mostly spheroidal free-living actinopod protozoans characterized by axopodial pseudopodia, some with filopodia and a few with reticulate rhizopodia. Skeleton, if

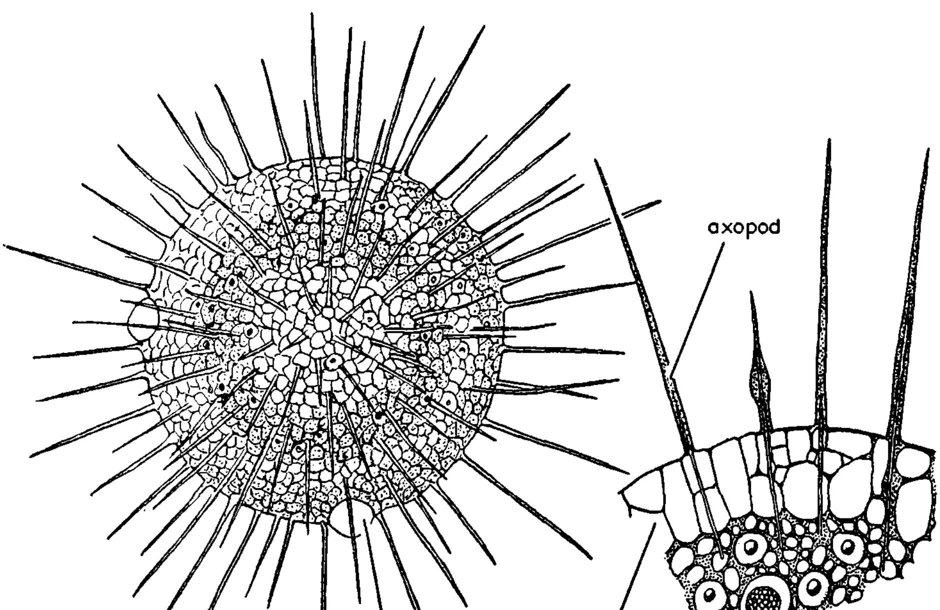

FIG. 3. Typical heliozoan lacking skeletal parts (*Actinosphaerium eichornii* EHR., Rec.). *A*, Whole organism, showing spheroidal form of body and radially diverging axopods (×700). *B*, Section of peripheral region and axopods which penetrate the ectoplasmic layer and terminate in the outer part of the endoplasm (×1,000) *(after Bütschli)*.

present, consisting typically of discrete siliceous scales and spines but in some uncertainly classified forms comprising a chitinoid network more or less impregnated by silica or rarely composed wholly of silica. Except for a few marine types, exclusively inhabitants of fresh waters. *Pleisto.-Rec.*

Order ACTINOPHRYDEA Hartmann, 1913

Naked heliozoans with one or more nuclei, lacking a centroplast; axopodia commonly reaching to edge of nucleus but may barely penetrate the ectoplasm. *Rec.*

This order includes the very common *Actinosphaerium* STEIN (Fig. 3), with well-differentiated ectoplasm and endoplasm; *Actinophrys* EHR., which lacks such distinction, widely distributed in fresh waters; and *Camptonema* SCHAUDINN, which resembles *Actinosphaerium* but is confined to marine waters.

Order CENTROHELIDIA Kühn, 1926

Heliozoans with excentric location of the nucleus and proved or inferred presence of a centroplast; mostly having a skeleton of siliceous plates or spines and plates but

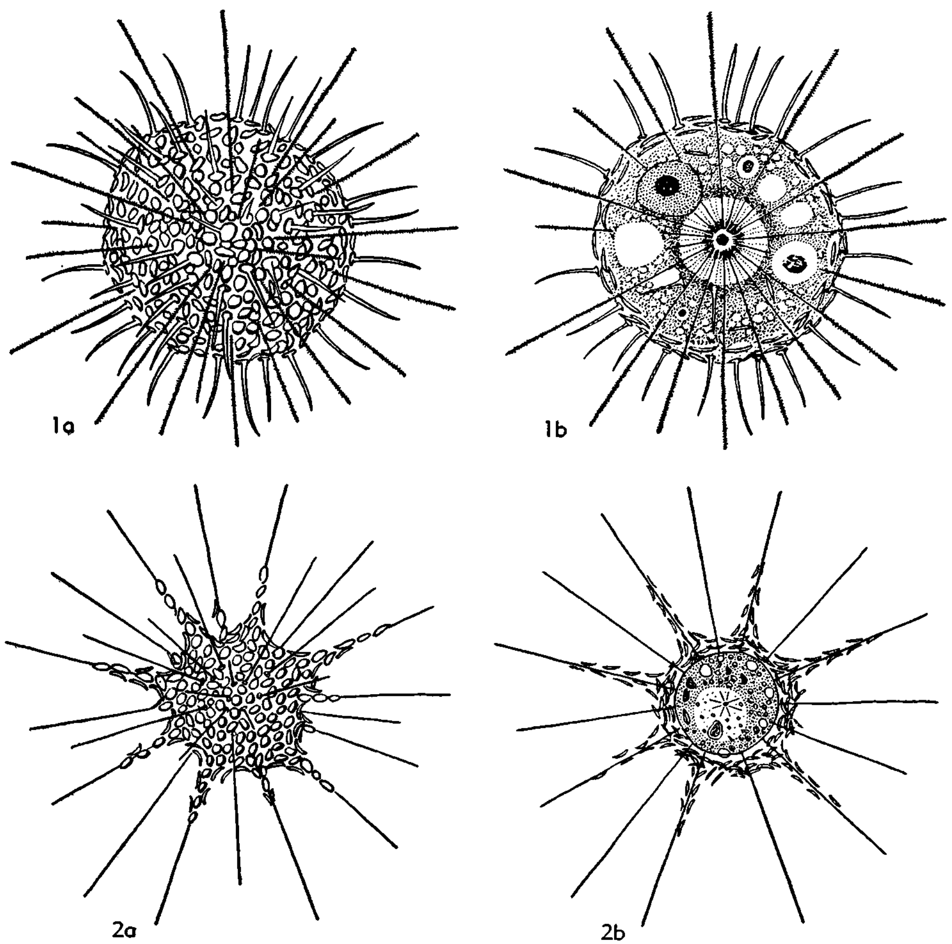

FIG. 4. Heliozoans provided with siliceous hard parts. *1a, b, Acanthocystis aculeata* HERTWIG & LESSER, Rec., exterior view and cross section, showing skeletal plates and spines; this species has a clearly defined centroplast and an excentric nucleus (×500) *(after Stern). 2a. b, Radiophrys pallida* SCHULZE, Rec., exterior and cross section, siliceous scales around body and extending outward along basal parts of axopods (×300) *(after Penard).*

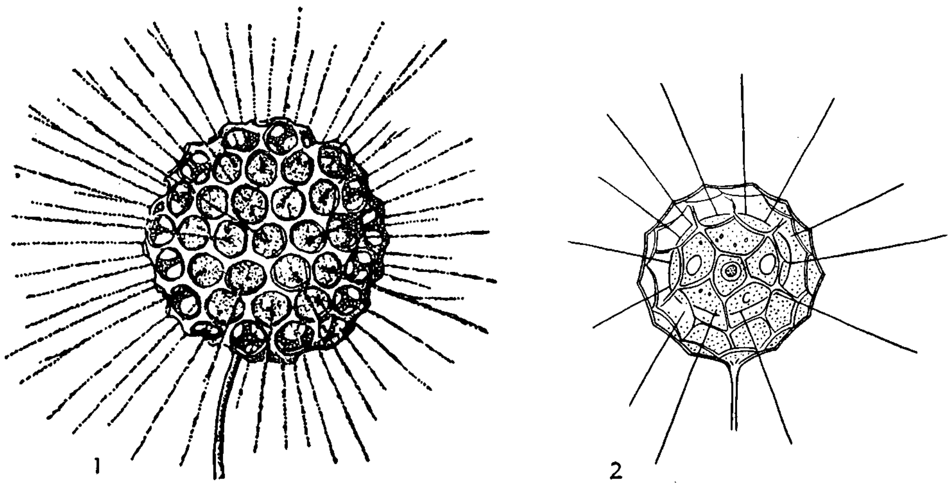

FIG. 5. Desmothoracan heliozoans. *1, Clathrulina elegans* CIENKOWSKI, Rec., exterior of body and part of stalked attachment (×500) *(after Leidy). 2, Hedriocystis reticulata* PENARD, Rec. (×600) *(after Penard).*

some forms naked; typically spheroidal, free-living but a few sessile. *Rec.*

This group includes suborders named Aphrothoraca HERTWIG (1871), Chlamydophora HERTWIG (1871), and Chalarothoraca HERTWIG & LESSER (1874). Typical skeleton-bearing representatives of the Chalarothoraca are *Acanthocystis* CARTER (1863), *Raphidophrys* ARCHER (1876), and *Raphidocystis* PENARD (1904), which are illustrated to show the nature and arrangement of their hard parts (Fig. 4). Scattered plates and spines of such heliozoans are likely to be found in microfossil collections from fresh-water deposits.

Order DESMOTHORACA Hertwig & Lesser, 1874

Subglobular free or fixed actinopods with continuous reticulate exoskeleton of a chitinoid substance more or less impregnated by silica or rarely consisting entirely of silica; pseudopodia of filopod type, without axoneme, but branching or even anastomosing in some; centroplast lacking. Fresh-water habitat. *Pleisto.-Rec.*

Clathrulina CIENKOWSKI, 1867 [**C. elegans*]. Family Clathrulinidae CLAUS. Shows typical characters of order; attached by a stalk. *Pleisto.*(Ger.-Swed.)-*Rec.*——FIG. 5,*1*. **C. elegans,* Rec.; adult individual showing test and radiating pseudopodia, ×400 (after Hertwig).

Hedriocystis HERTWIG & LESSER, 1874 [**H. pellucida*]. Family Clathrulinidae. Resembles *Clathrulina* but polygonal openings of test much larger. *Rec.*——FIG. 5,*2*. *H. reticulata* PENARD, Rec.; body and part of stalk, ×1,000 (after Penard).

Various other genera (*Monomastigocystis* DE SAEDELEER, *Orbulinella* ENTZ, *Elaster* GRIMM, etc.) are omitted, for it is sufficient here to indicate general characters of the group.

Order HELIOFLAGELLIDA Doflein, 1907

Mostly subglobular organisms bearing generally both axopodia and flagella, also commonly with a centroplast; hard parts lacking; habitat fresh waters. *Rec.*

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RADIOLARIA

By Arthur Shackleton Campbell

INTRODUCTION

Radiolaria are marine protozoans belonging to the lowly organized division (Plasmodroma or Rhizoflagellata) that includes the common *Amoeba,* dinoflagellates, and innumerable foraminifers. These are free-living one-celled animals characterized by the presence of protoplasmic extensions termed pseudopodia or flagella. They are classified by most zoologists as an order (or subclass) of the class Rhizopoda (or subphylum Sarcodina) but by some are grouped with acantharians and heliozoans in a class called Actinopoda. This latter classification is adopted here.

The radiolarians have not been studied in the detail they deserve. Among factors which have tended to retard research on them are: (1) their very small size, which necessitates laborious techniques for isolating them and optimum conditions for examining them; (2) the very great number of different kinds, described in widely scattered publications in several different languages, without comprehensive monographs which unite the fossil and Recent genera into a logical system; and (3) lack of realization, until recently, of the usefulness of these organisms in certain phases of applied paleontology and biological oceanography.

The present contribution had its inception in micropaleontological studies which the late Prof. Bruce Clark and I undertook during the period 1936-1945. We realized that taxonomy of the Radiolaria needed revision, and Dr. Clark suggested that the whole group be re-examined. A start on this task had to be delayed, however, until I was asked to prepare this section of the Protozoa for the *Treatise.*

The taxonomic treatment given is conservative, for only essential changes have been introduced and revision of genera has been limited. Mainly, the changes are those needed to bring designations of Radiolaria into line with provisions of the International Rules of Zoological Nomenclature and decisions of the International Zoological Congress meeting at Copenhagen in 1953. If some disagree with features of the classification proposed, they must grant that many problems are exposed. Later examination may lead to better solutions of some of these questions. Practical applications of the study of fossil Radiolaria are assisted not only by records of occurrences, but especially by bringing together into one system both fossil and Recent genera.

Excluded from consideration are generic names to which no species are assigned and those doubtfully placed among Radiolaria by their authors. Among these are plant spores or inorganic bodies.

Illustrations of significant genera accompany the systematic text. Species belonging to some subgenera of especially important genera are also figured. These are mainly those of genera which may have stratigraphic significance.

The systematic text is believed to be complete to July 30, 1952.

The recent treatment of Radiolaria in the new *Traité de Paléontologie* (1953) outlines a different concept of the subclass from that developed herein. The French authors propose an elaborate system including detailed acceptance of Schewiakoff's studies of the Acantharina. The order of treatment of the families and other divisions of Spumellina and Nassellina differs also from that developed in this section of the *Treatise on Invertebrate Paleontology.* The Phaeodarina are considered essentially as herein developed. Detailed examination of the two contributions will reveal other minor differences.

To all who have assisted in preparation of this work I am obliged, especially for the genial help of Prof. J. W. Durham, ICZN Commissioner Robert L. Usinger, W. Riedel, the Editor and his staff. However, I alone must be held responsible for errors of omission and commission.

MORPHOLOGY

Knowledge of the morphology of the soft parts of Radiolaria is important to understanding the classification and life habits of these organisms.

SOFT PARTS

The living matter of radiolarians, commonly termed **cytoplasm**, may be differentiated into 3 divisions: (1) a cortical layer, termed **extracapsular cytoplasm**; (2) an intracapsular layer containing the **nucleus**; and (3) the **central capsule**, mucoid or chitinous in nature, separating the 2 layers. This capsule distinguishes the Radiolaria from all other Protozoa; even groups such as the Heliozoa, which are intimately related to the Radiolaria, do not possess this unique structure. The extracapsular cytoplasm consists of an assimilative layer (**matrix**), which lies immediately next to the central capsule; a vacuolated layer (**calymma**), which is frothy and appears to vary with the physiological state of the individual; and an enclosing layer (**sarcodictyum**), outside the other 2 layers. Radiating through the whole extracapsular protoplasm are contractile threads that give rise to **axopodial pseudopods**, which seem to arise in the matrix of the extracapsular layer, just outisde of the central capsule. The central capsule is single in all but the Phaeodarina, a radiolarian group that is rarely represented among fossils. In this group, the central capsule is multiple. The capsule may be considered a permanent structure, although there is evidence that it may rupture or dissolve during certain phases of reproduction. Generally it is perforated or contains one or more apertures. These apertures constitute one of the bases upon which higher-rank divisions of the group are separated. The central capsule is seldom fossilized.

The intracapsular cytoplasm is denser than the extracapsular portion. Within it are various inclusions, among which are protein reserves, symbiotic cells, and large crystals. At its center is the large spherical nucleus, provided with the usual nuclear components. The whole cell is thus a complicated structure, and each of its elaborations has a peculiar, special physiological function. In a general way, the extracapsular cytoplasm is concerned with flotation, movement, food-gathering, digestion, respiration, and the reception of external stimuli. The intracapsular cytoplasm, on the other hand, is largely concerned with reproduction and to a limited extent with assimilation and storage. A diagram illustrates relationships of the structures (Fig. 6).

HARD PARTS

The skeleton, or hard parts, of a radiolarian may be termed **scleracoma**, in contrast with the whole soft body of the animal, called **malacoma**. The scleracoma differs greatly in the different suborders of Radiolaria and in appropriate following parts of the text is discussed with special regard to features that distinguish the many genera. Distinction of genera largely depends on skeletal characters, because they provide the only usable basis for differentiating the multitude of forms which occurs among these protistans. It is true undoubtedly that Radiolaria show as great a diversity of form as any of the comparable groups in the animal kingdom, and this diversity invites establishment of many taxonomic divisions. The various kinds of

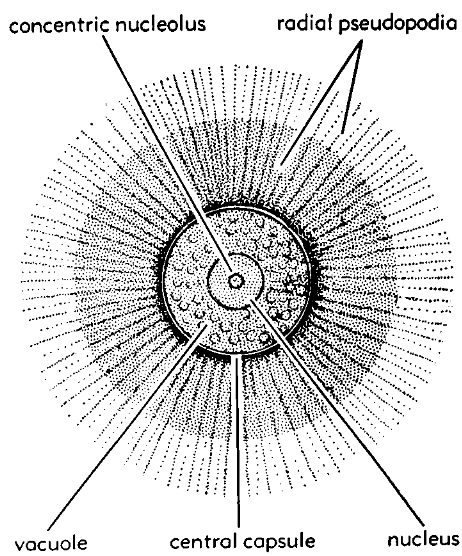


FIG. 6. Diagrammatic cross section of a radiolarian showing relationships of soft parts.

skeletal tests are composed of different materials, and thus shell composition is important at the higher levels of classification. The same essential shapes are repeated in shells of differing composition. Fortunately for the paleontologist, most shells are composed of opaline silica. A few primitive genera in each of the subdivisions lack shells or have only isolated spicules.

Almost nothing is known as to the manner of forming the hard parts of Radiolaria, except that the vacuolated layer is able to secrete silica or other mineral substance. The deposit thus laid down, however, does not conform strictly to the alveolated structure of the sarcodictyum beneath.

Individual variations found in different specimens of the same species of Radiolaria are not well understood. The effect of physical and chemical factors upon shell formation has not been studied specifically. The influence of temperature upon dimensions in some other testate protozoans is well known and, in these forms, size differences commonly are a function of critical temperatures at the moment of deposit. Three chief sorts of structural variation are recognized in Radiolaria: (1) normal genetic variations characteristic of particular species; (2) responses to depth at which the species lives and by which a given species may display differing characters distinctive of deep- or shallow-water environments; and (3) polymorphism related in some way to different stages in a complex life cycle. The last has not been demonstrated satisfactorily by modern methods of investigation. In part at least, the different types of individual variation may be responsible for some of the large number of species which have been described.

The somatic polymorphism occasioned by varying depth environments results in the formation of widely diversified small individuals in warm surface waters and large individuals in cold deep waters. Generally, the shells of surface-dwelling pelagic Radiolaria are delicate and have numerous slender apophyses, large pores, thin bars between the pores, and diverse spinous armor. Deep-water forms, on the contrary, are massive, solid, less apt to be burrlike, provided with short apophyses, and have small pores with thick trabeculae.

Most of the many shapes found among Radiolaria seem to have been developed as a means of maintaining the animal within certain depth limits. Various structural modifications, such as globular and hat-shaped tests and long pseudopods, serve to retard sinking and thus to keep the more or less passive radiolarian in that upper ocean zone where food is produced by photosynthesis. The various surface extensions of the radiolarian have slight protective function.

MORPHOLOGICAL TERMS APPLIED TO RADIOLARIANS

The general account of morphological features distinguished in the soft and hard parts of radiolarians introduces only a few of the terms which are needed for description of these organisms. Others are given in parts of the text devoted to explanation of main divisions designated as suborders, because the structural characters and nomenclature of parts in each are somewhat different. A compilation of all morphological terms in a single alphabetically arranged list, with accompanying brief definitions, has been judged useful and is given here. The letters A, N, P, and S, which accompany various terms, indicate the suborders Acantharina, Nassellina, Phaeodarina, and Spumellina, respectively, and thus serve to identify the taxonomic divisions within which the terms are mainly or exclusively used. Terms not accompanied by one or more of these index letters have general application.

GLOSSARY OF MORPHOLOGICAL TERMS

abdomen. Third joint of nasselline shell (N).

acanthin. Organic compound of strontium sulfate forming skeletal rods (A).

aglet. Tiny plate pierced by a single pore (A).

alveole. Vacuole or space.

anchor branch. Curved hooklet (P).

aperture. Large main opening of shell.

apical horn. Spine at apex of nasselline or phaeodarine shell (N, P).

apophysis. Lateral transverse process of radial spine (A).

areolate. Weblike or reticulated.

arms. Flat extensions from central region of shell.

articulate. Hollow, septate tube.

aspinal pore. Tiny opening in plates which lie immediately at sides of radial spines bordered by primary branches of latter (A).
astral. Starlike.
astropyle. Nipple-like projection from central capsule of Phaeodarina (P).
axopodial pseudopod. Permanent rod-supported protoplasmic extension of radiolarian cell.
basal feet. *See* feet.
basal leaf cross. Broad wings on radial spines (A).
basal pores. Small openings in basal horizontal plate of some Triospyridicae.
bow. Curved rod.
brush. Bunch of fine terminal branches (P).
by-spines. Small accessory spines additional to radial spines (A, S).
calymma. Frothy layer of cytoplasm.
capsule. *See* central capsule.
central capsule. Mucoid or chitinous sac enclosing intracapsular cytoplasm and nucleus (A, N).
centrogenous skeleton. Supporting rods which are generated at cell center (A).
cephalis. First or apical chamber of Nassellina (N).
chromatophore. Colored body within cytoplasm with power of photosynthesis.
collar pores. Tiny apertures which occur in horizontal plate at base of cephalis in some Nassellina (N).
columella. Vertical rod within shell-cavity; in Stephaniicae, vertical rod between 2 horizontal rings (N).
comb. Radial series of knobs or projections (A).
concrescence. Union of radial spines.
condyle. Swollen knobs on shell surface (A).
coronal pores. Tiny openings which lie at periphery of shields, surrounding the aspinal pores but not touching the radial spines (A).
cortical shell. Outermost of the concentric shells of Spumellina (S).
crest. *See* comb (A).
cupola. Large vaulted dome (N, S).
cytoplasm. Protoplasm exclusive of the nucleus.
dendrite. Branched free style (P).
dentate. With small toothlike projections.
diametral spine. Opposite radial spines basally fused and passing through diameter of central capsule (A).
dimple. Small depression (A).
diploconical. Shell formed by fusion of bases of 2 cones opposite in one axis.
equatorial space. Four-sided region resulting from formation of basal leaf cross (A).
equatorial spine. Radial spine arising on shell equator (A).
extracapsular cytoplasm. Protoplasm outside central capsule.
feet. Radial appendages extending from ultimate joint of nasselline or phaeodarine shell (N, P).
fenestrated. Having open meshwork (N, S).
frenulum. Small cylinder connecting nasal mouth and internal part of nasal tube of style near base of galea in Phaeodarina (P).
galea. Conical process (P).
gate. Large opening or fissure (S).
geotomical axis. Minor axis with small spines (A).
girdle. Spiral or annular shelf (S).
girdle zone. Circular central region with shelves.
helicoidal. Asymmetrical coil (S).
hydrotomical axis. Major axis with large spines (A).
icosacanthic law. *See* Müllerian law (A).
internal columella. *See* columella (N).
intracapsular layer. Protoplasm within central capsule exclusive of nucleus.
joint. Segment of nasselline shell (N).
keel. Vertical sail-like plate.
lattice shell. Test formed of meshwork (A, N, P).
leaf cross. *See* basal leaf cross (A).
lentelliptical shell. Lens-shaped shell with elliptical outline.
malacoma. Collective name for soft parts.
mantle. Variously formed covering or coat.
matrix. Assimilative portion of cytoplasm.
medullary shell. Internal concentric shell (S).
Müllerian law. Plan of circles expressed by radial spines dividing the shells of Acantharina into equatorial, temperate, tropical, and polar zones (A).
nasal tube. *See* rhinocanna (P).
nucleolus. Intranuclear body.
nucleus. Kernel or dynamic center of cell responsible for maintenance and heredity.
operculum. Flat pore-bearing base of podoconus in Nasselina; in Phaeodarina, central portion of astropyle (N, P).
oral teeth. Sharp triangular projections around basal shell opening (P).
parapylae. Accessory tubular apertures of central capsule in addition to astropyle (P).
parmal pores. Pores piercing the shield and bordered only by united branches of apophyses (A).
patagium. Interbrachial spongy veil (S).
peripolar space. Three-sided pyramidal space resulting from formation of basal leaf cross (A).
perispinal pores. Holes composed of 4 united aspinal pores (A).
perizonal space. Four-sided region resulting from formation of basal leaf cross (A).
perradial plane. Meridian plane (A).
phaeodella. Granule forming part of phaeodium (P).
phaeodium. Voluminous aggregate of pigmented cytoplasmic granules (P).
pharynx. Internal oral tube (P).
planispiral. Plane defined by a flat coil (S).
podoconus. Internal cone within central capsule of Nassellina (N).
polar space. Four-sided region resulting from formation of basal leaf cross (A).
polar spine. Opposite radial spines defining one axis of shell (A).
polar tubules. External cylinders opposite in main shell axis (S).
pore-frame. Raised edge around area enclosing pore.

pore-plate. *See* operculum.
post-abdomina. Joints succeeding third segment of nasselline shell (N).
principal spines. Large regularly placed spikes or needles (A, S).
proboscis. Distal cylindrical tube extending from astropyle (P).
pseudopodium. External cytoplasmic extension from body of cell.
pylome. Osculum or large opening usually only in outermost of concentric shells (S).
radial beam. Internal rods usually connecting concentric lattice shells (S).
radial tube. Centrifugal cylinder (A).
radial spines. Tangential rods or needles (A, P).
rhinocanna. Curved cylinder or prismatic tube embracing central capsule on one side and the galea on the other side (P).
rosettes. Flower-shaped buttons within hexagonal pore frames.
sagittal ring. Hoop reinforcing latticed wall in medial vertical plane (N).
sarcodictyum. Outermost layer of cytoplasm.
scleracoma. Collective name for hard skeletal parts.
sieve-plate. Flat, circular porous plate (S).
sheath. Receptacle or container.
shield. Flat or curved lateral outgrowth at one or more levels of radial spine, forming by fusion the lattice shell of some Acantharina (A).
spicule. Discrete skeletal element (P, S).
spongy. Foamy or loosely organized tissue (P, S).
stricture. Contraction between successive shell joints (N).
style. Tubules which arise from the galea (P).
suture. Joining of adjacent structures.
sutural pores. Pores bordered by sutures along the meeting branches of 2 or more adjacent radial spines (A).
tabulate. With smooth plates (P).
thorax. Second shell joint in Nassellina (N).
thorn. Short, sharply pointed triangular or conical surface extension (S).
tripod. Stool-shaped shell formed from divergent rods united at common center (N).
tropical spine. Radial spine disposed according to Müllerian law and marking tropical zone (A).
twin-shell. Shell with median transverse constriction (S).
vacuole. Space inside cytoplasm.
veil. Variously formed weblike or netlike film.
wing. Solid or fenestrated extension from side wall of nasselline shell (N).
zooxanthellae. Yellow intracellular symbionts.

BIOLOGY

REPRODUCTION

The life cycle of Radiolaria is imperfectly understood; much work on it remains to be done. Binary fission certainly occurs, and multiple division or budding has been described in the Thalassicolidae and some Acantharina. The central capsule is said to become irregular and the nucleus to break up into granules which become transformed into minute nuclei. Sexual reproduction and gamete formation is postulated but cannot be said to have been demonstrated. Modern cytological techniques have not been applied to the study of these forms, but chromosomes are certainly formed as among other protozoans. Among Heliozoa, the life cycle is understood in *Actinophrys* and *Actinosphaerium* at least. The marine Radiolaria are less easy to study than these fresh-water forms in which existence of sexual stages is authenticated.

Much of the reproductive activity seems to take place in epidemic form, after local, temporary enrichment of the water with silica. In this way, as among diatoms, vast numbers of individuals are produced suddenly. The pulses are seasonal or otherwise periodic.

MODE OF LIFE

Radiolaria usually can live without solid food if light is abundant. This ability is attributed to action of the yellow cells in various parts of the cytoplasm, especially in the calymma. The yellow cells (spherical bodies with distinct cellulose wall, 2 chromatophores, starch grains, and single nucleus) are identified collectively as **zooxanthellae** and belong to the genus *Chrysidella.* Several species are reported to inhabit both foraminifers and radiolarians. They multiply by binary fission in large numbers and, of course, are symbiotic. It is because of these symbionts and dependence of Radiolaria upon them for food that maintenance of the organisms within depth ranges of the sea penetrated by light is so important. Among the Acantharina, the yellow bodies are located only within the intracapsular protoplasm. In the Phaeodarina, which mostly dwell at depths below the light floor of the sea, yellow cells are absent, being replaced by dark bodies. At least some Radiolaria take in particles of animal food and digest them within temporary vacuoles located in deeper layers of the protoplasm. Some Radiolaria are luminescent.

ECOLOGY

MODERN FORMS

Radiolaria are invariably marine animals which occur in all climates and depths. Under normal conditions, they float freely in the water, at the surface or close to sea-bottom, and in shallow water or at great depths. Active propulsive movements are lacking, but limited vertical movement is connected with physiological processes affecting the gas content of the alveolated protoplasmic layer. Although radiolarians are greatly favored by water of medium salinity, they are not absent in seas of high or low salinity. Scarcely any radiolarians are peculiarly coastal or neritic in distribution. A few may drift accidentally into larger bays.

No radiolarians inhabit fresh waters, although one supposed family (Traquairiidae), of the suborder Acantharina is claimed to have inhabited coal swamps. These so-called radiolarians have proved to be misidentified plant spores. Other reported fresh-water forms have been shown to belong to the Heliozoa.

With respect to local distribution, Radiolaria generally show the same relations as other pelagic organisms. Since they are incapable of active horizontal locomotion, the dispersion of different species depends on oceanic currents, winds and waves, and all accidental agencies that affect transport of other planktonic forms. Such passive movements bring about wider distribution of individual species than commonly is attained by active wandering. As a result of migrations, the number of cosmopolitan species is relatively large. Similar species occur in the 3 great ocean basins, but local species also are found, and local faunas may be distinguished by species peculiar to them. The Radiolaria are distributed throughout all the seas. Like most other organisms, they reach maximum richness in tropical waters, whereas frigid zones are characterized by great numbers of individuals of relatively few kinds. The surface of the sea everywhere at a little distance from land appears replete with radiolarians. In the Pacific Ocean, however, they flourish most richly. Those of the Atlantic are less numerous in kinds. The Arctic, Antarctic, and temperate seas are filled with radically different types from those of the warmer oceans. Surface faunal zones differ sharply from those of deeper waters.

Vertical distribution in the ocean is imperfectly divided into several life zones: (1) the region penetrated by abundant light, which reaches from the surface to 25 fathoms (45.5 m.); (2) intermediate depths, which contain floating members of the group beneath the light floor; and (3) the bottom of the deep sea, which is characterized by a browsing fauna. The middle zone is divided into 3 subzones: an upper, ranging from 25 to 150 fathoms (45.5 to 274 m.); a middle, from 150 to 2,000 fathoms (274 to 3,650 m.); and a lower, from 2,000 to 3,000 fathoms (3,650 to 5,475 m.). Among the 4 recognized suborders of radiolarians, the Phaeodarina and some Nassellina generally are found in abyssal waters. Nearly all Spumellina, Nassellina, and Acantharina occur near the surface. Haecker (13) makes an ecological distinction between microradiolarians and macroradiolarians, which may have some importance in connection with the vertical distribution of these organisms. Since deep-water and near-surface types may often be distinguished by their morphology, not only in characters mentioned previously but in the abundance of foamy kinds among surface dwellers, it becomes possible to determine something of the conditions under which radiolarian-bearing sediment was laid down.

Rich accumulations of Radiolaria occur in deep-sea oozes. Although pelagic material skimmed from the surface of the sea and collected in nets which draw plankton from intermediate depths are more or less filled with these organisms, a still greater number of species is obtained from bottom deposits. The skeletons found in ocean mud may belong to species which live at or near the surface, at intermediate levels, or at the bottom, and they may even include fossils. Almost all observed remains belong to the Spumellina or Nassellina; the Phaeodarina occur only sparingly and Acantharina generally are wanting, for their soft skeletons readily dissolve. Abundance of Radiolaria varies greatly according to composition and origin of the deposits. In general, marine deposits may be divided into (1) terrigenous muds and (2) abyssal deposits. The terrigenous muds include all sediment derived from the coasts of adjacent land masses, extending outward from these coasts for distances of 200 miles or more. They contain varying amounts of Radiolaria. The abyssal oozes mostly commence at 100 to 200 miles offshore. Commonly they are very uniform, corresponding to the constancy of the sea above them, and they may be distinguished as (1) radiolarian ooze, (2) foraminiferal *(Globigerina)* ooze, and (3) red clay.

Radiolarian ooze includes oceanic deposits, the greater part of which (75 per cent or more) is composed of the siliceous shells of these creatures. Such relatively pure oozes are limited to certain areas of the Pacific and Indian oceans. Deposits in which Radiolaria comprise less than 5 per cent of the organic contents are called mixed radiolarian ooze. This kind is more common than the relatively pure ooze and has wider distribution on many parts of the ocean floor. When carefully treated with acids, radiolarian ooze appears as a fine, white powder; in the raw state, it is yellowish or may be red.

Foraminiferal ooze rich in the siliceous skeletons of radiolarians covers extensive areas at depths below 1,800 fathoms (3,280 m.); it is replaced by red clay at depths of 2,200 fathoms (4,000 m.) or more. When dried, such ooze is a fine white or gray powder, containing 50 to 80 per cent $CaCO_3$. Removal of the calcium carbonate leaves a residue consisting mainly of the tests of siliceous organisms.

Red clay is quantitatively the most important deep-sea deposit, covering a large part of the deep-sea floor. Calcareous matter is largely lacking in the red clay, but volcanic ash, pumice, particles of lava, and radiolarian tests are common. Some investigators believe that the red clay is formed largely by decomposition of radiolarian ooze.

Some long deep-sea cores taken by modern methods display mixed faunas of Recent and Tertiary species. The significance of such core samples has only lately come to be realized in oceanographic investigations (21).

FOSSIL FORMS

About 60 per cent or more of the Recent deep-sea sediments containing radiolarians occur between 1,800 and 2,200 fathoms (3,300 and 4,000 m.), and in minor part extending downward to about 3,750 fathoms (6,800 m.). Accordingly, the argument has been advanced that beds containing fossil Radiolaria must have been formed at similar depths. Radiolarians may be deposited in much shallower water, however, and it is even probable that some deposits consist of strand-line accumulations carried inland under special circumstances, as is inferred in explanation of some early Tertiary deposits of Trinidad. No information on the rate of accumulation of radiolarian-bearing sediments seems to be available, but a modern deposit of diatoms, 10 to 15 cm. in thickness and 20 miles in length, is known to have been formed on the Oregon coast during a 3-day storm with high winds and rains. Tests of *Globigerina* are reported to have been carried by local winds several miles inland from the coast of Ireland and mixed with fresh-water and wind-blown sediments. Obviously, these are not abyssal sediments, and the contained organisms give no hint of the origin of the deposit. It is also evident that they are rare accidental accumulations. The extensive Eocene siliceous shales of California, with alternating beds of Radiolaria and Foraminifera, may have accumulated in a shallow sea at some distance from land as a result of alternating periods of accelerated reproduction during frequently recurrent times of favorable conditions for each of the 2 types of organisms. Occurrence of fossil Radiolaria in abundance is not *ipso facto* proof of deep-water sedimentation but only of pelagic origin of the fossils. Deep-water deposits generally lack large, land-derived fragments such as logs or sizable clastic detritus. They do not contain rooted plants. Shells of typical shallow-water animals, such as rudistids, tide-flat snails, and sand-dollars, are absent. The clastic deposit is commonly in the form of fine or flocculent material. Manganese oxide and phillipsite are important minerals. Deep-sea deposits mostly occur as sheets which cover wide areas. Structures produced by wind and waves are lacking. Coarse sandstones are absent. All features must be examined before judgment is pronounced as to the mode of making any given radiolarian-bearing deposit. Few deposits on present-day lands offer indisputable evidence of deep-sea origin.

Most radiolarian-bearing cherts are thought to be of shallow-water origin. Extensive chert beds of this sort are found in supposedly Jurassic rocks (Franciscan) of California, Ordovician strata of New York, and Cretaceous and Eocene deposits of Ecuador.

The Franciscan formation comprises a heterogeneous but rather distinctive assemblage of shallow-water marine clastics, chemical deposits, and some organic sediments. These beds of great thickness were deposited in a sinking geosynclinal trough that extended the whole length of the Coast Ranges in California and Oregon. Extensive volcanism, particularly during accumulation of the upper Franciscan, resulted in outpourings of pillow basalts and andesites. Sills, dikes, and laccoliths of diabase and basalt were formed commonly. Association of the Franciscan cherts, well described by Davis (9), with pillow basalts and serpentine indicates introduction of the silica from volcanic sources. The cherts are chemical sediments and the Radiolaria are accidental inclusions. The great amount of silica supplied by the volcanoes created conditions favorable for the multiplication of these animals. Nearly conclusive evidence indicates that the Franciscan is of shallow-water origin. In southwestern Ecuador, analogous Cretaceous and Eocene cherts with Radiolaria are similarly associated with volcanics.

Ruedemann & Wilson (22) maintain that the Ordovician cherts of New York are of deep-water origin. It is possible, indeed, that some cherts were accumulated in deep water, whereas others were laid down in shallow seas. The same is true of soft siliceous radiolarian shales, novaculites, and other sediments of different ages which contain these fossils. Clark & Campbell (8) judge that upper Eocene radiolarian shale of the Mt. Diablo area (California) is of shallow-water origin, although some other geologists think that depths may have been as much as 1,000 fathoms (1,800 m.). Estimating the depth of deposition of fossil Radiolaria on the basis of depth range for the same genera in modern seas, Ruedemann believes that a mixed fauna of shallow- and deep-water forms must have been deposited at depths no less than the greatest inhabited by the deep-water forms. Aberdeen (1), however, points out that almost every genus has both shallow- and deep-water species and that modern species vary greatly in depth distribution; accordingly, interpretation of the environment of fossil species by analogy is not necessarily reliable. Aberdeen believes that best evidence of depth lies in structures of the shell. Nearly all deposits of fossil Radiolaria are those of upper-zone pelagic types. The great array of spherical, elliptical, and especially spongy kinds, which occur in vast numbers in deposits of Barbados, Trinidad, California, and elsewhere, are all free-floaters, differing almost only in detail from Recent planktonic faunas, especially those of the tropics. Representatives of the Nassellina in the same deposits are kinds that freely developed radial apophyses. It must be remembered also that empty shells of these floating organisms may drift a long way from their point of origin before they settle down and become enclosed in sediment. For this reason, some deposits of these fossils are not autogenous. Bottom- and middle-zone forms may become associated in this way with surface-dwelling kinds and a death assembly (thanatocoenose) results.

DISTRIBUTION

STRATIGRAPHIC VALUE

The value of fossil Radiolaria for stratigraphy is diminished by the long ranges of many genera. Some seem to extend throughout the whole post-Precambrian geological column and others through a number of systems. Only a few genera are limited sharply to part of a single system. Furthermore, the number of species is tremendous, so that, despite general limitation to very short geological ranges (21), identifications and establishment of the ranges of individual species are very difficult indeed. Many species remain to be described. The selection of index forms and correlation of faunas in widely separated geographic provinces cannot be undertaken satisfactorily under conditions of present knowledge.

On the other hand, the usefulness of Radiolaria in local correlations is well recognized and is especially important where a number of different radiolarian-bearing rocks occur in a stratigraphic sequence and where these display differences in faunal composition or ecological conditions. Some formations can be followed and identified positively for long distances by their radiolarian contents. Extensive use has been made of these fossils in this manner in Ecuador (30). Thus, Radiolaria seem to be as useful as Foraminifera and other fossils in localities where they occur, especially if they are abundant. Also, often they can be used in the solution of stratigraphic problems (14, pp. 166-167) where other fossils have little value or are absent. The principal difficulty lies in our lack of knowledge of these organisms and in the relatively elaborate processing required to prepare them for study. Few micropaleontologists understand the necessary research techniques, and most are bewildered by the multitude of finely differentiated species encountered. However, the Radiolaria can be mastered as easily as other groups which have been used for stratigraphic purposes, and they offer the possibility of solutions not readily arrived at by study of various other fossils.

GEOLOGICAL OCCURRENCE

Radiolaria are found in important groups of marine sedimentary rocks in all continents and on some of the larger islands. By the aid of modern methods it has been demonstrated that many hard rocks contain numerous well-preserved specimens of these primitive organisms. Some rocks are composed essentially of closely compacted masses or radiolarian shells. Soft marls and clays may be filled with such shells, and even quartzites may contain them. Radiolarites extend throughout nearly the whole column of fossiliferous geological formations. They are most common in strongly folded pre-orogenic sediments of the flysch type in geosynclines. Volcanic products are commonly adjacent.

SUPPOSED PRECAMBRIAN

The presence of Radiolaria in Precambrian rocks of Brittany, along the Vendée coast, has been reported (6), largely upon insecure evidence. All described specimens (19 genera, 45 species, and many indeterminate forms) came from a single sample. Most of these Radiolaria are poorly preserved and illustrations of them are highly reconstructed. The shells are much smaller than modern forms to which they seem to be related. The fossil-bearing matrix is interbedded with gneiss, and its exact age is open to question. Somewhat arbitrarily, it is herein classed as Cambrian.

Radiolaria found near Adelaide, Australia, which comonly have been assigned to the Precambrian, now are credited to the Cambrian (14). Until the stratigraphy of these deposits is more clearly understood, the presence of Radiolaria in Precambrian formations cannot be affirmed reliably.

PALEOZOIC

The number of Radiolaria known from Paleozoic strata is much smaller than that from Mesozoic or Cenozoic deposits. Rüst (25) counted 109 genera and 261 species which had been reported up to 1892 in rocks of this era. In the Ordovician of New York, 19 genera and 33 species belonging to planktonic types were recorded but only 27 species from the Silurian. Devonian rocks, according to Rüst, contain 64 species, but numerous others have been added since his time. Cherts, limestones, and tuffs rich in these organisms occur in New South Wales, and the Caballos chert of the Marathon basin of Texas contains a fauna of 18 genera and 24 species. The greater part of these pre-Carboniferous rocks contain forms which belong to the Sphaerellari. Only a few records of Carboniferous Radiolaria are trustworthy, for most of the 199 so-called Carboniferous species reported by Rüst come from radiolarian-bearing rocks in Sicily now classified as Jurassic. Only 8 genera and 12 species are known from the Permian, the Word and Leonard formations of the Texas Marathon basin being the best-known North American occurrences of Radiolaria of this age. With few exceptions, all Paleozoic Radiolaria are of simple form, consisting mostly of latticed spherical, elliptical, or lens-shaped shells. Many Nassellina belong to the Plectellari, although some large Cyrtellari are known.

MESOZOIC

Well-preserved Radiolaria have been recovered from the principal divisions of the marine Mesozoic. RÜST counts 421 species, of which only 21 are from the Triassic. For the most part, the great development occurs in the Jurassic (232 species), especially from the Alps, where marine subdivisions are more or less prolific in these fossils. Silicified coprolites, flints, jaspers, novaculites, hornstones, and cherts are fertile sources of these fossils everywhere in the Jurassic. The age of some radiolarian-bearing rocks assigned to the Jurassic in Asia, particularly Japan (14), and also in California is now considered uncertain. Rocks of the Danau plateau of Kalimanten (Dutch Borneo), with an area of about 40,000 square miles, which seem to comprise a nearly flat elevated sea-bottom, are assigned to the Jurassic by most students. The Danau formation contains a radiolarian fauna of 32 genera and 100 species. The Franciscan radiolarian chert of California, similarly assigned to the Jurassic and often correlated with the Danau formation, carries a uniform but very small fauna of only 10 genera and 13 species in an area of 25,000 square miles or more. These 2 formations have the greatest areal extent of any known radiolarian-bearing rocks.

RÜST reports only 168 Cretaceous Radiolaria, but about 3 times as many have been added since his records were made. Extensive studies of various Italian localities provide most of these new records. Rocks elsewhere are known to contain rich undescribed faunas, among which those from the Funks formation (northern California) and Water Canyon formation of the San Joaquin Valley (central California) are especially abundant in kinds and numbers. Extensive deposits of Radiolaria occur in Ecuador and large faunas are known to occur in Java, Rotti, and other parts of the East Indies.

Mesozoic radiolarian faunas contain great numbers of different kinds of very large Triacartilae and abound in basally fenestrated Nassellina. The number of ringed Spumellina (*Saturnalis* and similar genera) is great. The genus *Cenellipsis* is common but Triospyridicae generally are scarce. These Mesozoic faunas are easily distinguished from those of other eras. Some students of fossil Radiolaria believe that Mesozoic faunas are widely distributed (21).

CENOZOIC

The great majority of described fossil Radiolaria belong to Cenozoic formations, and these are mainly from upper Eocene formations. One report describes these fossils in Paleocene strata (Missouri).

Lower and middle Eocene faunas are recorded in Alabama, Trinidad, and New Zealand but are poorly known. Upper Eocene marls and clays, especially in Barbados, are very rich in radiolarians and afford some of the classic examples of these fossils; nearly every geological and biological collection possesses some specimens from Barbados. About 500 species from this island have been described. Sicily also abounds in fruitful tripoli deposits, long known for their utility as polishing powders.

The Oligocene of New Zealand (Omaru), famous for its beautiful and varied diatom flora, is rich in Radiolaria. Oligocene beds of Cuba and Trinidad contain large but undescribed faunas.

Among the best-known Miocene radiolarian deposits are those of the Mohnian and Delmontian stages of California. Faunas from Italy, particularly that of Reggio Emelia, near Naples, are important. Smaller Miocene faunas occur elsewhere in Europe and North and South America.

The Pico formation of the Los Angeles area (California) yields an interesting Pliocene fauna, but the largest and most varied fauna (328 species) of this age is found on Rotti (East Indies). Hardly any other Pliocene faunas are known. Undifferentiated Cenozoic Radiolaria have been described from several parts of South America.

Cenozoic Spumellina and Nassellina are intimately related in general character to forms which now occur in Recent deep-sea oozes, especially those of the Pacific area (21). At least 1,500 species have been described from Cenozoic deposits.

METHODS OF STUDY

SEPARATION

Methods of separating the shells of Radiolaria from matrix containing them differ greatly from techniques generally employed by students of Foraminifera.

RECENT FORMS

Radiolaria, especially those from deep-sea cores with much calcareous matrix, can be prepared by boiling a small sample in a glass beaker or test tube in concentrated HCl under a chemical hood or with arrangement to direct the fumes away from the operator. Much gas usually is evolved, and care must be taken that particles do not cling to sides of the container or overflow. The acid should be added to the container little by little before flame is applied. After the material has broken down, the sample should be allowed to cool and the residue to settle. The supernatant liquid may then be decanted carefully. The residue should next be boiled in H_2O_2, and, after cooling, it should be washed in distilled water and stored in weak alcohol in tightly corked bottles. Refractory samples must be treated according to directions given for preparation of fossils.

FOSSIL FORMS

Samples of sedimentary deposits, especially shales containing fossil shells of Radiolaria, are broken into fragments, put into a beaker, and boiled under a chemical hood for 15 to 20 minutes in concentrated HCl. Without washing, an equal volume of concentrated HNO_3 is added and boiled in the same beaker for a similar length of time, or until brown fumes disappear. After thorough washing with water and careful decanting, the sample is boiled in concentrated H_2SO_4 until organic matter is removed. The process may take an hour, or exceptionally more than 12 hours, and judgment must be used to determine when it has been completed. The sulphuric acid treatment may be repeated if necessary. The sample is next washed in a liberal amount of water with repeated decantations. After all trace of acid disappears, NaOH pellets or small portions of sticks should be added and boiling repeated. If the sample has not disintegrated previously, it will do so now. Care must be taken to avoid an excess of NaOH which may destroy the specimens. Wash the sample once more and boil with a few drops of HCl in order to neutralize the alkali. The sample, generally consisting of very clean beautiful specimens, may now be stored in weak alcohol in small vials.

Another method sometimes employed is as follows: (1) Place a 10-gram sample of dry fragmented sediment in a 400-ml. beaker with distilled water to which 4 or 5 grams of tetrasodium pyrophosphate has been added, and set the sample aside for 24 hours. If undispersed clay remains, add more of the reagent and allow the sample to soak for another day. The next steps are directed to segregation and concentration of the Radiolaria. (2) Rotate the sample rapidly in a beaker and allow it to stand 10 minutes, after which the water should be poured off gently. Repeat until a clean residue is obtained. If clay remains, more reagent may be added and the sample boiled for a half hour. Further decanting at 10-minute intervals should be continued until a clay-free residue remains. (3) Decant now at 5-minute intervals, saving the decanted part, and gradually reduce the decanting period to 1- or 2-minute intervals. (4) Next, boil the decanted residues for about 30 minutes in distilled water with 10-per cent concentrated H_2SO_4 until the organic matter is removed. (5) Wash the residue in distilled water and store as usual. This process sometimes proves successful when other methods fail, especially in samples containing much clay matrix.

EXAMINATION

SLIDE PREPARATION

To make slides of specimens prepared by one of the methods described, small amounts of sample residue should be withdrawn by pipette from a bottle and dropped on a clean glass slide. Allow the water to evaporate on a warm electric plate until the preparation is completely dry. Place a drop of mounting medium over the specimen-containing area while the slide is warm, lay a cover slip in position, and reheat the slide gently until the medium spreads evenly to all edges of the slip. Then the slide may be withdrawn from the plate and allowed to cool. Hyrax, because of its high refractive index, is preferable to Canada balsam but may not be available. Specimens mounted in this way are not arranged in order.

Sometimes, for special reasons, ordered rows of specimens are prepared before the cover slip is added. In order to make such arrangement of shells, one should add a small amount of gum arabic to the center of the slide and put the specimens near by. When the gum is dried, small brushes or fine needles may be used under a compound binocular dissecting microscope to arrange the specimens in suitable order. Individuals are picked up singly and placed in regular rows in the gum. When so placed, the specimens may be fixed in position by breathing upon the slide gently. Further treatment with mounting medium is according to schedule. For diagnostic purposes and usual laboratory routine, the unsorted mount is satisfactory, but ordered rows of specimens are desirable in a reference collection or for exhibition.

THIN SECTIONS

Specimens enclosed in a very hard matrix, such as chert, novaculite, and other refractory material, generally are examined in thin sections. It is best to grind a small polished surface first in order to find a plane containing a large number of suitably oriented specimens. Sections should not be ground as thin as those usually made for mineral determinations.

Thin sections of radiolarian shells require special interpretation, for specimens sectioned obliquely may appear as ovals, and cross sections as circles. Conical forms in these views may appear to belong to radically different genera. KOBAYASHI (14) gives an excellent discussion of some of these difficulties.

MICROSCOPIC METHODS

A compound biological microscope with powers ranging from ×50 to ×700 is required for the study of these minute organisms. A binocular instrument is most satisfactory. Good lighting is required and should come from an artificial source. Green light obtained by interposing a suitable filter is desirable, especially for continued observations. A camera lucida helps the worker. With aid of this instrument, drawings made to scale can be accumulated rapidly. Simple photographic methods have been described (6).

AGE DETERMINATION

For determining the age of a previously unstudied radiolarian fauna, the traditional method has been to ascertain the percentage of species of Cyrtellari in the whole fauna and to compare it with similar percentages in classic European faunas. In Europe, the Cyrtellari comprise 22 per cent of known Paleozoic faunas, 55 per cent of the Jurassic, 35 per cent of the Cretaceous, and 50 per cent of the Cenozoic. Percentages are sometimes calculated on number of individuals counted in thin sections or by taking genera as the unit. All this comes about because the Cyrtellari are best known in the European Jurassic and less so in formations of other ages. Recent studies (14) do not bear out age determinations based on this method. Many questions as to specific identifications, influence of ecological factors, geographic distribution, accidental assemblies, conditions of differential fossilization, deformation of individuals due to fossilization, and effect of other factors cast doubt on the reliability of this method and any conclusions drawn from it. By this method the Franciscan and Danau formations were correlated with each other. The study of radiolarian assemblages by comparison with faunas of known ages probably is more sound. Statistical methods may be useful.

CLASSIFICATION

PRINCIPLES

The classification of Radiolaria depends mostly upon hard parts which form the shell. The outstanding feature of the different families, genera, and species of Radiolaria is the geometrical form of the test. Nearly every figure found in symmetrical 3-dimensional geometrical structures is reproduced in some member of this group. Irregular shapes are rare and they are derived from regular forms. The geometrical system thus seems to be a logical, simple plan capable of expressing the genetic history and relations of the multitudinous forms belonging to Radiolaria.

HISTORY

The classification of Radiolaria by early authors (to 1884) has been stated by HAECKEL (12), who gives reasons for rejection of systems proposed by EHRENBERG, MÜLLER, HERTWIG, BÜTSCHLI, and others. Later monographers, especially RÜST, HAECKER, and POPOFSKY, largely have followed the system proposed by HAECKEL. None of these or other authors, most of whom have been concerned principally with description of particular faunas, has reviewed the Radiolaria as a whole. Neither HAECKER nor POPOFSKY considered fossil radiolarians especially, and RÜST (23-26) did not treat Recent forms. HAECKER (13) removed the Orosphaeridae from the Phaeodarina to the Spumellina, and rejected HAECKEL's Prunoidea, which he included with the Sphaeroidea, at least in part. POPOFSKY (19) united the Stephaniicae and Cannobotrydicae as Orboidea, in the Nassellina, but otherwise followed HAECKEL and HAECKER in most other divisions.

The system herein adopted is mainly that of HAECKEL but accepts HAECKER's placement of the Orosphaeridae and rejects the union of HAECKEL's Prunoidea and Sphaeroidea, and also POPOFSKY's Orboidea. HAECKER's Lamprocycladidae and Plectopyramididae in the Nassellina are also rejected. Other unaccepted categories are evident in organization of the systematic text. These exclusions are based on a reexamination of the various groups as a whole, rather than on the partial basis of their arrangement.

The complex classification of the Phaeodarina presents a special problem. HAECKEL's arrangement of these forms, which is adopted in the *Treatise,* differs chiefly from that of HAECKER, followed by POPOFSKY (20), in separation of the Coelodendridae and Coelographididae. The general system here presented is the first since HAECKEL's Challenger report, which treats Radiolaria as a whole, including both fossil and Recent genera.

PHYLOGENY

For the purpose of constructing a genealogical tree of the Radiolaria, available sources of information are: (1) paleontology, (2) comparative development, and (3) comparative structure. The third of these is the most satisfactory, and by its aid we are able to recognize the general features of probable radiolarian phylogeny.

The agreement of all Radiolaria in essential structure of the central body (capsule) distinguishes them from other Protozoa and justifies the conclusion that the whole group developed from a common undifferentiated stem form. The simplest Spumellina, without a skeleton but with a spherical body, seems to be the radical form, and the genus *Procyttarium* closely approximates the common ancestor of the whole group. The Radiolaria are judged to be closely related to the Heliozoa, which probably gave rise to them.

The Spumellina may be regarded as the common stem of Radiolaria, for they possess in simplest, least differentiated form all characters that distinguish Radiolaria essentially from other protozoans. Furthermore, the Spumellina lack the positive characters which set apart the remaining suborders. The Acantharina, Nassellina, and Phaeodarina are interpreted as divergent branches of the genealogical tree which have separated in different directions and are only connected through their respective simplest members, viz., *Actinelius, Cystidium,* and *Phaeodina* (FIG. 7).

The Acantharina are distinguished by (1) the centrally generated skeleton, (2) the peculiar chemical nature of the skeleton, and (3) the disposition of pores of the central capsule. All forms of the Acantharina may be derived from *Actinelius,* which seems to have arisen from *Procyttarium* by division of some primitive pseudopods into soft, flexible extensions, while others became firm and rigid, with skeletal supporting rods. The Acantharina are widely divergent from other suborders and are treated first in the systematic text in order to stress this difference.

The Nassellina are peculiarly distinguished from other suborders by the pore-bearing plate which closes off the oral pole of the conical structure (podocone) within the central capsule. The Nassellina are connected through *Cystidium* to *Procyttarium*. *Cystidium* may be considered a *Procyttarium* with a very different central capsule. It may have arisen from *Procyttarium* by obliteration of numerous, evenly distributed pores of the central capsule at one pole of the capsule, accompanied by better development of them at the opposite pole. The concentration of these pores at one pole led to further development of the podoconus (Fig. 8).

The Phaeodarina are sharply marked off from other Radiolaria by (1) the double membrane of the central capsule, (2) the tubular opening (astropyle) at one pole, and (3) the presence of an aggregate of dark granules (phaeodium). The stem form is *Phaeodina* and others may derive from it. *Phaeodina,* in turn, may have arisen from *Procyttarium,* presuming that the 3 essential characters listed above appeared mostly by successive steps through intermediate stages. Thus, the gradual reduction of numerous fine pores of the central capsule may have resulted in a tubular main aperture approximately in the fashion postulated for the Nassellina, and the phaeodium may have appeared progressively from some sort of modified symbiontism. The double capsule membrane could have formed in a single step. In any case, these are easy evolutionary developments. The Phaeodarina are among the most complex Radiolaria. With respect to their multiform skeletons, most of the series seem to be due to genetic factors and few to adaptive modifications. Of the last, those related to flotation are the most important.

Suprageneric Divisions of Radiolaria

(First figures in parentheses indicate number of genera and second the number of subgenera.)

Porulosida *(order)* (474;504) *Cam.-Rec.*
Acantharina *(suborder)* (72;86) *Eoc.-Rec.*
Astrolophi *(division)* (32;39) *Eoc.-Rec.*
Astrolophicae *(superfamily)* (5;8) *Eoc.-Rec.*
Astrolophidae *(family)* (2;3) *Rec.*
Litholophidae (1;2) *Rec.*
Acanthochiasmatidae (2;3) *Eoc.-Rec.*
Acanthochiasmatinae *(subfamily)* (1;3) *Rec.*
Chiastolinae (1) *Eoc.-Rec.*
Actinastricae *(superfamily)* (3) *Rec.*
Actinastridae *(family)* (1) *Rec.*
Rosettidae (1) *Rec.*
Trizonidae (1) *Rec.*
Astrolonchicae *(superfamily)* (24;31) *Mio.-Rec.*
Astrolonchidae *(family)* (14;19) *Mio.-Rec.*
Astrolonchinae *(subfamily)* (5;2) *Rec.*
Stauracanthinae (4;4) *Rec.*
Zygacanthinae (5;13) *Mio-Rec.*
Acanthostauridae *(family)* (7;7) *Rec.*
Acanthostaurinae *(subfamily)* (4;2) *Rec.*
Lithopterinae (3;5) *Rec.*
Acantholonchidae *(family)* (3;5) *Rec.*
Acanthophracti *(division)* (40;47) *Rec.*
Dorataspidicae *(superfamily)* (28;30) *Rec.*
Dorataspididae *(family)* (18;25) *Rec.*
Dorataspidinae *(subfamily)* (10;17) *Rec.*
Dorataspidides *(tribe)* (8;13) *Rec.*
Phractaspidides (2;4) *Rec.*
Tessarapelmatinae *(subfamily)* (8;8) *Rec.*
Tessarapelmatides *(tribe)* (4;6) *Rec.*
Stauraspidides (4;2) *Rec.*
Astrocapsidae *(family)* (5) *Rec.*
Astrocapsinae *(subfamily)* (2) *Rec.*
Cenocapsinae *(subfamily)* (1) *Rec.*
Porocapsinae *(subfamily)* (2) *Rec.*
Aspidommatidae *(family)* (5;5) *Rec.*
Belonaspidicae *(superfamily)* (12;17) *Rec.*
Belonaspididae *(family)* (6;5) *Rec.*
Belonaspidinae *(subfamily)* (5;2) *Rec.*
Phatnaspidinae (1;3) *Rec.*
Hexalaspididae *(family)* (4;8) *Rec.*
Diploconidae (2;4) *Rec.*
Spumellina *(suborder)* (402;418) *Cam.-Rec.*
Collodari *(division)* (26;28) *Ord.-Rec.*
Thalassicolicae *(superfamily)* (7;11) *Dev.-Rec.*
Thalassicolidae *(family)* (5;6) *Dev.-Rec.*
Cristallosphaeridae (1) *Rec.*
Collozoidae (1;5) *Rec.*
Thalassosphaericae *(superfamily)* (15;11) *Ord.-Rec.*
Thalassosphaeridae *(family)* (5;5) *Rec.*
Sphaerozoidae (3;6) *Ord.-Rec.*
Meyenellidae (2) *Jur.*
Thalassothamnidae (3) *Rec.*
Lithacanthidae (2) *Rec.*
Orosphaericae *(superfamily)* (4;6) *Rec.*
Orosphaeridae *(family)* (4;6) *Rec.*
Orosphaerinae *(subfamily)* (2;2) *Rec.*
Orosceninae (2;4) *Rec.*
Sphaerellari *(division)* (376;390) *Cam.-Rec.*
Liosphaericae *(superfamily)* (149;133) *Cam.-Rec.*
Liosphaeridae *(family)* (16;24) *Cam.-Rec.*
Liosphaerinae *(subfamily)* (2;6) *Ord.-Rec.*
Ethmosphaerinae (4;6) *Cam.-Rec.*
Thecosphaerinae (3;6) *Jur.-Rec.*
Cromyosphaerinae (1) *Cret.-Rec.*
Caryosphaerinae (1) *Dev.-Rec.*
Plegmosphaerinae (5;6) *Cam.-Rec.*
Protosphaeridae *(family)* (1) *Cret.*
Collosphaeridae (17;13) *Ord.-Rec.*
Collosphaerinae *(subfamily)* (15;11) *Ord.-Rec.*
Clathrosphaerinae (2;2) *Rec.*
Dorysphaeridae *(family)* (5;2) *Ord.-Mio.*
Stylosphaeridae (18;22) *Cam.-Rec.*
Stylosphaerinae *(subfamily)* (3;8) *Dev.-Rec.*
Xiphostylinae (4;10) *Cam.-Rec.*
Amphistylinae (3;4) *Jur.-Rec.*
Cromyostylinae (2) *Rec.*

Caryostylinae (1) *Rec.*
Spongostylinae (5) *Cret.-Rec.*
Triposphaeridae *(family)* (5) *Ord.-Cret.*
Staurosphaeridae (14;12) *Cam.-Rec.*
Staurosphaerinae *(subfamily)* (3;4) *Ord.-Rec.*
Staurolonchinae (5;4) *Cam.-Rec.*
Stauracontiinae (1;4) *Jur.-Rec.*
Staurocromyinae (2) *Cret.-Rec.*
Staurocaryinae (1) *Rec.*
Staurodoradinae (2) *Ord.-Rec.*
Pentasphaeridae *(family)* (1) *Cret.*
Cubosphaeridae (21;14) *Dev.-Rec.*
Cubosphaerinae *(subfamily)* (2) *Rec.*
Hexastylinae (5;4) *Jur.-Rec.*
Hexalonchinae (4;6) *Dev.-Rec.*
Hexacontiinae (3;4) *Eoc.-Rec.*
Hexacromyinae (1) *Mio.-Rec.*
Centralonchinae (3) *Rec.*
Hexadoradinae (3) *Cret.-Rec.*
Astrosphaeridae *(family)* (50;46) *Cam.-Rec.*
Astrosphaerinae *(subfamily)* (9;16) *Cam.-Rec.*
Heliosphaerinae (6;14) *Ord.-Rec.*
Actinommatinae (4;6) *Dev.-Rec.*
Cromyommatinae (3;2) *Cam.-Rec.*

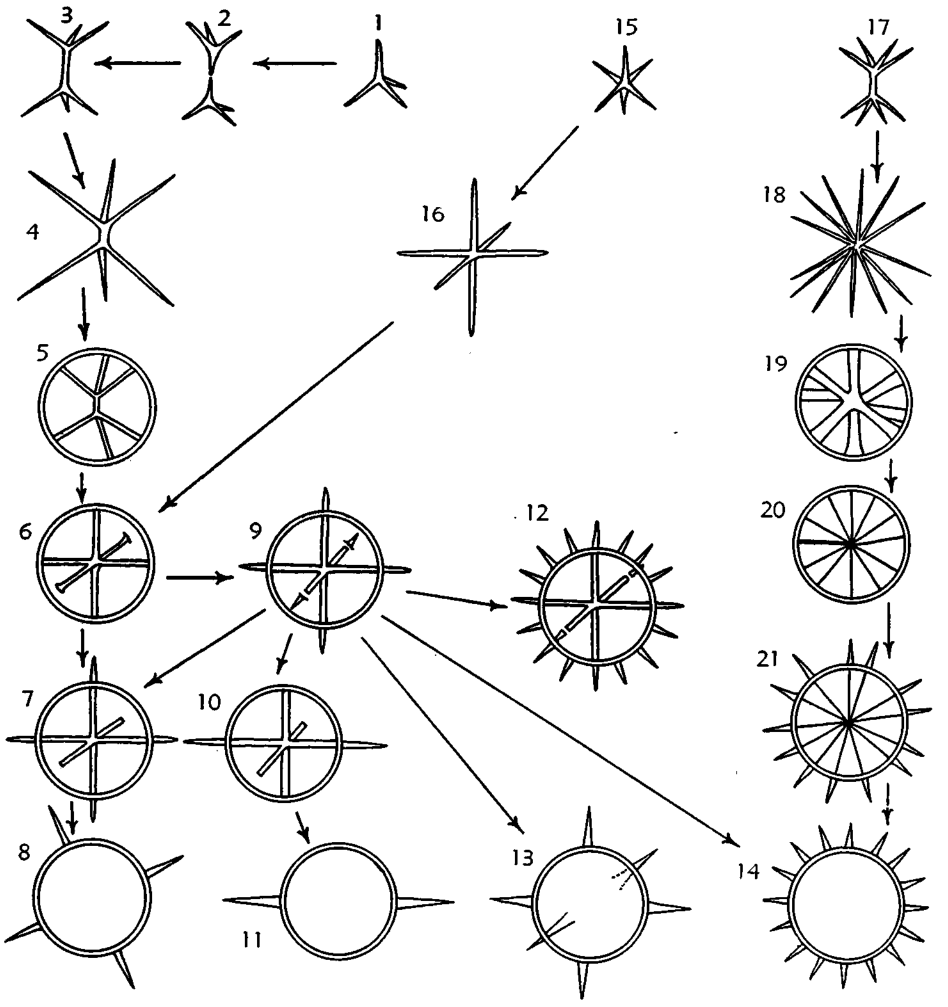


FIG. 7. Phylogenetic relationships of the Spumellina, showing inferred evolution of skeletal ray patterns in Radiolaria. Primitively these consist of radially arranged spines alone (1-4, 15-16, 17-18) or, in more complex forms, of spines and a spheroidal lattice shell. Monocentric 4-ray types (1, 2) by pairing may produce dicentric forms (3-5) which give rise to secondarily monocentric 6-ray and other patterns. Similar evolution of multiray skeletons is suggested. Evolutionary trends are indicated by arrows and architectural types by letters: (1) 4-ray, (2-4) double 4-ray, (5,6) *Stigmosphaera,* (7) hypothetical intermediate form, (8) staurosphaerid, (9) *Centrolonche,* (10) *Stigmosphaerostylus,* (11) stylosphaerid, (12) *Acanthosphaera,* (13) cubosphaerid, (14) astrosphaerid, (15) thalassosphaerid, (16) *Lithacanthus,* (17) double 4-ray, (18) Cytocladus, (19,20) *Stigmosphaera,* (21) *Heterosoma* (48).

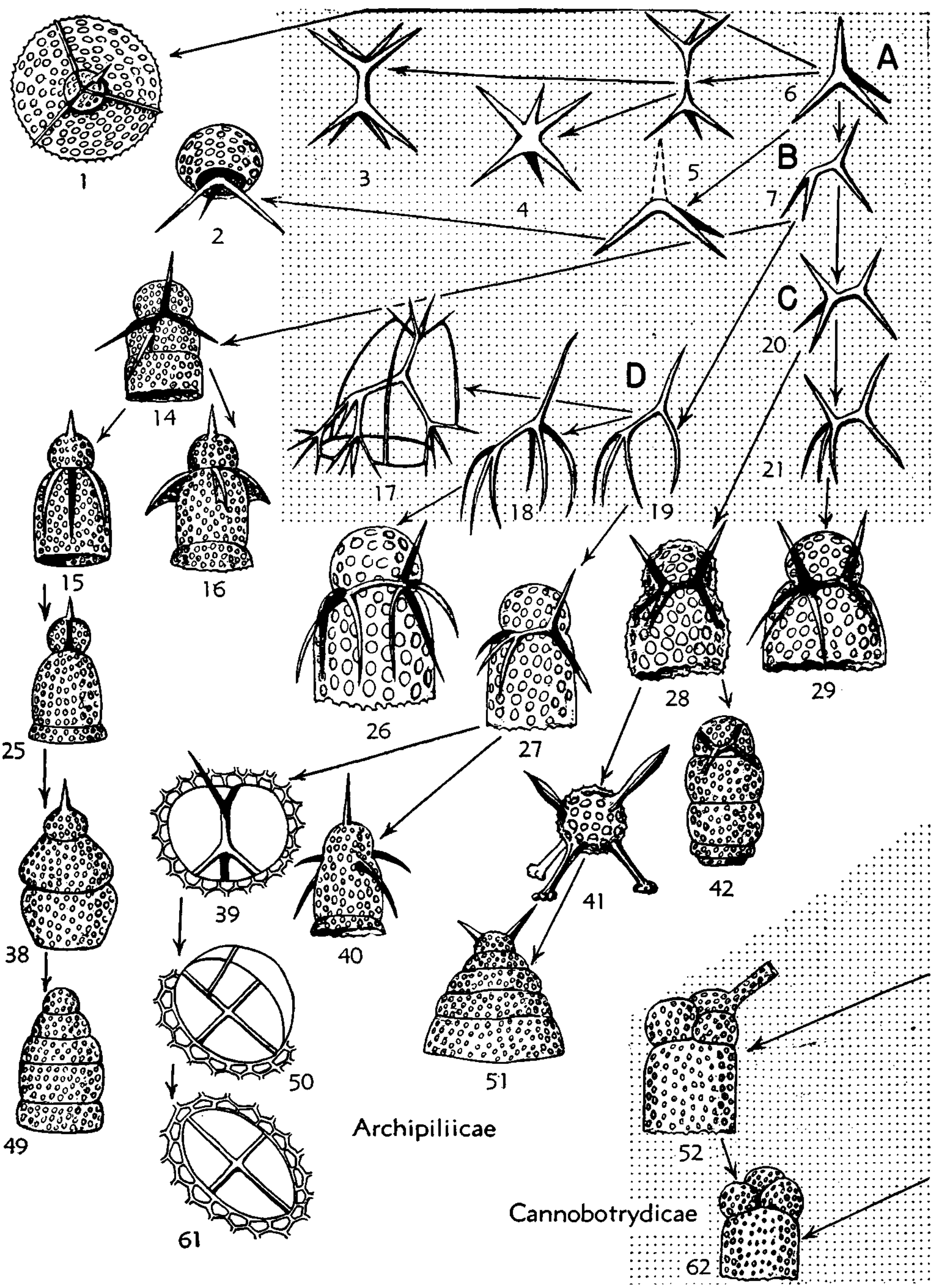
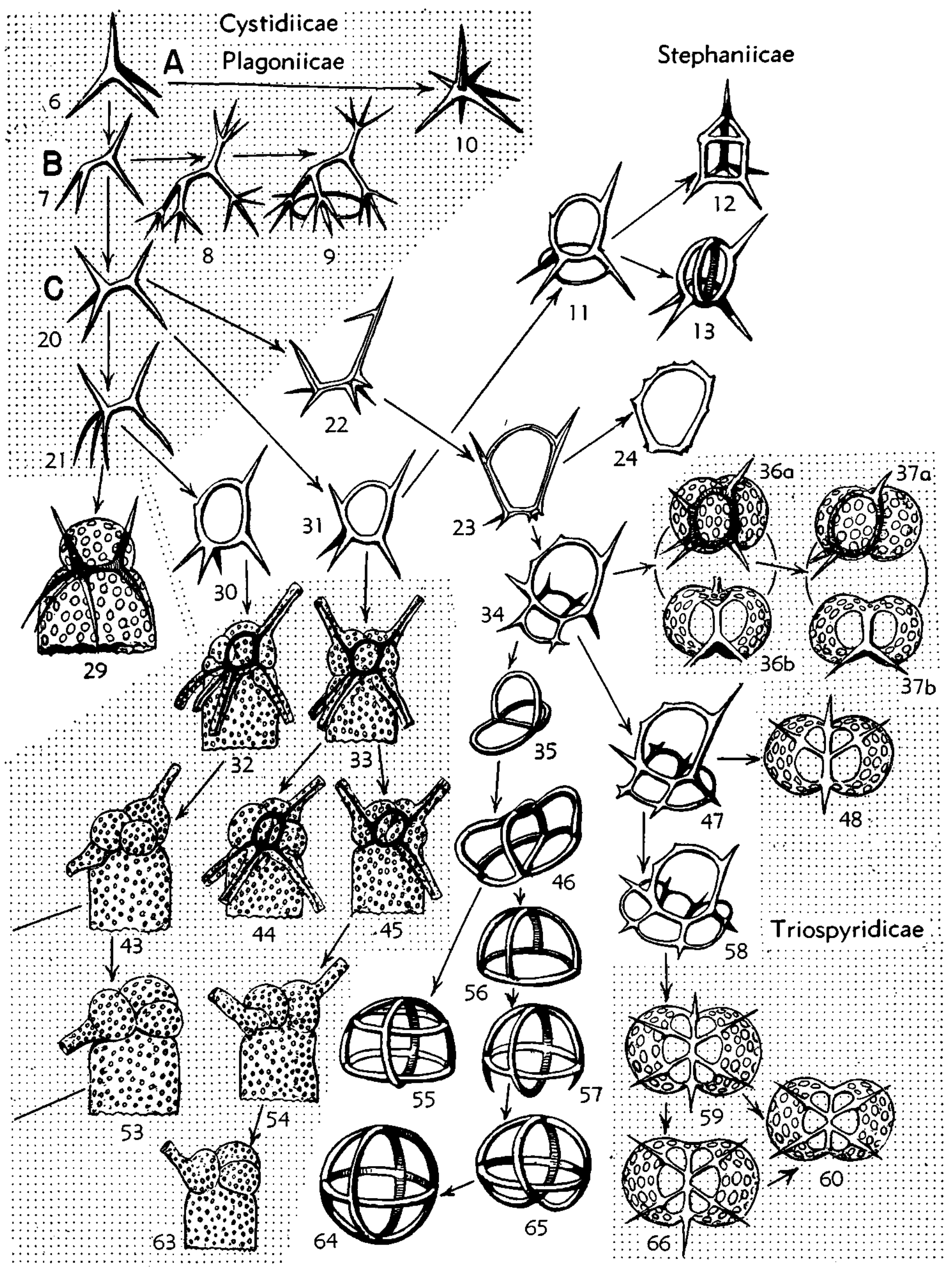


FIG. 8. Phylogeny of the Nassellina. All of these radiolarians are thought to be derivatives of relatively simple types illustrated by (*A*) *Plagoniscus*, (*B*) *Periplecta*, (*C*) *Plagiocarpa*, and (*D*) *Campylacantha*. The superfamilies Cystidiicae and Plagioniicae are represented by 3-10, 17-21, and the Stephaniicae by 11-13, 30, and other numbers in the unshaded area at right; these belong to the division Plectellari. The



superfamily Archipiliicae is represented by 26-29 and other numbers in the unshaded area at left; the Cannobotrydicae by 52 and other numbers in the central shaded area below; and the Triospyridicae by figures in the shaded area at lower right; they belong to the division Cyrtellari (48).

Arachnosphaerinae (3;2) *Rec.*
Sphaeropylinae (3) *Dev.-Rec.*
Stomatosphaerinae (1) *Rec.*
Spongiommatinae (21;6) *Cam.-Rec.*
Dactyliosphaeridae *(family)* (1) *Cret.*
Ellipsidiicae *(superfamily)* (65;76) *Cam.-Rec.*
Ellipsidiidae *(family)* (11;6) *Cam.-Rec.*
Druppulidae (19;27) *Ord.-Rec.*
Sponguridae (10;11) *Ord.-Rec.*
Spongurinae *(subfamily)* (6;7) *Ord.-Rec.*
Spongodruppinae (4;4) *Carb.-Rec.*
Artiscidae *(family)* (3;4) *Cret.-Rec.*
Cyphantidae (9;12) *Dev.-Rec.*
Panartidae (6;12) *Rec.*
Zygartidae (7;4) *Rec.*
Zygartinae *(subfamily)* (2) *Rec.*
Ommatocampinae (2;4) *Mio.-Rec.*
Desmocampinae (2) *Rec.*
Monaxoniinae (1) *Rec.*
Cenodiscicae *(superfamily)* (109;129) *Cam.-Rec.*
Cenodiscilae *(subsuperfamily)* (48;46) *Cam.-Rec.*
Cenodiscidae *(family)* (7;8) *Cam.-Rec.*
Cenodiscinae *(subfamily)* (2) *Sil.-Rec.*
Trochodiscinae (5;8) *Cam.-Rec.*
Phacodiscidae *(family)* (22;28) *Cam.-Rec.*
Phacodiscinae *(subfamily)* (5;4) *Eoc.-Rec.*
Dorydiscinae (2) *Mio.*
Heliosestrinae (12;14) *Dev.-Rec.*
Heliodiscinae (3;10) *Cam.-Rec.*
Coccodiscidae *(family)* (19;10) *Dev.-Rec.*
Coccodiscinae *(subfamily)* (2) *Dev.-Rec.*
Stylocycliinae (6) *Jur.-Rec.*
Astracturinae (11;10) *Trias.-Rec.*
Euchitoniilae *(subsuperfamily)* (61;83) *Cam.-Rec.*
Euchitoniidae *(family)* (38;63) *Cam.-Rec.*
Euchitoniinae *(subfamily)* (25;42) *Dev.-Rec.*
Archidiscinae (2;5) *Jur.-Rec.*
Flustrellinae (2;5) *Cam.-Rec.*
Ommatodiscinae (2;2) *Paleoc.-Rec.*
Stylodictyinae (7;9) *Perm.-Rec.*
Pylodiscidae *(family)* (8) *Eoc.-Rec.*
Pylodiscinae *(subfamily)* (3) *Rec.*
Triopylinae (3) *Rec.*
Discopylinae (2) *Eoc.-Rec.*
Spongodiscidae *(family)* (15;20) *Ord.-Rec.*
Spongodiscinae *(subfamily)* (2;4) *Dev.-Rec.*
Spongopylinae (1;2) *Eoc.-Rec.*
Spongotrochinae (6;6) *Ord.-Rec.*
Spongobrachiinae (6;8) *Jur.-Rec.*
Laracariicae *(superfamily)* (53;52) *Cam.-Rec.*
Laracariidae *(family)* (7) *Eoc.-Rec.*
Laracariinae *(subfamily)* (2) *Rec.*
Coccolarcinae (2) *Eoc.-Rec.*
Spongolarcinae (2) *Rec.*
Larcopylinae (1) *Rec.*
Larnacillidae *(family)* (8) *Paleoc.-Rec.*
Larnacillinae *(subfamily)* (2) *Rec.*
Larnacalpidinae (5) *Paleoc.-Rec.*
Cenolarcopylinae (1) *Plio.*
Pyloniidae *(family)* (10;14) *Jur.-Rec.*
Pyloniinae *(subfamily)* (4;8) *Rec.*
Monozoniinae (3;6) *Jur.-Rec.*
Tetrapyloniinae (3) *Jur.-Rec.*
Tholoniidae *(family)* (12;18) *Rec.*
Tholoniinae *(subfamily)* (4;6) *Rec.*
Amphitholinae (4;4) *Rec.*
Staurotholinae (4;8) *Rec.*
Zonariidae *(family)* (3) *Rec.*
Litheliidae (6;12) *Dev.-Rec.*
Litheliinae *(subfamily)* (2;4) *Dev.-Rec.*
Larcospirinae (4;8) *Dev.-Rec.*
Strebloniidae *(family)* (3) *Rec.*
Strebloniinae *(subfamily)* (2) *Rec.*
Streblopylinae (1) *Rec.*
Phorticidae *(family)* (2;4) *Cam.-Rec.*
Soreumatidae (2;4) *Rec.*
Osculosida *(order)* (427;258) *Cam.-Rec.*
Nassellina *(suborder)* (324;224) *Cam.-Rec.*
Plectellari *(division)* (70;26) *Ord.-Rec.*
Cystidiicae *(superfamily)* (2) *Rec.*
Cystidiidae *(family)* (2) *Rec.*
Plagoniicae *(superfamily)* (25) *Ord.-Rec.*
Plagoniidae *(family)* (9) *Ord.-Rec.*
Plagoniinae *(subfamily)* (2) *Ord.-Rec.*
Triplagiinae (2) *Dev.-Rec.*
Tetraplagiinae (4) *Ord.-Rec.*
Enneaplagiinae (1) *Rec.*
Plectaniidae *(family)* (16) *Rec.*
Plectaniinae *(subfamily)* (3) *Rec.*
Triplectinae (5) *Rec.*
Tetraplectinae (7) *Rec.*
Enneaplegmatinae (1) *Rec.*
Stephaniicae *(superfamily)* (43;26) *Trias.-Rec.*
Stephaniidae *(family)* (7;2) *Trias.-Rec.*
Stephaniinae *(subfamily)* (2) *Eoc.-Rec.*
Lithocircinae (5;2) *Trias.-Rec.*
Cyrtostephanidae *(family)* (1) *Rec.*
Semantididae (9) *Jur.-Rec.*
Semantidinae *subfamily* (6) *Jur.-Rec.*
Cortiniscinae (3) *Eoc.-Rec.*
Acanthodesmiidae *(family)* (11;15) *Jur.-Rec.*
Acanthodesmiinae *(subfamily)* (2) *Rec.*
Zygostephaninae (2;2) *Jur.-Rec.*
Eucoronidinae (3;7) *Eoc.-Rec.*
Trissocyclinae (4;6) *Rec.*
Paratympanidae *(family)* (15;9) *Jur.-Rec.*
Protympaniinae *(subfamily)* (6;9) *Cret.-Rec.*
Paratympaninae (2) *Rec.*
Dystympaniinae (1) *Jur.-Rec.*
Eutympaniinae (6) *Jur.-Rec.*
Cyrtellari *(division)* (254;198) *Cam.-Rec.*
Triospyridicae *(superfamily)* (46;33) *Jur.-Rec.*
Triospyrididae *(family)* (28;27) *Jur.-Rec.*
Triospyridinae *(subfamily)* (4;9) *Eoc.-Rec.*
Dipodospyridinae (6) *Eoc.-Rec.*
Tetrarrhabdinae (2;2) *Eoc.-Rec.*
Pentaspyridinae (3) *Eoc.-Rec.*
Hexaspyridinae (3;2) *Eoc.-Rec.*
Therospyridinae (4;2) *Cret.-Rec.*
Petalospyridinae (4;8) *Jur.-Rec.*
Circospyridinae (2;4) *Jur.-Rec.*
Tholospyrididae *(family)* (5;2) *Mio.-Rec.*
Tholospyridinae *(subfamily)* (2;2) *Mio.-Rec.*
Tiarospyridinae (2) *Rec.*
Spyridobotrydinae (1) *Rec.*
Phormospyrididae *(family)* (6) *Eoc.-Rec.*
Phormospyridinae *(subfamily)* (2) *Eoc.-Rec.*
Rhodospyridinae (4) *Eoc.-Rec.*
Androspyrididae *(family)* (7;4) *Eoc.-Rec.*
Androspyridinae *(subfamily)* (2) *Rec.*
Perispyridinae (3;2) *Rec.*
Paradictyinae (2;2) *Eoc.-Rec.*

Archipiliicae *(superfamily)* (194;165) *Cam.-Rec.*
Archipiliilae *(subsuperfamily)* (45;25) *Cam.-Rec.*
Archipiliidae *(family)* (19;8) *Cam.-Rec.*
Archipiliinae *(subfamily)* (12;4) *Cam.-Rec.*
Archiperinae (7;4) *Rec.*
Archiphormididae *(family)* (16;10) *Ord.-Rec.*
Archiphormidinae *(subfamily)* (12;6) *Ord.-Rec.*
Archiphatninae (4;4) *Jur.-Rec.*
Archicorythidae *(family)* (10;7) *Cam.-Rec.*
Archicorythinae *(subfamily)* (6;5) *Cam.-Rec.*
Archicapsinae (4;2) *Perm.-Rec.*
Sethopiliilae *(subsuperfamily)* (60;48) *Cam.-Rec.*
Sethopiliidae *(family)* (27;12) *Jur.-Rec.*
Sethopiliinae *(subfamily)* (17;12) *Jur.-Rec.*
Sethoperinae (10) *Jur.-Rec.*
Sethophormididae *(family)* (18;29) *Cam.-Rec.*
Sethophormidinae *(subfamily)* (16;29) *Cam.-Rec.*
Sethophatninae (2) *Rec.*
Lophophaenidae *(family)* (15;7) *Cam.-Rec.*
Lophophaeninae *(subfamily)* (9;7) *Cam.-Rec.*
Adelocyrtidinae (6) *Cam.-Rec.*
Theopiliilae *(subsuperfamily)* (51;50) *Cam.-Rec.*
Theopiliidae *(family)* (21;15) *Jur.-Rec.*
Theopiliinae *(subfamily)* (15;13) *Jur.-Rec.*
Theoperinae (6;2) *Jur.-Rec.*
Theophormididae *(family)* (11;19) *Jur.-Rec.*
Theophormidinae *(subfamily)* (8;19) *Jur.-Rec.*
Theophatninae (3) *Rec.*
Theocorythidae *(family)* (19;16) *Cam.-Rec.*
Theocorythinae *(subfamily)* (12;10) *Cam.-Rec.*
Theocapsinae (7;6) *Dev.-Rec.*
Triacartilae *(subsuperfamily)* (38;42) *Ord.-Rec.*
Triacartidae *(family)* (10;8) *Perm.-Rec.*
Triacartinae *(subfamily)* (7;4) *Perm.-Rec.*
Stichoperinae (3;4) *Perm.-Rec.*
Artophormididae *(family)* (8;9) *Jur.-Rec.*
Artophormidinae *(subfamily)* (4;7) *Jur.-Rec.*
Stichophatninae (4;2) *Cret.-Rec.*
Stichocorythidae *(family)* (20;25) *Ord.-Rec.*
Stichocorythinae *(subfamily)* (16;23) *Ord.-Rec.*
Stichocapsinae (4;2) *Dev.-Rec.*
Cannobotrydicae *(superfamily)* (14) *Jur.-Rec.*
Cannobotrydidae *(family)* (3) *Jur.-Rec.*
Glycobotrydidae (7) *Eoc.-Rec.*
Pylobotrydidae (4) *Eoc.-Rec.*
Pylobotrydinae *(subfamily)* (2) *Rec.*
Botryocampinae (2) *Eoc.-Rec.*
Phaeodarina *(suborder)* (103;34) *Cret.-Rec.*
Phaeodinicae *(superfamily)* (14;10) *Rec.*
Phaeodinidae *(family)* (2) *Rec.*
Caementellidae (1) *Rec.*
Cannorrhaphididae (3) *Rec.*
Cannorrhaphidinae *(subfamily)* (2) *Rec.*
Catinulinae (1) *Rec.*
Aulacanthidae *(family)* (7;10) *Rec.*
Aulacanthinae *(subfamily)* (6;10) *Rec.*
Aulactiniinae (1) *Rec.*
Astracanthidae *(family)* (1) *Rec.*
Aulosphaericae *(superfamily)* (20;6) *Cret.-Rec.*
Sagosphaeridae *(family)* (8) *Rec.*
Sagosphaerinae *(subfamily)* (5) *Rec.*
Sagmariinae (3) *Rec.*
Aulosphaeridae *(family)* (9;6) *Rec.*
Aulosphaerinae *(subfamily)* (6;6) *Rec.*
Auloniinae (3) *Rec.*
Cannosphaeridae *(family)* (3) *Cret.-Rec.*
Challengeriicae *(superfamily)* (41;16) *Rec.*
Challengeriidae *(family)* (7;9) *Rec.*
Challengeriinae *(subfamily)* (4;9) *Rec.*
Pharyngellinae (3) *Rec.*
Cadiidae *(family)* (1) *Rec.*
Medusettidae (8;4) *Rec.*
Medusettinae *(subfamily)* (3) *Rec.*
Gazellettinae (5;4) *Rec.*
Porospathididae *(family)* (1) *Rec.*
Atlanticellidae (6) *Rec.*
Castanellidae (8) *Rec.*
Castanellinae *(subfamily)* (7) *Rec.*
Circocastaneinae (1) *Rec.*
Circoporidae *(family)* (7) *Rec.*
Circoporinae *(subfamily)* (6) *Rec.*
Haeckelianinae (1) *Rec.*
Tuscadoridae *(family)* (3;3) *Rec.*
Conchariicae *(superfamily)* (9) *Rec.*
Conchariidae *(family)* (9) *Rec.*
Conchariinae *(subfamily)* (2) *Rec.*
Neosphaeroconchidiinae (5) *Rec.*
Conchopsidinae (2) *Rec.*
Coelodendricae *(superfamily)* (19;2) *Rec.*
Coelodendridae *(family)* (4;2) *Rec.*
Coelodendrinae *(subfamily)* (2;2) *Rec.*
Coelodryminae (2) *Rec.*
Coelographididae *(family)* (15) *Rec.*
Coelographidinae *(subfamily)* (7) *Rec.*
Coelothyrinae (2) *Rec.*
Coelotetraceradinae (3) *Rec.*
Coelotholinae (3) *Rec.*

The following synoptic table shows the distribution of the systematic categories of Radiolaria herein recognized.

Statistical Summary

Orders	Sub-orders	Super-families	Families	Sub-families	Genera	Sub-genera
Porulosida	Acantharina	5	15	14	72	86
	Spumellina	7	42	81	402	418
	Total	12	57	95	474	504
Osculosida	Nassellina	6	27	62	324	224
	Phaeodarina	5	19	25	103	34
	Total	11	46	87	427	258
Grand Total		23	103	182	901	762

SYSTEMATIC DESCRIPTIONS

Subclass RADIOLARIA Müller, 1858

[=Polycystina EHR., 1838; Rhizopoda radiata MULLER, 1858; Echinocystida CLAPAREDE, 1858; Rhizopoda HKL., 1861; Cytophora HKL., 1862]

Marine pelagic protozoans emitting many slender radially disposed pseudopodia; with a tough-walled, generally porous central capsule separating the protoplasm into 2 regions. A rigid skeleton, mainly external but partly internal, and commonly siliceous, is usually present; hard parts may consist of spicules. *Cam.-Rec.*

Order PORULOSIDA Haeckel, 1887

[as Porulosa; emend. CAMPBELL, herein] [=Holotrypasta HKL., 1887]

Pores distributed everywhere on the surface of the globular central capsule. *Cam.-Rec.*

Suborder ACANTHARINA Haeckel, 1862

[as Acantharia; emend. CAMPBELL, herein] [=Panacantha HKL., 1878; Acanthometrea HERTWIG, 1879; Actipylea HKL., 1887]

Central capsule with a thin simple membrane; skeleton centrogenous, composed of acanthin or strontium sulphate. *Eoc.-Rec.*

MORPHOLOGICAL FEATURES

The Acantharina are distinguished from all other Radiolaria by the distinctive centrally generated **centrogenous skeleton** composed of radial spines, which arise at the central point of the central capsule and which are invariably solid. The regularity in arrangement of the spines is remarkable, for only in one subdivision do they depart from the plan of circles expressed by the **Müllerian law (icosacanthic law)** (Fig. 1). The 20 spines emerge from the body along 5 circles which are comparable to the **equatorial**, 2 **tropical** and 2 **circumpolar** circles of the terrestrial globe. In some genera the constant 20 spines are dissimilar in size and form, but even among these the 5 zones may be distinguished. Four **equatorial spines** may be set apart from the 16 others by size or other differentiation. When these principal spines are recognized, the others can be seen to consist of 8 polar **spines**, which lie in the same meridional planes **(perradial planes)** as the 4 **principal spines,** and 8 **tropical spines**, which lie in 2 different perradial planes, intersecting the others at an angle of 45 degrees. All equatorial spines are exactly alike in some groups, whereas in others, the 2 opposite spines of one equatorial axis are much larger or different in form from those of the crossing axis. The major equatorial axis with the large spines is termed the **hydrotomical axis** and the minor axis with smaller spines, the **geotomical axis.**

The central junction of the **radial spines** is effected in 4 different ways: (a) by the simple apposition of the pyramidal central ends or bases of the spines; (b) by a **basal leaf cross** (4 broad wings on each spine), supported one upon the other; (c) by the central fusion of the meeting bases of the 20 spines; and (d) by the fusion of each of the opposite spines in pairs. Of these different types, the first is the most common and is the kind displayed by *Acanthometron*. The spines at the central base are pointed in the form of a pyramid, and the triangular faces of the neighboring pyramids are simply placed one against the other. The second type (basal leaf cross) is exemplified in *Phyllostaurus*; it apparently developed from the first type. Immediately above the basal pyramid, rising from its radial edges are 4 broad, thin, triangular leaves or wings; the meeting edges of adjacent wings are placed in such manner that between bases of each group of 3 or 4 adjacent spines a hollow, pyramidal space remains. The apex of this pyramidal space is directly toward the center of the sphere but separated from it by the small basal pyramid; its open end is directed outward. The 22 hollow, pyramidal spaces are disposed as 4 **equatorial spaces,** 8 **perizonal spaces,** 8 **peripolar spaces,** and 2 opposite **polar spaces.** These spaces are 4-sided, except for the peripolar ones, which are 3-sided. The third type of central junction results from the fusion of all the spines as a solid star of 20 rays *(Astrolithium)*. **Diametral spines** characterize the fourth type *(Acanthochiasma)*. These are simple opposite spines which are fused basally into one spine passing through the diameter of the central capsule; these spines may be loosely crossed. Some spines are twisted like a screw or are spirally convoluted.

The **radial spines** may be of one of 3 basic forms: (a) those of circular cross section; (b) those of ellipsoidal or lanceolate cross section; and (c) those of square cross section. The apex of the spine is usually pointed but may be truncate or bifid or even 4-sided pyramidal; in some the apex is toothed. Bifid spines may be so deeply cleft as to become forked. The lateral transverse processes or **apophyses** of the radial spines are significant structures. They are wanting in some groups, whereas in others they are perfectly free; or in more complex types, their meeting ends may form a **lattice shell.** The apophyses carry 2 or 4 opposite processes, or 4 crossed ones.

Among the divisions of the Acantharina, the Acanthophracti display extensive complexity of structure brought about by differences in the growth of the radial spines. The equal spines of the Dorataspidicae have equidistant outgrowths or **shields** from one or more levels which by their fusion result in one or more latticed concentric shells, whereas the spines of unequal length in the Belonaspidicae are expressed by characteristic changes in the skeleton and axial relations. In the Dorataspidicae, innumerable tiny plates **(aglets)** unite with each other along the sutures to form a pavemented shell; each aglet is pierced by a minute pore. The surfaces of such shells are commonly **dimpled.** The **perispinal pores** or holes of *Porocapsa* and *Cannocapsa* result from the internal development of radial spines which fail to reach the surface; the radial spines of these genera are shorter than the shell radius and do not reach its outer wall. But in an ideal prolongation of each spine the shell is pierced by a single large opening, the **perispinal pore** or hole, composed of 4 united aspinal pores; some perispinal pores are cruciform. In other genera, **radial tubes** result from prolongation of the holes as centrifugal cylinders, of which there is one in each ideal prolongation of the inner spine of the shell. The pores or meshes, especially in the Dorataspididae, are varied and generally may be differentiated into 2 groups, designated as **sutural pores** and **parmal pores.** The sutural pores are bordered by the meeting branches of the apophyses of 2, 3, or 4 adjacent spines and consequently also by the sutures along which they join. The parmal pores, on the contrary, are bordered only by the united branches of the apophyses of a single spine and pierce the shield or lattice plate formed by the apophysis. The parmal pores again can be divided into 2 different groups, termed **aspinal pores** and **coronal pores.** Aspinal pores are those which lie immediately at the sides of the radial spine and are bordered by the primary branches of its apophysis. Coronal pores are those which lie at the periphery of the lattice plates, surrounding in a circle or crown the aspinal pores and not touching the spine itself. The number and size of the coronal pores is commonly large and the pores themselves may vary in form. Peculiar accessory spines called **by-spines,** cover the surface of many members of the Dorataspidicae; commonly these are parallel to the radial spines from the lattice plates of which they arise. They tend to be perpendicular to the branched ends of the apophyses, so that a pair of divergent by-spines belonging to the meeting apophyses of the 2 adjacent spines arises near each suture. These by-spines are rarely bristle-like; generally they undulate, recurve, and are forked or arborescent. The 20 plates found in the shells of some Hexalaspididae bear high **crests** or **combs** on the surface separating the funnel-shaped dimples. Swollen knobs or **condyles** occur in some Dorataspididae on the apophyses, and on the shell surface where they may be connected across the sutural divisions.

Important large monographs by POPOFSKY (30-34) and SCHEWIAKOFF (45) give data on biology, life-histories, cytology, and ecology of the Acantharina. SCHEWIAKOFF divides the group into 4 "orders": Holacantha, Symphyacantha, Chaunacantha, and Arthracantha. He lists 17 families, of which 10 are new.

Division ASTROLOPHI Campbell, nov.

[=Acanthometrida HKL., 1862]

Lattice-shell lacking; skeleton composed of radial rods. *Eoc.-Rec.*

Superfamily ASTROLOPHICAE Haeckel, 1882

[*ex* Astrolophida; emend. CAMPBELL, herein]
[=Actinelida HKL., 1887]

Diametral spines 10 to 200, not disposed according to the Müllerian law. *Eoc.-Rec.*

Family ASTROLOPHIDAE Haeckel, 1882

[as Astrolophida; emend. CAMPBELL, herein]

Spines radiating from common center within spherical capsule. *Rec.*

Astrolophus HKL., 1882 [**A. stellaris* HKL., 1887]. Variable number of simple radial spines, different in size, intermingled.——FIG. 9,*5*. *A. solaris* HKL., Rec., ×150 (42).

Actinelius HKL., 1865 [**A. pupureus;* SD herein] [=*Podactinelius* SCHRÖDER, 1906]. A variable number of simple spines, all similar in size and form.

- **A. (Actinelius)** [=*Actinelarium* HKL., 1887 (obj.)]. Radial spines cylindrical, conical, or spindle-shaped, circular in section.——FIG. 9,*1*. *A. (A.) primordialis* HKL., Rec., ×50 (42).
- **A. (Actinelidium)** HKL., 1887 [**A. protogenes*]. Radial spines compressed, 2-edged, elliptical in section.
- **A. (Actinelonium)** HKL., 1887 [**A. pallidus* HKL., 1865; SD herein]. Radial spines quadrangular, prismatic or pyramidal, square in section.

Family LITHOLOPHIDAE Haeckel, 1862

[as Litholophida; emend. CAMPBELL, herein]
[=Gigartaconidae SCHEW., 1926 *(partim)*]

Spines within a conical space or quadrant of a sphere, developed from a common center. *Rec.*

Litholophus HKL., 1862 [**L. rhipidium;* SD herein][=*Gigartacon* SCHEW., 1926 *(partim)*]. Variable number of quadrangular divergent spines, united at their pyramidal bases at apex of conical central capsule.

- **L. (Litholophus)** [=*Litholophidium* HKL., 1887 (obj.)]. Radial spines 10 to 20 (commonly 12 to 16).
- **L. (Litholopharium)** HKL., 1887 [**L. pyramidalis;* SD herein]. Radial spines 10.——FIG. 9,*7*. *L. (L.) decapristis* HKL., Rec. ×100 (42).

Family ACANTHOCHIASMATIDAE Haeckel, 1862

[as Acanthochiasmida; emend. CAMPBELL, herein]
[=Chiastolida HKL., 1887]

Simple diametral spines loosely crossed at center. *Eoc.-Rec.*

Subfamily ACANTHOCHIASMATINAE Haeckel, 1862

[as Acanthochiasmida *(partim)*; emend. CAMPBELL, herein]
[=Acanthoplegmida SCHEW., 1926]

Diametral spines 10, derived from the concrescence of 20 radial spines. *Rec.*

Acanthochiasma KROHNE, 1860 [**A. rubescens*] [=*Acanthocyrta, Acanthoplegma, Acanthocolla, Acanthospira* SCHEW., 1926 *(partim)*]. Characters of subfamily.

- **A. (Acanthochiasma)** [=*Acanthochiasmarium* POP., 1904 (obj.)] Spines cylindrical or conical; circular in section.——FIG. 9,*2*. *A. (A.) cruciata* POP., Rec., ×240 (48).
- **A. (Acanthochiasmidium)** POP., 1904 [**A. plana;* SD herein]. Spines compressed and sharply pointed at ends.
- **A. (Acanthochiasmonium)** POP., 1904 [**A. quadrangula;* SD herein]. Spines prismatic; square in section.

Subfamily CHIASTOLINAE Haeckel, 1887

[as Chiastolidina; emend. CAMPBELL, herein]

Diametral spines 16, derived by the concrescence of 32 radial spines. *Eoc.-Rec.*

Chiastolus HKL., 1887 [**C. amphicopium*] FIG. 9,*3*. **C. amphicopium*, Rec., ×50 (42).

Superfamily ACTINASTRICAE Popofsky, 1904

[as Actinastra; emend. CAMPBELL, herein]

Radial spines 18 to 32, not disposed according to Müllerian law. *Rec.*

Family ACTINASTRIDAE Popofsky, 1904

[=Astrolophida HKL., 1882 *(partim)*]

Radial spines 32, simple. *Rec.*

Actinastrum HKL., 1887 [**A. legitimum;* SD herein]. Spines disposed in 4 meridional planes with distal ends in 5 parallel zones; central ends of spines supported one on another in spherical central capsule.

Family ROSETTIDAE Popofsky, 1904

Radial spines 20, arranged in a rosette. *Rec.*

Rosetta POP., 1904 [**R. triangularis;* SD herein]. Spines spear-shaped.——FIG. 9,*9*. **R. triangularis*, Rec., ×400 (48).

Family TRIZONIDAE Popofsky, 1904

Radial spines 18 similar in form and length, arranged in 3 girdle zones, each with 6 spines. *Rec.*

Trizona POP., 1904 [**T. brandti*].——FIG. 9,*8*. **T. brandti*, Rec., ×500 (48).

Superfamily ASTROLONCHICAE Haeckel, 1882

[*ex* Astrolonchida; emend. CAMPBELL, herein]
[=Acanthonida HKL., 1882]

Radial spines 20, arranged according to Müllerian law. *Mio.-Rec.*

Family ASTROLONCHIDAE Haeckel, 1882

[as Astrolonchida; emend. CAMPBELL, herein] [=Acanthometridae, Acanthonidae POP., 1904; Pseudolithidae, Acanthometridae, Stauroconidae, Conaconidae, Phyllostauridae, SCHEW., 1926 *(partim)*]

Spines nearly equal in length and similar in form. *Mio.-Rec.*

Subfamily ASTROLONCHINAE Haeckel, 1882

[as Astrolonchida *(partim)*; emend. CAMPBELL, herein] [=Phractacanthida HKL., 1887]

Each spine with 2 opposite apophyses or lateral transverse processes; less commonly with 2 longitudinal rows of opposite apophyses. *Rec.*

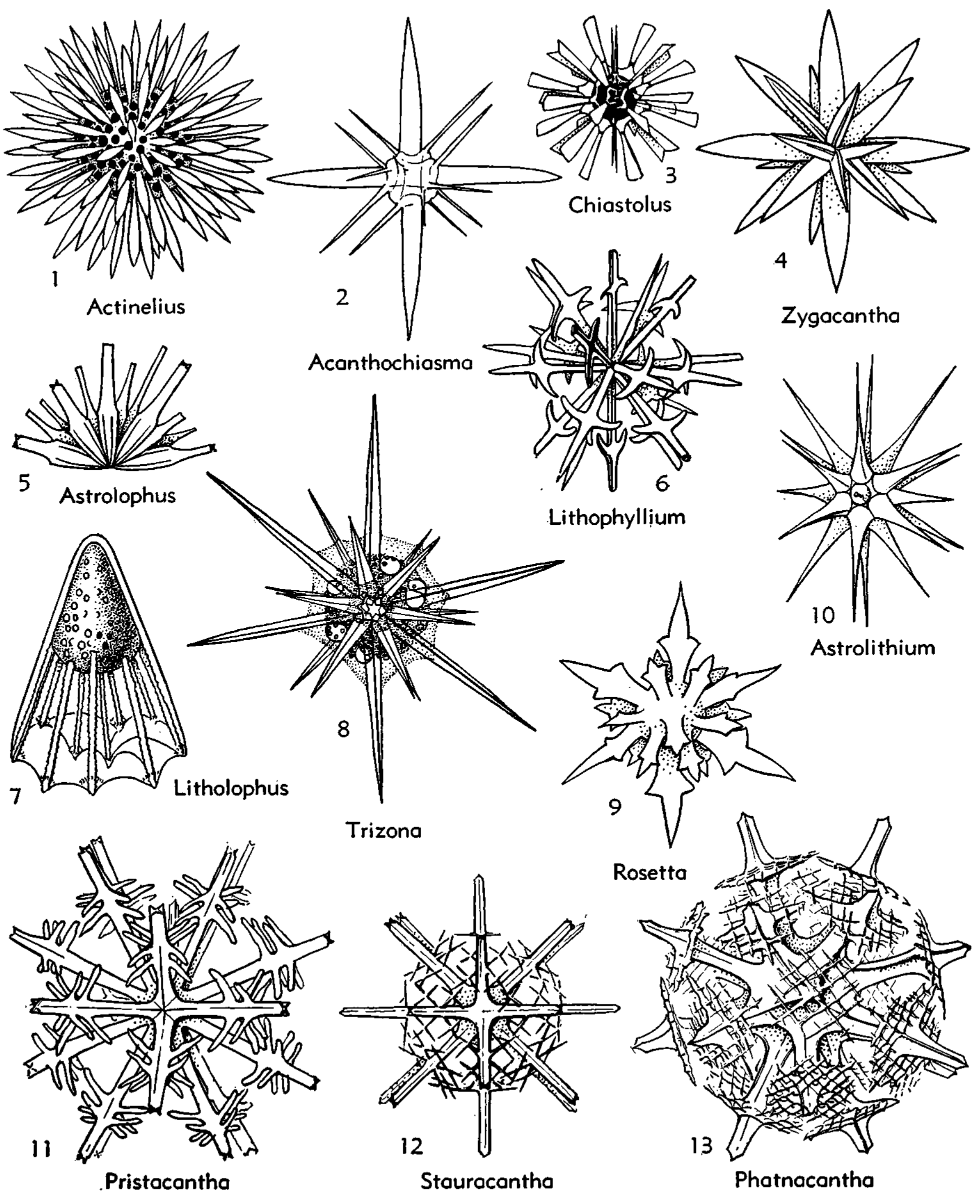


FIG. 9. Astrolophidae, Litholophidae, Acanthochiasmatidae, Rosettidae, Trizonidae, Astrolonchidae (p. D32-D34).

Astrolonche Hkl., 1882 [**A. bicruciata* Hkl., 1887]. Each spine with 4 to 8 or more simple apophyses arranged in 2 opposite longitudinal rows, or rarely in 6 opposite rows.

A. (Astrolonche) [=*Astroloncharium* Hkl., 1887 (obj.)]. Each spine with 2 longitudinal rows of apophyses, opposite in one meridional plane.

A. (Astrolonchidium) Hkl., 1860 [**Acanthometra serrata* Hkl., 1860; SD herein]. Each spine with 3 parallel double rows of opposite apophyses.

Dicranophora Schew., 1926 [**D. bütschlii*]. Spines 4-edged, proximally flattened and cylindrical distally, each with 2 forked apophyses forming lattice-shell at center where basal pyramids occur.

Doracantha Hkl., 1882 [**D. dorataspis* Hkl., 1887]. Each spine with 2 latticed or fenestrated apophyses.

Lithophyllium Müller, 1858 [**L. foliosum*]. Each spine with 2 unbranched opposite apophyses.——Fig. 9,*6*. *L. gladiatum* Hkl., Rec., ×100 (42).

Phractacantha Hkl., 1882 [**P. bifurca* Hkl., 1887]. Each spine with 2 branched but not latticed opposite apophyses.

Subfamily STAURACANTHINAE Haeckel, 1887

[as Stauracanthida; emend. Campbell, herein]

Each spine with cross of 4 free apophyses or crossed longitudinal rows of apophyses. *Rec.*

Stauracantha Hkl., 1882 [**S. orthostaura* Hkl., 1887]. Apophyses branched but not latticed.

S. (Stauracantha) [=*Stauracanthonium* Hkl., 1887 (obj.)]. Apophyses not forked but crossed by perpendicular branches in tangential planes parallel to cross of quadrangular spine.—Fig. 9,*12*. **S. (S.) orthostaura,* Rec., ×100 (42).

S. (Stauracanthidium) Hkl., 1887 [**S. stauraspis;* SD herein]. Apophyses forked, each spine with 2 divergent branches not parallel to cross axis of quadrangular spine.

Phatnacantha Hkl., 1882 [**P. tessaraspis* Hkl., 1887]. Apophyses forming a lattice plate by communicating branches.——Fig. 9,*13*. *P. icosaspis* Hkl., Rec., ×150 (42).

Pristacantha Hkl., 1887 [**P. octadon;* SD herein]. Simple apophyses 8 to 16 or more, arranged in 4 longitudinal rows in pairs forming a cross.——Fig. 9,*11*. **P. octadon,* Rec., ×100 (42).

Xiphacantha Hkl., 1862 [**Acanthometra quadridentata* Müller, 1858]. Apophyses simple.

X. (Xiphacantha) [=*Xiphacanthonia* Hkl., 1887 (obj.)]. Apophyses small, toothlike or hooked, not winglike; spine edges commonly narrow.

X. (Xiphacanthidium) Hkl., 1887 [**X. ciliata;* SD herein]. Apophyses broad, compressed, winglike large plates; spine edges commonly broad, prominent.

Subfamily ZYGACANTHINAE Haeckel, 1887

[as Zygacanthida; emend. Campbell, herein]

Spines lacking apophyses or lateral transverse processes. *Mio.-Rec.*

Zygacantha Müller, 1858 [**Z. lanceolata;* SD herein] [=*Conacon, Tetralonche* Schew., 1926 *(partim)*]. Spines simple, compressed, 2-edged, elliptical or rhomboidal in section. *Rec.*

Z. (Zygacantha) [=*Zygacantharium* Hkl., 1887 (obj.); *Stellolonche* Pop., 1904]. Spine at central base without leaf cross and with hollow pyramidal compartments.——Fig. 9,*4*. *Z. (Z.) latifolia* Pop., Rec., ×240 (48).

Z. (Zygacanthidium) Hkl., 1887 [**Zygacantha dichotoma* Müller, 1858; SD herein][=*Amphistaurus, Stauracon* Schew., 1926 *(partim)*]. Spines at central bases with cross of 4 prominent leaves; adjoined edges of lamellae forming 22 hollow pyramidal compartments.

Z. (Zygacanthonium) Hkl., 1887 [**Astrolithium dicopum* Hkl., 1862; SD herein]. Spines at center perfectly grown together, forming a solid star of 20 rays.

Acanthometron Hkl., 1887 [**Acanthometra pellucida* Müller, 1858; SD herein][=*Amphiacon, Stauracon* Schew., 1926 *(partim)*]. Round, cylindrical, or conical radial spines, without basal leaf cross. *Rec.*

A. (Acanthometron) [=*Acanthometrella* Hkl., 1887 (obj.)]. Radial spines of similar size and form without basal leaf cross or apophyses.

A. (Acanthopophysa) Pop., 1904 [**A. armatum;* SD herein]. Similar radial spines with apophyses.

A. (Amphimetron) Pop., 1904 [**A. spinosum;* SD herein]. Two radial spines longer than 18 others.

A. (Quadrimetron) Pop., 1904 [**A. arachnoide;* SD herein]. Four radial spines longer than 16 others.

Acanthonia Hkl., 1882 [**Acanthometra tetracopa* Müller, 1858] [=*Conacon, Heterocon* Schew., 1926 *(partim)*]. Spines at central base 4-edged, prismatic or pyramidal. *Rec.*

A. (Acanthonia) [=*Acanthonium* Hkl., 1887 (obj.); *Acolonche, Quadristaurus* Pop., 1904]. Spines at central base without leaf cross and hollow pyramidal compartments.

A. (Acanthonidium) Hkl., 1887 [**Acanthometra echinoides* Claparède & Lachmann, 1858; SD herein][=*Amphiacantha, Stellacantha* Pop., 1904]. Spines at central base with broad leaf cross composed of 4 prominent lamellae; meeting edges form 22 hollow compartments.

A. (Acantholithium) Hkl., 1887 [**A. stellata*] [=*Heliolithium* Schew., 1926]. Spines at central base fused as a solid star of 20 rays.

Astrolithium Hkl., 1860 [**A. bifidum* Hkl., 1862] [=*Pseudolithium* Schew., 1926 *(partim)*]. Long radial spines grown together at central base as a solid star of 20 rays. *Mio.-Rec.*——Fig. 9,*10*. *A. bulbiferum* Hkl., Rec., ×150 (42).

Phyllostaurus Hkl., 1862 [**Acanthometra sicula*]. Spines with basal leaf cross at central base; 4

prominent lamellae propped on one another, forming 22 hollow compartments. *Rec.*

P. (Phyllostaurus). Radial spines of similar size and form.

P. (Acostaurus) HKL., 1887 *(partim)* [**P. aequatoralis*; SD herein]. Four radial spines stouter and longer than 16 others.

P. (Phyllolonche) POP., 1904 [**P. conicus;* SD herein]. Four radial spines very much longer than 16 others.

Family ACANTHOSTAURIDAE Haeckel, 1882

[as Acanthostaurida; emend. CAMPBELL, herein] [=Quadrilonchida HKL., 1887; Acanthometridae, Stauroconidae SCHEW., 1926]

Spines of very different sizes, 4 equatorial ones much larger than others. *Rec.*

Subfamily ACANTHOSTAURINAE Haeckel, 1882

[as Acanthostaurida *(partim)*; emend. CAMPBELL, herein]

Spines simple, lacking apophyses. *Rec.*

Acanthostaurus HKL., 1862 [**Acanthometra puperascens* HKL., 1860; SD herein]. Equatorial spines equal and similar; 8 tropical and 8 polar spines nearly equal.

A. (Acanthostaurus) [=*Acostaurus* HKL., 1887]. All 20 spines separated, with center united only by triangular faces of leaf-shaped edges of their pyramidal bases.

A. (Staurolithium) HKL., 1862 [**Astrolithium cruciatum* HKL., 1860]. All 20 spines fused at center forming a single star-shaped mass.

Belonostaurus HKL., 1887 [**B. quadratus;* SD herein]. Equatorial spines 4, much longer than others; 8 tropicals very different from 8 polars.

Lonchostaurus HKL., 1862 [**Acanthometra hastata* HKL., 1860; SD herein]. Equatorial spines 4, differing in size and form, principal one in longitudinal axis, larger than laterals, opposites of each pair equal; 16 other spines much smaller (8 tropicals commonly larger than 8 polars).——FIG. 10,*1*. *L. bifurcus* HKL., Rec., ×100 (42).

Zygostaurus HKL., 1887 [**Z. amphithecus;* SD herein]. Equatorial spines 4, unequal in size and form, both laterals in transverse axis equal but both in longitudinal axis very different, frontal larger than caudal; other spines as in *Lonchostaurus*.——FIG. 10,*2*. *Z. sagittalis* HKL., Rec., ×100 (42).

Subfamily LITHOPTERINAE Haeckel, 1887

[as Lithopterida; emend. CAMPBELL, herein]

Two opposite transverse apophyses on all or part of the 20 spines. *Rec.*

Lithoptera MÜLLER, 1858 [**L. fenestrata;* SD herein]. Apophyses branched or latticed.

L. (Lithoptera) [=*Lithopteroma* HKL., 1887 (obj.)]. Apophyses on all spines.

L. (Lithopteranna) HKL., 1887 [**L. tetraptera;*

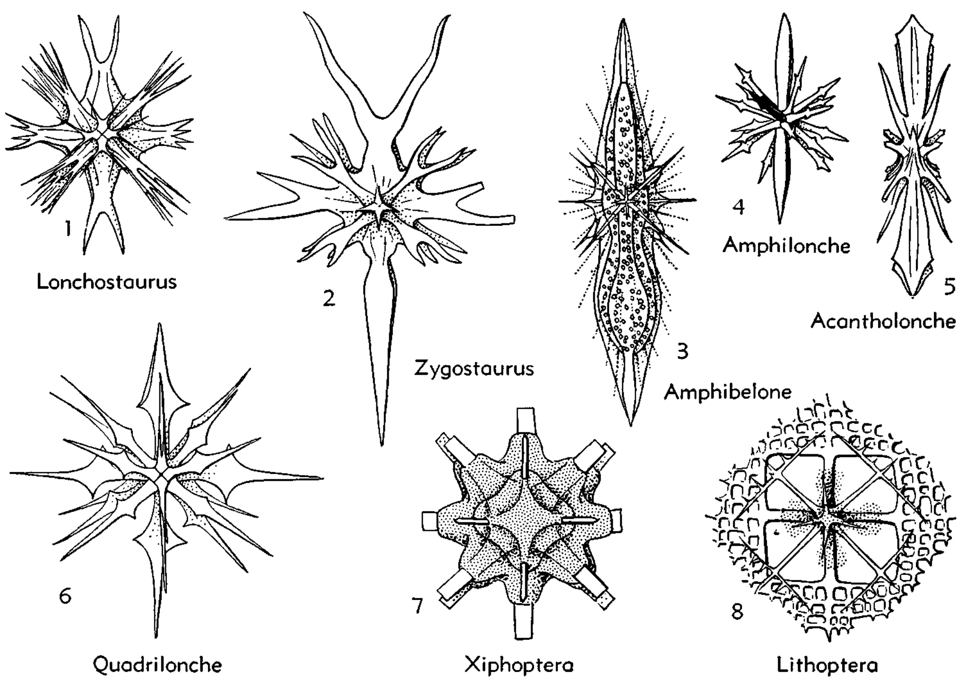


FIG. 10. Acanthostauridae, Acantholonchidae (p. D35, D36).

SD herein] [=*Acanthoptera* Pop., 1904]. Apophyses only on 4 equatorial spines.

L. (Lithopterella) Hkl., 1887 [**L. quadrata;* SD herein]. Apophyses on 4 equatorial and 8 tropical spines; 8 polar spines without apophyses.——Fig. 10,*8*. **L. (L.) quadrata* Rec., ×100 (42).

Quadrilonche Hkl., 1887 [**Q. tetrastaura;* SD herein]. Apophyses simple.

Q. (Quadrilonche) [=*Quadriloncharium* Hkl., 1887 (obj.)] Apophyses on equatorial spines.

Q. (Quadrilonchidium) Hkl., 1887 [**Q. mesostaura;* SD herein]. Apophyses on all spines.——Fig. 10,*6*. **Q. (Q.) mesostaurus* Rec., ×150 (42).

Xiphoptera Hkl., 1882 [**X. tessaractena* Hkl., 1887]. Apophyses branched but not latticed on some or all spines.——Fig. 10,*7*. *X. dodecactena* Rec., ×100 (42).

Family ACANTHOLONCHIDAE Haeckel, 1882

[as Acantholonchida; emend. Campbell, herein] [=Amphilonchida, Amphilithida Hkl., 1882; Acanthometridae, Amphilithidae, Gigartaconidae, Phyllostauridae Schew., 1926 *(partim)*]

Like Acanthostauridae except that 2 opposite equatorial spines in the longitudinal axis are much larger than the 18 others. *Rec.*

Acantholonche Hkl., 1882 [**A. amphipolaris* Hkl., 1887]. Two principal spines similar, others very unequal, small, with 8 tropicals and 2 transverse equatorials much larger than rudimentary polars.——Fig. 10,*5*. *A. peripolaris* Hkl., Rec., ×100 (42).

Amphibelone Hkl., 1862 [**Acanthometra anomalia* Hkl., 1860] [=*Cruciforma* Mielck, 1907]. Frontal and caudal spines very different, others small, nearly equal.

A. (Amphibelone) [=*Amphibelonium* Hkl., 1887 (obj.)]. All 20 spines separate but with triangular sides of their triangular bases in contact at center without prominent leaf cross.——Fig. 10,*3*. *A. (A.) cultellata* Hkl., Rec., ×100 (42).

A. (Amphibelithium) Hkl., 1887 [**A. clavaria*]. All spines fused at center in star form.

Amphilonche Hkl., 1862 [**A. belonoides;* SD herein] [=*Acantholonche* Pop., 1904 (*non* Hkl., 1882), *Zygolonche* Pop., 1904; *Cruciforma* Pop., 1906; *Heteracon* Schew., 1926 *(partim)*]. Frontal and caudal principal spines similar, 18 others smaller and nearly equal.

A. (Amphilonche) [=*Amphiloncharium* Hkl., 1887 (obj.)]. Spines united at center by triangular faces of their pyramidal bases without basal leaf cross.——Fig. 10,*4*. *A. (A.) diodon* Hkl., Rec., ×100 (42).

A. (Amphilithium) Hkl., 1882 [**A. concreta* Hkl., 1887]. Spines basally fused into single star with 2 large and 18 small rays.

A. (Amphilonchidium) Hkl., 1887 [**Acanthometra ovata* Müller, 1858; SD herein] [=*Zygolonchidium* Pop., 1904; *Amphistaurus* Schew., 1926 *(partim)*]. Broad leaf cross formed by 4 prominent triangular lamellae; pyramidal compartments 22.

Division ACANTHOPHRACTI Hertwig, 1879

[as Acanthophractida; emend. Campbell, herein]

Lattice shell complete. *Rec.*

Superfamily DORATASPIDICAE Haeckel, 1862

[*ex* Dorataspida; emend. Campbell, herein] [=Haplophracta, Sphaerophracta Hkl., 1887; Stratosphaera, Ramosphaera Pop., 1906 *(partim)*]

Simple spherical shell composed of 20 to 80 aglets, each with a single aspinal pore; radial spines disposed according to Müllerian law. *Rec.*

Family DORATASPIDIDAE Haeckel, 1862

[as Dorataspida; emend. Campbell, herein] [=Dictyacanthidae Schew., 1926 *(partim); non* Dorataspidae Pop., 1906 (=Belonaspididae)]

Shell composed of branched apophyses of 20 equal radial spines. *Rec.*

Subfamily DORATASPIDINAE Haeckel, 1862

[as Dorataspida *(partim)*; emend. Campbell, herein] [=Diporaspida Hkl., 1887; Dorataspinae Pop., 1906]

Shell composed of meeting branches of 2 opposite apophyses on each spine or of 20 perforated plates produced by concrescence of branches. *Rec.*

The Dorataspidinae are classed as shown below, or are divided alternatively into 2 groups, termed Cladophracta and Peltophracta (20). A second scheme includes groups called Laevisphaerida and Asprosphaerida (30).

Tribe DORATASPIDIDES Haeckel, 1862

[as Dorataspida *(partim)*; emend. Campbell, herein] [=Ceriaspida Hkl., 1887]

Spherical shell composed of 20 perforated plates produced by union of branches of apophyses; meshes partly sutural and partly parmal. *Rec.*

Dorataspis Hkl., 1860 [**D. loricata* Hkl., 1862; SD herein] [=*Thoracaspis* Hkl., 1882 *(partim); Coscinaspis* Hkl., 1887 *(partim)*]. Two aspinal pores in each plate, surface of shell without combs, dimples, and by-spines.

D. (Dorataspis) [=*Dorataspidium* Hkl., 1887 (obj.)]. Sutures 54; each pole of main axis bearing 2 hexagonal plates meeting in a polar suture and 2 minor pentagonal plates not meeting; entire shell has 8 hexagonal and 12 pentagonal plates (8 tropicals, 4 polars).——FIG. 11,6. *D. (D.) typica* HKL., Rec., ×150 (42).

D. (Doratasparium) HKL., 1887 [**D. fusigera;* SD herein]. Sutures 52; each pole of main axis with 4 plates meeting at a point; entire shell has 4 hexagonal plates (equatorial) and 16 pentagonal plates (8 tropicals, 8 polars).

Acontasparium HKL., 1887 [**A. lanceolatum*] [=*Acontaspis* HKL., 1882; *Globispinum* POP., 1906]. Plates smooth, perforated by 80 to 200 parmal pores (2 aspinal, 2 coronal, 2 sutural ones in each plate), surface without by-spines.

Acontaspis HKL., 1882 [**A. hastata* HKL., 1887] [=*Acontasparium, Acontaspidium* HKL., 1887 (obj.)] Surface of shell dimpled and with network of prominent crests.——FIG. 11,14. **A. hastata,* Rec., ×150 (42).

Ceriaspis HKL., 1882 [**C. lacunosa* HKL., 1887]. Surface of shell with many dimples separated by network of elevated combs; no by-spines.

C. (Ceriaspis) [=*Ceriasparium* HKL., 1887 (obj.)]. Small funnel-shaped dimples 70 to 100, each with 1 or 2 pores at bottom; plates with 20 large dimples in center, 2 aspinal pores and 50 to 100 small dimples containing 1 sutural pore; no blind dimples.

C. (Ceriaspidium) HKL., 1887 [**C. inermis;* SD herein]. Funnel-shaped dimples 176 to 182, partly closed at bottom or perforated by 1 or 2 pores; blind dimples 104 to 108, at corners of 20 plates.——FIG. 11,5. *C. (C.) favosa* HKL., Rec., ×150 (42).

Coscinaspis HKL., 1887 [**C. peripora;* SD herein] [=*Craniaspis* POP., 1906]. Plates perforated by 80 to 200 parmal pores (2 aspinal, 2 to 10 coronal on each); surface without by-spines.

C. (Coscinaspis) [=*Coscinasparium* HKL., 1887 (obj.)]. Plates smooth, without crests or dimples.——FIG. 11,12. *C. (C.) parmipora* HKL., Rec., ×150 (42).

C. (Coscinaspidium) HKL., 1887 [**C. ceriopora*]. Surface dimpled; prominent crests form network.

Diporaspis HKL., 1887 [**D. nephropora;* SD herein]. Like *Dorataspis* but with 52 sutures and many by-spines.

D. (Diporaspis) [=*Diporasparium* HKL., 1887 (obj.)]. Each pole of main axis with 4 plates which meet at common point; shell with 4 hexagonal (equatorial) and 16 pentagonal plates (8 tropicals, 8 polars).——FIG. 11,7. **D. (D.) nephropora,* Rec., ×200 (42).

D. (Diporaspidium) HKL., 1887 [**D. zygopora*]. Shell with 8 hexagonal plates (4 equatorial, 4 polar) and 12 pentagonal plates (8 tropical, 4 polar).

Hystrichaspis HKL., 1887 [**H. pectinata;* SD herein][=*Siphonaspis* HKL., 1887 (obj.)]. Like *Ceriaspis* but with numerous by-spines.

H. (Hystrichaspis) [=*Hystrichasparium* HKL., 1887 (obj.)]. Plates with 2 large dimples in center (each with 1 to 3 pairs of pores) and 50 to 100 small dimples (each with sutural pores); no blind dimples.——FIG. 11,9. **H. (H.) pectinata,* Rec., ×150 (42).

H. (Hystrichaspidium) HKL., 1887 [**H. dorsata;* SD herein]. Differs from *Ceriaspidium* only in having by-spines.

Stegaspis HKL., 1882 [**Orophaspis diporaspis* HKL., 1887][=*Orophaspis* HKL., 1887 (obj.)]. Like *Dorataspis* but 2 simple or branched free apophyses extend outside of shell on opposite sides of each radial spine.

S. (Stegaspis). Apophyses with anastomosed branches forming perforated shields.

S. (Orophasparium) HKL., 1887 [**Orophaspis astrolonche* HKL., 1887; SD herein]. Apophyses not branched.

S. (Orophaspidium) HKL., 1887 [**Orophaspis furcata;* SD herein]. Apophyses branched but not anastomosed.——FIG. 11,10. **S. (O.) furcata* (HKL.), Rec., ×150 (42).

Tribe PHRACTASPIDIDES Haeckel, 1887

[as Phractaspida; emend. CAMPBELL, herein]

Shell composed of meeting branches of apophyses, without perforated plates; all meshes sutural. *Rec.*

Phractaspis HKL., 1882 [**P. prototypus* HKL., 1887][=*Phractasplenium* HKL., 1887 (obj.)]. Condyles of apophysis branch ends without spines.

P. (Phractaspis) [=*Phractasparium* HKL., 1887 (obj.)]. Shell with 22 meshes and 40 sutures, each spine with 4 branches, apophyses simply forked.——FIG. 11,13. *P. (P.) complanata* HKL., Rec., ×150 (42).

P. (Phractaspidium) HKL., 1887 [**P. constricta;* SD herein]. Meshes 40 to 80, sutures 80 to 100, each spine with 6 to 8 branches, apophyses doubly forked or even highly ramified.

Pleuraspis HKL., 1882 [**P. horrida* HKL., 1887]. Condyles of apophysis branch ends with by-spines.

P. (Pleuraspis) [=*Pleurasparium* HKL., 1887 (obj.)]. Shell with 20 to 24 meshes and 36 to 48 sutures, each spine commonly with 4 branches bearing 2 simply forked apophyses.——FIG. 11,17. **P. (P.) horrida,* Rec., ×150 (42).

P. (Pleuraspidium) HKL., 1887 [**P. ramosa*]. Mostly with 40 to 80 meshes, 80 to 100 sutures, and each spine with 6 to 8 branches bearing apophyses forked at least twice.

Subfamily TESSARAPELMATINAE Campbell, nov.

[=Tessaraspida HKL., 1887]

Like Dorataspidinae except that each radial spine bears 4 crossed apophyses, opposite in pairs. *Rec.*

Tribe TESSARAPELMATIDES Campbell, nov.
[=Tessaraspida HKL., 1887 *(partim)*]

Shell composed of 20 perforated plates or fenestrated shields, each with at least 4 pores. *Rec.*

Tessarapelma HKL., 1882 [**Tessaraspis arachnoides* HKL., 1887][=*Tessaraspis* HKL., 1887 (obj.)]. Plates with 80 aspinal pores (4 crossed pores on each plate); surface smooth, without by-spines.

T. (Tessarapelma) [=*Tessarasparium* HKL., 1887 (obj.)]. Condyles of adjacent plates connected by permanent open sutures.

T. (Tessaraspidium) HKL., 1887 [**Tessaraspis concreta;* SD herein]. Sutures of adjacent plates obliterated.——FIG. 11,*2*. **T. (T.) concretum* (HKL.), Rec., ×150 (42).

Haliommatidium MÜLLER, 1858 [**H. echinoides;* SD herein] [=*Lychnaspis* HKL., 1862, obj., *non* SCHEW., 1926 (=*Phatnaspis*)]. Differs from *Tessarapelma* in having numerous by-spines.

H. (Haliommatidium) [=*Lychnaspidium* HKL., 1887 (obj.)]. Sutures between plates obliterated.

H. (Lychnasparium) HKL., 1887 [**Lychnaspis undulata* HKL., 1887; SD herein]. Condyles of adjacent plates connected by permanent open sutures.——FIG. 11,*3*. **H. (L.) undulatum* (HKL.), Rec. ×150 (42).

Hylaspis HKL., 1887 [**H. serrulata;* SD herein]. Like *Icosaspis* but surface with many by-spines. ——FIG. 11,*1*. **H. serrulata,* Rec., ×150 (42).

Icosaspis HKL., 1882 [**I. tabulata* HKL., 1887] [=*Dictyacantha* SCHEW., 1926 *(partim)*]. Plates perforated by 160 to 300 parmal pores (4 crossed aspinal pores in each plate, surrounded by 4 to 12 coronal pores), surface without by-spines.

I. (Icosaspis) [=*Icosasparium* HKL., 1887 (obj.)]. Condyles of adjacent plates jointed by permanent open sutures.——FIG. 11,*4*. *I. (I.) elegans* HKL., Rec., ×100 (42).

I. (Icosaspidium) HKL., 1887 [**Haliommatidium tetragonopum* HKL., 1862; SD herein][=*Tignisphera* POP., 1906]. Sutures obliterated.

Tribe STAURASPIDIDES Haeckel, 1887
[as Stauraspida; emend. CAMPBELL, herein]

Shell composed of meeting branches of crossed apophyses only, or with 4 to 12 perforated plates formed by spines, each plate bearing 4 crossed pores. *Rec.*

Stauraspis HKL., 1882 [**S. cruciata* HKL., 1887]. Without perforated plates; branch ends of condyles of apophyses without by-spines.

S. (Stauraspis) [=*Staurasparium* HKL., 1887 (obj.)]. Apophyses unbranched, each spine with 4 sutural condyles.

S. (Stauraspidium) HKL., 1887 [**S. stauracantha;* SD herein]. Apophyses branched, each spine with 8 to 20 sutural condyles.——FIG. 11,*8*. **S. (S.) stauracantha,* Rec., ×150 (42).

Dodecapsis HKL., 1887 [**D. tricinata;* SD herein]. Plates 12, formed by united apophysis branches of 4 equatorial and 8 polar spines, otherwise like *Zonaspis.*——FIG. 11,*15*. **D. tricinata,* Rec., ×200 (42).

Echinaspis HKL., 1882 [**E. dichotoma* HKL., 1887]. Differs from *Stauraspis* in having by-spines on condyles of branch ends.——FIG. 11,*11*. *E. echinoides* HKL., Rec., ×150 (42).

Zonaspis HKL., 1887 [**Z. cingulata;* SD herein] [=*Sonaspis* DELAGE & HEROUARD, 1896 (obj.)]. Plates 4, formed by union of apophysis branches of 4 equatorial spines, each with 4 crossed aspinal pores; apophysis branches of 16 other spines (8 tropical and 8 polar) not forming a lattice plate; each condyle like by-spines.——FIG. 11,*16*. *Z. equatorialis* HKL., Rec., ×150 (42).

Family ASTROCAPSIDAE Haeckel, 1887
[as Astrocapsida; emend. CAMPBELL, herein]

Radial spines equal, joined at center, short (enclosed within shell), or long (extended beyond shell); shell bears 20 large perispinal pores or 80 small aspinal pores. *Rec.*

Subfamily ASTROCAPSINAE Haeckel, 1887
[as Astrocapsida *(partim)*; emend. CAMPBELL, herein]

Radial spines connected with porous shell, as long as its radius or longer; shell pierced by 80 aspinal pores, 4 around each spine. *Rec.*

Astrocapsa HKL., 1887 [**A. stellata;* SD herein]. Spines longer than radius of shell, with free external prolongations piercing perispinal holes, 4 aspinal pores around each spine.——FIG. 12,*2*. *A. coronata* HKL., middle part of spine with 4 aspinal pores, Rec., ×200 (42).

Sphaerocapsa HKL., 1882 [**S. cruciata* HKL., 1887]. Spines without external prolongation, their distal ends inserted into perispinal holes, each having 4 aspinal pores.——FIG. 12,*1*. **S. cruciata,* Rec., ×75 (42).

Subfamily CENOCAPSINAE Haeckel, 1887
[as Cenocapsida; emend. CAMPBELL, herein]

Radial spines lacking. *Rec.*

Cenocapsa HKL., 1887 [**C. nirvana*]. Shell cavity simple, pierced by 20 perispinal pores.——FIG. 12,*5*. **C. nirvana,* entire shell with pavement of small plates and 20 cruciform perispinal pores. Rec., ×100 (42).

Subfamily POROCAPSINAE Haeckel, 1887
[as Porocapsida; emend. CAMPBELL, herein]

Radial spines not connected with porous shell, shorter than radius, with 20 perispinal pores. *Rec.*

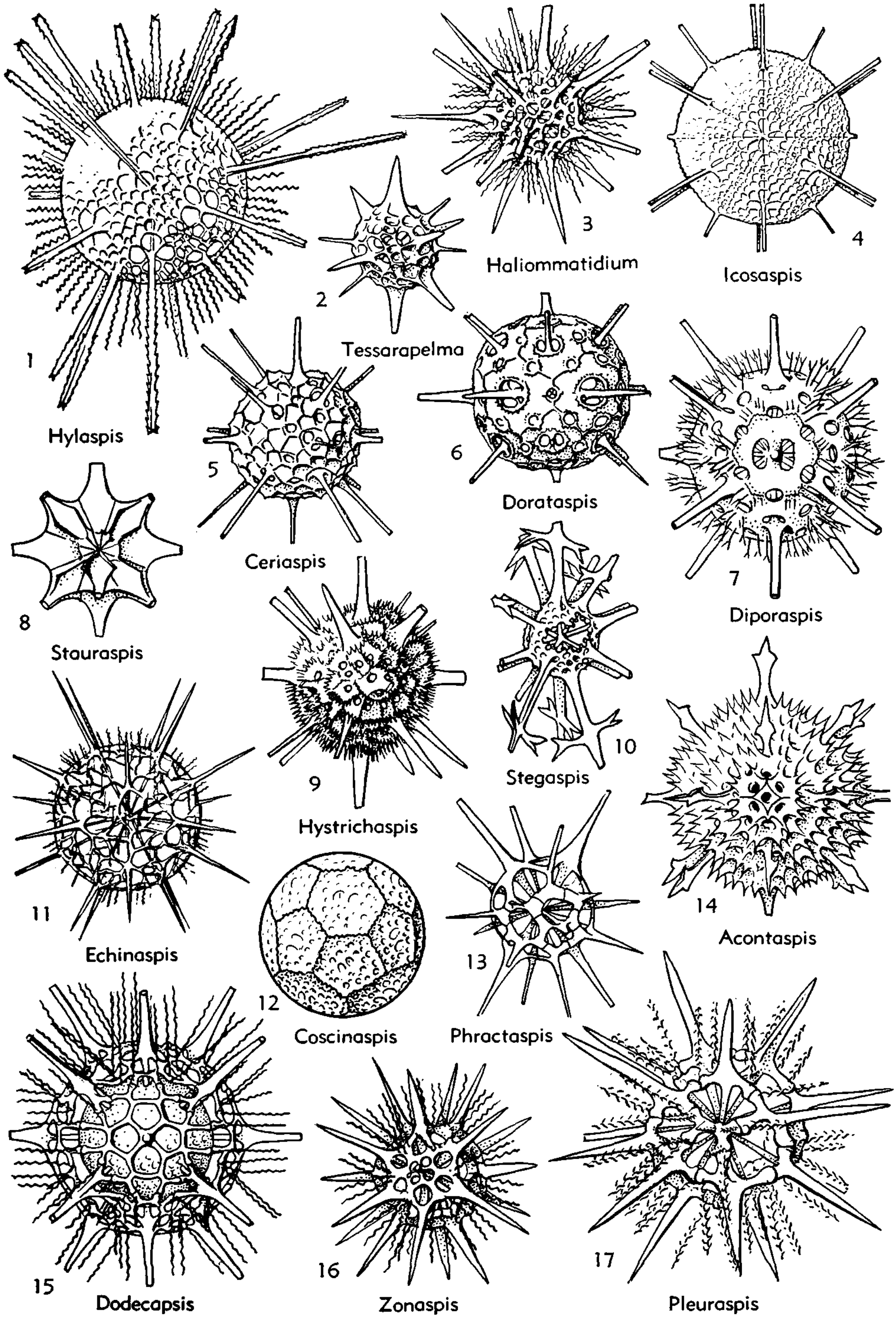


FIG. 11. Dorataspididae (p. D37, D38).

Porocapsa HKL., 1887 [**P. murrayana;* SD herein]. Distal ends of spines not connected with perispinal pores, which are simple, not prolonged into radial tubes.——FIG. 12,*4*. **P. murrayana,* central capsule filled with vacuoles and many small granules in central radii. Rec., ×100 (42).

Cannocapsa HKL., 1887 [**C. stethoscopium;* SD herein]. Like *Porocapsa* but perispinal pores prolonged outward as radial tubes.——FIG. 12,*3*. **C. stethoscopium,* Rec., ×100 (42).

Family ASPIDOMMATIDAE Campbell, nov.

[=Ommatida HKL., 1862 *(partim);* Phractopeltida, Phractopelmida HKL., 1882; Diplophracta HKL., 1887]

Like Dorataspididae, shell composed of branched apophyses of 20 radial spines, but has a double spherical shell. *Rec.*

Aspidomma HKL., 1862 [**Haliomma hystrix* MÜLLER, 1858; SD herein][=*Phractopeltis* HKL., 1882 (obj.)]. No free apophyses outside shell wall.

A. (Aspidomma) [=*Phractopeltidium* HKL., 1887 (obj.)]. Outer shell composed of 20 plates with sutures grown together.

A. (Phractopeltaris) HKL., 1887 [**Phractopelta dorataspis;* SD herein]. Outer shell wall with plates separated.——FIG. 12,*7*. **A. (A.) dorataspis* (HKL.), Rec., ×150 (42).

Dorypelma HKL., 1882 [**Dorypelta stauroptera* HKL., 1887][=*Dorypelta* HKL., 1887 (obj.)]. External free apophyses on 8 tropical spines and 4 polars; 4 equatorials and 4 polars simple.

D. (Dorypelma) [=*Dorypeltarium* HKL., 1887 (obj.)]. Free apophyses unbranched.

D. (Dorypeltidium) HKL., 1887 [**Dorypelta furcata;* SD herein]. Free apophyses branched, not anastomosed.

D. (Dorypeltonium) HKL., 1887 [**Dorypelta tessaraspis;* SD herein]. Free apophyses anastomosed.——FIG. 12,*8*. **D. (D.) tessaraspis* (HKL.), Rec., ×150 (42).

Octopelta HKL., 1887 [**O. scutella;* SD herein]. External free apophyses on 8 tropicals; 4 equatorials and 8 polars simple.——FIG. 12,*9*. **O. scutella,* prox. part of 2 meeting spines, Rec., ×150 (42).

Pantopelta HKL., 1887 [**P. icosaspis*]. Each spine with 2 free external apophyses.——FIG. 12,*6*. **P. icosaspis,* section through double shell, Rec., ×150 (42).

Stauropelma HKL., 1882 [**Stauropelta cruciata* HKL., 1887][=*Stauropelta* HKL., 1887 (obj.)]. External free apophyses on 8 tropicals and 8 polars; 4 equatorials simple.——FIG. 12,*10*. **S. cruciatum* (HKL.), Rec., ×150 (42).

Superfamily BELONASPIDICAE Haeckel, 1887

[*ex* Belonaspida; emend. CAMPBELL, herein] [=Prunophracta HKL., 1887; Ramososphaera POP., 1906 *(partim)*; Pseudolithidae SCHEW., 1926 *(partim)*]

Elliptical, lenticular or diploconical lattice shell composed of branched apophyses of spines, the 20 radial spines of different sizes meeting at center and disposed according to the Müllerian law. *Rec.*

Family BELONASPIDIDAE Haeckel, 1887

[as Belonaspida; emend. CAMPBELL, herein] [=Dorataspidae POP., 1906]

Simple ellipsoidal lattice shells; 2 opposite equatorial spines larger than 2 others. *Rec.*

Subfamily BELONASPIDINAE Haeckel, 1887

[as Belonaspida *(partim)*; emend. CAMPBELL, herein] [=Coleaspida HKL., 1887]

Shell has 40 parmal pores (2 aspinal pores in each plate) and mostly no coronal pores. *Rec.*

Belonaspis HKL., 1882 [**B. pandanus* HKL., 1887]. Surface with many by-spines but lacking dimples or crests.——FIG. 13,*6*. *B. datura* HKL., Rec., ×150 (42).

Coleaspis HKL., 1882 [**C. coronata* HKL., 1887]. Like *Belonaspis* but has network of prominent crests on dimpled surface.

C. (Coleaspis). Both equatorial spines nearly like 18 others.

C. (Coleaspidium) HKL., 1887 [**C. hydrotomica*]. Both equatorial spines much larger and peculiarly different in form from 18 others.——FIG. 13,*3*. **C. (C.) hydrotomica,* Rec., ×150 (42).

Cribosphaera POP., 1906 [**Coscinaspis polypora* HKL., 1887]. Shell smooth, with many sutural and coronal pores in addition to parmal pores. ——FIG. 13,*2*. **C. polypora* HKL., single lattice plate, Rec., ×150 (42).

Dictyaspis HKL., 1887 [**Dorataspis solidissima* HKL., 1862; SD herein]. Like *Coleaspis* but lacks by-spines.

Thoracaspis HKL., 1882 [**T. ellipsoides* HKL., 1887]. Like *Belonaspis* but lacks by-spines.——FIG. 13,*1*. *T. bipennis* (HKL.), Rec., ×150 (42).

Subfamily PHATNASPIDINAE Haeckel, 1887

[as Phatnaspida; emend. CAMPBELL, herein]

Shell has 80 to 2,000 parmal pores (2 aspinal pores on each plate) and 2 to 100 coronal pores. *Rec.*

Phatnaspis HKL., 1882 [**P. lacunaria* HKL., 1887]. Lacks by-spines.

P. (Phatnaspis) [=*Phatnasparium* HKL., 1887 (obj.)]. Compressed spine on each rhomboidal plate bordered at edges by aspinal pores and at sides by primary diagonal crests.——FIG. 13,*4*. *P. (P.) cristata* HKL., Rec., ×150 (42).

P. (Phatnaspidium) HKL., 1887 [**P. haliommidium;* SD herein]. Cylindrical or quadrangular spine on each plate bordered by 4 aspinal pores forming cross.

P. (Phatnasplenium) HKL., 1887 [**P. orthopoda;* SD herein]. Like *P. (Phatnaspis)* but placement of pores and crests interchanged.

Family HEXALASPIDIDAE Haeckel, 1887

[as Hexalaspida; emend. CAMPBELL, herein]

Simple discoidal or lenticular shells composed of branched apophyses of spines; 6 large spines in hydrotomical axis along margin, other spines small. *Rec.*

Hexalaspis HKL., 1887 [**H. heliodiscus;* SD herein]. Spines not surrounded by prominent sheaths.

H. (Hexalaspis) [=*Hexalasparium* HKL., 1887 (obj.)]. Six hydrotomical spines equal.——FIG. 13,*5*. **H. (H.) heliodiscus,* Rec., ×150 (42).

H. (Hexalaspidium) HKL., 1887 [**H. sexalata;* SD herein]. Two opposite equatorial hydrotomical spines much larger than 4 others (polars).

Hexacolpus HKL., 1887 [**H. nivalis;* SD herein]. Six hydrotomical spines surrounded by prominent sheaths, other spines rudimentary.

H. (Hexacolpus) [=*Hexacolparium* HKL., 1887 (obj.)]. Hydrotomical spines nearly equal.

H. (Hexacolpidium) HKL., 1887 [**H. trypanon;* SD herein]. Equatorials much larger than 4 polars.——FIG. 13,*10*. *H. (H.) infundibulum* HKL., Rec., ×150 (42).

Hexaconus HKL., 1887 [**H. ciliatus;* SD herein]. Like *Hexacolpus* but 14 nonhydrotomical spines well developed.

H. (Hexaconus) [=*Hexaconarium* HKL., 1887 (obj.)]. Hydrotomical spines equal.

H. (Hexaconidium) HKL., 1887 [**H. echinatus;* SD herein]. Equatorial spines much larger than 4 polars.——FIG. 13,*8*. **H. (H.) echinatus,* Rec. ×150 (42).

Hexonaspis HKL., 1887 [**H. hexapleura;* SD herein]. Like *Hexacolpus* but hydrotomical spines not surrounded by sheaths.

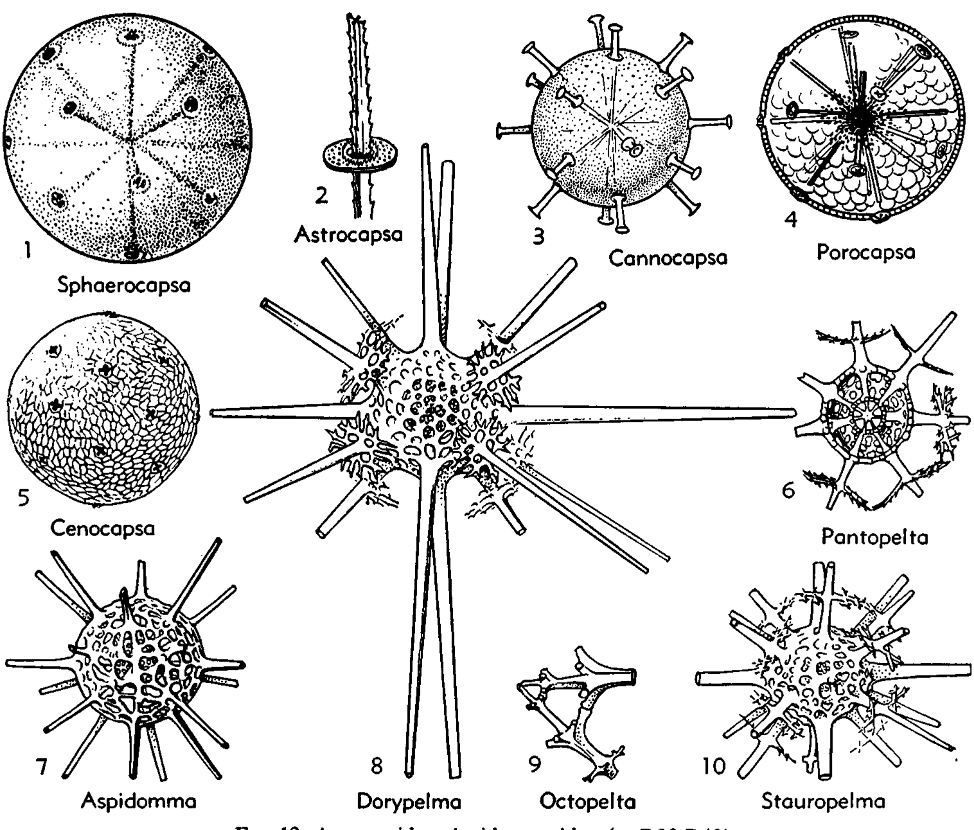


FIG. 12. Astrocapsidae, Aspidommatidae (p. D38-D40).

H. (Hexonaspis) [=*Hexonasparium* HKL., 1887 (obj.)]. Hydrotomical spines equal.

H. (Hexonaspidium) HKL., 1887 [**H. hastata;* SD herein]. Equatorials much larger than 4 polars.—FIG. 13,9. **H. (H.) hastata,* Rec., ×150 (42).

Family DIPLOCONIDAE Haeckel, 1862

[as Diploconida; emend. CAMPBELL, herein]

Simple discoidal shells with 2 very large equatorial spines developed from a minute central lattice shell, surrounded by conical to cylindrical or compressed sheaths. *Rec.*

Diploconus HKL., 1862 [*non* Zittel, 1868][**D. fasces;* SD herein]. Equatorial spines exceptionally large, others small and curved; resembles Roman fascis.

D. (Diploconus) [=*Diploconium* HKL., 1887 (obj.)]. Shell elliptical in cross section, compressed from both poles of sheath axis.

D. (Diploconulus) HKL., 1887 [**D. amalla;* SD herein]. Shell circular in cross section, not compressed.——FIG. 13,*11*. **D. (D.) amalla,* Rec., ×150 (42).

Diplocolpus HKL., 1887 [**D. costatus;* SD herein]. Small spines rudimentary or externally absent.

D. (Diplocolpus) [=*Diplocolpulus* HKL., 1887 (obj.)]. Shell circular in cross section.——FIG. 13,*7*. **D. (D.) costatus,* Rec., ×150 (42).

D. (Diplocolpium) HKL., 1887 [**D. sulcatus;* SD herein]. Shell elliptical in cross section, compressed from both poles.

Suborder SPUMELLINA Ehrenberg, 1875

[as Spumellaria; emend. CAMPBELL, herein]
[=Peripylea HERTWIG, 1879; Peripylaria HKL., 1882]

Simple thick-walled central capsule uniformly pierced by fine pores; generally spherical skeleton opaline siliceous but may be lacking; protoplasm may be highly vacuolated. *Cam.-Rec.*

MORPHOLOGICAL FEATURES

The Spumellina are a primitive group of Radiolaria in which the central capsule is usually enclosed by a peripherally generated siliceous shell, and a globular form that distinguishes many free-floating organisms. In some Spumellina, lattice shells are lacking, and simple disjoined needle-like, radiate, or otherwise modified **spicules** may occur. In some large Collodari, very large peculiar duplex-branched double spicules occur. Fused spicules compose the lattice shell in one group of these forms. Spicules are frequent fossils. More often the spumelline shell is developed as a hollow lattice or fenestrate sphere having similar or dissimilar pores; rarely these develop internal or external tubules. Complex Spumellina may have 5 or more concentric shells, which may be alike or unlike in numerous ways; rarely cubical internal shells are found. The outermost shell is termed the **cortical shell,** and the innermost, the **medullary shell;** there may be, however, several concurrent cortical or medullary shells. The concentric shells are united and supported by **radial beams,** which have constant numbers and positions in the different groups. A few forms have only a single shell and enclosed internal beams. The surface may be smooth or rough, and the pores may be flush or marked by elevated hexagonal or otherwise-shaped framework containing them and spines of various shapes and sizes. The spines are commonly distributed evenly, rising from the pore frames, or they may be restricted to opposed poles. Some are needle-like, others swordlike, and still others form tripartite blades. The 2 opposite main spines may be dissimilar in size; rarely they are joined at the free tips with a ring around the lattice shell. Long **principal spines,** 1 to 6 in number, occur on some types of Spumellina, tending to be arranged in opposite pairs disposed along mutually perpendicular axes of a cube. Any of these spines can be found among members of the Spumellina having a single or a number of concentric shells, and the range of combinations is great. In some species, spines are very numerous and less ordered in arrangement. In addition to the types of main spines described, accessory needle-like **by-spines** are common. Shells having these by-spines tend to resemble a burr and undoubtedly they float more easily than shells which lack such spines.

Less abundant than the naked, spiculate, or latticed spherical forms, but comprising an important shell type in the Spumellina, is a lattice shell produced along a single axis and thus of elliptical outline. **Spongy** shells are more common among these elliptical shells than in the spherical ones. In them the spongy shell is cortical. Spines similar to those found among spherical types occur and are similar or dissimilar in the same ways. Peculiar **polar tubules** occur in the main axis at opposed poles, and such do not occur in spherical Spumellina. **Thorns** similar to those found on a rose stem occur in all the above types of shell. Also in both main types and in others, a **pylome** or osculum occurs as a large opening, usually only in the outermost of several concentric shells. Peculiar **twin shells,** usually resulting from constrictions, distinguish a few Ellipsidiicae.

In most flattened or discoidal Cenodiscicae which are produced by unequal growth in 2 axes, a porous **sieve plate** or perforated lidlike disc occurs, and concentric rings surround the central chamber. Spines radiate from this center so as to subdivide the rings into radial chambers. In some, also, the central chamber may have spirally wound laminae around it. In others, a phacoid or lenticular shell occurs, and branched or unbranched radial spines may radiate from the margin, giving rise to a sunburst or starlike form. In other Cenodiscicae, the shell has a spongy texture in whole or part and there may be spongy arms or projections which are either forked or simple. An outer mantle or veil surrounds the shell in some of these, and an interbrachial spongy veil **(patagium)** connects the extended arms of some. Spiral laminae occur in the central part of many shells of this type.

Girdles of simple or triradiate form surround the central chamber of a few aberrant Laracariicae, and **gates**, consisting of large fissure or openings, are found between the girdles. The girdles are developed from elliptical latticed rings which enclose the primary shell; they may lie in 1 to 3 different planes. Gates may be **fenestrated.** Trizonal growth results from the development of alternately placed girdles. Large vaulted domes **(cupolas)**, with or without fenestrated veils, distinguish most girdled forms. Some have repeated annular divisions. Finally, the ultimate members of this superfamily become **planispiral**, like *Nautilus,* or asymmetrically spiral **(helicoidal)**, as in

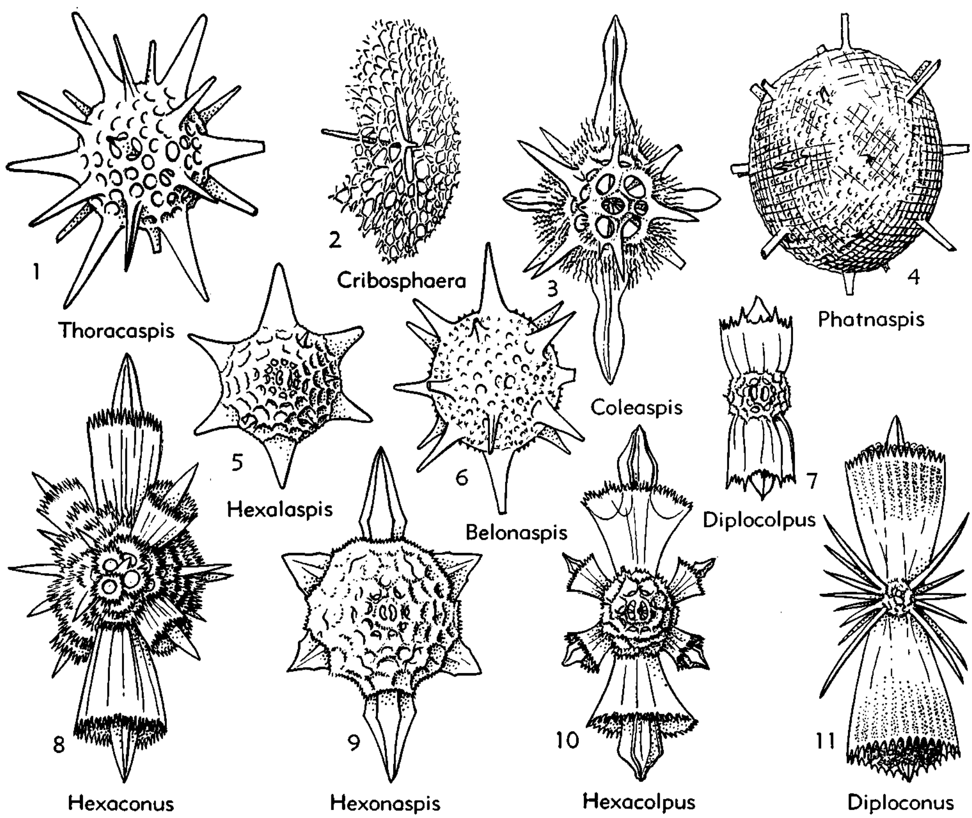


FIG. 13. Belonaspididae, Hexalaspididae, Diploconidae (p. D40-D42).

Helix. The terminus of this series is an irregular heap of chambers.

Descriptions of the biology, including reproduction and ecology, of the Spumellina are given by DREYER (16), HAECKER (22), and HAECKEL (20).

Division COLLODARI Haeckel, 1882

[as Collodaria; emend. CAMPBELL, herein]
[=Sphaerocollida POP., 1911]

Large spherical cells; with discrete spicules, or shells composed of fused spicules. *Ord.-Rec.*

Superfamily THALASSICOLICAE Haeckel, 1862

[*ex* Thalassicolida; emend. CAMPBELL, herein]
[=Colloidea HKL., 1887]

Skeleton consists only of isolated spicules within protoplasm, or entirely lacking. *Dev.-Rec.*

Family THALASSICOLIDAE Haeckel, 1862

[as Thalassicolida; emend. CAMPBELL, herein]
[=Thalassophysidae BRANDT, 1902]

Growth solitary, individuals not associated in colonies. *Dev.-Rec.*

Thalassicola HUXLEY, 1851 [**T. nucleata*] [=*Calcaromma* THOMPSON, 1877]. Nucleus spherical, unbranched; no intracapsular alveoles but large round ones in extracapsular calymma. *Dev.* (Texas)-*Rec.*

T. (Thalassicola) [=*Thalassicollidium* HKL., 1887 (obj.)]. Membrane of central capsule areolated, with small polygonal plates and very numerous fine radial pores. *Dev.-Rec.*——FIG. 14. *T. (T.) melacapsa* HKL., Rec., ×112 (42).

T. (Thalassicollarium) HKL., 1887 [**T. zanclea* HKL., 1862; SD herein]. Membrane of central capsule structureless but with abundant pores. *Rec.*

Myxobrachia HKL., 1870 [**M. pluteus*] [=*Thalassophysa* HKL., 1882 (obj.)]. Like *Thalassicola* but nucleus in central capsule papillate or branched. *Rec.*

Procyttarium HKL., 1879 [**P. primordiale*] [=*Actissa* HKL., 1887 (obj.)]. Nucleus spherical, simple; no alveoles within or outside central capsule. *Rec.*

P. (Procyttarium). Capsule spherical.

P. (Actidiscus) HKL., 1887 [**P. discoides;* SD herein]. Capsule lenticular, one axis shortened.

P. (Actilarcus) HKL., 1887 [**P. larcoides*]. Capsule lenticular, 3 axes different.

P. (Actiprunum) HKL., 1887 [**P. prunoideum;* SD herein]. Capsule ellipsoidal.

Thalassolampe HKL., 1862 [**T. margarodes;* SD herein]. Like *Procyttarium* but with large round alveoles in central capsule. *Rec.*——FIG. 15,*1*. *T. maxima* HKL., Rec., ×2.5 (42).

Thalassopila HKL., 1882 [**T. cladococcus* HKL., 1887]. Nucleus papillate or branched; large round alveoles in central capsule but not outside. *Rec.*——FIG. 15,*2*. **T. cladococcus*, Rec., ×10 (42).

Family CRISTALLOSPHAERIDAE Popofsky, 1911

Many discrete skeletal bodies in globular or irregular mass of protoplasm. *Rec.*

Cristallosphaera POP., 1911 [**C. cristalloides*]. Irregular hexagonal raised meshes on skeletal bodies.——FIG. 15,*3*. **C. cristalloides*, Rec., ×200 (48).

Family COLLOZOIDAE Haeckel, 1862

[as Collozoida; emend. CAMPBELL, herein]

Growth exclusively colonial. *Rec.*

Collozoum HKL., 1862 [**C. inerme;* SD herein]. No spicules or other skeletal parts.

C. (Collozoum) [=*Collodinum* HKL., 1887 (obj.)]. Central capsule subspherical.

C. (Collodastrum) HKL., 1887 [**C. pelagicum* HKL., 1862; SD herein]. Capsule irregular.

C. (Collodiscus) HKL., 1887 [**C. coeruleum* HKL., 1862; SD herein]. Capsule discoidal.

C. (Collophidium) HKL., 1887 [**C. serpentinium;* SD herein]. Capsule cylindrical, contorted.——FIG. 15,*6*. **C. serpentinium*, Rec., ×5 (42).

C. (Colloprunum) HKL., 1887 [**C. ovatum;* SD herein]. Capsule ellipsoidal.

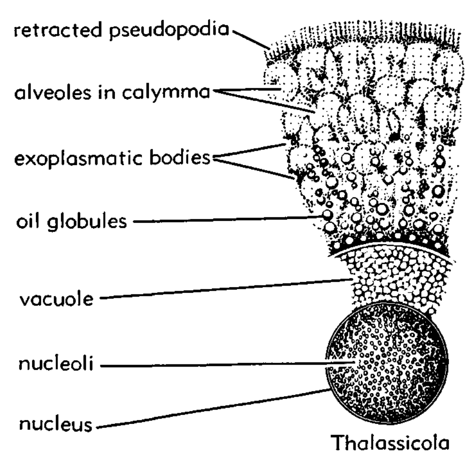


FIG. 14. Thalassicolidae (p. D44).

Superfamily THALASSOSPHAERICAE Haeckel, 1862

[*ex* Thalassosphaerida; emend. CAMPBELL, herein] [=Beloidea HKL., 1887]

Skeleton imperfect, commonly composed of many spicules irregularly distributed in calymma. *Ord.-Rec.*

Family THALASSOSPHAERIDAE Haeckel, 1862

[as Thalassophaerida; emend. CAMPBELL, herein] [=Physematidae BRANDT, 1902]

Growth invariably solitary. *Rec.*

Thalassosphaera HKL., 1862 [*non* HKL., 1887] [**Sphaerozoum bifurcum* HKL., 1860][=*Thalassoxanthium* HKL., 1887 (obj.)]. Spicules branched or compound; no alveoles.

T. (Thalassosphaera) [=*Thalassoxanthoma* HKL., 1887 (obj.)]. Needle-like simple or bifurcate branches at ends of rodlike spicules.

T. (Thalassoxanthella) HKL., 1887 [**T. medusium;* SD herein]. Spicules with 3 or more branches diverging from points on spicules.——FIG. 15,*8. T. (T.) cervicorne* HKL., Rec., ×150 (42).

Calosphaera CAMPBELL, 1951 [*pro Thalassosphaera* HKL., 1887 (*non* HKL., 1862)][**Thalassosphaera belonium* HKL., 1887]. Spicules unbranched; no alveoles.

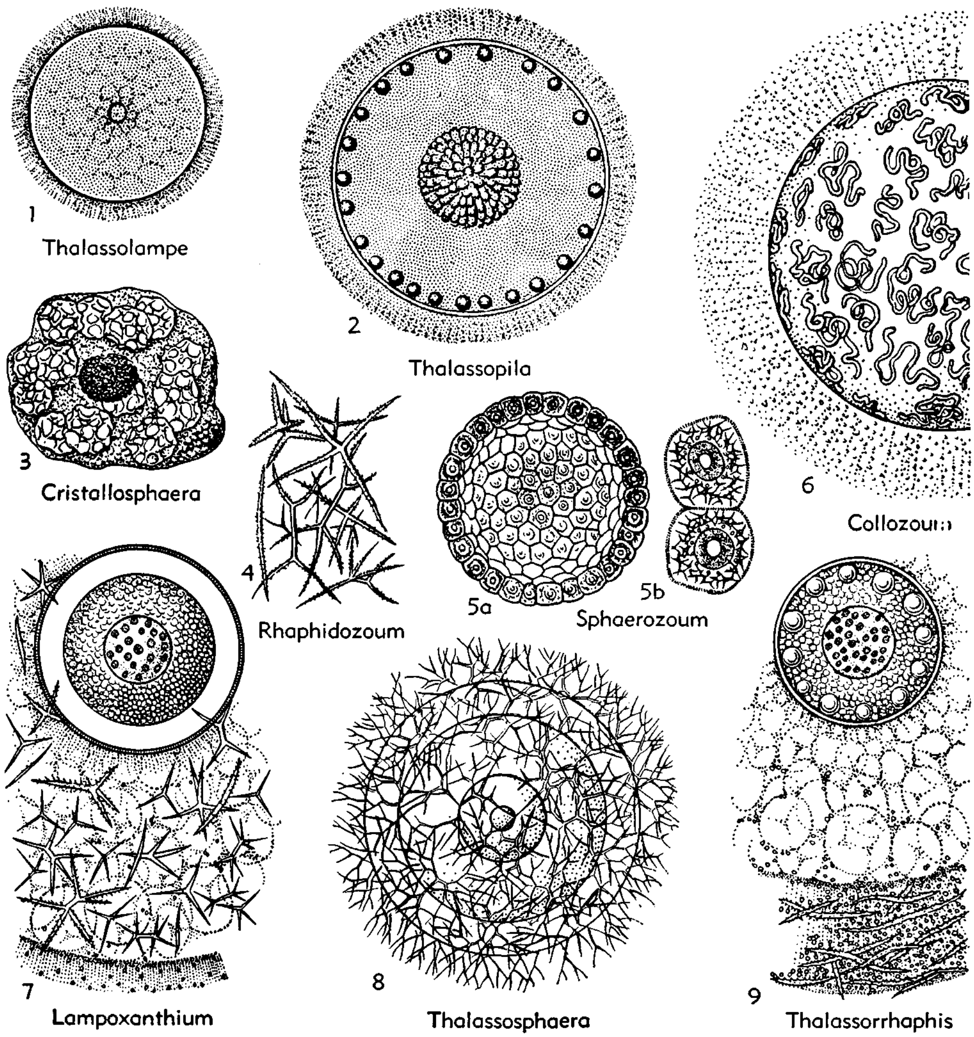


FIG. 15. Cristallosphaeridae, Collozoidae, Thalassosphaeridae, Sphaerozoidae (p. D44-D46).

Lampoxanthium HKL., 1887 [**L. tetractinium;* SD herein]. Many large alveoles in calymma but none in central capsule; spicules branched.

L. (Lampoxanthium) [=*Lampoxanthella* HKL., 1887 (obj.)]. Spicules radiate, all similar.

L. (Lampoxanthomma) HKL., 1887 [**L. punctatum;* SD herein]. Spicules with branches at ends, all similar.

L. (Lampoxanthura) HKL., 1887 [**L. pandora*]. Spicules partly simple radiate, partly twinned-radiate.——FIG. 15,*7*. **L. (L.) pandora,* capsule with fine pore canals, dark nucleoli in nucleus, spicules scattered in alveolated calymma, Rec., ×50 (42).

Physematium MEYEN, 1834 [**P. atlanticum*]. Spicules unbranched; many large alveoles in central capsule but not in calymma.

Thalassorrhaphis CAMPBELL, 1953 [*pro Thalassoplancta* HKL., 1887 (*non* HKL., 1862)] [**Thalassoplancta brevispicula* HKL., 1887 (=*Lampoxanthium brevispiculum* HKL., 1887)] [=*Thalassoraphis* CAMPBELL, 1951 (obj.)]. Spicules unbranched; many large alveoles in calymma. ——FIG. 15,*9*. **T. brevispicula* (HKL.), central capsule with clear vacuoles, oil droplets, and spicules in cortex, alveolate calymma, Rec., ×50 (42).

Family SPHAEROZOIDAE Haeckel, 1862

[as Sphaerozoida; emend. CAMPBELL, herein]

Growth exclusively colonial. *Ord.-Rec.*

Sphaerozoum MEYEN 1834 [**S. fuscum;* SD herein (=*S. punctatum* MÜLLER, 1858)]. Spicules branched or radiate, of a single kind. *Ord.*(N.Y.)-*Rec.*

S. (Sphaerozoum) [=*Sphaerozonoceras* HKL., 1887 (obj.)]. Spicules rodlike, with 1 to 4 rays at each end. *Ord.*(N.Y.)-*Rec.*——FIG. 15,*5*. *S. (S.) alveolatum* HKL., Rec.; *5a,* gross structure, ×15; *5b,* cells showing spicules and thick-walled alveoles, ×50 (42).

S. (Sphaerozonactis) HKL., 1887 [**S. triactinium;* SD herein]. Spicules radiate, 3 to 4 branches from a single point. *Rec.*

S. (Sphaerozonura) HKL., 1887 [**S. geminatum;* SD herein]. Spicules rodlike, with variable number of branches at each end. *Rec.*

Belonozoum HKL., 1887 [**Sphaerozoum spinulosum* MÜLLER, 1858; SD herein]. Spicules simple, not branched or radiate. *Rec.*

Rhaphidozoum HKL., 1862 [**Thalassicola acufera* MÜLLER, 1855]. Spicules partly simple and partly branched or radiate. *Rec.*

R. (Rhaphidozoum) [=*Rhaphidonactis* HKL., 1887 (obj.)]. Two to 4 shanks on radiate spicules.

R. (Rhaphidiceras) HKL., 1887 [**Sphaerozoum neapolitanum* BRANDT, 1881; SD herein]. Complex spicules with rays at both ends.

R. (Rhaphidonura) HKL., 1887 [**R. pandora;* SD herein]. Complex spicules include both radiate type with rays from central point and branched type with rays at both ends.——FIG. 15,*4*. **R. (R.) pandora,* group of spicules, Rec., ×100 (42).

Family MEYENELLIDAE Davis, 1950

Spicules with 3 to 4 rounded, club-shaped, or forked rays arising from common center. *Jur.*

Meyenella DAVIS, 1950 [**M. meyenella*]. Spicules not forked.

Palaeacantus DAVIS, 1950 [**P. spinosus*]. Spicules forked, Y- or H-shaped.

Family THALASSOTHAMNIDAE Haecker, 1906

Relatively huge, solitary forms with globular or branched central capsule, bearing one double spicule. *Rec.*

Thalassothamnus HAECKER, 1906 [**T. genista;* SD herein]. Capsule globular or lobate; central rod of spicule generally separated.——FIG. 16,*9*. *T. ramosus* HAECKER, Rec., ×15 (43).

Conostylus POP., 1907 [**C. diploconus;* SD herein]. Central rod of spicule solidly fused.——FIG. 16,*5*. **C. diploconus,* Rec., ×500 (48).

Cyrtocladus SCHRÖDER, 1906 [**C. gracilis;* SD herein]. Central rod of spicule partly fused; capsule dendritic.——FIG. 16,*8*. **C. gracilis,* Rec., ×15 (43).

Family LITHACANTHIDAE Popofsky, 1909

Single spicule with 4 to 6 mutually perpendicular rays diverging from common point and all in 1 or in 2 planes. *Rec.*

Lithacanthus POP., 1909 [**L. aculeatus;* SD herein]. Spicules 6-rayed.——FIG. 16,*3*. **L. aculeatus,* Rec., ×250 (35).

Tetracanthus POP., 1909 [**T. simplex*]. Spicule 4-rayed.——FIG. 16,*4*. **T. simplex,* Rec., ×250 (48).

Superfamily OROSPHAERICAE Haeckel, 1887

[*ex* Orosphaerida; emend. CAMPBELL, herein]
[=Phaeosphaeria HKL., 1879 *(partim)*]

Perfectly developed lattice shells. *Rec.*

Family OROSPHAERIDAE Haeckel, 1887

[as Orosphaerida; emend. CAMPBELL, herein]

Shell relatively large, spherical, rarely polyhedral or ellipsoidal, formed of thick bars; nodal points of coarse, irregular poly-

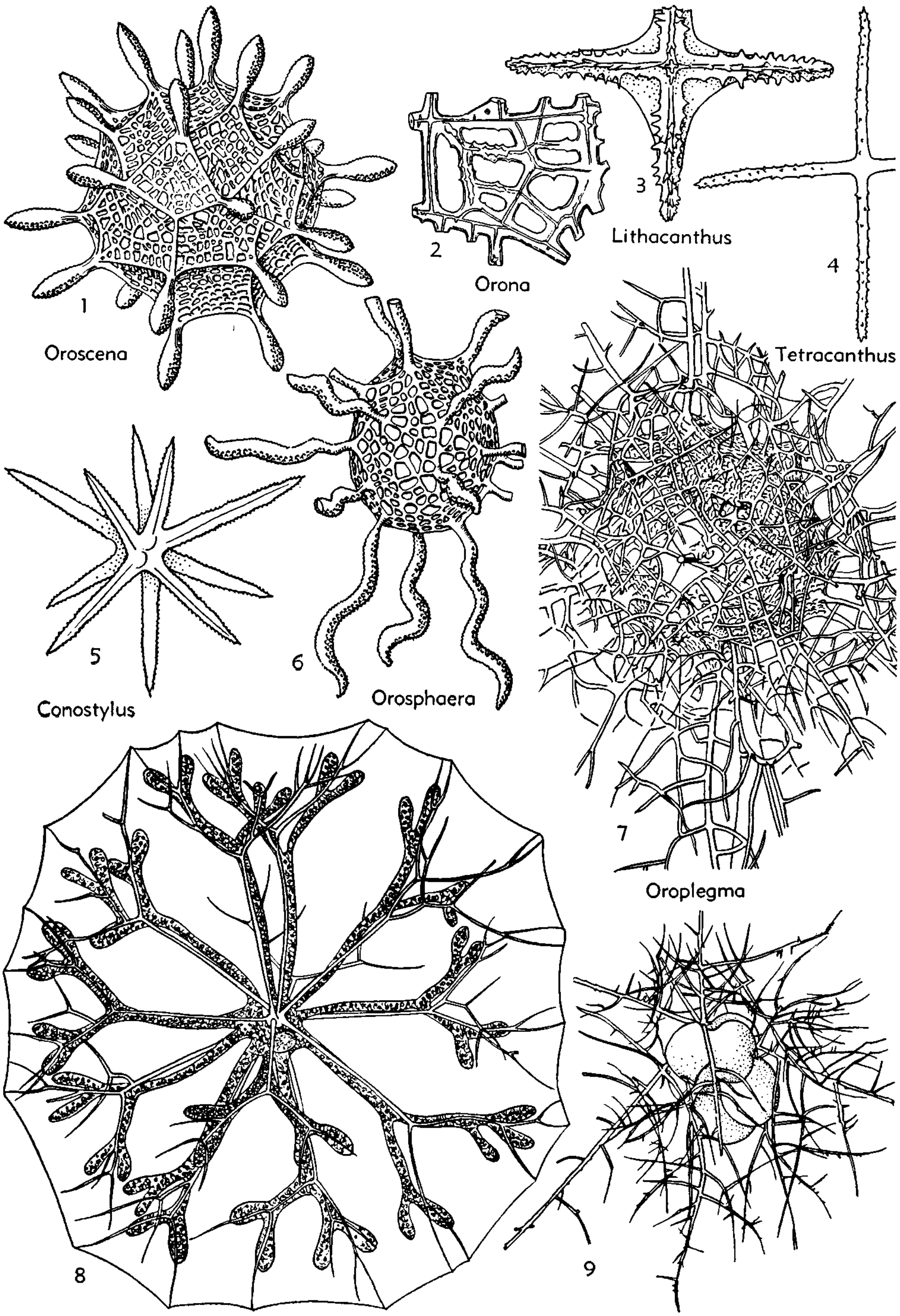


FIG. 16. Thalassothamnidae, Lithacanthidae, Orosphaeridae (p. D46-D48).

gonal meshes without starlike nodal points. *Rec.*

Subfamily OROSPHAERINAE Haeckel, 1887

[as Orosphaerida *(partim)*; emend. CAMPBELL, herein] [=Oronida HKL., 1887]

Surface of shell without pyramidal or tentlike elevations. *Rec.*

Orosphaera HKL., 1882 [**O. hastigera* HKL., 1887]. Shell subspherical, with many radial spines.

O. (Orosphaera) [=*Oronium* HKL., 1887 (obj.)]. Radial spines unbranched or lacking.——FIG. 16,*6*. *O. (O.) serpentina* HKL., Rec., ×20 (42).

O. (Orothamnus) HKL., 1887 [**O. arborescens;* SD herein]. Radial spines branched.

Orona HKL., 1887 [**O. maxima;* SD herein]. Shell subspherical, without radial spines.——FIG. 16,2. **O. maxima,* fragment of framework with air-filled central canals, Rec., ×150 (42).

Subfamily OROSCENINAE Haeckel, 1887

[as Oroscenida; emend. CAMPBELL, herein]

Shell surface with many pyramidal or tentlike elevations. *Rec.*

Oroscena HKL., 1887 [**O. gegenbauri;* SD herein]. Subspherical or polyhedral, with radial spines.

O. (Oroscena) [=*Oroscenium* HKL., 1887 (obj.)]. Spines unbranched.——FIG. 16,*1*. **O. (O.) gegenbauri,* Rec., ×20 (42).

O. (Orodendrum) HKL., 1887 [**O. huxleyi;* SD herein]. Spines branched.

Oroplegma HKL., 1887 [**O. diploplegmium;* SD herein]. Spongy shell enveloped by loose spongy skeleton; many radial spines.

O. (Oroplegma) [=*Oroplegmium* HKL., 1887 (obj.)]. Outer skeleton a fenestrate lamina.——FIG. 16,*7*. *O. (O.) diplosphaera* HKL., Rec., ×20 (42).

O. (Orodictyum) HKL., 1887 [**O. spongiosum;* SD herein]. Outer skeleton a complex framework.

Division SPHAERELLARI Haeckel, 1882

[as Sphaerellaria; emend. CAMPBELL, herein]

Shell latticed or spongy. *Cam.-Rec.*

Superfamily LIOSPHAERICAE Haeckel, 1882

[*ex* Liosphaerida; emend. CAMPBELL, herein] [=Sphaeroidea HKL., 1887]

Spherical latticed or spongy shells or concentrically multiple. *Cam.-Rec.*

Family LIOSPHAERIDAE Haeckel, 1882

[as Liosphaerida; emend. CAMPBELL, herein] [=Cenosphaeridae DEFLANDRE, 1952]

Without spines on shell surface. *Cam.-Rec.*

Subfamily LIOSPHAERINAE Haeckel, 1882

[as Liosphaerida *(partim)*; emend. CAMPBELL, herein] [=Carposphaerida HKL., 1882]

Two concentric lattice shells joined by radial beams. *Ord.-Rec.*

Liosphaera HKL., 1882 [**L. hexagonia* HKL., 1887]. Both shells cortical. *Ord.-Rec.*

L. (Liosphaera) [=*Melitomma* HKL., 1887 (obj.) *(partim)*]. Pores in both shells nearly equal in size and form. *Ord.*(Eng.)*-Rec.*——FIG. 17,*1b*. **L. (L.) hexagonia,* Rec., ×150 (42).

L. (Craspedomma) HKL., 1887 [**L. polypora;* SD herein]. Pores of both shells irregular. *Rec.*——FIG. 17,*1a*. **L. (L.) polypora,* Rec., ×150 (42).

Melitosphaera HKL., 1882 [**Carposphaera capillacea* HKL., 1887][=*Carposphaera* HKL., 1882; *Anthomma* (obj.), *Melitomma* HKL., 1887 (obj.) *(partim)*]. One shell medullary and one cortical. *Jur.-Rec.*

M. (Melitosphaera) HKL., 1882. Pores regular and similar, circular or hexagonal, within hexagonal frames. *Jur.-Rec.*——FIG. 17,*4a*. *M. (M.) melitomma* (HKL.), Rec., ×200 (42).

M. (Cerasosphaera) HKL., 1882 [**Carposphaera cerasus* HKL., 1887]. Cortical shell pores circular, without hexagonal frames; all pores regular, similar. *Eoc.-Rec.*——FIG. 17,*4b*. *M. (C.) minima* CL.-C., U.Eoc., Calif., ×150 (39).

M. (Phaenicosphaera) HKL., 1887 [**Carposphaera nodosa;* SD herein]. Cortical pores round, irregular, dissimilar. *Rec.*——FIG. 17,*4c*. **M. (P.) nodosa,* Rec., ×200 (42).

M. (Prunosphaera) HKL., 1882 [**Carposphaera prunulum* HKL., 1887]. Cortical shell pores polygonal, irregular, dissimilar. *Rec.*

Subfamily ETHMOSPHAERINAE Haeckel, 1862

[as Ethmosphaerida; emend. CAMPBELL, herein]

Single lattice shell. *Cam.-Rec.*

Ethmosphaera HKL., 1862 [**E. siphonophora*] [=*Etmosphaera* VINASSA, 1900 (obj.)]. Pores prolonged outward in conical or cylindrical tubules. *Cret.* (Italy), *Eoc.* (Calif.)*-Rec.*

E. (Ethmosphaera) [=*Ethmosphaerella* HKL., 1887 (obj.)]. Pore tubules conical. *Cret.-Rec.*——FIG. 17, *3b*. *E. (E.) polysiphonia* HKL., Rec., ×150 (42).

E. (Ethmosphaeromma) HKL., 1887 [**E. stenosiphonia;* SD herein]. Pore tubules cylindrical. *Eoc.-Rec.*——FIG. 17,*3a*. *E. (E.) ethmosiphonia* CL.-C., Eoc., Calif. ×150 (39).

Cenosphaera EHR., 1854 [**C. plutonis*] [=*Caenosphaera* BERTOLINI, 1935 (obj.)]. Pores simple. *Cam.*(Cosmop.)*-Rec.*

C. (Cenosphaera) [=*Circosphaera* HKL., 1887 (obj.)]. Pores circular, subregular, similar, without hexagonal frames. *Cam.-Rec.*——FIG. 17,*6d*. *C. (C.) compacta* HKL., Rec., ×150 (42).

C. (Cyrtidosphaera) HKL., 1862 [**C. reticulata*]

[=*Ceriosphaera* Hkl., 1882]. Pores irregularly polygonal, dissimilar, with polygonal frames. *Rec.*——Fig. 17,6*b*. *C.* (*C.*) *coronata* Hkl., Rec. ×200 (42).

C. (Phormosphaera) Hkl., 1882 [**C. primordialis* Hkl., 1887]. Like *C.* (*Cenosphaera*) but pores may be hexagonal. *Mio.-Rec.*——Fig. 17,6*a*. *C.* (*P.*) *durhami* C.-Cl., Mio., Calif., ×150 (35).

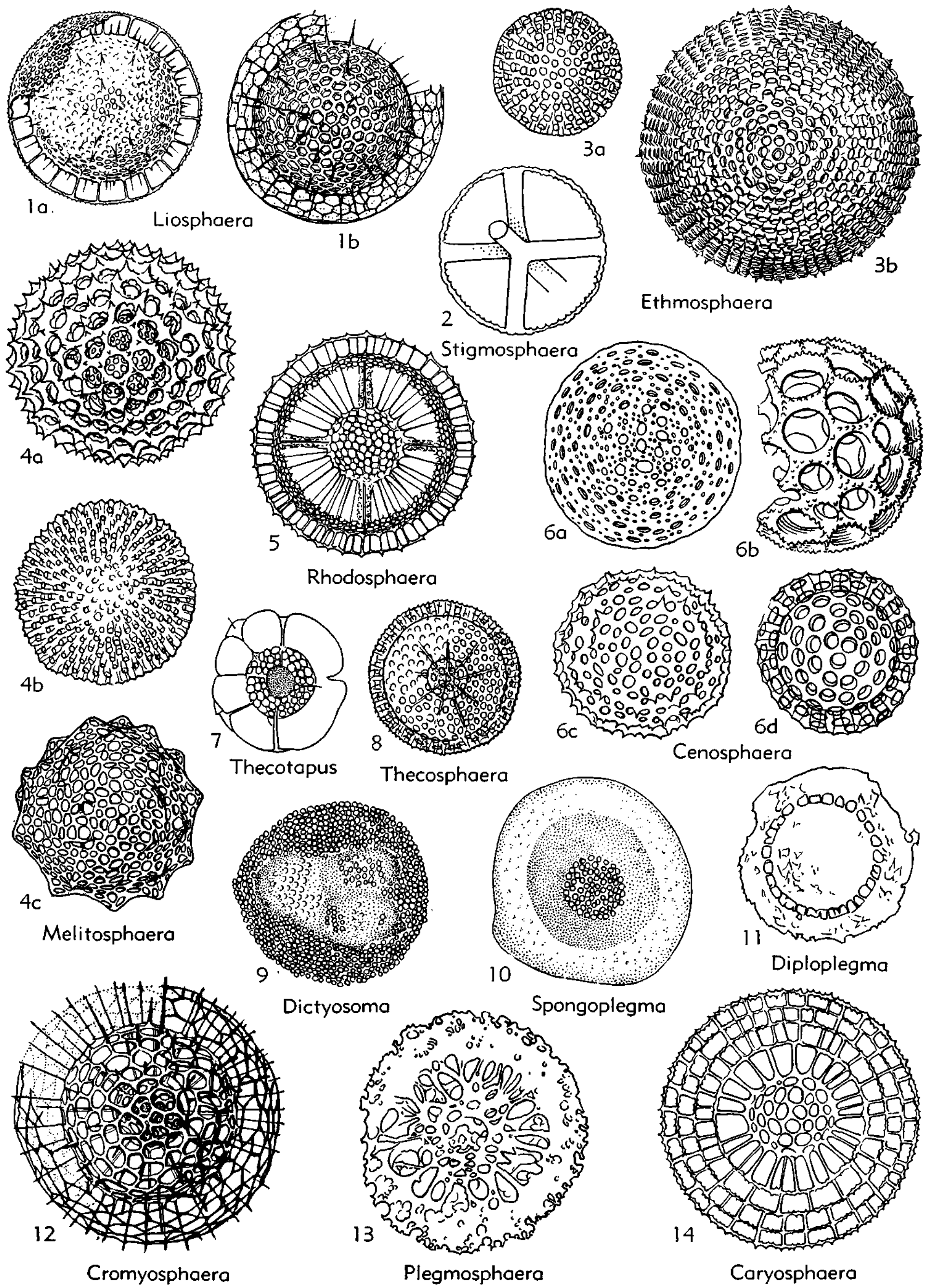


Fig. 17. Liosphaeridae (p. D48-D50).

C. (Porosphaera) HKL., 1887 [*C. antiqua; SD herein]. Pores round or irregular, dissimilar, without frames. *Mio.-Rec.*——FIG. 17,*6c*. *C. (P.) aspera* STÖHR, Mio., Italy, ×150 (53).

Sethosphaera HKL., 1882 [*S. entosiphonia* HKL., 1887]. Pores prolonged inward as conical or cylindrical tubules. *Rec.*

Stigmosphaera HKL., 1887 [*S. actinocentra; SD herein]. Radial beams diverge from point, bifurcate, and join inner shell surface. *Carb.-Rec.*——FIG. 17,*2*. *S. mira* RÜST, L.Carb., Ger., ×125 (51).

Subfamily THECOSPHAERINAE Haeckel, 1882
[as Thecosphaerida; emend. CAMPBELL, herein]

Three concentric lattice shells joined by radial beams. *Jur.-Rec.*

Thecosphaera HKL., 1882 [*T. tripodictyon* HKL., 1887][=*Teocommides* BERTOLINI, 1935]. Two medullary shells and one cortical. *Jur.-Rec.*

T. (Thecosphaera) [=*Thecosphaerantha* HKL., 1887 (obj.)]. Cortical shell pores circular or hexagonal, regular, in hexagonal frames; all pores alike. *Jur.-Rec.*

T. (Thecosphaerella) HKL., 1887 [*Haliomma inerme* HKL., 1860; SD herein]. Like *T. (Thecosphaera)* but all pores circular, without hexagonal frames. *Eoc.-Rec.*——FIG. 17,*8*. *T. (T.) californica* CL.-C., U.Eoc., Calif., ×150 (39).

T. (Thecosphaerina) HKL., 1887 [*T. capillacea; SD herein]. Cortical pores polygonal, irregular, dissimilar. *Rec.*

T. (Thecosphaeromma) HKL., 1887 [*T. maxima; SD herein]. Like *T. (Thecosphaerina)* but pores round. *Rec.*

Rhodosphaera HKL., 1882 [*R. hexagonia* HKL., 1887]. One medullary shell and 2 cortical ones. *Dev.-Rec.*

R. (Rhodosphaera) [=*Rhodosphaerella* HKL., 1887 (obj.)]. Pores of both cortical shells regular, similar. *Dev.-Rec.*——FIG. 17,*5*. *R. (R.) crucifera* RÜST, U.Carb., Ger., ×75 (51).

R. (Rhodosphaeromma) HKL., 1887 [*R. palliata; SD herein]. Pores of both cortical shells irreguular, dissimilar. *Rec.*

Thecotapus CAMPBELL, 1951 [*pro Thecosphaera* RÜST, 1885 (*non* HKL., 1882)][*Thecosphaera unica* RÜST, 1885]. Like *Rhodosphaera* but with minute pores in inner cortical shell and large circular pores with delicate frames in outer one. *Jur.*——FIG. 17,*7*. **T. unicus* (RÜST); Jur., Switz., ×100 (51).

Subfamily CROMYOSPHAERINAE Haeckel, 1882
[as Cromyosphaerida; emend. CAMPBELL, herein]

Four concentric shells joined by radial beams. *Cret.-Rec.*

Cromyosphaera HKL., 1882 [*C. quadriplex* HKL., 1887][=*Cromyosphaerium* HKL., 1882 (obj.)]. Two medullary shells and 2 cortical ones.——FIG. 17,*12*. *C. antarctica* HKL., Rec., ×200 (42).

Subfamily CARYOSPHAERINAE Haeckel, 1882
[as Caryosphaerida; emend. CAMPBELL, herein]

Five or more concentric shells joined by radial beams. *Dev.-Rec.*

Caryosphaera HKL., 1882 [*C. polysphaerica* BÜTSCHLI, 1882]. Two medullary shells and 3 cortical ones.——FIG. 17,*14*. *C. groddecki* RÜST, Dev., Ger., ×80 (51).

Subfamily PLEGMOSPHAERINAE Haeckel, 1882
[as Plegmosphaerida; emend. CAMPBELL, herein]

Shell partly or wholly a spongy framework. *Cam.-Rec.*

Plegmosphaera HKL., 1882 [*P. maxima* HKL., 1887][=*Enneaplegma* HKL., 1882]. Hollow spongy sphere without medullary shell. *Mio.-Rec.*

P. (Plegmosphaera) [=*Plegmosphaerantha* HKL., 1887 (obj.)]. Smooth inner and outer sides of spongy shell, closed by lattice plate with polygonal meshes. *Rec.*

P. (Plegmosphaerella) HKL., 1887 [*P. entodictyon; SD herein]. Smooth inner side but outer side rough, spongy, thorny, closed by smooth lattice plate. *Rec.*

P. (Plegmosphaeromma) HKL., 1887 [*P. exodictyon*]. Rough spongy inner side without lattice plate, outside closed by smooth lattice plate. *Rec.*

P. (Plegmosphaerusa) HKL., 1887 [*P. leptoplegma; SD herein]. Both sides of spongy wall rough, spiny, without lattice plate. *Mio.-Rec.*——FIG. 17,*13*. *P. (P.) churchi* C.-CL., Mio., Calif., ×150 (35).

Dictyosoma MÜLLER, 1858 [*D. spongiosum*][=*Spongodictyon* HKL., 1862 (obj.)]. Spongy sphere enclosing 2 medullary lattice shells. *Jur.-Rec.*

D. (Dictyosoma) [=*Dictyoplegma* HKL., 1862 (obj.)]. Spongy cortical layer in contact with outer medullary shell. *Jur.-Rec.*——FIG. 17,*9*. *D. (D.) integrum* RÜST, Jur., Ger., ×110 (51).

D. (Spongodictyoma) HKL., 1862 [*D. trigonizon* HKL., 1860; SD herein][=*Dictyosoma* HKL., 1862 (obj.)]. Smooth lattice plate or 3rd medullary shell inside spongy cortical shell. *Rec.*

Diploplegma HINDE, 1890 [*D. cinctum; SD herein]. Spongy or irregularly reticulate cortical and large medullary shells. *Ord.*——FIG. 17,*11*. **D. cinctum*, Ord., Scot., ×100 (44).

Spongoplegma HKL., 1882 [*S. urschauense* RÜST, 1885]. Spongy cortical shell and single medullary one. *Cam.-Rec.*——FIG. 17,*10*. **S. urschauense*, Jur., Ger., ×75 (51).

Styptosphaera HKL., 1882 [*S. spumacea* HKL., 1887]. No medullary shell. *Plio.-Rec.*

Family PROTOSPHAERIDAE Cayeux, 1897

Spherical lattice shell with many isolated spicules. *Cret.*

Protosphaera CAYEUX, 1897 [**P. hexagonalis*]. Small sharp points between pores.

Family COLLOSPHAERIDAE Haeckel, 1862

[as Collosphaerida; emend. CAMPBELL, herein] [=Radiolaria polyzoa MULLER, 1858]

Growth colonial, individuals joined by alveolar jelly and anastomosing pseudopodia; each central capsule with distinct, somewhat irregular shell. *Ord.-Rec.*

Subfamily COLLOSPHAERINAE Haeckel, 1882

[as Collosphaerida *(partim)*; emend. CAMPBELL, herein] [=Acrosphaerida HKL., 1882]

Single lattice shell present. *Ord.-Rec.*

Collosphaera MÜLLER, 1855 [**C. huxleyi;* SD herein] [=*Dermatosphaera* EHR., 1860]. Simple smooth shell. *Rec.*

C. (Collosphaera) [=*Discollosphaera* HKL., 1887 (obj.)]. Form irregular.——FIG. 18,*1*. *C. (C.) polygona* HKL., Rec., (42).

C. (Eucollosphaera) HKL., 1887 [**C. primordialis;* SD herein]. Form regular spherical.

Buccinosphaera HKL., 1887 [**B. invaginata;* SD herein]. Inwardly directed tubes with fenestrate walls. *Rec.*——FIG. 18,*2*. **B. invaginata,* large crystals in each cell, Rec., ×250 (42).

Caminosphaera HKL., 1887 [**C. furcata;* SD here-

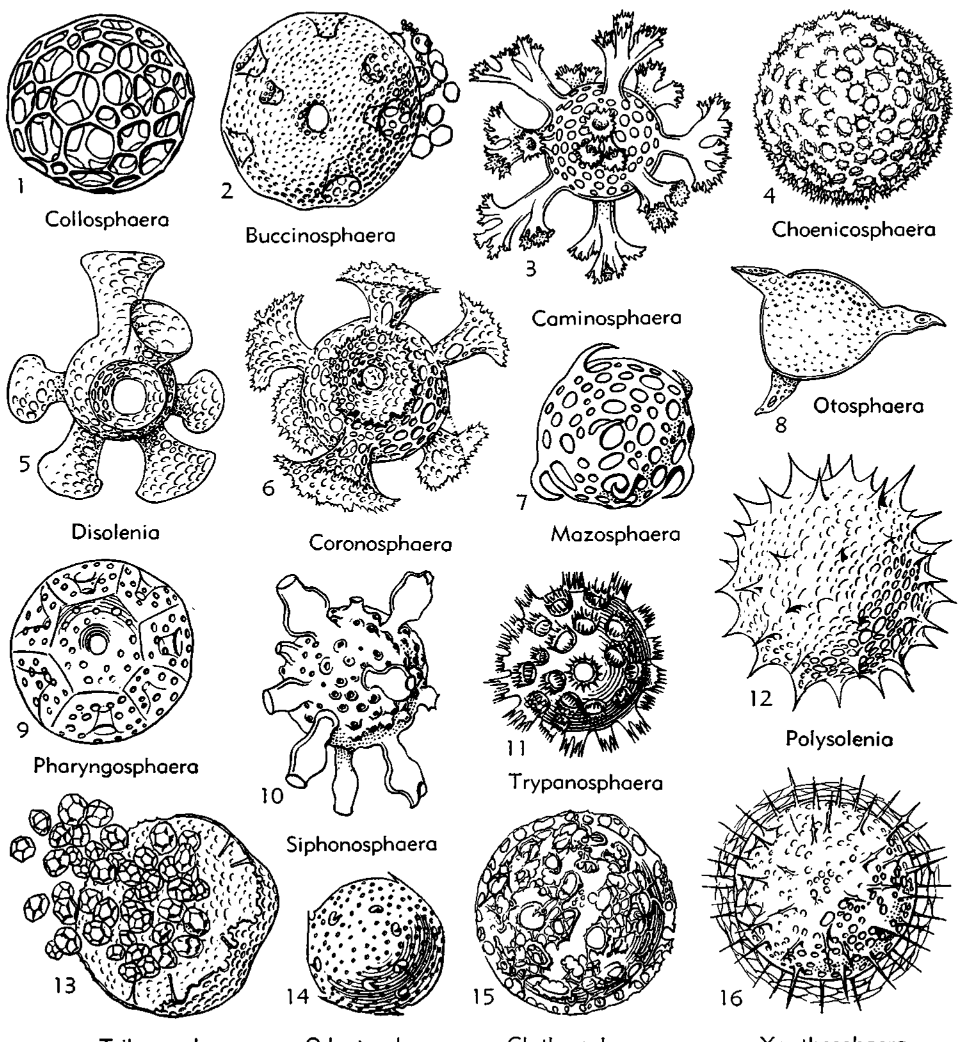


FIG. 18. Collosphaeridae (p. D51, D52).

in]. Pores prolonged outward in solid-walled branched tubules. *Rec.*——FIG. 18, *3. C. dendrophora* HKL., Rec., ×150 (42).

Choenicosphaera HKL., 1887 [**C. murrayana;* SD herein]. Radial spines form coronals around large pores. *Ord.*(N.Y.)-*Rec.*

C. (Choenicosphaera) [=*Choenicosphaerula* HKL., 1887 (obj.)]. Crown of spines around each pore. *Ord.-Rec.*——FIG. 18,*4.* **C. (C.) murrayana,* Rec., ×150 (42).

C. (Choenicosphaerium) HKL., 1887 [**C. flammabunda;* SD herein]. Crown of spines only around large pores. *Rec.*

Coronosphaera HKL., 1887 [**C. diadema;* SD herein]. Pores prolonged outward in fenestrate tubules with crown of spines around mouth. *Rec.* ——FIG. 18,*6. C. calycina* HKL., Rec., ×150 (42).

Disolenia EHR., 1860 [**D. follis*][=*Pentasolenia, Tetrasolenia, Trisolenia* EHR., 1872; *Solenosphaera* HKL., 1887 (obj.)]. Like *Coronosphaera* but no spines at tubule mouths. *Rec.*

D. (Disolenia) [=*Solenophracta* HKL., 1887 (obj.)]. Tubules cylindrical.

D. (Solenosphenia) HKL., 1887 [**Solenosphaera ascensionis;* SD herein]. Tubules conical, narrowing outward.

D. (Solenosphyra) HKL., 1887 [**Solenosphaera cornucopia;* SD herein]. Tubules funnel-shaped, flaring outward.——FIG. 18,*5.* **D. (S.) cornucopia* (HKL.), Rec., ×150 (42).

Mazosphaera EHR., 1860 [**M. laevis;* SD herein]. Pores prolonged outward in simple solid-walled tubules with tooth at mouth. *Rec.*——FIG. 18,*7. M. hippotis* HKL., Rec., ×200 (42).

Myxosphaera BRANDT, 1885 [**Thalassicola coerula* SCHNEIDER, 1858]. Small close-packed simple shells, bluish. *Rec.*

Odontosphaera HKL., 1887 [**O. monodon;* SD herein]. Single spine at edge of each large pore. *Rec.*——FIG. 18,*14.* **O. monodon,* Rec., ×150 (42).

Otosphaera HKL., 1887 [**O. polymorpha;* SD herein]. Like *Mazosphaera* but walls of tubules fenestrate. *Rec.*——FIG. 18,*8.* **O. polymorpha,* Rec., ×150 (42).

Pharyngosphaera HKL., 1887 [**P. stomodaea*]. Pores prolonged inward by solid-walled tubules. *Rec.*——FIG. 18,*9.* **P. stomodaea,* Rec., ×200 (42).

Polysolenia EHR., 1872 [**P. setosa*][=*Acrosphaera* HKL., 1882 (obj.)]. Surface with irregularly scattered radial spines. *Rec.*——FIG. 18,*12. P. echinoides* (HKL.), Rec., ×200 (42).

Siphonosphaera MÜLLER, 1858 [**S. tubulosa*]. Like *Mazosphaera* but mouths of tubules truncate, smooth. *Ord.*(N.Y.)-*Mio.* (Italy)-*Rec.*

S. (Siphonosphaera) [=*Holosiphonia* HKL., 1887 (obj.)]. All pores with tubules. *Ord.-Rec.*

S. (Merosiphonia) HKL., 1887 [**S. socialis;* SD herein]. Some pores lacking tubules. *Rec.*——FIG. 18,*10. S. (M.) pipetta* HKL., Rec., ×150 (42).

Tribonosphaera HKL., 1882 [**T. centripetalis* HKL., 1887]. Simple shell with inwardly directed beams. *Rec.*——FIG. 18,*13.* **T. centripetalis,* Rec., ×250 (42).

Trypanosphaera HKL., 1887 [**T. trepanata;* SD herein]. Like *Coronosphaera* but tubules solid-walled. *Rec.*

T. (Trypanosphaera) [=*Trypanosphaerula* HKL., 1887 (obj.)]. All pores with tubules.——FIG. 18,*11.* **T. (T.) trepanata,* Rec., ×150 (42).

T. (Trypanosphaerium) HKL., 1887 [**T. coronata;* SD herein]. Some pores lack tubules.

Subfamily CLATHROSPHAERINAE Haeckel, 1882

[as Clathrosphaerida; emend. CAMPBELL, herein[

Two concentric lattice shells. *Rec.*

Clathrosphaera HKL., 1882 [**C. circumtexta* HKL., 1887]. Outer surface smooth.

C. (Clathrosphaera) [=*Clathrosphaerula* HKL., 1887 (obj.)]. Shells joined by hollow tubes.——FIG. 18,*15.* **C. (C.) circumtexta,* Rec., ×200 (42).

C. (Clathrosphaerium) HKL., 1887 [**C. arachnoides;* SD herein]. Shells joined by solid rods.

Xanthosphaera HKL., 1882 [**X. capillacea* HKL., 1887]. Outer shell with spiny surface.——FIG. 18,*16. X. erinacea* HKL., Rec., ×200 (42).

Family DORYSPHAERIDAE Vinassa de Regny, 1898

Lattice shell single or concentrically multiple, with a single polar spine. *Ord.-Mio.*

Dorysphaera HINDE, 1890 [**D. reticulata*][=*Monostylus* CAYEAUX, 1897]. Single shell with one main spine, but short ones may cover surface. *Ord.*(Scot.)-*Mio.*(Italy).——FIG. 19,*3. D. ehrenbergi* VINASSA, Mio., Italy, ×150 (55).

Doryconthidium VINASSA, 1898 [**D. cayeuxi*]. Three concentric shells, secondary spines numerous. *Jur.-Mio.*——FIG. 19,*8. D. vinassianum* CARNEVALE, Mio., Italy, ×110 (36).

Dorydictyum HINDE, 1890 [*D. *simplex*]. Single shell with uniform reticulate lattice, fine alveoles; robust styliform main spine with length nearly equal to shell diameter. *Ord.-Cret.*——FIG. 19,*2.* **D. simplex,* Ord., Scot., ×100 (44).

Dorylonchidium VINASSA, 1898 [**D. hindei* VINASSA, 1898]. Two concentric shells, secondary spines present. *Paleoc.-Mio.*

D. (Dorylonchidium) [=*Dorylonchella* CL.-C., 1942 (obj.)]. Surface smooth or roughened by short, thin spines or thorns. *Paleoc.-Mio.*——FIG. 19,*7a. D. (D.) monoxiphos* CL.-C., U.Eoc., Calif., ×150 (39).

D. (Dorylonchomma) CL.-C., 1942 [*D. *fructiforme*]. Surface with stout, scattered spine or thorns. *Eoc.*——FIG. 19,*7b*. *D. (D.) grande* CL.-C., U.Eoc., Calif., ×100 (39).

Doryplegma HINDE, 1890 [**D. nasutum*; SD herein]. Cortical shell irregularly latticed or spongy, enclosing medullary shell. *Ord.*——FIG. 19,*4*. **D. nasutum*, Ord., Scot., ×100 (44).

Family STYLOSPHAERIDAE Haeckel, 1882

[as Stylosphaerida; emend. CAMPBELL, herein]

Lattice shell single or concentrically multiple, with 2 prominent polar spines, or rarely more, oppositely placed in one axis. *Cam.-Rec.*

Subfamily STYLOSPHAERINAE Haeckel, 1882

[as Stylosphaerida *(partim)*; emend. CAMPBELL, herein] [=Sphaerostylida HKL., 1882]

Two concentric lattice shells. *Dev.-Rec.*

Stylosphaera EHR., 1847 [**S. hispida* EHR., 1854; SD FRIZZELL 1951]. Two spines of equal length and form, or rarely with 3 to 5 spines. *Dev.-Rec.*

S. (Stylosphaera) [=*Stylosphaerella* HKL., 1887 (obj.)]. Pores nearly equal and similar; surface thorny or spiny. *Dev.-Rec.*——FIG. 19,*5b*. *S. (S.) melpomene* HKL., Rec., ×200 (42).

S. (Stylosphaerantha) HKL., 1887 [**S. calliope*; SD herein]. Like *S. (Stylosphaera)* but surface without spines or thorns. *Eoc.-Rec.*——FIG. 19,*5c*. **S. (S.) calliope*, Rec., ×200 (42).

S. (Stylosphaerissa) HKL., 1887 [**S. nana*; SD herein]. Pores irregular, dissimilar; surface without spines or thorns.——FIG. 19,*5a*. **S. (S.) nana*, Rec., ×300 (42).

S. (Stylosphaeromma) HKL., 1887 [**S. thalia*; SD herein]. Like *S. (Stylosphaerissa)* but with spines or thorns. *Rec.*

Saturnulus HKL., 1882 [**S. circulus* HKL., 1887]. Tips of polar spines joined by circular or elliptical ring. *Cret.-Rec.*——FIG. 19,*1*. *S. ellipticus* HKL., Rec., ×200 (42).

Sphaerostylus HKL., 1882 [**S. zittelii* RÜST, 1885]. Two free polar spines dissimilar. *Jur.-Rec.*

S. (Sphaerostylus) [=*Sphaerostylantha* HKL., 1887 (obj.)]. Pores regular, similar; surface without spines or thorns. *Jur.-Rec.*——FIG. 19,*6b*. *S. (S.) minutus* CL.-C., U.Eoc., Calif., ×150 (39).

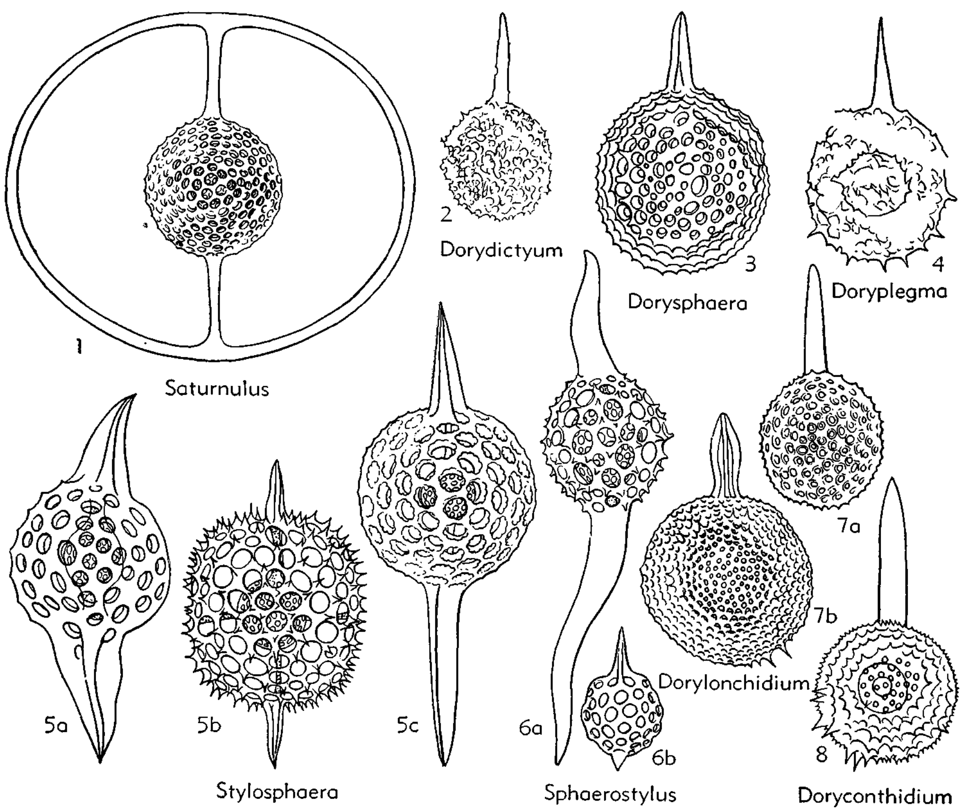


FIG. 19. Dorysphaeridae, Stylosphaeridae (p. D52-D54).

S. (Sphaerostyletta) Hkl., 1887 [**S. diadema*]. Pores regular, similar; surface spiny or thorny. *Rec.*

S. (Sphaerostylissa) Hkl., 1887 [**S. cottus;* SD herein]. Pores irregular, dissimilar; surface without spines or thorns. *Rec.*

S. (Sphaerostylomma) Hkl., 1887 [**S. ophidium*]. Pores irregular, dissimilar; surface with spines or thorns. *Rec.*——Fig. 19,*6a*. **S. (S.) ophidium,* Rec., ×150 (42) .

Subfamily XIPHOSTYLINAE Haeckel, 1882

[as Xiphostylida; emend. Campbell, herein]
[=Saturnalinae Deflandre, 1952]

Single lattice shell present. *Cam.-Rec.*

Xiphostylus Hkl., 1882 [**X. attenuatus* Rüst, 1885]. Polar spines dissimilar. *Cam.-Rec.*

X. (Xiphostylus) [=*Xiphostylantha* Hkl., 1887 (obj.)]. Pores regular, similar; surface without spines or thorns. *Cam.-Rec.*——Fig. 20,*7a*. *X. (X.) alcedo* Hkl., Rec., ×200 (42).

X. (Xiphostyletta) Hkl., 1887 [**X. pictus;* SD herein]. Pores regular, similar; surface spiny or thorny. *Rec.*——Fig. 20,*7b*. **X. (X.) pictus,* Rec., ×150 (42).

X. (Xiphostylissa) Hkl., 1887 [**X. trogon;* SD herein]. Pores irregular, dissimilar; surface without spines or thorns. *Rec.*——Fig. 20,*7d*. **X. (X.) trogon,* Rec., ×200 (42).

X. (Xiphostylomma) Hkl., 1887 [**X. emberiza;* SD herein]. Pores irregular, dissimilar; surface with spines or thorns. *Rec.*——Fig. 20,*7c*. **X. (X.) emberiza,* Rec., ×200 (42).

Saturnalis Hkl., 1882 [**S. circularis* Hkl., 1887]. Tips of polar spines joined by circular or elliptical ring. *Cret.-Rec.*

S. (Saturnalis) [=*Saturnalina* Hkl., 1887 (obj.)]. Ring smooth. *Cret.*(Cosmop.)-*Rec.*(Circumtrop.). ——Fig. 20,*3a*. *S. (S.) circoides* Hkl., Rec., ×200 (42).

S. (Saturnalium) Hkl., 1887 [**S. rotula;* SD herein]. Ring spiny. *Cret.*(Cosmop.)-*Rec.*(trop.). ——Fig. 20,*3b*. **S. (S.) rotula,* Rec., ×200 (42).

Stigmosphaerostylus Rüst, 1892 [**S. notabilis*] [=*Stigmosphaerocephalus* Pop., 1911 (obj.)]. Polar spines similar; shell interior with 4 strong beams in equatorial plane in right-angle cross. *L.Carb.*, Ger.——Fig. 20,*10*. **S. notabilis,* L.Carb., Ger., ×75 (51).

Xiphosphaera Hkl., 1882 [**X. tredecimporata* Rüst, 1885]. Two similar polar spines, rarely 3 to 5. *Ord.-Rec.*

X. (Xiphosphaera) [=*Xiphosphaerantha* Hkl., 1887 (obj.)]. Pores regular, similar; surface without spines or thorns. *Rec.*——Fig. 20,*9d*. *X. (X.) venus* Hkl., Rec., ×200 (42).

X. (Xiphosphaerella) Hkl., 1887 [**X. pallas;* SD herein]. Pores regular, similar; surface papillose to spiny or thorny. *Eoc.-Rec.*——Fig. 20,*9a*. **X. (X.) pallas,* Rec., ×150 (42).

X. (Xiphosphaerissa) Hkl., 1887 [**X. ceres;* SD herein]. Pores irregular, dissimilar; surface without spines or thorns. *Ord.-Rec.*——Fig. 20,*9b*. *X. (X.) macracantha* Ruedemann & Wilson, Ord., N.Y., ×150 (50).

X. (Xiphosphaeromma) Hkl., 1887 [**X. vesta;* SD herein]. Pores irregular, dissimilar; surface spiny or thorny. *Rec.*——Fig. 20,*9c*. **X. (X.) vesta,* Rec., ×150 (42).

Subfamily AMPHISTYLINAE Haeckel, 1882

[as Amphistylida; emend. Campbell, herein]

Three concentric lattice shells. *Jur.-Rec.*

Amphistylus Hkl., 1882 [**A. clio* Hkl., 1887]. Polar spines dissimilar; surface without spines or thorns. *Jur.-Rec.*——Fig. 20,*2*. *A. zitteli* Vinassa, U.Jur., Italy, ×200 (55).

Amphisphaera Hkl., 1882 [**A. neptunus* Hkl., 1887][=*Amphisphaeridium* Hkl., 1887]. Polar spines similar. *Cret.-Rec.*

A. (Amphisphaera) [=*Amphisphaerantha* Hkl., 1887 (obj.)]. Pores regular, similar; surface without spines or thorns. *Cret.-Rec.*——Fig. 20,*1a*. *A. (A.) ceres* Cl.-C., U.Eoc., Calif., one spine broken, ×200 (39).

A. (Amphisphaerella) Hkl., 1887 [**A. apollo;* SD herein]. Pores regular, similar; surface spiny or thorny. *Rec.*

A. (Amphisphaerissa) Hkl., 1887 [**A. cronos;* SD herein]. Pores irregular, dissimilar; surface without spines or thorns. *Rec.*——Fig. 20,*1b*. *A. (A.) pluto* Hkl., Rec., ×200 (42).

A. (Amphisphaeromma) Hkl., 1887 [**A. mars;* SD herein]. Pores irregular, dissimilar; surface shiny or thorny. *Rec.*

Saturninus Hkl., 1882 [**S. triplex* Hkl., 1887]. Tips of polar spines joined by circular or elliptical ring. *Cret.-Rec.*

Subfamily CROMYOSTYLINAE Haeckel, 1882

[as Cromyostylida; emend. Campbell, herein]

Four concentric lattice shells, 2 medullary and 2 cortical. *Rec.*

Cromyostylus Hkl., 1882 [**C. gladius* Hkl., 1887]. Polar spines dissimilar.

Stylocromyum Hkl., 1882 [**S. amphipyramis* Hkl., 1887; SD herein]. Polar spines similar.

Subfamily CARYOSTYLINAE Haeckel, 1882

[as Caryostylida; emend. Campbell, herein]

Five or more concentric lattice shells. *Rec.*

Caryostylus Hkl., 1882 [**C. hexalepas* Hkl., 1887][=*non Caryoxiphus, Caryodoras, Caryolonche* Hkl., 1882]. Polar spines similar.

Subfamily SPONGOSTYLINAE Haeckel, 1882

[as Spongostylida; emend. Campbell, herein]

Spherical spongy shells, with or without enclosed lattice shells. *Cret.-Rec.*

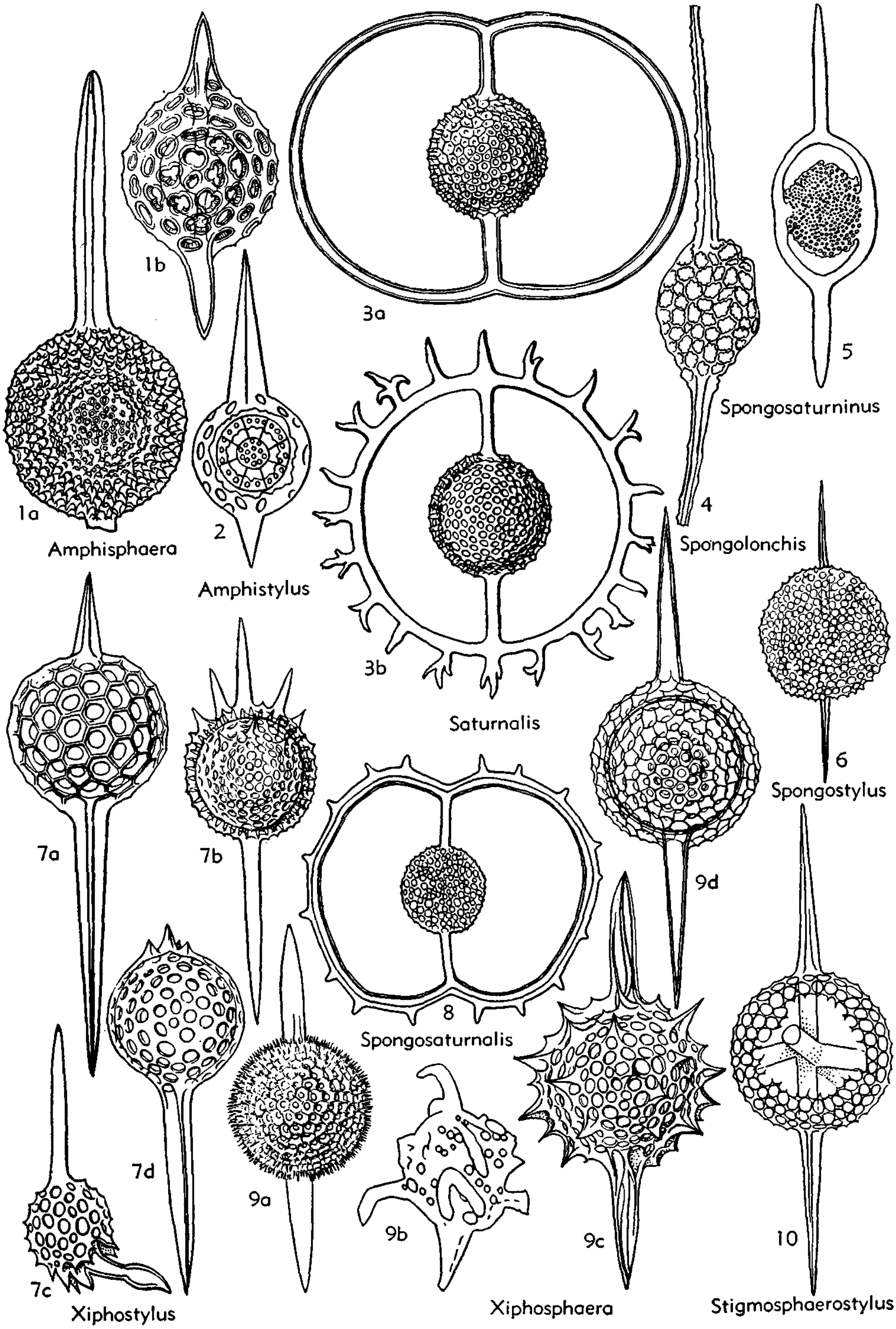


FIG. 20. Stylosphaeridae (p. D54-D56).

Spongostylus HKL., 1882 [*S. *hastatus* HKL., 1887] [=*Spongostylium* HKL., 1882]. One simple medullary shell. *Rec.*——FIG. 20,*6*. *S. gladiatus* (EHR.), Rec., ×200 (41).

Spongolonchis HKL., 1887 [*S. *compacta* HKL., 1887][*non Spongolonche* HKL., 1882]. Solid spongy shell. *Cret.-Rec.*——FIG. 20,*4*. *S. grandis* C.-CL., Cret., Calif., ×100 (35).

Spongosaturnalis C.-CL., 1944 [*S. *spiniferus*]. Solid spongy shell, tips of polar spines joined by circular or elliptical ring. *Cret.*——FIG. 20,*8*. *S. *spiniferus,* Cret., Calif., ×100 (35).

Spongosaturninus C.-CL., 1944 [*S. *ellipticus*]. Like *Spongosaturnalis* but has 2 medullary lattice shells. *Cret.*——FIG. 20,*5*. *S. *ellipticus,* Cret., Calif., ×100 (35).

Spongostylidium HKL., 1882 [*S. *streptacanthum* HKL., 1887]. Like *Spongosaturninus* but lacks a ring. *Rec.*

Family TRIPOSPHAERIDAE Vinassa de Regny, 1898

Single or multiple concentric spongy or latticed shells with 3 to 4 equidistant main radial spines. *Ord.-Cret.*

Triposphaera HINDE, 1890 [*T. *peachi;* SD herein] [=*Trisphaera* SQUIN., 1904]. Spongy cortical shell, latticed medullary one; 3 main radial spines and many small by-spines. *Ord.-Cret.*(Italy).——FIG. 21,*1*. *T. armata* HINDE, Ord., Scot., ×150 (44).

Phyletripes CAMPBELL, 1951 [*pro Hexastylus* RÜST, 1885 (*non* HKL., 1882)][**Hexastylus primaevus* RÜST, 1885]. Single smooth lattice shell, 3 short, blunt main spines. *Jur.*——FIG. 21,*2*. *P. *primaevus* (RÜST), L.Jur., Switz., ×100 (51).

Rüstia VINASSA, 1898 [**Stauracontium inequale* RÜST, 1892]. Three concentric lattice shells, 4 main radial spines in opposite pairs. *U.Jur.*——FIG. 21,*7*. *R. elegantula* VINASSA, U.Jur., Sicily, ×150 (55).

Trilonche HINDE, 1899 [*T. *vetusa;* SD herein]. Two concentric lattice shells; 3 main radial spines, by-spines present or absent. *Dev.*(Austral.)-*L.Carb.* (Eng.).——FIG. 21,*3*. *T. *vetusa,* Dev., Austral., ×200 (44).

Xiphostaurus VINASSA, 1898 [**Staurostylus xiphophorus* RÜST, 1892]. Three concentric lattice shells; 4 main radial spines with one much elongated. *U.Jur.*——FIG. 21,*6*. *X. titonicus* VINASSA, U.Jur., Italy, ×200 (55).

Family STAUROSPHAERIDAE Haeckel, 1882

[as Staurosphaerida; emend. CAMPBELL, herein]

Lattice shell single or concentrically multiple, with 4 main radial spines in a plane forming a right-angle cross. *Cam.-Rec.*

Subfamily STAUROSPHAERINAE Haeckel, 1882

[as Staurosphaerida (*partim*); emend. CAMPBELL, herein] [=Staurostylida HKL., 1882]

Single lattice shell present. *Ord.-Rec.*

Staurosphaera HKL., 1882 [*S. *crassa* DUNIKOWSKI, 1882]. Main radial spines similar. *Ord.-Rec.*

S. (Staurosphaera) [=*Staurosphaerissa* HKL., 1887 (obj.)]. Pores irregular, dissimilar; surface smooth. *Eoc.-Rec.*——FIG. 21,*17c*. *S. (S.) megapora* (EHR.), U.Eoc., ×100 (41).

S. (Staurosphaerantha) HKL., 1887 [*S. *cruciata;* SD herein]. Pores regular, similar; surface smooth. *Ord.-Rec.*——FIG. 21,*17b*. *S. (S.) sancta* RUEDEMANN & WILSON, Ord., N.Y., ×100 (50).

S. (Staurosphaerella) HKL., 1887 [*S. *philippi;* SD herein]. Pores regular, similar; surface spiny. *Rec.*——FIG. 21,*17a*. *S. *(S.) philippi,* Rec., ×150 (42).

S. (Staurosphaeromma) HKL., 1887 [*S. *bartholomaei;* SD herein]. Pores irregular, dissimilar; surface spiny. *Rec.*

Staurostylus HKL., 1882 [*S. *graecius* HKL., 1887]. Opposite pair of main radial spines larger than other. *Jur.-Rec.*——FIG. 21,*16*. *S. italicus* RÜST, Cret., Italy, ×60 (51).

Stylostaurus HKL., 1882 [*S. *caudatus* HKL., 1887]. One main spine elongated. *Ord.-Rec.*——FIG. 21,*5*. *S. *caudatus,* Rec., ×200 (42).

Subfamily STAUROLONCHINAE Haeckel, 1882

[as Staurolonchida; emend. CAMPBELL, herein]

Two concentric lattice shells. *Cam.-Rec.*

Staurolonche HKL., 1882 [*S. *robusta* RÜST, 1885] [=*Staurobelone, Staurodoras* HKL., 1887; (*non Staurodoras,* HKL., 1882)]. Main spines unbranched. *Cam.-Rec.*

S. (Staurolonche) [=*Staurolonchantha* HKL., 1887 (obj.)]. Pores regular, similar; surface smooth. *Cam.-Rec.*——FIG. 21,*10*. *S. (S.) pertusa* HKL., Rec., ×150 (42).

S. (Staurolonchella) HKL., 1887 [*S. *straussii;* SD herein]. Pores regular, similar; surface spiny. *Rec.*

S. (Staurolonchissa) HKL., 1887 [*S. *holbachii;* SD herein]. Pores irregular, dissimilar; surface smooth. *Rec.*

S. (Staurolonchura) HKL., 1887 [*S. *epicurii;* SD herein]. Pores irregular, dissimilar; surface spiny. *Rec.*

Cromyostaurolonche CL.-C., 1944 [*C. *cruciformis*]. Cortical shell spongy; main spines unbranched. *Mio.*——FIG. 21,*14*. *C. *cruciformis,* Mio., Calif., ×150 (39).

Staurancistra HKL., 1882 [*S. *quadricuspis* HKL., 1887]. Like *Staurolonche* but main spines branched. *Mio.*——FIG. 21,*13*. *S. elegans* VINASSA, Mio., Italy, ×200 (55).

Staurolonchidium HKL., 1887 [**Haliomma perspicuum* EHR., 1875; SD herein]. Pair of opposite main spines larger than others. *Jur.-Rec.*——FIG.

21,*11*. *S. tuberosum* Rüst, Cret., Italy, ×90 (51).

Stauroxiphus Hkl., 1887 [**S. gladius*]. One of main spines larger than others. *Rec.*——Fig. 21,*12*. **S. gladius*, Rec., ×200 (42).

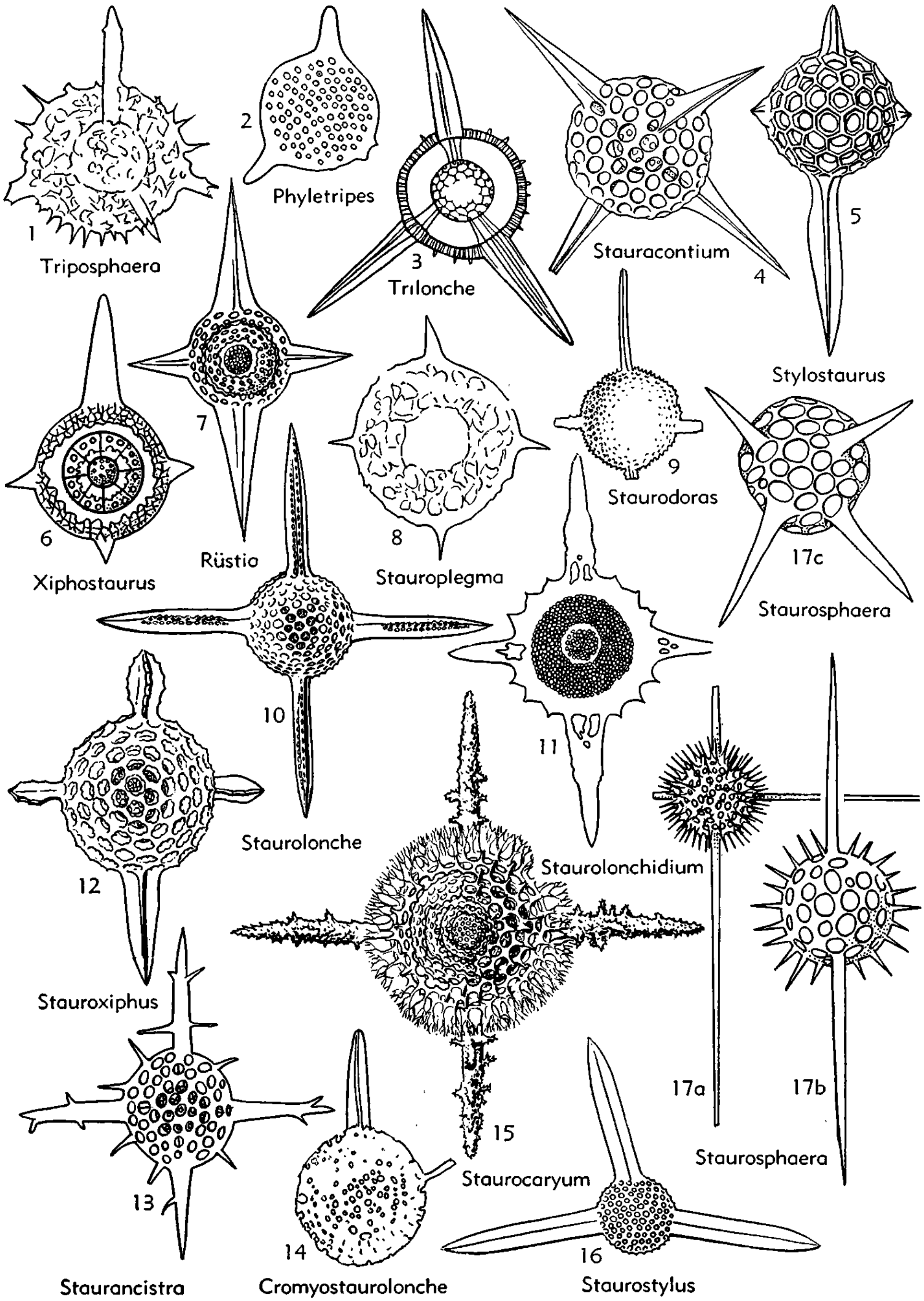


Fig 21. Triposphaeridae, Staurosphaeridae (p. D56-D58).

Subfamily STAURACONTIINAE Haeckel, 1882
[as Stauracontida; emend. CAMPBELL, herein]

Three concentric lattice shells. *Jur.-Rec.*

Stauracontium HKL., 1882 [**S. cruciferum* HKL., 1887]. *Jur.-Rec.*

S. (Stauracontium) [=*Stauracontarium* HKL., 1887 (obj.)]. Pores regular, similar; surface smooth. *Jur.-Rec.*——FIG. 21,*4*. *S. (S.) tetracanthium* (EHR.), Rec., ×200 (41).

S. (Stauracontellium) HKL., 1887 [**Actinomma daturaeforme* STÖHR, 1880; SD herein]. Pores regular, similar; surface spiny. *Rec.*

S. (Stauracontidium) HKL., 1887 [**S. antarcticum*]. Pores irregular, dissimilar; surface smooth. *Rec.*

S. (Stauracontonium) HKL., 1887 [**S. setosum;* SD herein]. Pores irregular, dissimilar; surface spiny. *Rec.*

Subfamily STAUROCROMYINAE Haeckel, 1882
[as Staurocromyida; emend. CAMPBELL, herein]

Four concentric lattice shells. *Cret.-Rec.*

Staurocromyum HKL., 1882 [**S. quadruplex* HKL., 1887]. Main spines unbranched. *Cret.-Rec.*

Cromyostaurus HKL., 1882 [**C. verticellatus* HKL., 1887]. Main spines branched. *Rec.*

Subfamily STAUROCARYINAE Haeckel, 1882
[as Staurocaryida; emend. CAMPBELL, herein]

Five or more concentric lattice shells. *Rec.*

Staurocaryum HKL., 1882 [**S. arborescens* HKL., 1887].——FIG. 21,*15*. **S. arborescens,* Rec., ×100 (42).

Subfamily STAURODORADINAE Haeckel, 1882
[as Staurodorida; emend. CAMPBELL, herein]

Shell comprising a solid spongy sphere. *Ord.-Rec.*

Staurodoras HKL., 1882 [**S. mojsisovicsii* DUNIKOWSKI, 1882]. Lacks differentiated medullary lattice shells. *Jur.-Rec.*——FIG. 21,*9*. *S. eocenica* CL.-C., U.Eoc., Calif., ×150 (39).

Stauroplegma HINDE, 1890 [**S. brevispina*]. Medullary shells present. *Ord.*——FIG. 21,*8*. **S. brevispina,* Ord., Scot., ×150 (44).

Family PENTASPHAERIDAE Squinabol, 1904

Single lattice shell with 5 radial spines in a single plane. *Cret.*

Pentasphaera SQUIN., 1904 [**P. longispina*]. Spines equidistant.——FIG. 22,*5*. **P. longispina,* Cret., Italy, ×100 (52).

Family CUBOSPHAERIDAE Haeckel, 1882
[as Cubosphaerida; emend. CAMPBELL, herein]

Lattice shell single or concentrically multiple, with 6 main radial spines in two planes, meeting at right angles. *Dev.-Rec.*

Subfamily CUBOSPHAERINAE Haeckel, 1882
[as Cubosphaerida *(partim)*; emend. CAMPBELL, herein]
[=Hexacaryida HKL., 1882]

Five or more concentric shells. *Rec.*

Cubosphaera HKL., 1887 [**C. cubaxonia* HKL., 1887; SD herein]. Main spines all similar, unbranched.——FIG. 22,*7*. **C. cubaxonia,* Rec., ×200 (42).

Hexacaryum HKL., 1882 [**H. arborescens* HKL., 1887]. Main spines all similar, branched.——FIG. 22,*4*. **H. arborescens,* Rec., ×200 (42).

Subfamily HEXASTYLINAE Haeckel, 1882
[as Hexastylida; emend. CAMPBELL, herein]

Single lattice shell present. *Jur.-Rec.*

Hexastylus HKL., 1882 [*non* RÜST, 1885 (=*Phyletripes* CAMPBELL, 1951)] [**H. phaenaxonius* HKL., 1887] [=*Exastylus* VINASSA, 1898; *Hexastilus* PRINCIPI, 1909 (obj.)]. Main spines similar. *Jur.-Rec.*

H. (Hexastylus) [=*Hexastylanthus* HKL., 1887 (obj.)]. Pores regular, similar; surface smooth. *Jur.-Rec.*——FIG. 22,*6c*. **H. (H.) phaenaxonius,* Rec., ×200 (42).

H. (Hexastylettus) HKL., 1887 [**H. solonis;* SD herein]. Pores regular, similar; surface spiny. *Rec.*——FIG. 22,*6b*. **H. (H.) solonis,* Rec., ×200 (42).

H. (Hexastylissus) HKL., 1887 [**H. triaxonius;* SD herein]. Pores irregular, dissimilar; without secondary spines. *Rec.*——FIG. 22,*6a*. **H. (H.) triaxonius,* Rec., ×400 (42).

H. (Hexastylurus) HKL., 1887 [**H. dictyotus;* SD herein]. Pores irregular, dissimilar; surface spiny. *Rec.*——FIG. 22,*6d*. **H. (H.) dictyotus,* Rec., ×270 (42).

Hexacladus VINASSA, 1900 [**H. pantanellii*] [=*Xexacladus* VINASSA, 1900 (obj.)]. Each main spine with distal trifurcations. *Mio.*——FIG. 22,*3*. **H. pantanellii,* Mio., Italy, ×400 (55).

Hexapyramis SQUIN., 1903 [**H. pantanellii*]. Main spines latticed pyramids, unbranched or branched distally. *Cret.*——FIG. 22,*1*. **H. pantanellii,* Cret., Italy, ×60 (52).

Hexastylarium HKL., 1887 [**H. elongatum*] [=*Exastylarium* VINASSA, 1898 (obj.)]. An opposite pair of spines larger than others. *Jur.* (Italy)-*Rec.*——FIG. 22,*2*. *H. dunikowskyi* VINASSA, U.Jur., Italy, ×200 (55).

Hexastylidium HKL., 1882 [**H. rhomboides* HKL., 1887]. Spines of one opposite pair not alike, those of the other pairs equal. *Rec.*

Subfamily HEXALONCHINAE Haeckel, 1882
[as Hexalonchida; emend. CAMPBELL, herein]

Two concentric lattice spheres. *Dev.-Rec.*

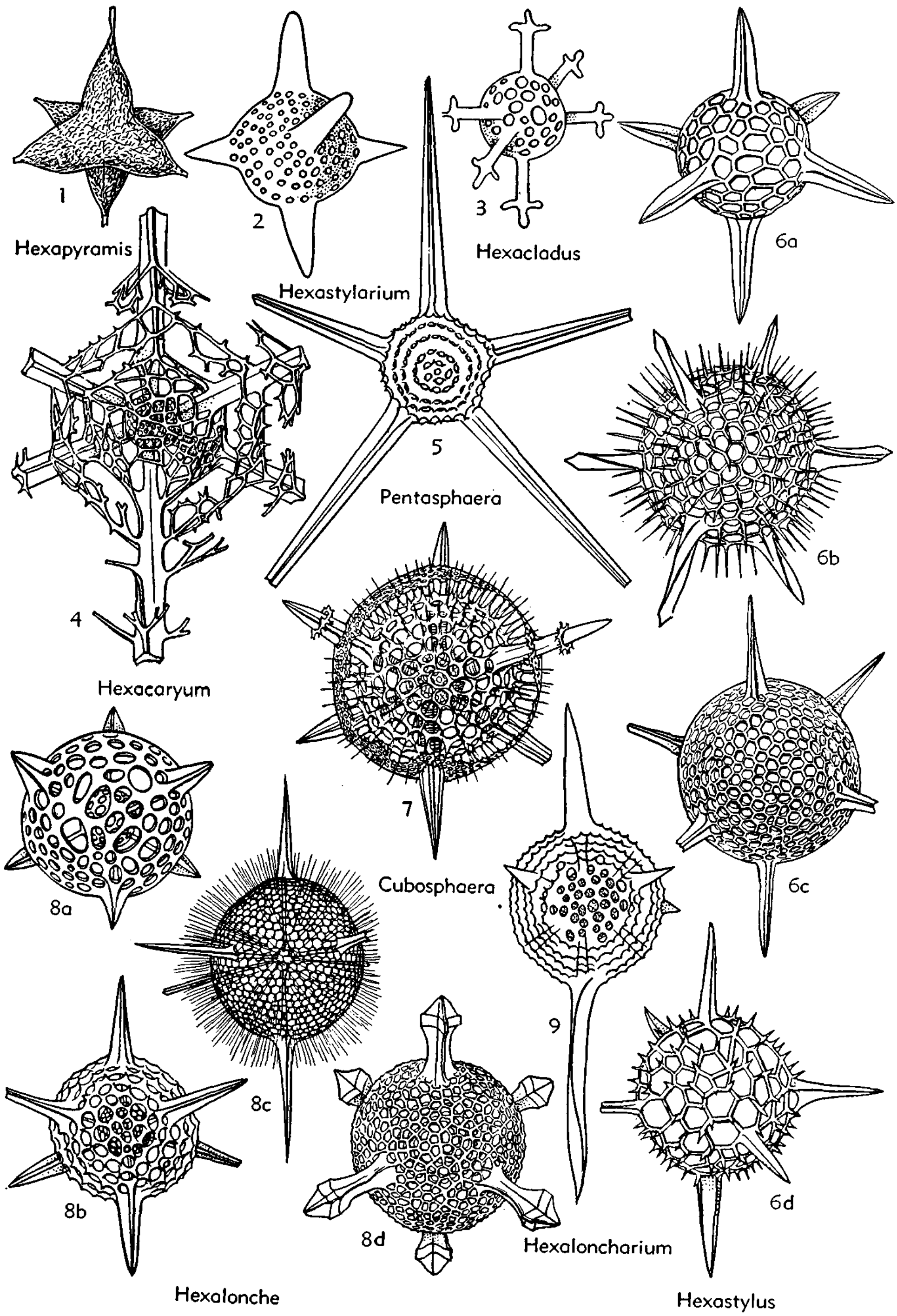


Fig. 22. Pentasphaeridae, Cubosphaeridae (p. D58-D60).

Hexalonche HKL., 1882 [**H. phaenaxonia* HKL., 1887]. Main spines all similar, unbranched. *Dev.-Rec.*

H. (Hexalonche) [=*Hexalonchara* HKL., 1887 (obj.)]. Pores regular, similar; surface without by-spines. *Dev.-Rec.*——FIG. 22,*8d*. *H. (H.) rosetta,* Rec., ×200 (42).

H. (Hexalonchetta) HKL., 1887 [**H. amphisiphon;* SD herein]. Pores regular, similar; surface spiny. *Rec.*——FIG. 22,*8c*. **H. (H.) amphisiphon,* Rec., ×150 (42).

H. (Hexalonchilla) HKL., 1887 [**H. pythagorea;* SD herein]. Pores irregular, dissimilar; surface without by-spines. *Rec.*——FIG. 22,*8a*. **H. (H.) pythagorea,* Rec., ×200 (42).

H. (Hexalonchusa) HKL., 1887 [**H. philosophica;* SD herein]. Pores irregular, dissimilar; surface spiny. *Rec.*——FIG. 22,*8b*. **H. (H.) philosophica,* Rec., ×200 (42).

Hexaloncharium HKL., 1887 [**H. philosophicum;* SD herein]. One pair of spines different from others. *Mio.-Rec.*——FIG. 22,*9*. *H. archimedes* VINASSA, Mio., Italy, ×200 (55).

Hexalonchidium HKL., 1882 [**H. axonometrum* HKL., 1887]. Spines of one opposite pair not alike, those of other pairs equal. *Rec.*

Hexancistra HKL., 1882 [**H. tricuspis* HKL., 1887]. Main spines all similar, branched. *Rec.*

H. (Hexancistra) [=*Hexancora* HKL., 1887 (obj.)]. Each spine with 3 simple branches.——FIG. 23,*7b*. **H. (H.) tricuspis,* Rec., ×150 (42).

H. (Hexapitys) HKL., 1882 [**H. mirabilis* HKL., 1887]. Each spine with 3 rows of verticillate lateral branches.——FIG. 23,*7a*. **H. (H.) mirabilis,* Rec., ×150 (42).

Subfamily HEXACONTIINAE Haeckel, 1882

[as Hexacontida; emend. CAMPBELL, herein]

Three concentric lattice shells. *Eoc.-Rec.*

Hexacontium HKL., 1882 [**H. phaenaxonium* HKL., 1887]. Main spines all similar, unbranched. *Eoc.*(Italy)*-Rec.*

H. (Hexacontium) [=*Hexacontanna* HKL., 1887 (obj.)]. Pores regular, similar; surface smooth. *Eoc.-Rec.*——FIG. 23,*8c*. *H. (H.) axotrias* HKL., Rec., ×150 (42).

H. (Hexacontella) HKL., 1887 [**H. favosum;* SD herein]. Pores regular, similar; surface spiny. *Rec.*——FIG. 23,*8a*. *H. (H.) floridum* HKL., Rec., ×200 (42).

H. (Hexacontosa) HKL., 1887 [**H. axophaenum;* SD herein]. Pores irregular, dissimilar; surface smooth. *Rec.*

H. (Hexacontura) HKL., 1887 [**H. papillosum;* SD herein]. Pores irregular, dissimilar; surface spiny.——FIG. 23,*8b*. **H. (H.) papillosum,* Rec., ×200 (42).

Hexacontarium HKL., 1887 [**H. dentatum;* SD herein]. One pair of opposite spines larger than others. *Rec.*

Hexadendron HKL., 1882 [**H. quadricuspis* HKL., 1887]. Main spines all similar, but branched. *Rec.*——FIG. 23,*9*. *H. bipinnatum* HKL., Rec., ×200 (42).

Subfamily HEXACROMYINAE Haeckel, 1882

[as Hexacromyida; emend. CAMPBELL, herein]

Four concentric lattice shells. *Mio.-Rec.*

Hexacromyum HKL., 1882 [**H. elegans*] [=*Hexacromidium* HKL., 1882 (obj.)]. Main spines all similar.——FIG. 23,*6*. **H. elegans,* Rec., ×200 (42).

Subfamily CENTROLONCHINAE Campbell, nov.

Main spines joined at center of single or multiple concentric lattice shell. *Rec.*

Centrolonche POP., 1911 [**C. hexalonche*]. Single lattice shell.——FIG. 23,*1*. **C. hexalonche,* Rec., ×300 (48).

Centracontarium POP., 1911 [**C. hexacontarium*]. Two concentric lattice shells.——FIG. 23,*4*. **C. hexacontarium,* Rec., ×150 (48).

Stylacontarium POP., 1911 [**C. bispiculum*]. Three concentric shells; all but one pair of opposite spines restricted to interior.——FIG. 23,*5*. **S. bispiculum,* Rec., ×200 (48).

Subfamily HEXADORADINAE Haeckel, 1882

[as Hexadorida; emend. CAMPBELL, herein]

Spongy spherical or octahedral shell, with or without medullary lattice shells. *Cret.-Rec.*

Hexadoras HKL., 1882 [**H. axophaena* HKL., 1887]. Single medullary lattice shell. *Cret.-Rec.*——FIG. 23,*3*. *H. tyrelli* C.-CL., Cret., Calif., ×150 (35).

Cubaxonium HKL., 1887 [**H. spongiosum*]. Solid spongy shell. *Rec.*

Hexadoridium HKL., 1882 [**H. streptacanthum* HKL., 1887]. Two concentric medullary lattice shells. *Cret.-Rec.*——FIG. 23,*2*. *H. magnificum* C.-CL., Cret., Calif., ×100 (35).

Family ASTROSPHAERIDAE Haeckel, 1882

[as Astrosphaerida; emend. CAMPBELL, herein]
[=Astrosphaeridae MAST, 1910]

Lattice shell single or concentrically multiple, with 8 or more (commonly 20 to 60) radial spines. *Cam.-Rec.*

Subfamily ASTROSPHAERINAE Haeckel, 1882

[as Astrosphaerida *(partim)*; emend. CAMPBELL, herein]
[=Diplosphaerida HKL., 1882; Haliommida HKL., 1887]

Two concentric shells. *Cam.-Rec.*

Astrosphaera HKL., 1887 [**A. hexagonalis;* SD herein]. Two extracapsular shells joined by long radial spines; both shells with by-spines. *Rec.*

A. (Astrosphaera) [=*Astrosphaerella* HKL., 1887 (obj.)]. Main spines unbranched.——FIG. 24,*3b*. **A. (A.) hexagonalis*, Rec., ×150 (42).

A. (Astrosphaeromma) HKL., 1887 [**A. sideraea*; SD herein]. Main spines with 3 rows of lateral branches.——FIG. 24,*3a*. *A. (A.) stellata* HKL., Rec. ×150 (42).

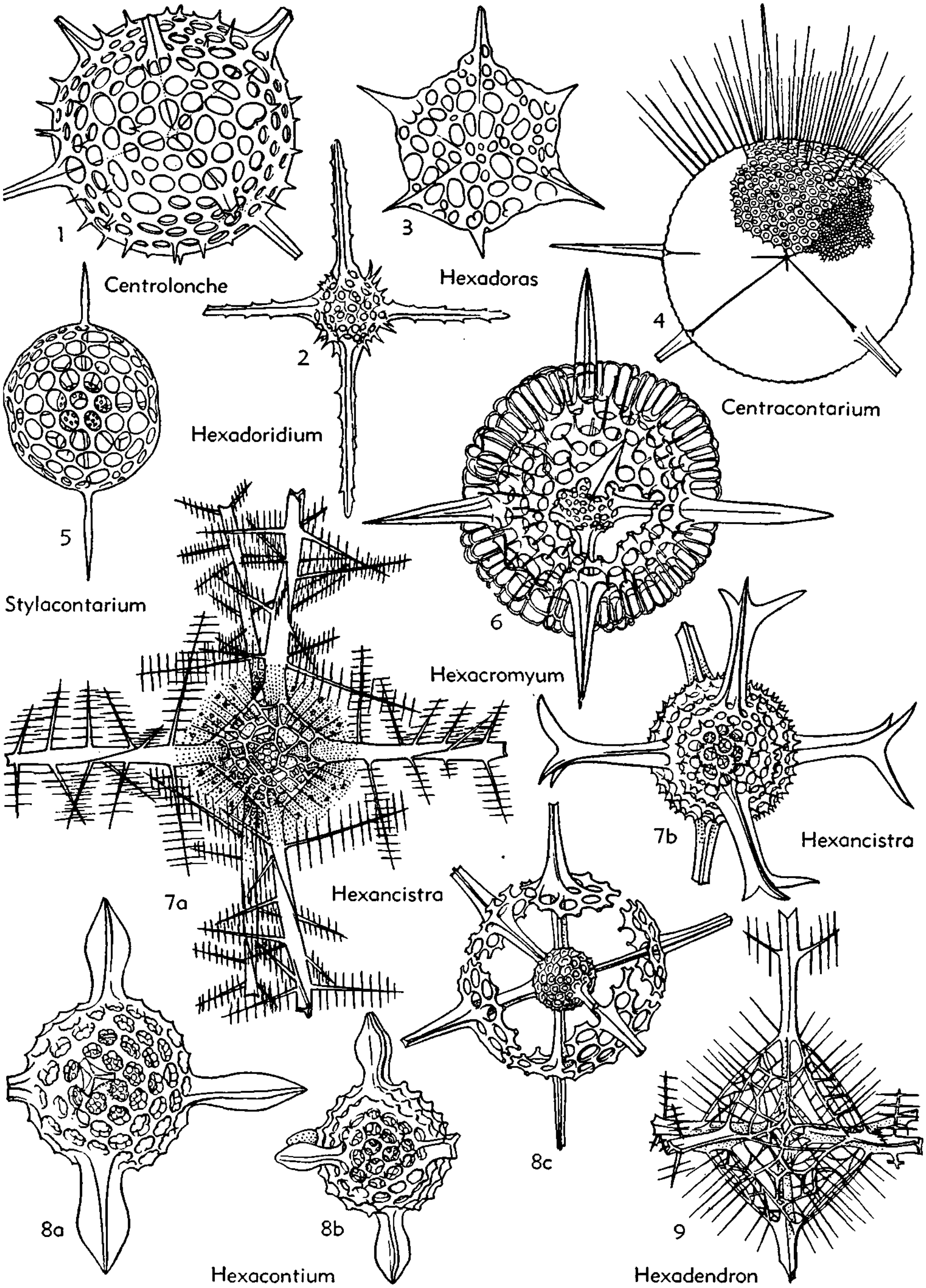


FIG. 23. Cubosphaeridae (p. D60).

Diplosphaera Hkl., 1860 [**D. gracilis* Hkl., 1862]. Resembles *Astrosphaera* but outer shell lacks by-spines. *Rec.*

D. (Diplosphaera) [=*Diplosphaeromma* Hkl., 1887 (obj.)]. Radial spines with 3 rows of lateral branches.

D. (Diplosphaerella) Hkl., 1887 [**D. hexagonalis*]. Radial spines simple.——Fig. 25,*4*. **D. (D.) hexagonalis,* Rec., ×100 (42).

Drymosphaera Hkl., 1882 [**D. hexagonalis* Hkl., 1887]. Like *Astrosphaera* but inner shell lacks by-spines. *Rec.*

D. (Drymosphaera) [=*Drymosphaerella* Hkl., 1887 (obj.)]. Radial by-spines unbranched.——Fig. 24,*4a*. *D. (D.) polygonalis* Hkl., Rec., ×100 (42).

D. (Drymosphaeromma) Hkl., 1887 [**D. dendrophora;* SD herein][=*Drymyoma* Jörg., 1905 (obj.)]. Radial by-spines branched.——Fig. 24,*4b*. **D. (D.) dendrophora,* Rec., ×100 (42).

Elatomma Hkl., 1887 [**E. pinetum;* SD herein]. A cortical and a medullary shell, former covered by branched radial spines. *Rec.*

E. (Elatomma) [=*Elatommella* Hkl., 1887 (obj.)]. Outer shell pores regular, similar.

E. (Elatommura) Hkl., 1887 [**E. juniperinum;* SD herein]. Outer shell pores irregular, dissimilar.——Fig. 24,*2*. **E. (E.) juniperinum,* Rec., ×200 (42).

Haliomma Ehr., 1838 [**H. aequoreum* Ehr., 1844] [=*Sethosphaera* Hkl., 1879 (obj.)]. Like *Elatomma,* but outer shell covered by unbranched radial spines, similar. *Ord.-Rec.*

H. (Haliomma) [=*Haliommura* Hkl., 1887 (obj.)]. Outer shell pores irregular, dissimilar, spines not covering whole surface. *Ord.-Rec.* ——Fig. 24,*1c*. *H. (H.) compactum* Hkl., Rec., ×200 (42).

H. (Haliommantha) Hkl., 1887 [**H. castanea* Hkl., 1862; SD herein]. Outer shell pores regular, similar; surface wholly covered by radial spines. *Rec.*

H. (Haliommetta) Hkl., 1887 [**H. circumtextum;* SD herein]. Outer shell pores regular, similar, spines not wholly covering surface. *Rec.*——Fig. 24,*1b*. **H. (H.) circumtextum* Rec., ×200 (42).

H. (Haliomilla) Hkl., 1887 [**H. capillaceum* Hkl., 1862; SD herein]. Outer shell pores irregular, dissimilar, radial spines covering whole surface. *Rec.*——Fig. 24,*1a*. *H. (H.) rhodococcus* (Hkl.), Rec., ×200 (42).

Heliosoma Hkl., 1882 [**H. radians* Hkl., 1887]. Like *Elatomma* but outer shell covered by unbranched main spines and smaller by-spines. *Cam.-Rec.*

H. (Heliosoma) [=*Heliosomantha* Hkl., 1887 (obj.)]. Outer shell pores regular, similar. *Cam.-Rec.*——Fig. 25,*6a*. **H. (H.) radians,* Rec., ×150 (42).

H. (Heliosomura) Hkl., 1887 [**H. hastatum;* SD herein]. Outer shell pores irregular, dissimilar. *Rec.*——Fig. 25,*6b*. **H. (H.) hastatum,* Rec., ×200 (42).

Heteracantha Mast, 1910 [**H. dentata;* SD herein]. Main spines mostly 3-angled; by-spines branched and unbranched; thick-walled shell with funnel-shaped pores. *Rec.*——Fig. 25,*1*. **H. dentata,* Rec., ×300 (47).

Heterosoma Mast, 1910 [**H. heptacanthum;* SD herein]. Main spines unbranched, by-spines branched. *Rec.*——Fig. 25,*2*. **H. heptacanthum,* Rec., ×300 (47).

Leptosphaera Hkl., 1887 [**L. hexagonalis;* SD herein]. Like *Elatomma* but by-spines lacking. *Rec.*

L. (Leptosphaera) [=*Leptosphaerella* Hkl., 1887 (obj.)]. Radial spines unbranched.——Fig. 25,*3*. **L. (L.) hexagonalis,* Rec., ×100 (42).

L. (Leptosphaeromma) Hkl., 1887 [**Diplosphaera spinosa* Hertwig, 1879; SD herein]. Radial spines with 3 rows of lateral branches.

Subfamily HELIOSPHAERINAE Haeckel, 1882

[as Heliosphaerida; emend. Campbell, herein]
[=Coscinomida Hkl., 1887; Monosphaerinae Mast, 1910]

Single shell present. *Ord.-Rec.*

Heliosphaera Hkl., 1862 [**H. echinoides*]. Radial spines of 2 kinds, large and small. *Ord.-Rec.*

H. (Heliosphaera) [=*Heliosphaerantha* Hkl., 1887 (obj.)]. Pores regular, similar. *Rec.*——Fig. 25,*9*. *H. (H.) hexagonaria* Hkl., Rec., ×150 (42).

H. (Heliosphaeromma) Hkl., 1887 [**H. polygonaria;* SD herein]. Pores irregular, dissimilar. *Rec.*

Acanthosphaera Ehr., 1858 [**A. haliphormis* Ehr., 1861]. Pores not tubulate, radial spines unbranched, similar. *Ord.-Rec.*

A. (Acanthosphaera) [=*Rhaphidosphaera* Hkl., 1882 (obj.)]. Pores irregular, dissimilar, spines not at all nodal points. *Ord.-Rec.*——Fig. 25,*7c*. *A. (A.) angulata* Hkl., Rec., ×150 (42).

A. (Rhaphidocapsa) Hkl., 1887 [**A. mucronata;* SD herein]. Pores regular, similar, spines not at all nodal points. *Rec.*——Fig. 25,*7a*. *A. (R.) clavata* Hkl., Rec., ×150 (42).

A. (Rhaphidococcus) Hkl., 1862 [**Heliosphaera tenuissima* Hkl., 1862; SD herein]. Pores regular, similar, radial spines at all nodal points. *Rec.*——Fig. 25,*7b*. *A. (R.) castanea* Hkl., Rec., ×150 (42).

A. (Rhapidodrymus) Hkl., 1887 [**A. capillaris;* SD herein]. Pores irregular, dissimilar, radial spines at all nodal points. *Rec.*

Cladococcus Müller, 1856 [**C. arborescens* Müller, 1858]. Radial spines branched but stem not forked. *Rec.*

C. (Cladococcus) [=*Cladococcalis* Hkl., 1887 (obj.)]. Branches not ramified, pores regular, similar.

C. (Cladococcinus) Hkl., 1887 [**C. quadricupis;* SD herein]. Branches not ramified, pores irregular, dissimilar.

C. (Cladococcodes) Hkl., 1887 [**C. scoparius;* SD herein]. Branches ramified, pores regular, similar.——Fig. 25,*10a*. **C. (C.) scoparius*, Rec., ×150 (42).

C. (Cladococcurus) Hkl., 1887 [**C. abietinus;* SD herein]. Branches ramified, pores irregular, dissimilar.——Fig. 25,*10b*. *C. (C.) dendrites* Hkl., Rec., ×100 (42).

Conosphaera Hkl., 1882 [**C. platyconus* Hkl., 1887]. Radial spines comprise fenestrate-walled hollow cones. *Jur.-Rec.*——Fig. 25,*5*. *C. orthoconus* Hkl., Rec., ×100 (42).

Coscinomma Hkl., 1887 [**C. amphisiphon;* SD herein]. Single shell with hollow conical tubular spines, as well as solid radial spines. *Rec.*

C. (Coscinomma) [=*Coscinommarium* Hkl., 1887 (obj.)]. Pores prolonged both inside and outside surface.——Fig. 25,*8*. **C. amphisiphon*, Rec., ×150 (42).

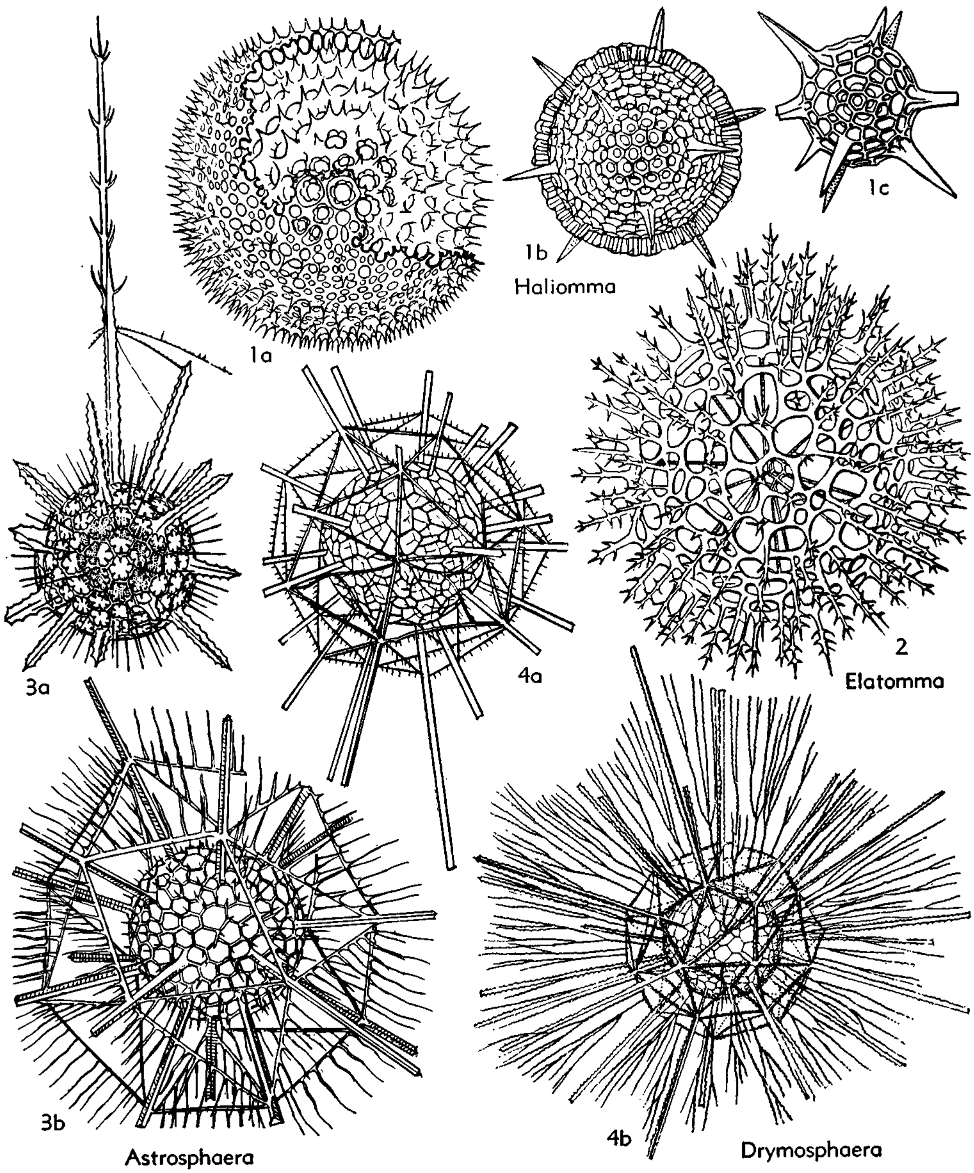


Fig. 24. Astrosphaeridae (p. D61, D62).

C. (Coscinommonium) HKL., 1887 [*C. endosiphon*]. Pores prolonged internally; not external.

Elaphococcus HKL., 1882 [**C. furcatus* HKL., 1887]. Radial spines with forked stems. *Rec.*

E. (Elaphococcus) [=*Elaphococcinus* HKL., 1887 (obj.)]. Pores regular, similar.

E. (Elaphococculus) HKL., 1887 [**E. dichotomus;* SD herein]. Pores irregular, dissimilar.

Subfamily ACTINOMMATINAE Haeckel, 1862

[as Actinommida; emend. CAMPBELL, herein]
[=Heterosphaerinae MAST, 1910]

Three concentric lattice shells. *Dev.-Rec.*

Actinomma HKL., 1862 [**Haliomma trinacrium* HKL., 1860]. Radial spines unbranched, all similar. *Dev.-Rec.*

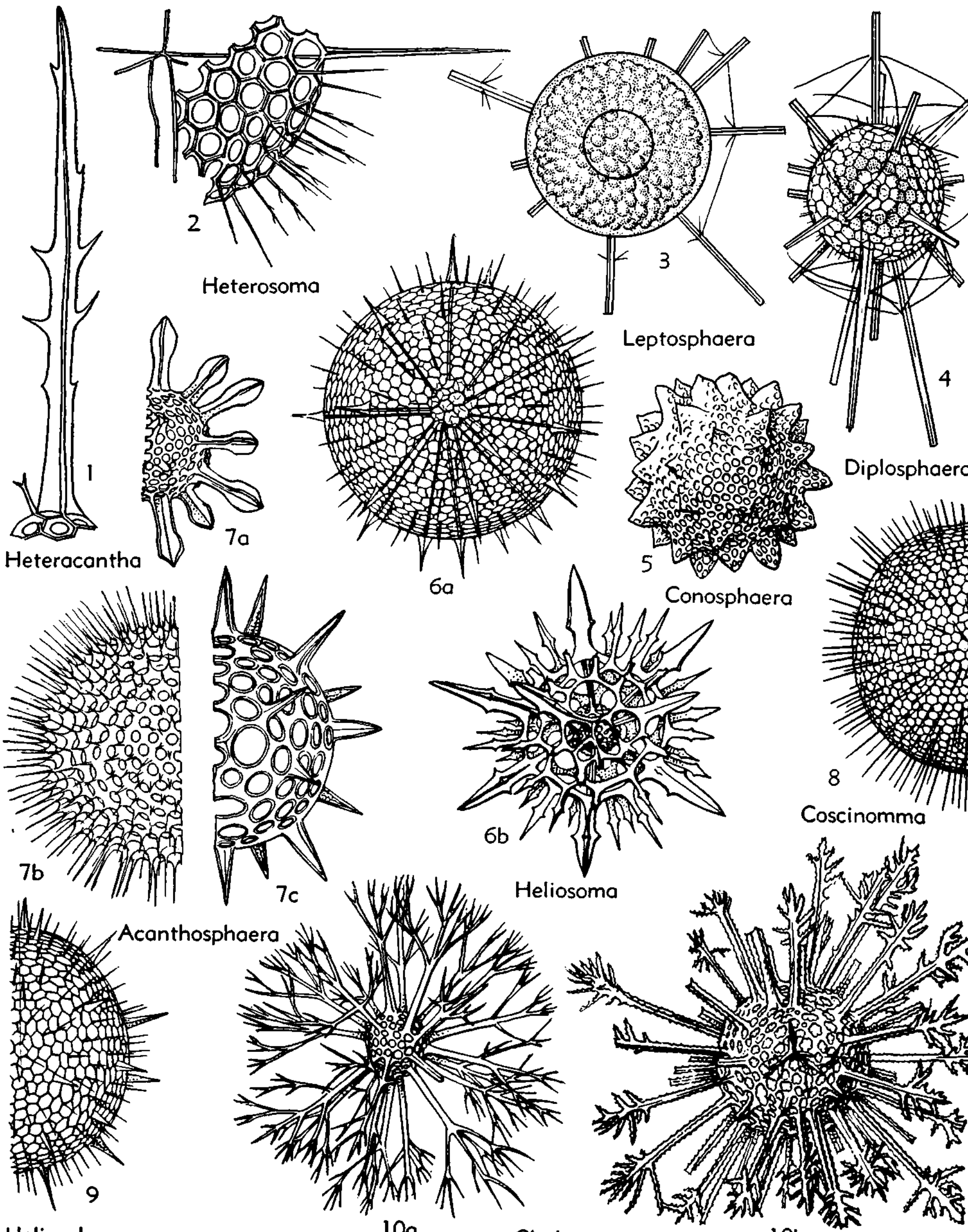


FIG. 25. Astrosphaeridae (p. D62, D63).

A. (Actinomma) [=*Actinometta* Hkl., 1887 (obj.)]. Outer shell pores regular, similar; spines not covering entire surface. *Dev.-Rec.*——Fig. 26,*3a*. *A. (A.) denticulatum* Hkl., Rec., ×200 (42).

A. (Actinommantha) Hkl., 1887 [**A. hexagonium;* SD herein]. Outer shell pores regular, similar; spines covering entire surface. *Rec.*

A. (Actinommilla) Hkl., 1887 [**A. spinigerum* Stöhr, 1880; SD herein]. Outer shell pores

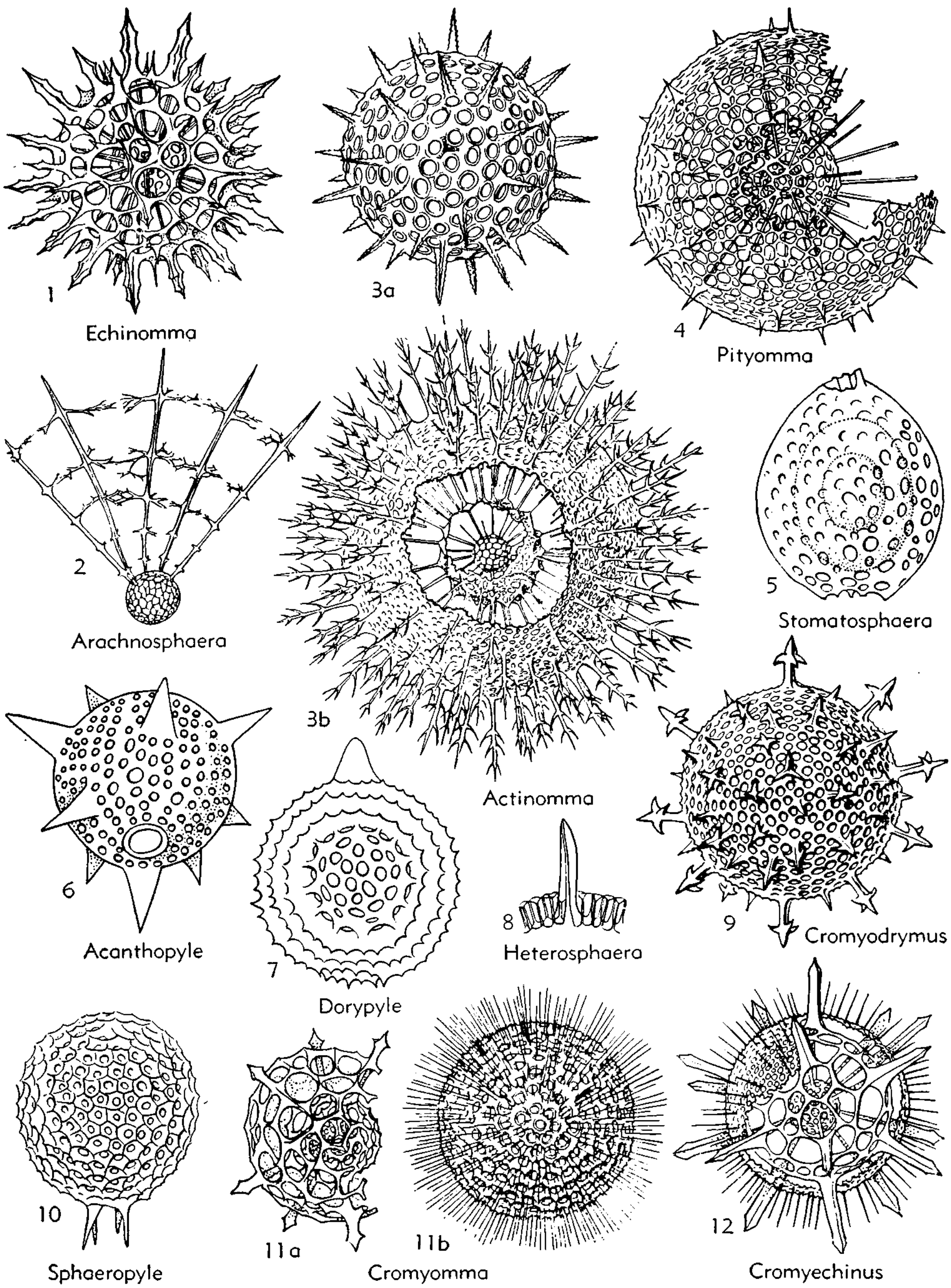


Fig. 26. Astrosphaeridae (p. D65, D66).

irregular, dissimilar; spines covering entire surface. *Eoc.-Rec.*

A. (Actinommura) HKL., 1887 [**A. capillaceum;* SD herein]. Outer shell pores irregular, dissimilar; spines not covering entire surface. *Rec.* ——FIG. 26,*3b.* **A. (A.) capillaceum,* Rec., ×150 (42).

Echinomma HKL., 1882 [**E. echinidium* HKL., 1887]. Radial spines unbranched, dissimilar in size. *Carb.-Rec.*

E. (Echinomma) [=*Echinommetta* HKL., 1887 (obj.)]. Outer shell pores regular, similar. *Rec.*

E. (Echinommura) HKL., 1887 [**E. toxopneustes* HKL., 1887; SD herein]. *Carb.-Rec.*——FIG. 26,*1.* **E. (E.) toxopneustes,* Rec., ×200 (42).

Heterosphaera MAST, 1910 [**H. tenuis;* SD herein]. Outer shell with many by-spines. *Rec.*——FIG. 26,*8.* **H. tenuis,* Rec., ×300 (47).

Pityomma HKL., 1882 [**P. scoparium* HKL., 1887]. Radial spines branched. *Carb.-Rec.*——FIG. 26, *4. P. drymodes* HKL., Rec., ×150 (42).

Subfamily CROMYOMMATINAE Haeckel, 1882
[as Cromyommida; emend. CAMPBELL, herein]

Four concentric lattice shells. *Cam.-Rec.*

Cromyomma HKL., 1882 [**C. villosum* HKL., 1887][=*Chromyomma* JÖRG., 1891 (obj.)]. Radial spines unbranched, all similar. *Cam.-Rec.*

C. (Cromyomma) [=*Cromyommetta* HKL., 1887 (obj.)]. Outer shell pores regular, similar. *Rec.* ——FIG. 26,*11b.* **C. villosum,* Rec., ×150 (42).

C. (Cromyommura) HKL., 1887 [**C. perspicuum;* SD herein]. Outer shell pores irregular, dissimilar. *Cam.-Rec.*——FIG. 26,*11a. C. (C.) mucronatum* HKL., Rec., ×100 (42).

Cromyechinus HKL., 1882 [**C. icosacanthus* HKL., 1887][=*Chromyechinus* JÖRG., 1905 (obj.)]. Radial spines unbranched, dissimilar in size. *Rec.* ——FIG. 26,*12.* **C. (C.) icosacanthus,* Rec., ×150 (42).——FIG. 40,*5. C.* sp., Rec., ×150 (42).

Cromyodrymus HKL., 1882 [**C. quadricuspis* HKL., 1887]. Radial spines branched. *Cret.-Rec.*—— FIG. 26,*9.* **C. quadricuspis,* Rec., ×200 (42).

Subfamily ARACHNOSPHAERINAE Haeckel, 1862
[as Arachnosphaerida; emend. CAMPBELL, herein]
[=Caryommida HKL., 1887]

Five or more concentric lattice shells. *Rec.*

Arachnosphaera HKL., 1862 [**A. oligacantha;* SD herein]. Polygonal meshes.

A. (Arachnosphaera) [=*Arachnosphaerella* HKL., 1887 (obj.)]. Innermost shell pores hexagonal. ——FIG. 26,*2. A. (A.) hexasphaera* POP., Rec., ×150 (48).

A. (Arachnosphaeromma) HKL., 1887 [**A. tenuissima;* SD herein]. Innermost shells pores irregularly polygonal.

Arachnopila HKL., 1887 [**A. hexagonella;* SD herein]. Triangular meshes without diagonal bars between.

Caryomma HKL., 1887 [**C. regulare;* SD herein]. Like *Cromyomma* but has one more shell.

Subfamily SPHAEROPYLINAE Dreyer, 1889
[as Sphaeropylida; emend. CAMPBELL, herein]

Lattice shell single or concentrically multiple, with a pylome at one pole of outermost shell. *Dev.-Rec.*

Sphaeropyle DREYER, 1889 [**S. langi;* SD herein]. Four or more similar radial spines in 3 mutually perpendicular planes. *Dev.-Rec.*——FIG. 26,*10. A. mespilus* DREYER, Rec., ×250 (40).

Acanthopyle VINASSA, 1898 [**A. dreyeri*]. Single shell with large circular pylome and many similar spines. *Jur.*——FIG. 26,*6.* **A. dreyeri,* U.Jur., Italy, ×200 (55).

Dorypyle SQUIN., 1904 [**D. cretacea*]. Single shell with large pylome and one spine at pole opposite pylome. *Cret.*——FIG. 26,*7.* **D. cretacea,* Cret., Italy, ×133 (52).

Subfamily STOMATOSPHAERINAE Campbell, nov.
[=Amphistomida DREYER, 1889]

Lattice shell with 2 pylomes oppositely placed. *Rec.*

Stomatosphaera DREYER, 1889 [**S. dinoceras;* SD herein]. Single spherical shell.——FIG. 26,*5. S. amphistoma* DREYER, Rec., ×100 (40).

Subfamily SPONGIOMMATINAE Haeckel, 1887
[as Spongiommida; emend. CAMPBELL, herein]
[=Rhizosphaerida HKL., 1882 (*partim*); Spongosphaerinae MAST, 1910]

Spherical or polyhedral spongy shell, with or without medullary shells. *Cam.-Rec.*

Spongiomma HKL., 1887 [**Spongechinus multiaculeatus* DUNIKOWSKI, 1882; SD herein]. Solid spongy sphere with many unbranched radial spines. *Jur.-Rec.*

S. (Spongiomma) [=*Spongiommura* HKL., 1887 (obj.)]. Large and small spines. *Jur.-Rec.*

S. (Spongiommella) HKL., 1887 [**S. radiatum;* SD herein]. Spines all similar. *Rec.*

Acanthospongus MAST, 1910 [**A. minutus*]. Solid spongy sphere with branched anastomosing spines. *Rec.*

Arachnospongus MAST, 1910 [**A. varians*]. Two or more medullary shells with spongy network between outermost and next shell. *Rec.*——FIG. 27,*5.* **A. varians,* Rec., ×300 (47).

Astrospongus MAST, 1910 [**A. ramosus;* SD herein]. Like *Arachnospongus* but with spongy network outside cortical shell, and with large and small spines only on outer shell. *Rec.*——FIG. 27,*7.* **A. ramosus,* Rec., ×300 (47).

Centrocubus HKL., 1887 [**C. cladostylus;* SD herein]. Cube-shaped medullary shell with 8 main radial spines produced from corners and with or without other spines. *Rec.*——FIG. 28,*3.* **C. cladostylus,* Rec., ×50 (42).

Diplospongus Mast, 1810 [**D. dendrophorus*]. Small medullary shell and spongy network between 2 cortical shells. *Rec.*——Fig. 27,*1*. **D. dendrophorus,* Rec., ×250 (47).

Dispongia Pop., 1911 [**D. velata*]. Solid spongy sphere with outer veil formed by short spines. *Rec.*——Fig. 27,*8*. **D. velata,* Rec., ×125 (48).

Exocentroconcha Mast, 1910 [**E. minor;* SD here-

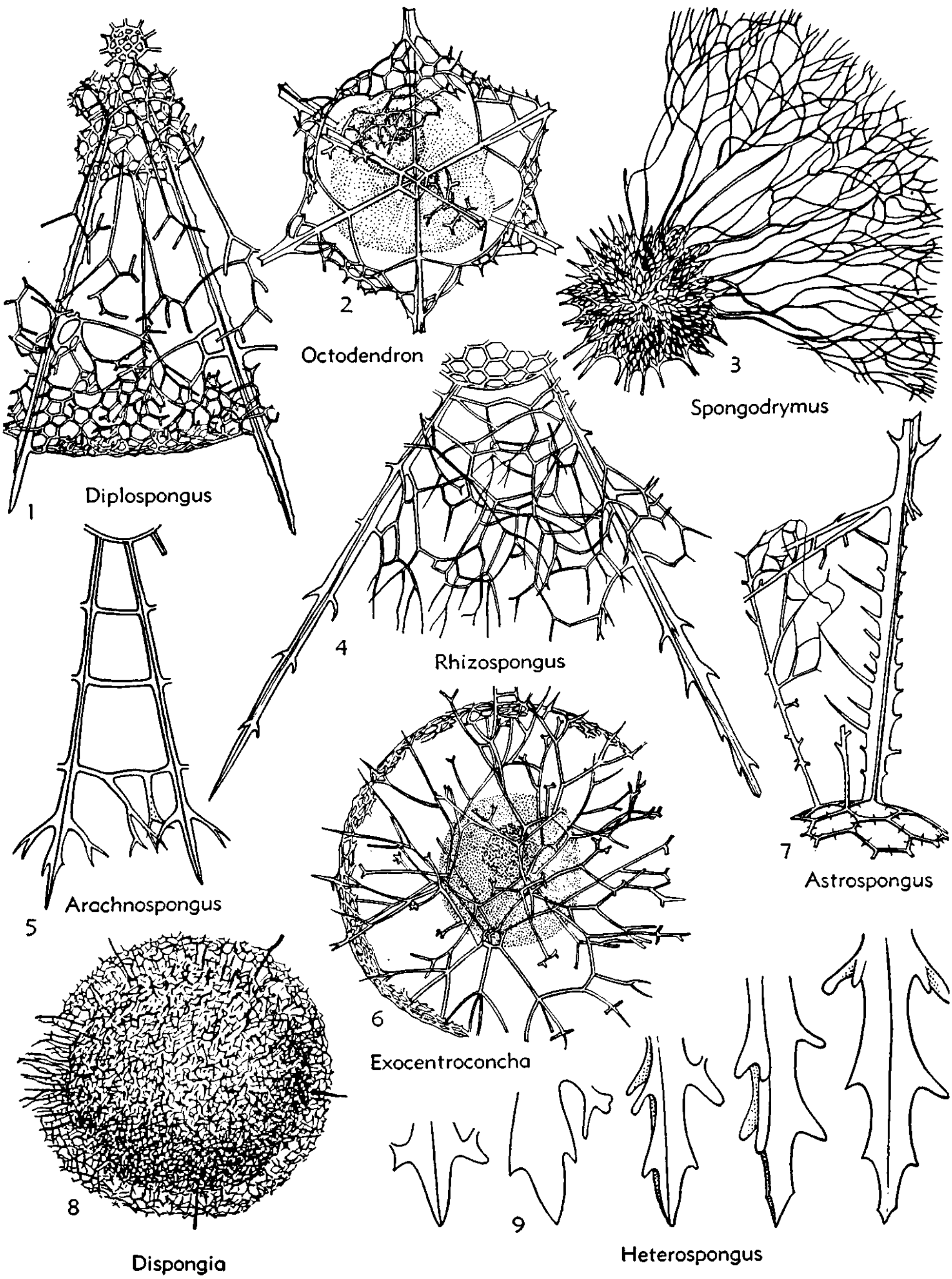


Fig. 27. Astrosphaeridae (p. D66-D68).

in]. Medullary shell strongly excentric. *Rec.*——FIG. 27,6. **E. minor*, Rec., ×250 (47).

Heterospongus MAST, 1910 [**H. varians*]. Like *Centrocubus* but 8 main spines branched. *Rec.*——FIG. 27,9. **H. varians*, Rec., ×300 (47).

Lychnosphaera HKL., 1882 [**L. regina* HKL., 1887]. Medullary shell with free by-spines and joined to spongy cortical by main radial spines. *Rec.*——FIG. 28,4. **L. regina*, Rec., ×75 (42).

Octodendron HKL., 1887 [**O. cubocentron;* SD herein]. Like *Cubocentron* but latticed cortical shell surrounded by spongy network which may bear small radial spines. *Rec.*

O. (Octodendron) [=*Octodendridium* HKL., 1887 (obj.)]. Without secondary radial spines.——FIG. 27,2. **O. (O.) cubocentron*, Rec., ×200 (42).

O. (Octodendronium) HKL., 1887 [**O. verticellatum;* SD herein]. Secondary radial spines 24 or more. *Rec.*

Rhizoplegma HKL., 1882 [**R. polyacanthum* HKL., 1887] [=*Lonchosphaera* POP., 1909]. Like *Lychnosphaera* but medullary shell lacks by-spines. *Jur.-Rec.*

R. (Rhizoplegma) [=*Rhizoplegmarium* HKL., 1887 (obj.)]. Radial spines without branches. *Jur.-Rec.*

R. (Rhizoplegmidium) HKL., 1887 [**R. radicatum;* SD herein]. Lateral branches on 3 edges of radial spines between shells. *Rec.*——FIG. 28,2. **R. (R.) radicatum*, Rec., ×100 (42).

Rhizosphaera HKL., 1860 [**R. leptomitra;* SD herein]. Like *Rhizoplegma (Rhizoplegma)* but has 2 medullary shells and latticed cortical shell surrounded by spongy network. *Rec.*——FIG. 28,1. *R. serrata* HKL., Rec., ×150 (42).

Rhizospongus MAST, 1910 [**R. arachnoideus;* SD herein]. Single lattice shell with spongy network between radial spines; no by-spines. *Rec.*——FIG. 27,4. **R. arachnoideus*, Rec., ×250 (47).

Spongechinus HKL., 1882 [**S. setosus* HKL., 1887]. Hollow spongy sphere with many simple, similar spines. *Rec.*

Spongioconcha MAST, 1910 [**S. inversa*]. Spongy network between medullary and cortical lattice shells; long radial spines on latter. *Rec.*

Spongodrymus HKL., 1882 [**S. elaphococcus* HKL., 1887]. Solid spongy sphere with many branched radial spines. *Rec.*——FIG. 27,3. **S. elaphococcus*, Rec., ×100 (42).

Spongopila HKL., 1882 [**S. dichotoma* HKL., 1887]. Like *Rhizospongus* but radial spines developed from surface of spongy network. *Carb.-Rec.*

Spongosphaeromma HKL., 1887 [**Spongosphaera heliodes* HKL., 1862; SD herein] [=*Spongosphaera* HKL., 1887 (obj.) (*non* EHR., 1847)]. Two medullary lattice shells surrounded by spongy cortical shell bearing many radial spines. *Cam.-Rec.*——FIG. 28,5. *S. streptacantha* (HKL.), Rec., ×200 (42).

Spongothamnus HKL., 1887 [**S. furcatus;* SD herein]. Like *Spongechinus* but spines branched. *Rec.*

Tetrasphaera POP., 1911 [**T. spongiosa*]. Three concentric lattice shells joined by radial beams which by anastomosis form loose spongy network between outer shells; many short irregular spines on surface. *Rec.*——FIG. 28,6. **T. spongiosa*, Rec., ×275 (48).

Family DACTYLIOSPHAERIDAE Squinabol, 1904

Single spherical lattice shell surrounded by an elliptical latticed ring. *Cret.*

Dactyliosphaera SQUIN., 1904 [**D. silviae*]. Ring bears 2 opposite radial spines and numerous shorter by-spines.——FIG. 28,7. **D. silviae*, Cret., Italy, ×133 (52).

Superfamily ELLIPSIDIICAE Haeckel, 1887

[*ex* Ellipsida; emend. CAMPBELL, herein]
[=Prunoidea HKL., 1887]

Elliptical or cylindrical, fenestrated or spongy shell; commonly articulated by annular transverse strictures. *Cam.-Rec.*

Family ELLIPSIDIIDAE Haeckel, 1887

[as Ellipsida; emend. CAMPBELL, herein]

Single elliptical lattice shell. *Cam.-Rec.*

Ellipsidium HKL., 1887 [**E. datura;* SD herein]. Numerous radial spines; without polar tubules. *Dev.-Rec.*——FIG. 29,1. *E. aculeatum* RÜST, L.Carb., Harz Mts., Ger., ×100 (51).

Axellipsis HKL., 1887 [**A. perforata;* SD herein]. Shell cavity with transverse axial rods; surface spiny. *Jur.-Rec.*——FIG. 29,2. *A. longitudinalis* RÜST, Jur., Sicily, ×150 (51).

Axoprunum HKL., 1887 [**A. stauraxonium*]. Like *Ellipsoxiphus* but has 4 internal rods in main axis and 2 in transverse axis. *Rec.*——FIG. 29,11. **A. stauraxonium*, Rec., ×200 (42).

Cenellipsis RÜST, 1885 [**C. jaspidea;* SD herein] [=*Ellipsis* HKL., 1887 (obj.); *Haeckeletta* CHABAKOV, 1937]. Without polar tubules, spines, or internal rods. *Cam.-Rec.*

C. (Cenellipsis) [=*Cenellipsium* HKL., 1887 (obj.)]. Network regular. *Cam.-Rec.*——FIG. 29,6b. *C. (C.) faceta* HKL., Rec., ×200 (42).

C. (Cenellipsula) HKL., 1887 [**C. infundibulum;* SD Frizzell 1951]. Network irregular. *Cam.-Rec.*——FIG. 29,6a. **C. (C.) infundibulum*, Rec., ×200 (42).

Ellipsostigma HINDE, 1899 [**E. australe*]. Four radial main spines; by-spines arise from shell center. *Dev.*——FIG. 29,4. **E. australe*, Dev., Austral., ×200 (44).

Ellipsostylus HKL., 1887 [**E. psittacus;* SD herein]

[=*Ellipostylus* VINASSA (obj.)]. Two opposite dissimilar polar spines. *Jur.-Rec.*

E. (Ellipsostylus) [=*Ellipsostyletta* HKL., 1887 (obj.)]. Network regular. *Jur.-Rec.*——FIG. 29, *10*. **E. (E.) psittacus,* Rec., ×268 (42).

E. (Ellipsostylissa) HKL., 1887 [**E. hirundo;* SD herein]. Network irregular. *Rec.*

Ellipsoxiphus DUNIKOWSKI, 1882 [**E. parvoforaminus;* SD herein][=*Ellipsoxiphium* HKL., 1887 (obj.)]. Two similar opposite polar spines. *Jur.-Rec.*

E. (Ellipsoxiphus) [=*Ellipsoxiphilla* HKL., 1887 (obj.)]. Network irregular. *Jur.-Rec.*——FIG. 29,*7a*. *E. (E.) bipolaris* HKL., Rec., ×300 (42).

E. (Ellipsoxiphetta) HKL., 1887 [**E. flosculus;* SD herein]. Network regular. *Eoc.-Rec.*——FIG. 29,*7b*. *E. (E.) elegans* HKL., Rec., ×200 (42).

Lithapium HKL., 1887 [**L. pyriforme;* SD herein]. Elliptical or pear-shaped; single spine on one pole. *Cam.-Rec.*,——FIG. 29,*8*. **L. pyriforme,* Rec., ×200 (42).

Lithomespilus HKL., 1882 [**L. phloginus* HKL., 1887]. On one pole a cluster of spines. *Cam.-Rec.*——FIG. 29,*5*. **L. phloginus,* Rec., ×300 (42).

Pipettella HKL., 1887 [**E. prismatica;* SD herein]. Two similar opposite polar, fenestrated tubules. *Jur.-Rec.*——FIG. 29,*3*. **P. prismatica,* Rec., ×200 (42).

Tetracanthellipsis SQUIN., 1903 [**T. euganeus*]. Two opposite polar spines on main axis, one bifurcate. *Cret.*——FIG. 29,*9*. **T. euganeus,* Cret., Italy, ×80 (52).

Family DRUPPULIDAE Haeckel, 1887

[as Druppulida; emend. CAMPBELL, herein]
[Stylosphaeridae HAECKER, 1908 *(partim)*]

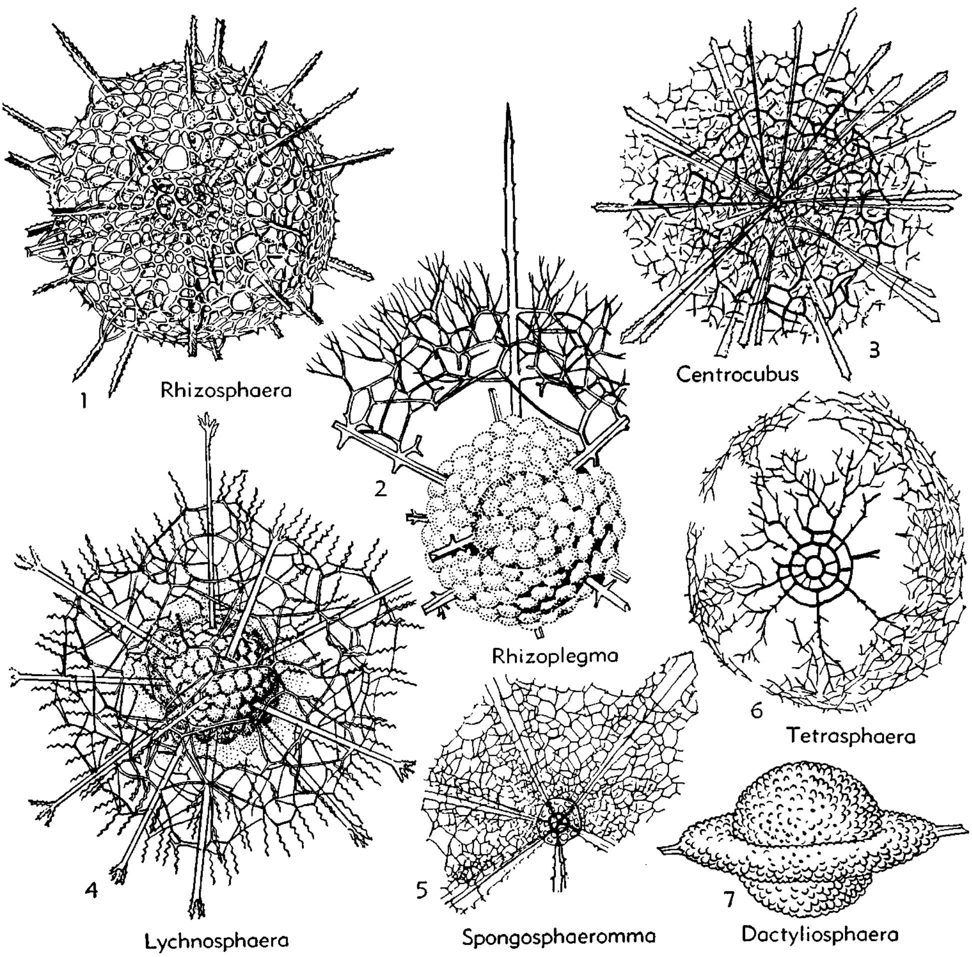


FIG. 28. Astrosphaeridae, Dactyliosphaeridae (p. D66-D68).

Two or more elliptical lattice shells. *Ord.-Rec.*

Druppula HKL., 1887 [**D. pandanus;* SD FRIZZELL, 1951][=*Coccymilium* HKL., 1887 (obj.)]. Simple double shell without polar tubules or spines. *Paleoc.-Rec.*

D. (Druppula) [=*Druppuletta* HKL., 1887 (obj.)]. Network regular. *Paleoc.-Rec.*——FIG. 30,*1*. **D. pandanus,* Rec., ×200 (42).

D. (Druppulissa) HKL., 1887 [**Haliomma ellipticum* STÖHR, 1880; SD herein]. Network irregular. *Eoc.-Rec.*

Caryodoras HKL., 1882 [**Cromyatractus tetraphractus* HKL., 1887 (=*Stylocromium tetraphractum* HKL., 1887)][=*Cromyatractus* (obj.), *Stylocromium* (obj.) HKL., 1887]. Two medullary and 2 or more cortical shells; 2 opposite similar polar spines. *Rec.*

C. (Caryodoras) [=*Cromyatractium* HKL., 1887 (obj.)].Two cortical and medullary shells.——FIG. 30,*5*. **C. (C.) tetraphractus* (HKL.), Rec., ×150 (42).

C. (Caryatractus) HKL., 1887 [**Cromyatractus cepicius;* SD herein]. Three or more cortical shells.

Cromyocarpus HKL., 1887 [**C. quadrifarius*]. Four or more concentric shells; numerous radial spines. *Rec.*

Cromyodruppa HKL., 1887 [**C. cepa;* SD herein]. Like *Cromyocarpus* but without spines. *Jur.-Rec.*

C. (Cromyodruppa) [=*Cromyodruppium* HKL., 1887 (obj.)]. Two cortical and medullary shells. *Jur.-Rec.*——FIG. 30,*3*. *C. (C.) prunulina* RÜST, Jur., Sicily, ×140 (51).

C. (Carpodruppula) HKL., 1887 [**C. mango;* SD herein]. Two medullary and 3 or more cortical shells. *Rec.*

Cromyodruppocarpus C.-CL., 1944 [**C. esterae*]. Several (2 or more) opposite polar spines at each main pole. *Mio.*——FIG. 30,*6*. **C. esterae,* Mio., Calif., ×150 (35).

Dorydruppa VINASSA, 1900 [**D. simonellii*]. One single polar spine; single medullary shell. *Mio.*——FIG. 30,*4*. **D. simonellii,* Mio., Italy, ×200 (55).

Druppocarpus HKL., 1887 [**D. ananassa;* SD

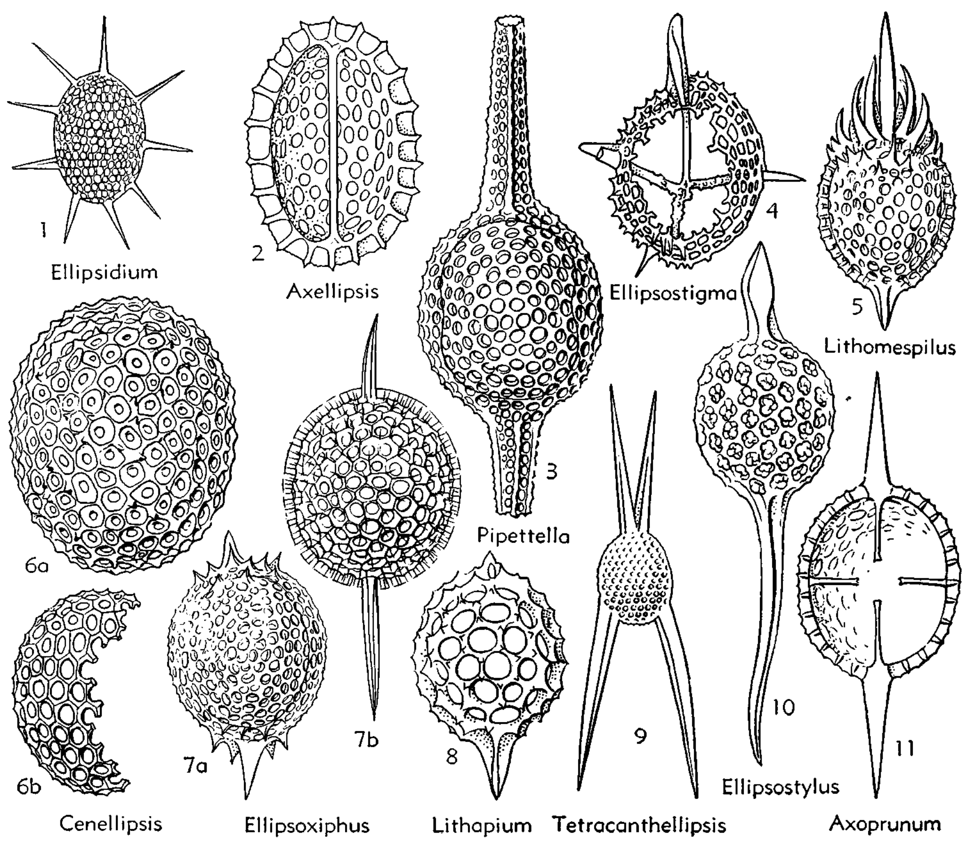


FIG. 29. Ellipsidiidae (p. D68, D69).

herein]. Double shell with numerous radial spines. *Eoc.-Rec.*

D. (Druppocarpus) [=*Druppocarpetta* HKL., 1887 (obj.)]. Network regular. *Rec.*

D. (Druppocarpissa) HKL., 1887 [**D. chamaerops;* SD herein]. Network irregular. *Eoc.-Rec.*

Druppalonche HINDE 1899 [**D. clavigera;* SD herein]. Three radial spines. *Ord.*——FIG. 30,9. **D. clavigera,* Ord., Eng., ×150 (44).

Druppatractus HKL., 1887 [**D. hippocampus;* SD FRIZZELL 1951][=*Drappatractus* CARNEVALE, 1908 (obj.); *Druppotractus* POP., 1911 (obj.)]. Simple medullary shell; 2 dissimilar polar spines. *Jur.-Rec.*

D. (Druppatractus) [=*Druppatractara* HKL., 1887 (obj.); *Druppatractaria* CL.-C., 1942 (obj.)]. Network regular; surface smooth. *Jur.-Rec.*——FIG. 30,*10a*. **D. (D.) hippocampus,* Rec., ×300 (42).

D. (Druppatractarium) HKL., 1887 [**D. diodon;* SD herein]. Network irregular; surface thorny or papillate. *Rec.*

D. (Druppatractoma) HKL., 1887 [**Stylosphaera laevis* EHR., 1875; SD herein]. Network irregular; surface smooth. *Rec.*

D. (Druppatractylis) HKL., 1887 [**D. ostracion;* SD herein]. Network regular; surface thorny or papillate. *Eoc.-Rec.*——FIG. 30,*10b*, **D. (D.) ostracion,* Rec., ×200 (42).

Druppastylus CAYEUX, 1897 [**D. hirsutus*][=*Doryprunum* VINASSA, 1900]. One single polar spine; double medullary shell. *Cret.-Mio.,* Belg.——FIG., 30,*2*. *D. apenninicus* (VINASSA), Mio., Italy, ×200 (55).

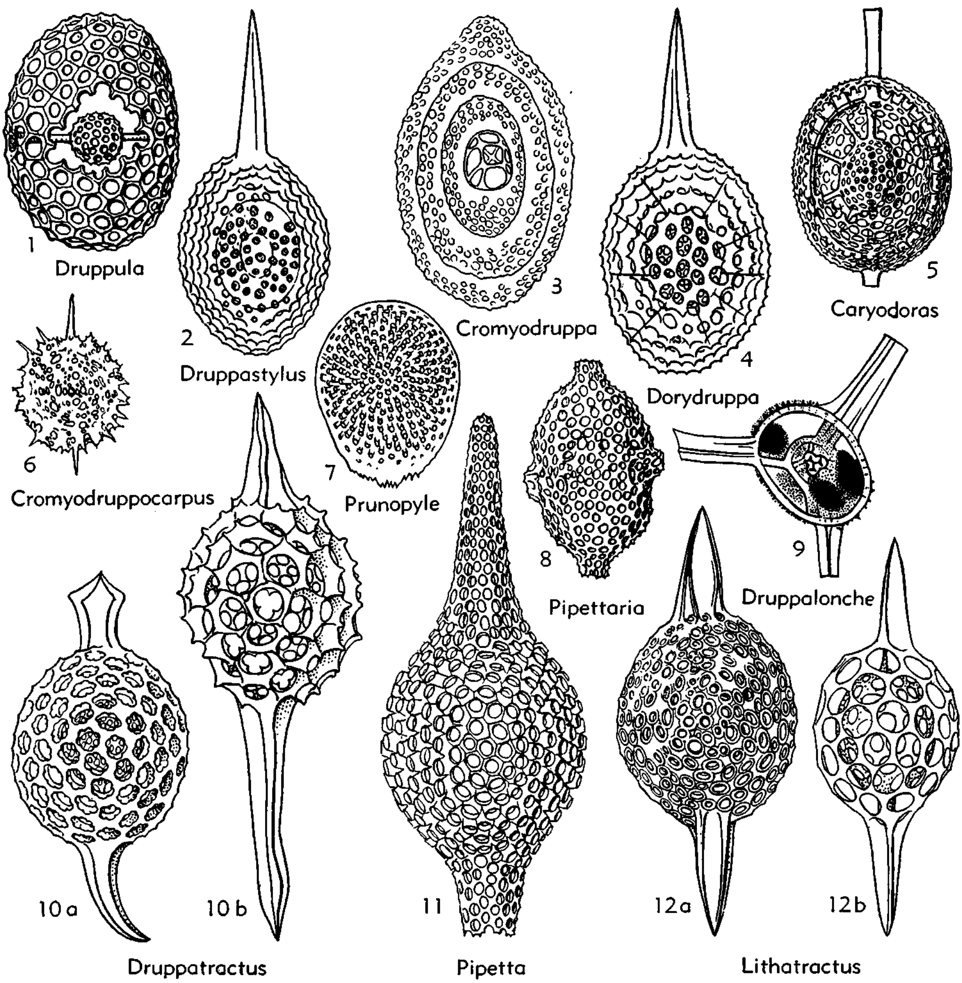


FIG. 30. Druppulidae (p. D70-D72).

Lithatractus Hkl., 1887 [**L. fragilis* (=*Stylosphaera fragilis* Hkl., 1887); SD herein]. Two similar polar spines; double medullary shell. *Jur.-Rec.*

L. (Lithatractus) [=*Lithatractara* Hkl., 1887 (obj.)]. Network regular; surface smooth. *Jur.-Rec.*——Fig. 30,*12b*. **L. (L.) fragilis*, Rec., ×200 (42).

L. (Lithatractium) Hkl., 1887 [**L. conostylus;* SD herein]. Network irregular, surface thorny or papillate. *Rec.*

L. (Lithatractona) Hkl., 1887 [**L. jugatus;* SD herein]. Network irregular; surface thorny or spiny. *Rec.* ——Fig. 30,*12a*. **L. (L.) jugatus*, Rec., ×200 (42).

L. (Lithatractylis) Hkl., 1887 [**L. echiniscus;* SD herein]. Network regular; surface thorny or papillate. *Eoc.-Rec.*

Pipetta Hkl., 1887 [**P. fusus;* SD herein]. Single medullary shell, otherwise as *Pipettaria. Mio.-Rec.,* Italy.——Fig. 30,*11*. **P. fusus*, Rec., ×200 (42).

Pipettaria Hkl., 1887 [**P. tubaria* (=*Cannartidium tubarium* Hkl., 1887); SD herein]. Double medullary shell; hollow fenestrated tubule on each pole of main axis. *Cret.-Rec.*——Fig. 30,*8*. **P. tubaria*, Rec., ×200 (42).

Prunocarpus Hkl., 1887 [**P. datura;* SD herein] [=*Artocarpium* Hkl., 1887 (obj.)]. Double medullary shell; numerous radial spines and no polar tubules. *Eoc.-Rec.*

P. (Prunocarpus) [=*Prunocarpetta* Hkl., 1887 (obj.)]. Network regular. *Eoc.-Rec.*

P. (Prunocarpilla) Hkl., 1887 [**P. artocarpium;* SD herein]. Network irregular. *Rec.*——Fig. 31,*1*. **P. (P.) artocarpium*, Rec., ×200 (42).

Prunulum Hkl., 1887 [**P. coccymelium;* SD herein] [=*Caryolithis* Ehr., 1847 *(nomen vanum); Coccymelium* Hkl., 1887 (obj.)]. Double medullary shell; without radial spines or tubules. *Dev.-Rec.*

P. (Prunulum) [=*Prunuletta* Hkl., 1887 (obj.)]. Network regular. *Dev.-Rec.*——Fig. 31,*5*. **P. (P.) coccymelium*, Rec., ×200 (42).

P. (Prunulissa) Hkl., 1887 [**Actinomma fenestratum* Stöhr, 1880; SD herein]. Network irregular; pores lobate or compound in some. *Eoc.-Rec.*

Prunopyle Dreyer, 1889 [**P. pyriformis;* SD herein]. Outermost shell at least has a large pylome. *Eoc.-Rec.*——Fig. 30,*7*. *P. occidentalis* Cl.-C., U.Eoc., Calif., ×100 (39).

Staurodruppa Hinde, 1899 [**S. praelonga;* SD herein]. Four similar radial spines crosswise in 2 axes; pores regular. *Dev.*——Fig. 31,*3*. **S. praelonga*, Dev., Austral., ×150 (44).

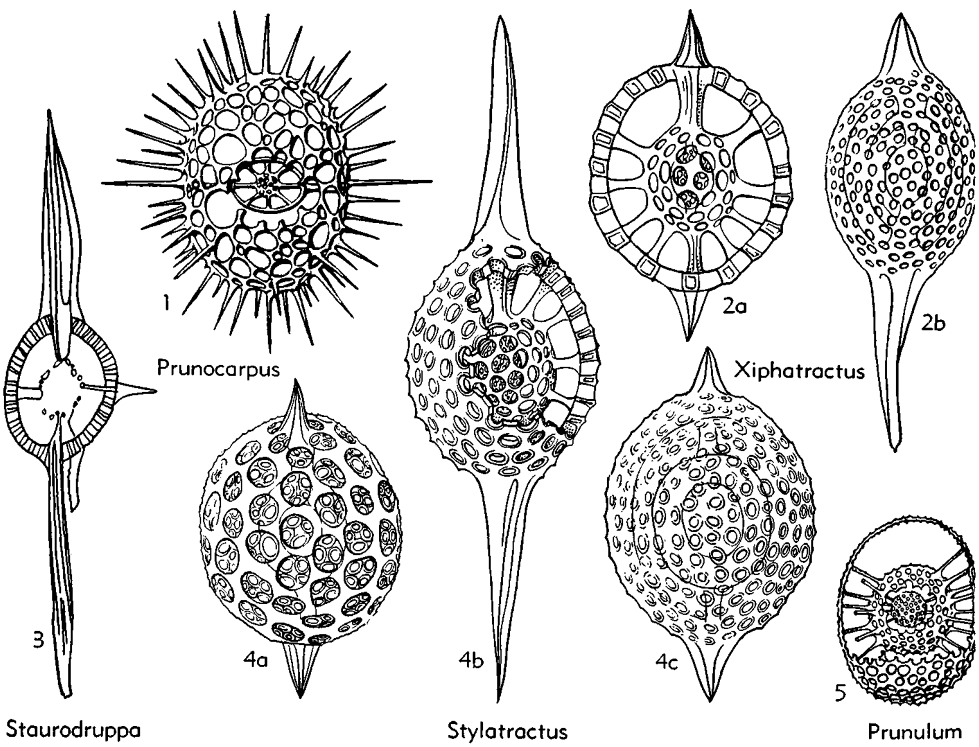


Fig. 31. Druppulidae (p. D72, D73).

Stylatractus Hkl., 1887 [*S. *neptunus* (=*Amphistylus neptunus* Hkl., 1887); SD herein] [=*Amphistylus* Hkl., 1882 *(partim)*]. Double medullary shell; 2 opposite similar polar spines. *Cret.-Rec.*

S. (Stylatractus) [=*Stylatractara* Hkl., 1887 (obj.)]. Network regular; surface smooth. *Cret.-Rec.*——Fig. 31,4c. *S. (S.) compactus* Hkl., Rec., ×200 (42).

S. (Stylatractium) Hkl., 1887 [*S. *papillosus;* SD herein]. Network irregular; surface thorny or papillate. *Rec.*

S. (Stylatractona) Hkl., 1887 [*S. *sethoporus;* SD herein]. Network irregular; surface smooth. *Rec.* ——Fig. 31,4a. **S. (S.) sethoporus,* Rec., ×200 (42).

S. (Stylatractylis) Hkl., 1887 [*S. *giganteus* (=*Amphistylus giganteus* Hkl., 1887); SD herein]. Network regular; surface thorny or papillate. *Eoc.-Rec.*——Fig. 31,4b. **S. (S.) giganteus,* Rec., ×100 (42).

Xiphatractus Hkl., 1887 [*X. *armadillo;* SD herein]. Double medullary shell; 2 opposite dissimilar polar spines. *Eoc.-Rec.*

X. (Xiphatractus) [=*Xiphatractara* Hkl., 1887 (obj.)]. Network regular; surface smooth. *Eoc.-Rec.*——Fig. 31,2b. **X. (X.) armadillo,* Rec., ×200 (42).

X. (Xiphatractium) Hkl., 1887 [*X. *glyptodon;* SD herein]. Network irregular; surface thorny or papillate. *Eoc.-Rec.*——Fig. 31,2a. **X. (X.) glyptodon,* Rec., ×200 (42).

X. (Xiphatractona) Hkl., 1887 [*S. *chlamydophorus*]. Network irregular; surface smooth. *Rec.*

X. (Xiphatractylis) Hkl., 1887 [**Stylosphaera spinulosa* Ehr., 1875]. Network regular; surface spiny or thorny. *Eoc.-Rec.*

Family SPONGURIDAE Haeckel, 1862

[as Spongurida; emend. Campbell, herein]

Spongy elliptical or cylindrical shell without equatorial strictures. *Ord.-Rec.*

Subfamily SPONGURINAE Haeckel, 1862

[as Spongurida *(partim)*; emend. Campbell, herein] [=Spongellipsida Hkl., 1887]

Lacking internal latticed medullary shell. *Ord.-Rec.*

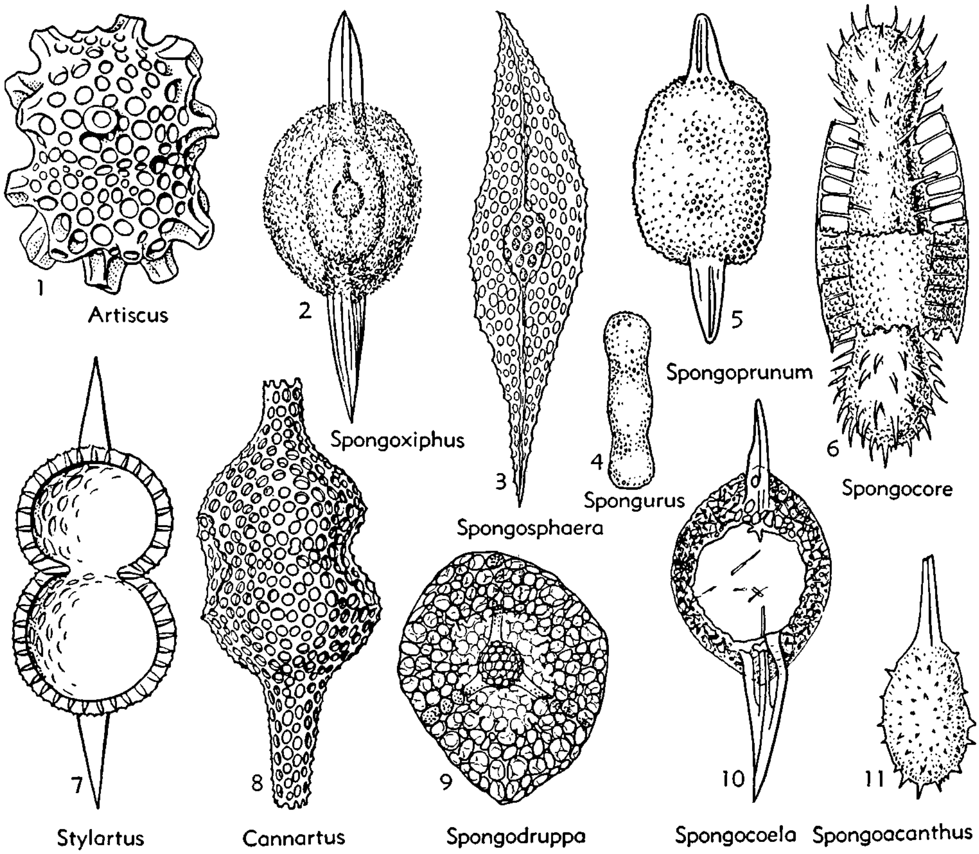


Fig. 32. Sponguridae, Artiscidae (p. D74).

Spongurus HKL., 1862 [*S. *cylindricus*]. Solid spongy shell without polar spines or lattice-mantle. *Dev.-Rec.*

S. (Spongurus) [=*Spongurella* HKL., 1887 (obj.)]. Surface armed with radial spines; spongy framework everywhere similar. *Dev.-Rec.*

S. (Spongurantha) HKL., 1887 [*S. *phlanga;* SD FRIZZELL 1951]. Surface without radial spines; spongy framework everywhere similar. *Paleoc.-Rec.*——FIG. 32,*4*. *S. (S.) smithi* C.-CL., Mio., ×150 (35).

S. (Spongurомма) HKL., 1887 [*S. *radians;* SD herein]. Surface with radial spines, but interior framework compact. *Rec.*

Spongellipsis HKL., 1887 [*S. *laevis;* SD herein]. Shell with hollow cavity but without latticed medullary shell; no polar spines. *Rec.*

S. (Spongellipsis) [=*Spongellipsarium* HKL.. 1887 (obj.)]. Without radial spines.

S. (Spongellipsidium) HKL., 1887 [*S. *setosa;* SD herein]. With radial spines.

Spongoacanthus SQUIN., 1903 [*S. *horridus*]. Hollow shell with a single polar spine. *Cret.*——FIG. 32,*11*. *S. *horridus,* Cret., Italy., ×80 (52).

Spongocoela HINDE, 1899 [*S. *citreum;* SD herein]. Hollow shell with 2 opposite similar polar spines. *Dev.*——FIG. 32,*10*. *S. *citreum,* Dev., Austral., ×150 (44).

Spongocore HKL., [*S. *vellata;* SD herein]. Solid shell with lattice-mantle but without polar spines. *Mio.-Rec.*

S. (Spongocore) [=*Spongocorina* HKL., 1887 (obj.)]. Shell not jointed. *Rec.*

S. (Spongocorissa) HKL., 1887 [*S. *puella;* SD herein]. Shell distinctly 3-jointed. *Mio.-Rec.*——FIG. 32,*6*. *S. (S.) puella,* Rec., ×200 (42).

Spongoprunum HKL., 1887 [*S. *amphilonche;* SD herein]. Solid shell without lattice mantle; 2 opposite polar spines. *Ord.-Rec.*——FIG. 32,*5*. *S. markleyense,* CL.-C., U.Eoc., Calif., ×150 (39).

Subfamily SPONGODRUPPINAE Haeckel, 1887

[as Spongodruppida; emend. CAMPBELL, herein]

Latticed medullary, and spongy cortical shell. *Carb.Rec.*

Spongodruppa HKL., 1887 [*S. *terebintha;* SD herein]. Simple medullary shell without polar spines. *Carb.-Rec.*

S. (Spongodruppa) [=*Spongodruppula* HKL., 1887 (obj.)]. Without radial spines. *Carb.-Rec.*——FIG. 32,*9*. *S. (S.) triradiata* RÜST, Carb., Harz Mts., Ger., ×80 (51).

S. (Spongodruppium) HKL., 1887 [*S. *frangula;* SD herein]. With radial spines. *Rec.*

Spongoliva HKL., 1887 [*S. *cerasina;* SD herein]. Double medullary shell; without polar spines. *Rec.*

S. (Spongoliva) [=*Spongolivetta* HKL., 1887]. Surface without radial spines.

S. (Spongolivina) HKL., 1887 [*S. *opuntina;* SD herein]. Surface armed with radial spines.

Spongosphaera EHR., 1847 [*S. *pachystylus* EHR., 1875][=*Spongatractus* HKL., 1887 (obj.)]. Simple medullary shell; 2 opposite polar spines. *Jur.-Rec.*——FIG. 32,*3*. *S. pleurosigma* (RÜST), Jur., Italy, ×100 (51).

Spongoxiphus HKL., 1887 [*S. *prunococcus;* SD herein]. Double medullary shell; 2 opposite polar spines. *Eoc.-Rec.*——FIG. 32,*2*. *S. *prunococcus,* Rec., ×150 (42).

Family ARTISCIDAE Haeckel, 1882

[as Artiscida; emend. CAMPBELL, herein]

Twin shell divided by equatorial stricture into 2 chambers; without medullary shell. *Cret.-Rec.*

Artiscus HKL., 1882 [*A. *paniscus* HKL., 1887]. Without polar appendages or hollow tubules. *Cret.-Rec.*

A. (Artiscus) [=*Artiscum* HKL., 1887 (obj.)]. Surface without radial spines or solid rods. *Cret.-Rec.*

A. (Artidium) HKL., 1887 [*A. *nodosus;* SD herein]. Surface with solid radial rods or spines. *Rec.*——FIG. 32,*1*. *A. (A.) nodosus,* Rec., ×300 (42).

Cannartus HKL., 1882 [*C. *violina* HKL., 1887]. Two hollow fenestrated tubules on main axis. *Rec.*——FIG. 32,*8*. *C. *violina,* Rec., ×200 (42).

Stylartus HKL., 1882 [*S. *bipolaris* HKL., 1887]. Two solid spines or a bundle of spines on each pole of main axis. *Rec.*

S. (Stylartus) [=*Stylartella* HKL., 1887 (obj.)]. One spine on each pole.——FIG. 32,*7*. *S. (S.) bipolaris,* Rec., ×150 (42).

S. (Stylartura) HKL., 1887 [*S. *palatus;* SD herein]. A bunch of spines on each pole.

Family CYPHANTIDAE Campbell, nov.

[=Cyphanida HKL., 1882]

Elliptical shell with 2 equatorial strictures; one or more medullary shells. *Dev.-Rec.*

Cyphanta HKL., 1887 [*C. *colpodes;* SD herein]. Like *Cyphinus* but without polar spines or tubules. *Dev.-Rec.*

C. (Cyphanta) [=*Cyphantella* HKL., 1887 (obj.)]. Surface smooth. *Dev.-Rec.*——FIG. 33,*1*. *C. (C.) piscis* RÜST, L.Dev., Ural Mts., ×100 (51).

C. (Cyphantissa) HKL., 1887 [*C. *hispida;* SD herein]. Surface spiny or thorny. *Rec.*

Astromma EHR., 1847 [*A. *entomocora*][=*Cypassus* HKL., 1887 (obj.)]. Double cortical and medullary shells; without polar spines or tubules. *Eoc.-Rec.*

A. (Astromma) [=*Didymocyrtis* HKL., 1862 (obj.); *Didymophormis* HKL., 1882]. Surface spiny or thorny. *Eoc.-Rec.*——FIG. 33,*3*. *A. (A.) puella* HKL., Rec., ×200 (42).

A. (Didymospyris) HKL., 1882 [*Cypassus palliatus* HKL., 1887]. Surface smooth. *Rec.*

Cannartidium HKL., 1887 [**C. amphiconicum;* SD herein]. Simple cortical and double medullary shell; with a hollow fenestrated polar tubule on each pole. *Eoc.-Rec.*

C. (Cannartidium) [=*Cannartidella* HKL., 1887 (obj.)]. Without spines or conical tubules. *Eoc.-Rec.*——FIG. 33,*6*. *C. (C.) bicinctum* HKL., Rec., ×200 (42).

C. (Canartidissa) HKL., 1887 [**C. mammiferum;* SD herein]. Conical fenestrated protuberances. *Rec.*

Cannartiscus HKL., 1887 [**C. amphiconiscus;* SD herein]. Simple cortical and medullary shells; with a hollow fenestrated tubule at each pole. *Mio.-Rec.*——FIG. 33,*8*. **C. amphiconiscus,* Rec., ×200 (42).

Cyphanidium HKL., 1887 [**C. amphistylium;* SD herein]. Resembles *Cyphinus* but has double medullary shell. *Rec.*

C. (Cyphanidium) [=*Cyphinidoma* HKL., 1887 (obj.)]. Single polar spine or a bunch of spines on each pole.

C. (Cyphinidura) HKL., 1887 [**C. coronatum;* SD herein]. Circle of spines on each pole.

Cyphinus HKL., 1882 [**C. amphacanthus* HKL., 1887]. Simple cortical and medullary shells; 2 opposite polar spines or cluster of spines. *Cret.-Rec.*

C. (Cyphinus) [=*Cyphinoma* HKL., 1887 (obj.)]. Single polar spine on each pole. *Cret.-Rec.*

C. (Cyphinura) HKL., 1887 [**C. amphilophus;* SD herein]. Cluster of spines on each pole. *Rec.*——FIG. 33,*4*. **C. (C.) amphilophus,* Rec., ×200 (42).

Cyphocolpus HKL., 1887 [**C. virginis;* SD herein]. Triple cortical and medullary shells without polar spines or tubules. *Rec.*——FIG. 33,2. **C. virginis,* Rec., ×200 (42).

Diplellipsis POP., 1909 [**D. lapidosa*]. Medullary twin shell with biscuit-shaped portions. *Rec.*——FIG. 33,*7*. **D. lapidosa,* Rec., ×400 (48).

Ommatospyris EHR., 1860 [**O. apicata* EHR., 1872] [=*Cyphonium* HKL., 1887 (obj.)]. Like *Cyphanta* but has double spherical or lenticular medullary shell. *Eoc.-Rec.*

O. (Ommatospyris). Surface smooth. *Eoc.-Rec.*——FIG. 33,*5*. *O. (O.) virginea* HKL., Rec., ×200 (42).

O. (Didymocyrtis) HKL., 1882 [**Cyphonium hexagonium* HKL., 1887][=*Ommatocyrtis* HKL., 1887 (obj.)]. Surface spiny or thorny. *Rec.*

Family PANARTIDAE Haeckel, 1887

[as Panartida; emend. CAMPBELL, herein]

External shell with 3 strictures; 2 concentric medullary shells. *Rec.*

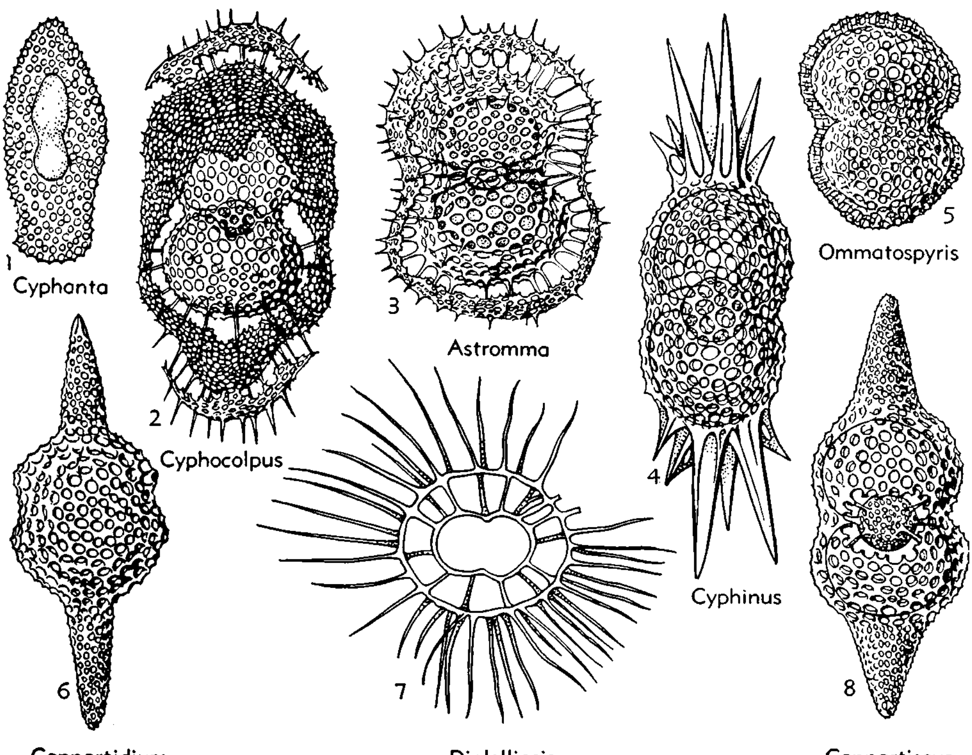


FIG. 33. Cyphantidae (p. D74, D75).

Panartus HKL., 1887 [*P. tetrathalmus; SD herein]. Single cortical and double medullary shells; no polar spines or tubules.

P. (Panartus) [=*Panartella* HKL., 1887 (obj.)]. Surface without spines or thorns; all 4 chambers similar. FIG. 34,*1*. **P. tetrathalmus*, Rec., ×200 (42).

P. (Panartissa) HKL., 1887 [*P. diploconus; SD herein]. Surface smooth; distal and proximal chambers dissimilar.

P. (Panartoma) HKL., 1887 [*P. quadriceps; SD herein]. Surface thorny; 4 chambers similar.

P. (Panartura) HKL., 1887 [*P. pluteus; SD herein]. Surface thorny; distal and proximal chambers dissimilar.

Panarium HKL., 1882 [*P. facettarium HKL., 1887]. Like *Panartus* but has 2 polar tubules.

P. (Panarium) [=*Panarelium* HKL., 1887 (obj.)]. Surface smooth.

P. (Panaromium) HKL., 1887 [*P. tubularium; SD herein]. Surface spiny or thorny.——FIG. 34,*4*. **P. tubularium*, Rec., ×200 (42).

Panicium HKL., 1887 [*P. amphacanthum; SD herein]. Simple cortical shell; 2 opposite apical spines or a cluster of spines at poles of main axis.

P. (Panicium) [=*Panicidium* HKL., 1887 (obj.)]. Single spine at each pole.

P. (Panartidium) HKL., 1887 [*P. coronatum; SD herein]. Cluster or circle of spines at each pole.——FIG. 34,*3*. **P. (P.) coronatum*, Rec., ×200 (42).

Peripanarium HKL., 1887 [*P. cenoconicum; SD herein]. Double cortical shell; 2 opposite polar fenestrated tubules.

Peripanartus HKL., 1887 [*P. amphiconus; SD herein]. Like *Peripanarium* but has no polar tubules or spines.

P. (Peripanartus) [=*Peripanartula* HKL., 1887 (obj.)]. Surface smooth.——FIG. 34,*2*. **P. amphiconus*, Rec., ×200 (42).

P. (Peripanartium) HKL., 1887 [*P. atractus; SD herein]. Surface thorny or spiny.

Peripanicium HKL., 1887 [*P. amphixiphus; SD herein]. Double cortical shell; a ring of spines, or only one spine on each pole.

P. (Peripanicium) [=*Peripanicea* HKL., 1887 (obj.)]. Single polar spine.

P. (Peripanicula) HKL., 1887 [*P. amphicorona; SD herein]. Cluster or circle of spines at each pole.——FIG. 34,*9*. **P. (P.) amphicorona*, Rec., ×200 (42).

Family ZYGARTIDAE Haeckel, 1882

[as Zygartida; emend. CAMPBELL, herein]

External shell with 5 or more strictures; 2 or more concentric medullary shells. *Mio.-Rec.*

Subfamily ZYGARTINAE Haeckel, 1882

[as Zygartida *(partim)*; emend. CAMPBELL, herein] [=Zygocampida HKL., 1887]

Triple cortical shell. *Rec.*

Zygartus HKL., 1882 [*Z. dolium HKL., 1887]. Hollow fenestrated polar tubule at each pole of main axis.

Zygocampe HKL., 1887 [*Z. chrysalidium (=*Zygartus chrysalis* HKL., 1887, obj.); SD herein]. Triple or multiple cortical shell without polar tubules.——FIG. 34,*7*. **Z. chrysalidium*, Rec., ×200 (42).

Subfamily OMMATOCAMPINAE Haeckel, 1887

[as Ommatocampida; emend. CAMPBELL, herein]

Cortical shell simple. *Mio.-Rec.*

Ommatocampe EHR., 1860 [*O. polyarthra EHR., 1872]. Without polar tubules. *Mio.-Rec.*

O. (Ommatocampe) [=*Ommatocampium* HKL., 1887 (obj.)]. Surface without thorns or spines. *Rec.*

O. (Ommatacantha) HKL., 1887 [*O. amphilonche]. Surface smooth or spiny; 2 strong spines on each pole.

O. (Ommatocampula) HKL., 1887 [*O. nereis; SD herein]. Surface spiny or thorny. *Mio.-Rec.* ——FIG. 34,*6*. **O. (O.) nereis*, Rec., ×200 (42).

O. (Ommatocorona) HKL., 1887 [*O. chaetopodium]. Surface spiny; a regular circle or corona of spines on each chamber. *Rec.*

Ommatartus HKL., 1882 [*O. amphicanna HKL., 1887]. Hollow fenestrated tubule on each pole. *Rec.*

Subfamily DESMOCAMPINAE Haeckel, 1887

[as Desmocampida; emend. CAMPBELL, herein]

Double cortical shell. *Rec.*

Desmocampe HKL., 1887 [*D. catenula; SD herein]. Without polar spines.

Desmartus HKL., 1887 [*D. larvalis; SD herein]. Fenestrated tubule on each pole.——FIG. 34,*5*. **D. larvalis*, Rec., ×200 (42).

Subfamily MONAXONIINAE Campbell, nov.

Triple medullary shell. *Rec.*

Monaxonium POP., 1911 [*M. perforatum]. FIG. 34,*8*. **M. perforatum*, Rec., ×200 (48).

Superfamily CENODISCICAE Haeckel, 1887

[*ex* Cenodiscida; emend. CAMPBELL, herein] [=Discoidea HKL., 1862]

Discoidal or lenticular fenestrated or spongy shell. *Cam.-Rec.*

Subsuperfamily CENODISCILAE Haeckel, 1887

[*ex* Cenodiscida; emend. CAMPBELL, herein] [=Phacodiscaria HKL., 1887]

External lenticular latticed cortical shell. *Cam.-Rec.*

Family CENODISCIDAE Haeckel, 1887

[as Cenodiscida; emend. CAMPBELL, herein]

Without medullary shell, chambered arms or equatorial girdle. *Cam.-Rec.*

Subfamily CENODISCINAE Haeckel, 1887

[as Cenodiscida *(partim)*; emend. CAMPBELL, herein] [=Zonodiscida HKL., 1887]

Lacking peripheral radial spines. *Sil.-Rec.*

Cenodiscus HKL., 1887 [**C. phacoides;* SD herein]. Margin wthout girdle or spines. *Cam.-Rec.*——FIG. 35,*1*. **C. phacoides,* Rec., ×100 (42).

Zonodiscus HKL., 1887 [**Z. saturnalis*]. Has solid equatorial girdle, but no radial spines. *Sil.-Rec.*——FIG. 35,*4*. *Z. dentatus* RÜST, Sil., Cabrières., ×150 (51).

Subfamily TROCHODISCINAE Haeckel, 1887

[as Trochodiscida; emend. CAMPBELL, herein]

Equatorial radial spines on margin. *Cam.-Rec.*

Trochodiscus HKL., 1887 [**T. cenophacus;* SD herein]. Ten to 20 or more marginal spines on disc. *Cam.-Rec.*

T. (Trochodiscus) [=*Trochodisculus* HKL., 1887 (obj.)]. Base of radial spines free. *Cam.-Rec.*

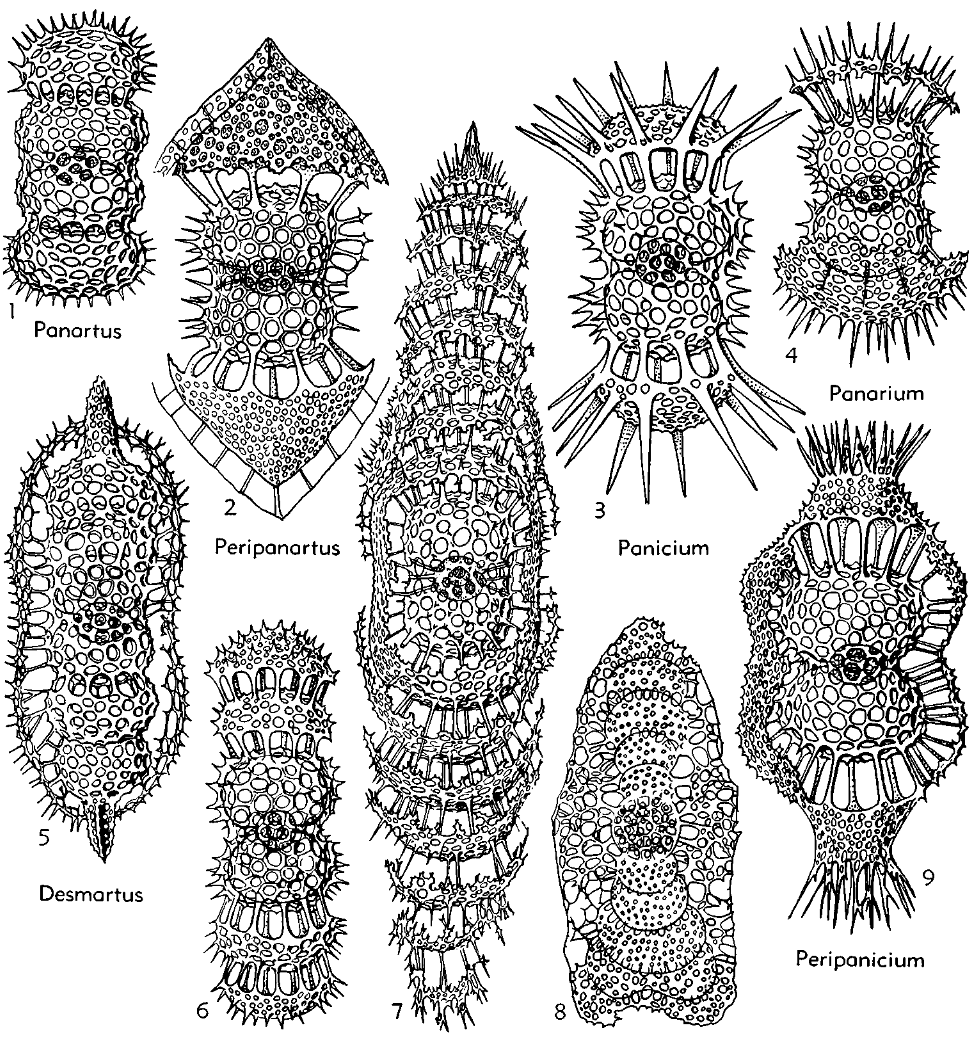


FIG. 34. Panartidae, Zygartidae (p. D76).

——FIG. 35,*3a*. *T. (T.) maximus* SQUIN., Cret., Italy, ×80 (52).

T. (Pristodiscus) HKL., 1887 [**T. stellaris;* SD herein]. Bases of radial spines connected by solid equatorial girdle. *Rec.*——FIG. 35,*3b*. **T. (P.) stellaris,* Rec., ×100 (42).

Crucidiscus HKL., 1887 [**C. endostaurus;* SD herein]. Four crossed radial spines on margin. *Cam.-Rec.*

C. (Crucidiscus) [=*Staurentodiscus* HKL., 1887 (obj.)]. Internal centripetal rods. *Cam.-Rec.*——FIG. 35,*6*. **C. (C.) endostaurus,* Rec., ×100 (42).

C. (Staurexodiscus) HKL., 1887 [**C. cuspidatus;* SD herein]. Without centripetal rods. *Rec.*

Dactyliodiscus SQUIN., 1903 [**D. cayeuxi*]. Circular hole in center; 8 marginal spines. *Cret.*——FIG. 35,*2*. **D. cayeuxi,* Rec., ×80 (52).

Theodiscus HKL., 1887 [**T. divinus;* SD herein]. Three marginal radial spines. *Cam.-Rec.*

T. (Theodiscus) [=*Theodiscoma* HKL., 1887 (obj.)]. Spines equidistant. *Cam.-Rec.*——FIG. 35,*5*. *T. (T.) brachyacanthus* RÜST, L.Carb., Ger., ×75 (51).

T. (Theodiscura) HKL., 1887 [**T. vanitatis;* SD herein]. Spines not equidistant. *Rec.*

Stylodiscus HKL., 1887 [**S. endostylus;* SD herein]. Two solid radial spines opposite in one axis. *Rec.*

S. (Stylodiscus) [=*Stylentodiscus* HKL., 1887 (obj.)]. Cavity with centripetal rods.——FIG. 35,*7*. **S. (S.) endostylus,* Rec., ×150 (42).

S. (Stylexodiscus) HKL., 1887 [**S. amphistylus;* SD herein]. Without centripetal rods.

Family PHACODISCIDAE Haeckel, 1882

[as Phacodiscida; emend. CAMPBELL, herein]

Single lenticular latticed cortical shell and single or double medullary shell; without chambered equatorial girdles. *Cam.-Rec.*

Subfamily PHACODISCINAE Haeckel, 1882

[as Phacodiscida *(partim)*; emend. CAMPBELL, herein] [=Sethodiscida HKL., 1882]

Margin of disc without radial spines. *Eoc.-Rec.*

Phacodiscus HKL., 1882 [**P. rotula* HKL., 1887]. Double medullary shell; margin without girdle. *Eoc.-Rec.*

P. (Phacodiscus) [=*Phacodiscinus* HKL., 1887 (obj.)]. Surface smooth. *Eoc.-Rec.*——FIG. 35,*8a*. **P. (P.) rotula,* Rec., ×200 (42).

P. (Phacodisculus) HKL., 1887 [**P. clypeus*]. Surface with elevated ribs or spines. *Rec.*——FIG. 35,*8b*. **P. clypeus,* Rec., ×200 (42).

Periphaena EHR., 1873 [**P. decora* EHR., 1875]. Simple medullary shell; margin with hyaline girdle. *Eoc.-Rec.*——FIG. 35,*12*. *P. cincta* HKL., Rec., ×200 (42).

Perizona HKL., 1882 [**P. scutella* HKL., 1887]. Double medullary shell; solid equatorial girdle. *Rec.*——FIG. 35,*9*. *P. pterygota* HKL., Rec., ×320 (42).

Phacopyle DREYER, 1889 [**P. stomatopora*]. Single pylome at one pole of lenticular shell. *Rec.*——FIG. 35,*11*. **P. stomatopora,* Rec., ×100 (40).

Sethodiscinus HKL., 1887 [*non Sethodiscus* HKL., 1882][**Sethodiscus lenticula* HKL., 1882; SD herein]. Simple medullary shell; neither girdle nor spines. *Eoc.-Rec.*

S. (Sethodiscinus). Surface smooth. *Rec.*——FIG. 35,*10*. **S. (S.) lenticula,* Rec., ×150 (42).

S. (Sethodisculus) HKL., 1887 [**Haliomma radians* EHR., 1854; SD herein]. Surface with elevated ribs or spines. *Eoc.-Rec.*

Subfamily DORYDISCINAE Campbell, nov.

[=Heliosestrida CARNEVALE, 1908 *(partim)*]

Single radial spine at one pole. *Mio.*

Dorydiscus CARNEVALE, 1908 [**D. bergontianus*]. Single medullary shell.——FIG. 36,*4*. **D. bergontianus,* Mio., Italy, ×110 (36).

Doryphacus CARNEVALE, 1908 [**D. poroacanthus;* SD herein]. Two concentric medullary shells.——FIG. 36,*3*. **D. poroacanthus,* Mio., Italy, ×110 (36).

Subfamily HELIOSESTRINAE Haeckel, 1887

[as Heliosestrida; emend. CAMPBELL, herein]

Margin of disc with 2 to 8 or more radial spines; more or less regularly disposed. *Dev.-Rec.*

Heliosestrum HKL., 1882 [**H. medusinum* HKL., 1887][=*Heliodiscus medusinus* HKL., 1887]. Radial spines 8; simple medullary shell. *Dev.-Rec.*

H. (Heliosestrum) [=*Heliosestantha* HKL., 1887 (obj.)]. Surface smooth; bases of radial spines without connecting girdle. *Dev.-Rec.*——FIG. 36,*1b*. **H. (H.) medusinum,* Rec., ×150 (42).

H. (Heliosestilla) HKL., 1887 [**H. octonum;* SD herein]. Surface armed with spines; no girdle. *Rec.*——FIG. 36,*1a*. **H. (H.) octonum,* Rec., ×150 (42).

H. (Heliosestomma) HKL., 1887 [**H. octangulum;* SD herein]. Surface smooth; solid equatorial girdle. *Rec.*

Astrosestrum HKL., 1882 [**A. ephyra* HKL., 1887]. Double medullary shell; 8 (7-9) radial spines. *Eoc.-Rec.*

A. (Astrosestrum) [=*Astrosestantha* HKL., 1887 (obj.)]. Surface smooth; bases of spines not connected by girdle. *Rec.*——FIG. 36,*9*. **A. (A.) ephyra,* Rec., ×150 (42).

A. (Astrosestilla) HKL., 1887 [**A. acanthastrum;* SD herein]. Surface spiny; bases of spines without girdle. *Eoc.-Rec.*

A. (Astrosestomma) HKL., 1887 [**A. pelagicum;* SD herein]. Surface smooth; solid girdle. *Rec.*

Distriactis HKL., 1887 [**D. lirianthus;* SD herein].

Radial spines 6; simple medullary shell. *Dev.-Rec.*——FIG. 36,*2*. *D. vetusa* HINDE, Dev., Austral., ×200 (44).

Heliosestarium C.-CL., 1944 [**H. cretaceum*]. Like *Distriactis* but has subequal radial spines; double medullary shell. *Cret.*——FIG. 36,*6*. **H. cretaceum*, Cret., Calif., ×150 (35).

Heterosestrum CL.-C., 1945 [**Stylodictya sexispinata* CL.-C., 1942]. Six similar radial spines; double medullary shell. *Eoc.*——FIG. 36,*5*. **H. sexispinatum*, U.Eoc., Calif., ×150 (39).

Phacotriactis SUTTON, 1896 [**P. triangula*]. Three short radial spines; triangular disc. *Eoc.*——FIG. 36,*10*. **P. triangula*, U.Eoc., Barbados, ×150 (54).

Phacostaurus HKL., 1882 [**P. oceanidus* HKL., 1887]. Four crossed radial spines; double medullary shell. *Rec.*

P. (Phacostaurus) [=*Phacostaurium* HKL., 1887 (obj.)]. Margin simple.——FIG. 36,*8a*. **P. (P.) oceanidus* HKL., Rec., ×150 (42).

P. (Astrostaurus) HKL., 1887 [**P. magnificus;* SD

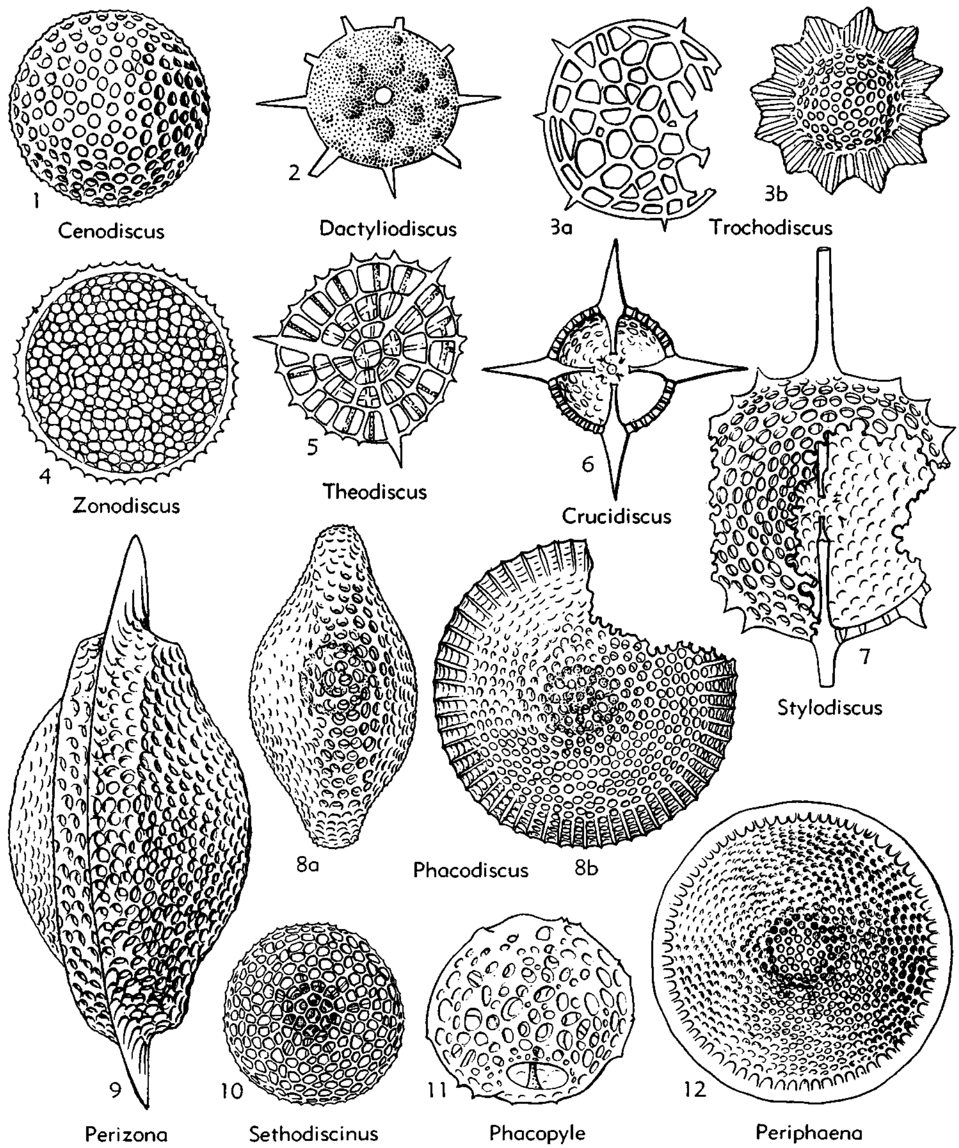


FIG. 35. Cenodiscidae, Phacodiscidae (p. D77, D78).

herein]. Margin with solid girdle, or a corona of spines.——FIG. 36,*8b*. **P. (A.) magnificus*, Rec., ×200 (42).

Phacostylus HKL., 1882 [**P. amphistylus* HKL., 1887]. Two opposite radial spines; double medullary shell. *Eoc.-Rec.*

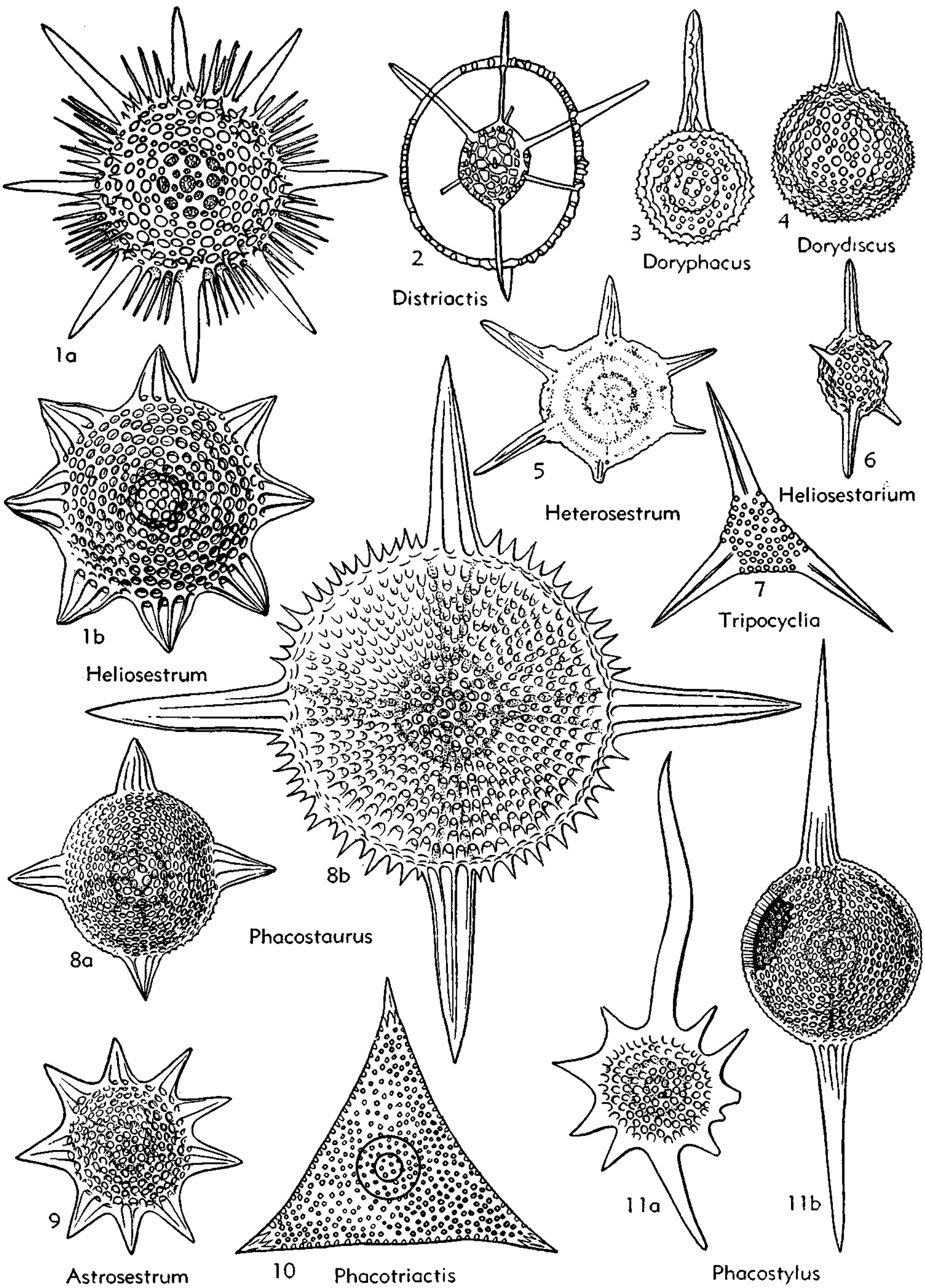


FIG. 36. Phacodiscidae (p. D78-D82).

P. (Phacostylus) [=*Phacostylium* HKL., 1887 (obj.)]. Margin simple. *Rec.*——FIG. 36,*11b*. **P. amphistylus,* Rec., ×150 (42).

P. (Astrostylus) HKL., 1887 [**P. caudatus;* SD herein]. Margin with solid equatorial girdle or corona of spines. *Eoc.-Rec.*——FIG. 36,*11a*. **P. (A.) caudatus,* Rec., ×150 (42).

Sethostaurus HKL., 1882 [**S. orthostaurus* HKL., 1887]. Like *Phacostaurus* but has simple medullary shell. *Cam.-Rec.*

S. (Sethostaurus) [=*Sethostaurium* HKL., 1887 (obj.)]. Margin simple. *Cam.-Rec.*——FIG. 37,*2a*. *S. (S.) rhombostaurus* HKL., Rec., ×300 (42).

S. (Heliostaurus) HKL., 1887 [**S. cruciatus* (=*Heliostaurus cruciatus* HKL., 1887); SD herein]. Margin with solid equatorial girdle. *Rec.*——FIG. 37,*2b*. **S. (H.) cruciatus,* Rec., ×150 (42).

Sethostylus HKL., 1881 [**S. distyliscus* HKL., 1887]. Two opposite radial spines; simple medullary shell. *Eoc.-Rec.*

S. (Sethostylus) [=*Sethostylium* HKL., 1887 (obj.)]. Margin simple. *Rec.*——FIG. 37,*4b*. **S. (S.) distyliscus,* Rec., ×200 (42).

S. (Heliostylus) HKL., 1887 [**S. dentatus;* SD herein]. Margin with girdle or corona of spines. *Eoc.-Rec.*——FIG. 37,*4a*. **S. (H.) dentatus,* Rec., ×150 (42).

Triactis HKL., 1882 [**Triactoma titonianum* RÜST, 1885][=*Triactoma* RÜST, 1885 (obj.); *Triactiscus* HKL., 1887 (obj.)]. Three marginal spines; simple medullary shell. *Jur.-Rec.*——FIG. 37,*3*. *T. tripyramis* HKL., Rec., ×200 (42).

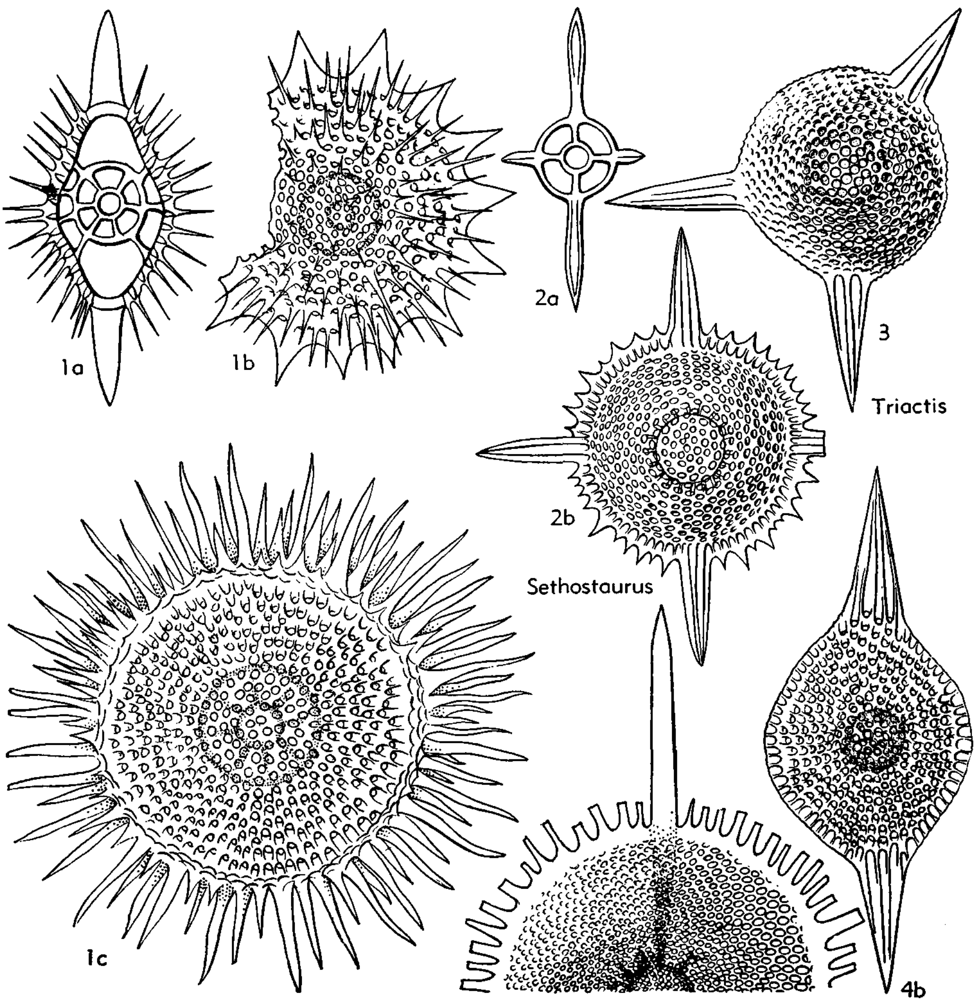


FIG. 37. Phacodiscidae (p. D81, D82).

Tripocyclia HKL., 1882 [**T. trigonum* RÜST, 1885]. Flat triangular disc; 3 strong spines; surface with minute pores. *Jur.* (cosmopol.).——FIG. 36,*7*. **T. trigonum,* Jur., Switz., ×120 (51).

Subfamily HELIODISCINAE Haeckel, 1882

[as Heliodiscida; emend. CAMPBELL, herein]
[=Eliodiscida CARNEVALE, 1908]

Variable number of radial spines (commonly 10 to 20 or more), mostly disposed irregularly. *Cam.-Rec.*

Heliodiscus HKL., 1882 [**H. inchoatus* RÜST, 1885]. Radial spines unbranched; medullary shell simple. *Cam.-Rec.*

H. (Heliodiscus) [=*Heliodiscetta* HKL., 1887 (obj.)]. Surface smooth; no girdle. *Cam.-Rec.* ——FIG. 38,*2c*. *H. (H.) asteriscus* HKL., Rec., ×150 (42).

H. (Heliodiscilla) HKL., 1887 [**H. pertusus* (=*Heliosestrum pertusum* HKL., 1887); SD herein]. Surface spiny; no girdle. *Rec.*——FIG. 38,*2a*. **H. (H.) pertusus,* Rec., ×200 (42).

H. (Heliodiscomma) HKL., 1887 [**H. cingulum;* SD herein]. Surface smooth; solid marginal girdle. *Rec.*——FIG. 38,*2b*. **H. (H.) cingulum,* Rec., ×150 (42).

H. (Heliodiscura) HKL., 1887 [**H. apollonis;* SD herein]. Surface spiny; solid marginal girdle. *Rec.*

Astrophacus HKL., 1882 [**A. asteriscus* HKL., 1887][=*Chilomma* EHR., 1838 *(nomen vanum)*]. Like *Heliodiscus* but has double medullary shell. *Dev.-Rec.*

A. (Astrophacus) [=*Astrophacetta* HKL., 1887 (obj.)]. Surface smooth; no girdle. *Dev.-Rec.* ——FIG. 37,*1c*. *A. (A.) solaris* HKL., Rec., ×150 (42).

A. (Astrophacilla) HKL., 1887 [**A. phacodiscus*]. Surface spiny; no girdle. *Rec.*——FIG. 37,*1a*. **A. (A.) phacodiscus,* Rec., ×150 (42).

A. (Astrophacomma) HKL., 1887 [**A. cingulum;* SD herein]. Surface smooth; solid girdle. *Eoc.-Rec.*

A. (Astrophacura) HKL., 1887 [**A. apollinis*]. Surface spiny; solid girdle. *Rec.*——FIG. 37,*1b*. **A. apollinis,* Rec., ×150 (42).

Heliocladus HKL., 1882 [**H. dendrocyclus* HKL., 1887 (=*Heliodrymus dendrocyclus* HKL., 1887)] [=*Heliodrymus* HKL., 1882 (obj.)]. Ten to 20 branched radial spines; simple medullary shell. *Eoc.-Rec.*

H. (Heliocladus). Surface smooth; no spines. *Eoc.-Rec.*——FIG. 38,*1b*. **H. (H.) dendrocyclus,* Rec. ×150 (42).

H. (Heliodendrum) HKL., 1887 [**Heliodrymus ramosus;* SD herein]. Armed with simple or branched spines. *Rec.*——FIG. 38,*1a*. **H. (H.) ramosus,* Rec., ×200 (42).

Family COCCODISCIDAE Haeckel, 1862

[as Coccodiscida; emend. CAMPBELL, herein]

One or more chambered equatorial girdles. *Dev.-Rec.*

Subfamily COCCODISCINAE Haeckel, 1862

[as Coccodiscida *(partim)*; emend. CAMPBELL, herein]
[=Lithocyclida HKL., 1882]

Circular disc without solid radial spines or chambered arms. *Dev.-Rec.*

Coccodiscus HKL., 1862 [**C. darwinii*]. Double medullary shell. *Cret.-Rec.*——FIG. 39,*2*. *C. goethei* HKL., Rec., ×200 (42).

Lithocyclia EHR., 1847 [**L. ocellus* EHR., 1854] [=*Stephanopyxis* HKL., 1887 (obj.)]. Single medullary shell. *Dev.-Rec.*——FIG. 39,*1*. *L. lenticula* HKL., Rec., ×200 (42).

Subfamily STYLOCYCLIINAE Haeckel, 1882

[as Stylocyclida; emend. CAMPBELL, herein]

Solid radial spines; no chambered arms. *Jur.-Rec.*

Stylocyclia EHR., 1847 [**S. dimidiata* EHR., 1875]. Two solid radial spines; simple medullary shell. *Eoc.-Rec.*——FIG. 39,*4*. *S. prionacantha* HKL., Rec., ×200 (42).

Amphicyclia HKL., 1882 [**A. chronometra* HKL., 1887]. Like *Stylocyclia* but has double medullary shell. *Eoc.-Rec.*——FIG. 39,*5*. **A. chronometra,* Rec., ×200 (42).

Astrocyclia HKL., 1882 [**A. solaster* HKL., 1887]. Numerous (5 to 60) solid radial spines; simple medullary shell. *Eoc.-Rec.*——FIG. 39,*3*. **A. solaster,* Rec., ×200 (42).

Coccocyclia HKL., 1882 [**C. liriantha* HKL., 1887]. Like *Astrocyclia* but has double medullary shell. *Eoc.-Rec.*——FIG. 40,*9*. *C. heliantha* HKL., Rec., ×200 (42).

Staurocyclia HKL., 1882 [**S. cruciata* HKL., 1887] [=*Coccostaurus* HKL., 1882 (obj.); *Phacostaurus* HKL., 1887 (obj.)]. Four crossed radial spines; simple medullary shell. *Eoc.-Rec.*——FIG. 39.*7*. **S. cruciata,* Rec., ×200 (42).

Trigonocyclia HKL., 1882 [**T. triangularis* HKL., 1887]. Three solid radial spines; simple medullary shell. *Jur.-Rec.*——FIG. 39,*6*. **T. triangularis,* Rec., ×200 (42).

Subfamily ASTRACTURINAE Haeckel, 1882

[as Astracturida; emend CAMPBELL, herein]

Several (2 to 4 or more) chambered arms with or without connecting patagium. *Trias.-Rec.*

Astractura HKL., 1882 [**A. ordinata* HKL., 1887]. Four crossed chambered arms; no patagium; simple medullary shell. *Eoc.-Rec.*

A. (Astractura) [=*Astracturium* HKL., 1887 (obj.)]. Distally blunt or truncate arms without terminal spine. *Eoc.-Rec.*

A. (Astractinium) HKL., 1887 [**Astromma aristotelis* EHR., 1856; SD herein]. *Eoc.-Rec.*

Amphiactura HKL., 1882 [**A. amphibrachia* HKL., 1887]. Two opposite chambered arms connected by patagium. *Rec.*——FIG. 40,*8*. **A. amphibrachia,* Rec., ×150 (42).

Astrococcus SUTTON, 1896 [**A. concinna*]. Like *Astractura* but has double medullary shell. *Eoc.* ——FIG. 40.7. **A. concinna,* Eoc., Barbados, ×150 (54).

Dicoccura CARTER, 1896 [**D. brevibrachia*]. Like *Amphiactura* but without patagium and has double medullary shell. *Eoc.*——FIG. 40,*4*. **D. brevibrachia,* Eoc., Barbados, ×100 (37).

Diplactura HKL., 1882 [**D. longa* RÜST, 1885]. Like *Dicoccura* but has single medullary shell and no patagium. *Trias.-Rec.*

D. (Diplactura) [=*Diplacturium* HKL., 1887 (obj.)]. Arms blunt or truncate, without terminal spine. *Trias.-Rec.*

D. (Diplactinium) HKL., 1887 [**D. diploconus* (=*Amphiactura diploconus* HKL., 1887)]. Arms with distal spine. *Rec.*——FIG. 40,*10*. **D. (D.) diploconus,* Rec., ×150 (42).

Echinactura HKL., 1887 [**E. culcita;* SD herein]. Five chambered arms connected by patagium; disc circular or pentagonal. *Rec.*

Hymenactura HKL., 1882 [**H. archimedes* HKL., 1887]. Three chambered arms connected by patagium; circular or triangular disc. *Eoc.-Rec.*

H. (Hymenactura) [=*Hymenacturium* HKL., 1887 (obj.)]. Arms blunt or truncate; no terminal spine. *Eoc.-Rec.*——FIG. 40,*1b*. **H. (H.) archimedes,* Rec., ×150 **(42).**

H. (Hymenactinium) HKL., 1887 [**H. copernici;* SD herein]. Distal end of each arm with terminal spine. *Eoc.-Rec.*——FIG. 40,*1a*. **H. (H.) copernici,* Rec., ×150 (42).

Pentactura HKL., 1882 [**Astromma pentactis* EHR., 1875]. Like *Echinactura* but without patagium. *Eoc.-Rec.*——FIG. 40,*2*. **P. pentactis* (EHR.), Eoc., Barbados, ×200 (42).

Stauractura HKL., 1882 [**S. octogena* HKL., 1887]. Like *Astractura* but with patagium. *Rec.*

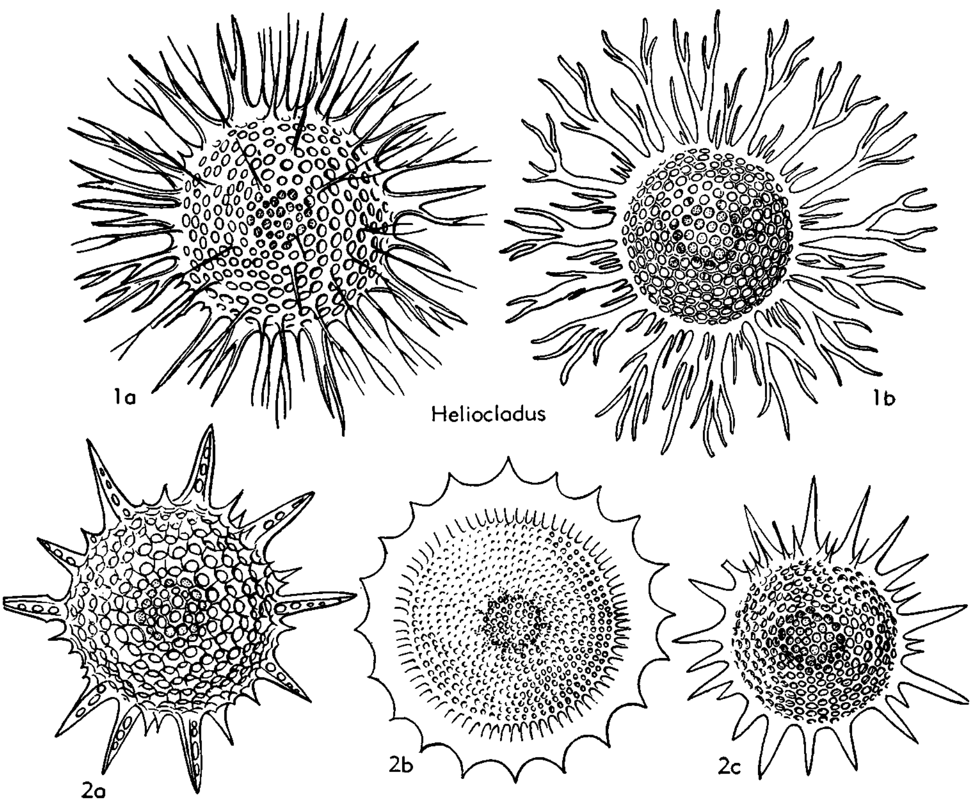


FIG. 38. Phacodiscidae (p. D82).

S. (Stauractura) [=*Stauracturium* Hkl., 1887 (obj.)]. Arms distally blunt or truncate, without terminal spine.

S. (Stauractinium) Hkl., 1887 [**S. medusina;* SD herein]. Arms with distal spine.

Staurococcura Carter, 1896 [**S. quaternarium*]. Like *Astractura* but has patagium and double medullary shell. *Eoc.*——Fig. 40,*3*. **S. quaternaria,* Eoc., Barbados, ×133 (37).

Trigonactura Hkl., 1882 [**T. weissmannii* Rüst, 1885]. Like *Hymenactura* but has patagium. *Trias.-Rec.*

T. (Trigonactura) [=*Trigonacturium* Hkl., 1887 (obj.)]. Arms distally blunt or truncate; without terminal spine. *Trias.-Rec.*

T. (Trigonactinium) Hkl., 1887 [**T. triacantha;* SD herein]. Arms distally with radial spine. *Eoc.-Rec.*——Fig. 40,*6*. **T. (T.) triacantha,* Rec., ×150 (42).

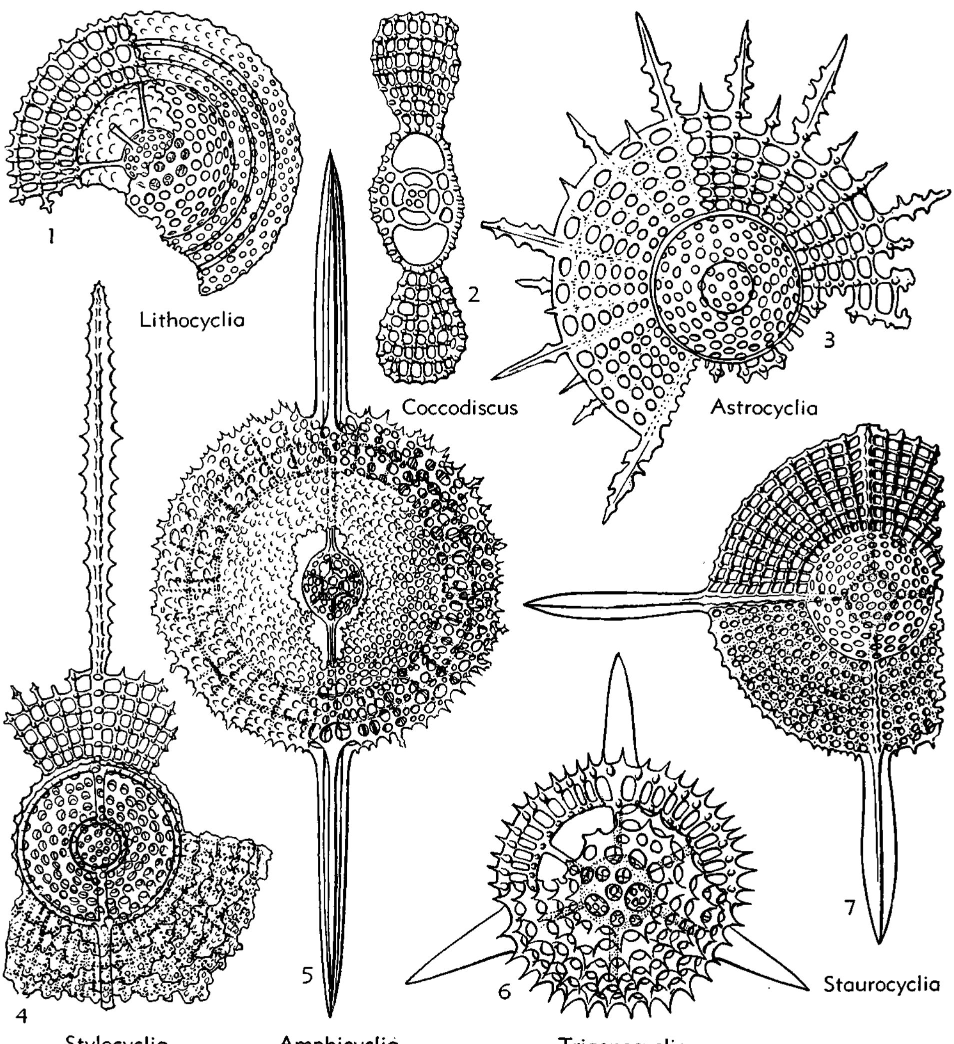


Fig. 39. Coccodiscidae (p. D82).

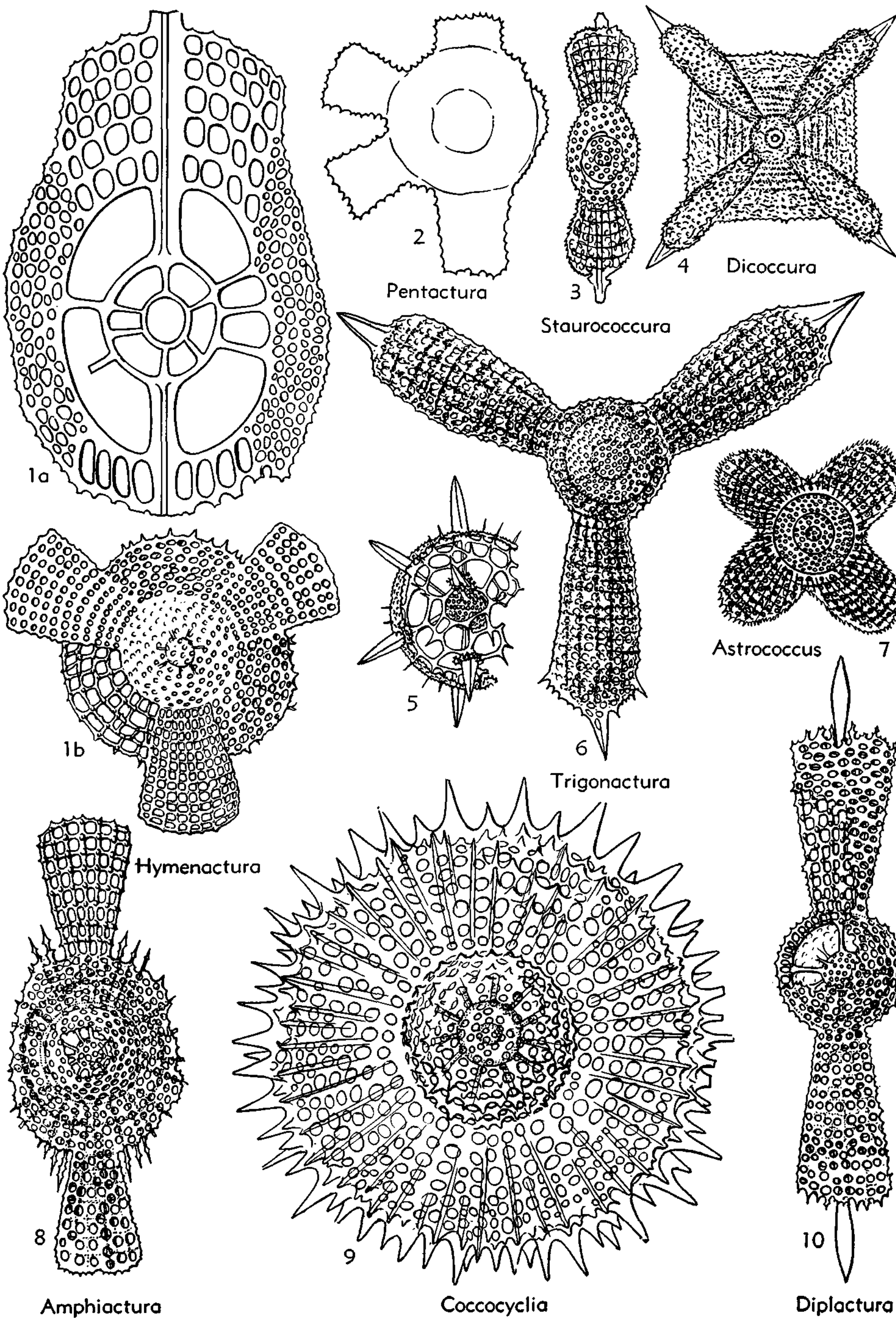


FIG. 40. Coccodiscidae (p. D82-D84). FIG. 40,5 is *Cromyechinus* sp. (p. D66).

Subsuperfamily EUCHITONIILAE Haeckel, 1887

[*ex* Euchitonida; emend. CAMPBELL, herein] [=Cyclodiscaria HKL., 1887]

Lenticular latticed shell wanting. *Cam.-Rec.*

Family EUCHITONIIDAE Haeckel, 1887

[as Euchitonida; emend. CAMPBELL, herein] [=Calidictya EHR., 1847 *(partim)*; Trematodiscida HKL. 1862; Discospirida HKL., 1882; Porodiscida HKL., 1887; Trematodiscidae FRIZZELL, 1951]

Flat disc-shaped shell with a simple central chamber surrounded by concentric rings which are divided by radial beams; porous sieve-plate covers disc. *Cam.-Rec.*

Subfamily EUCHITONIINAE Haeckel, 1887

[as Euchitonida *(partim)*; emend. CAMPBELL, herein]

Two to 4 (rarely 5 or 6) chambered or spongy arms in equatorial plane; with or without patagium. *Dev.-Rec.*

Euchitonia EHR., 1860 [**E. furcata* EHR., 1872]. Three undivided chambered arms; with a patagium; shell bilateral. *Cret.-Rec.*

E. (Euchitonia) [=*Stylactis* EHR., 1872 (obj.); *Styla* Stechow, 1921]. Arms blunt, without distal spine. *Cret.-Rec.*——FIG. 41,*2a*. *E. (E.) lanceolata* HKL., Rec., ×100 (42).

E. (Pteractis) EHR., 1872 [**Pteractis elegans*]. Arms distally with spine. *Rec.*——FIG. 41,*2b*. *E. (P.) carina* HKL., Rec., ×200 (42).

Amphibrachium HKL., 1882 [**A. diminutum* RÜST, 1885]. Two undivided opposite arms; no patagium. *Dev.-Rec.*

A. (Amphibrachium) [=*Amphibrachella* HKL., 1887 (obj.)]. Arms similar, distally blunt; no terminal spine. *Dev.-Rec.*

A. (Amphibrachidium) HKL., 1887 [**A. amphilonche;* SD herein]. Arms similar; with terminal spine. *Rec.*——FIG. 41,*5*. *A. (A.) dilatatum* HKL., Rec., ×50 (42).

A. (Amphibrachoma) HKL., 1887 [**A. indicum*]. Arms dissimilar; no terminal spine. *Rec.*

A. (Amphibrachura) HKL., 1887 [**A. clavula*]. Arms dissimilar; with terminal spine. *Rec.*

Amphicraspedium HKL., 1882 [**A. maclaganium* HKL., 1887]. Two forked opposite arms; with patagium. *Rec.*

A. (Amphicraspedium) [=*Amphicraspedon* HKL. 1887 (obj.)]. Arms similar; no terminal spine. ——FIG. 42,*1*. **A. (A.) maclaganium,* Rec., ×100 (42).

A. (Amphicraspedina) HKL., 1887 [**A. wyvilleanum*]. Arms dissimilar; no terminal spine.

A. (Amphicraspedula) HKL., 1887 [**A. murrayanum* (=*Amphimenium murrayanum* HKL., 1887)]. Arms dissimilar; with terminal spine.

Amphimenium HKL., 1882 [**A. zygartus* HKL., 1887]. Like *Ommatogramma* but patagium incomplete. *Eoc.-Rec.*——FIG. 41,*9*. **A. zygartus,* Rec., ×200 (42).

Amphirrhopalum HKL., 1887 [**A. ximorphum*] [=*Amphirhopalum* HKL., 1882 (obj.)]. Like *Amphibrachium* but has one or more distally forked arms; without patagium. *Rec.*

A. (Amphirrhopalum) [=*Amphirrhopalium* HKL., 1887]. Without terminal spine.

A. (Amphirrhopella) HKL., 1887 [**A. echinatum;* SD herein]. With terminal spine.——FIG. 42,*3*. **A. (A.) echinatum,* Rec., ×200 (42).

Chitonastrum HKL., 1882 [**S. triglochin* HKL., 1887]. Three distally forked arms; no patagium. *Cret.-Rec.*

C. (Chitonastrum) [=*Chitonastrella* HKL., 1887 (obj.)]. Arms similar. *Cret.-Rec.*

C. (Chitonastromma) HKL., 1887 [**C. jugatum;* SD herein (=*Dictyastrum jugatum* HKL., 1887)]. *Rec.*——FIG. 43,*4*. *C. (C.) lyra* HKL., Rec., ×100 (42).

Cyclastrum RÜST, 1898 [**C. infundibuliforme*]. Like *Chitonastrum* but has patagium. *Cret.*——FIG. 41,*10*. **C. infundibuliforme*. Cret., Cittiglio., ×300 (51).

Dicranastrum HKL., 1882 [**D. furcatum* HKL., 1887] [=*Ceratastrum* HKL., 1882]. Four bifurcate crossed arms; square shell. *Cret.-Rec.*

D. (Dicranastrum) [=*Dicranaster* HKL., 1887 (obj.)]. Each cross arm with 2 simple branches. *Cret.-Rec.*

D. (Tetracranastrum) HKL., 1887 [**D. bifurcatum*]. Cross arms with 4 terminal branches. *Rec.*——FIG. 42,*6*. **D. (T.) bifurcatum,* Rec., ×100 (42).

D. (Tricranastrum) HKL., 1882 [**D. wyvillei* (=*Tricranastrum wyvillei* HKL., 1887)]. Each cross arm with 3 terminal branches. *Rec.*

Dictyastrum EHR., 1860 [**D. angulatum* EHR., 1872]. Three undivided arms; without patagium; shell triangular. *Jur.-Rec.*

D. (Dictyastrum) [=*Dictyastrella* HKL., 1887 (obj.)]. Arms blunt; no terminal spine.——FIG. 41,*7*. *D. (D.) hexagonum* HKL., Rec., ×100 (42).

D. (Dictyastromma) HKL., 1887 [**D. trispinosum;* SD herein (=*Rhopalastrum trispinosum* HKL., 1887)]. Arms with terminal spine. *Rec.*

Hagiastrum HKL., 1882 [**H. plenum* RÜST, 1885]. Four crossed undivided arms; with patagium; shell quadrangular. *Jur.-Rec.*

H. (Hagiastrum) [=*Hagiastrella* HKL., 1887 (obj.)]. Both longitudinal arms similar. *Jur.-Rec.*

H. (Hagiastromma) HKL., 1887 [**H. mosis;* SD herein]. Longitudinal arms dissimilar. *Rec.*——FIG. 41,*12*. **H. (H.) mosis,* Rec., ×100 (42).

Hexactura HKL., 1882 [**Hexalastrum palmanthum* HKL., 1887][=*Hexalastrum* HKL., 1887 (obj.)]. Six simple arms; no patagium. *Jur.-Rec.*

H. (Hexactura). Arms similar. *Jur.-Rec.*

H. (Hexalastromma) HKL., 1887 [**H. orchidacea*

HKL., 1887 (=*Hexalastrum orchidaceum* HKL., 1887)]. Arms dissimilar. *Rec.*——FIG. 41,*8*. **H. (H.) orchidacea,* Rec., ×50 (42).

Hexinastrum HKL., 1882 [**H. geryonidum* HKL., 1887]. Like *Hexactura* but has patagium. *Rec.*

Histiastrum EHR., 1847. [**H. quaternarium* EHR., 1875]. Like *Stauralastrum* but has patagium. *Cret.-Rec.*

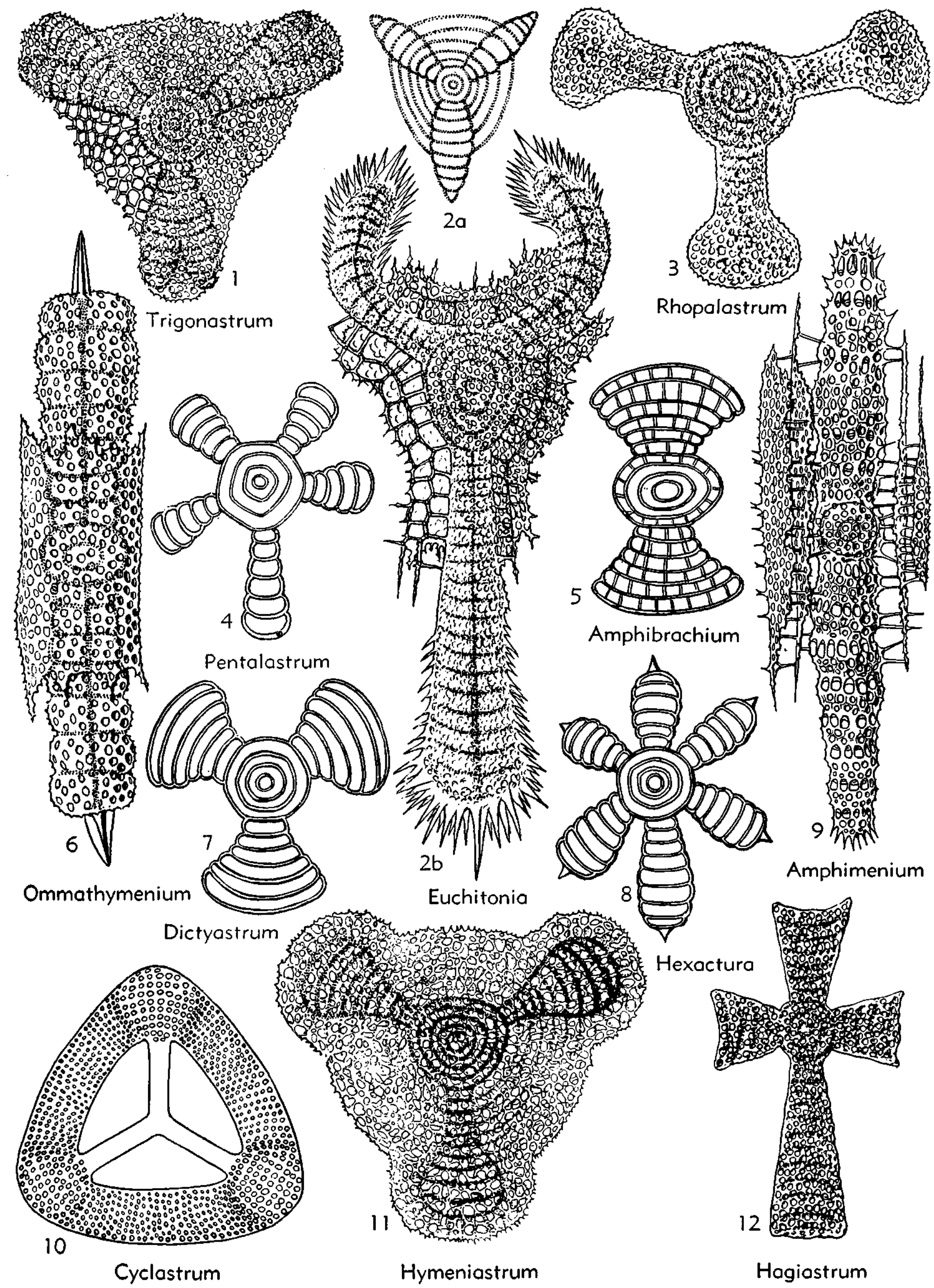


FIG. 41. Euchitoniidae (p. D86-D88).

H. (Histiastrum) [=*Histiastromma* HKL., 1887 (obj.)]. Arms distally spiny. *Cret.-Rec.*——FIG. 43,*5b*. *H. (H.) boseanum* HKL., 1887, Rec., ×200 (42).

H. (Histiastrella) HKL., 1887 [**H. quadrigatum*; SD herein]. Arms distally blunt. *Eoc.-Rec.*——FIG. 43,*5a*. *H. (H.) velastum* HKL., Rec., ×100 (42).

Hymeniastrum EHR., 1847 [**H. pythagorae*]. Like *Euchitonia* but has regular triangular shell. *Jur.-Rec.*

H. (Hymeniastrum) [=*Hymeniastrella* HKL., 1887 (obj.)]. Arms blunted. *Jur.-Rec.*——FIG. 41,*11*. *H. (H.) euclidis* HKL., Rec., ×150 (42).

H. (Hymeniastromma) HKL., 1887 [**Histiastrum ternarium* EHR., 1875]. Arms with distal radial spines. *Eoc.-Rec.*

Myelastrum HKL., 1882 [**M. medullare* HKL., 1887]. Like *D. (Tricranastrum)* but has 2-fold differentiation of arms. *Cret.-Rec.*

M. (Myelastrum) [=*Myelastrella* HKL., 1887 (obj.)]. Anterior arms lobate or cleft. *Cret.-Rec.*

M. (Myelastromma) HKL., 1887 [**M. octocorne*; SD herein]. All 4 arms lobate or cleft. *Rec.*——FIG. 42,*5*. **M. octocorne*, Rec., ×50 (42).

Ommathymenium HKL., 1887 [**Amphimenium amphistylium*; SD herein]. Two opposite similar arms distally with terminal spine; incomplete patagium. *Rec.*——FIG. 41,*6*. **O. amphistylium*, Rec., ×200 (42).

Ommatogramma EHR., 1860 [**O. naviculare* EHR., 1872]. Like *Ommathymenium* but patagium complete. *Rec.*——FIG. 42,*4*. **O. naviculare*, Rec., ×200 (41).

Pentalastrum HKL., 1882 [**P. asteracanthion* HKL., 1887]. Five undivided arms; no patagium. *Jur.-Rec.*

P. (Pentalastrum) [=*Pentalastrella* HKL., 1887 (obj.)]. All arms similar. *?Carb., Jur.-Rec.*

P. (Pentalastromma) HKL., 1887 [**P. ophidiaster*; SD herein]. Arms dissimilar. *Rec.*——FIG. 41,*4*. **P. (P.) ophidiaster*, Rec., ×100 (42).

Pentinastrum HKL., 1882 [**P. asteriscus* HKL., 1887]. Like *Pentalastrum* but has patagium. *Rec.*——FIG. 43,*6*. **P. asteriscus*, Rec., ×200 (42).

Pentophiastrum HKL., 1887 [**P. dicranastrum*; SD herein]. Like *Pentinastrum* but arms ramified. *Rec.*

P. (Pentophiastrum). Arms similar.

P. (Pentophiastromma) HKL., 1887 [**P. caudatum*; SD herein]. Arms dissimilar.——FIG. 42,*7*. **P. (P.) caudatum*, Rec., ×50 (42).

Rhopalastrum EHR., 1847 [**R. lagenosum*]. Like *Dictyastrum* but bilateral. *Jur.-Rec.*

R. (Rhopalastrum) [=*Rhopalastrella* HKL., 1887 (obj.)]. Arms blunt. *Jur.-Rec.* ——FIG. 41,*3*. **R. (R.) malleus* HKL., Rec., ×100 (42).

R. (Rhopalastromma) HKL., 1887 [**R. triceros*; SD herein]. Arms spiny. *Rec.*

Stauralastrum HKL., 1887 [**S. cruciforme*; SD herein]. Four undivided arms; no patagium; shell quadrangular. *Eoc.-Rec.*

S. (Stauralastrum) [=*Stauralastrella* HKL., 1887 (obj.)]. Arms blunt. *Rec.*

S. (Stauralastromma) HKL., 1887 [**S. rhopalophorum*; SD herein (=*Hagiastrum rhopalophorum* HKL., 1887)]. Arms spiny. *Eoc-Rec.*——FIG. 43,*2*. **S. rhopalophorum* Rec., ×150 (42).

Stephanastrum EHR., 1847 [**S. rhombus* EHR., 1854]. Four undivided arms; patagium with 4 large interbrachial openings (patagial girdles). *Eoc.-Rec.*

S. (Stephanastrum) [=*Stephanastromma* HKL., 1887 (obj.)]. Arms all similar. *Eoc.-Rec.*

S. (Stephanastrella) HKL., 1887 [**S. quadratum*; SD herein]. Two opposite arms larger than 2 cross arms. *Rec.*——FIG. 42,*2*. **S. (S.) quadratum* Rec., ×100 (42).

Tessarastrum HKL., 1887 [**T. straussii*; SD herein]. Like *Histiastrum* but symmetrically bilateral. *Cret.-Rec.*

T. (Tessarastrum) [=*Tessarastrella* HKL., 1887 (obj.)]. Principal arms similar. *Cret.-Rec.*——FIG. 43,*1*. **T. (T.) straussii*, Rec., ×200 (42).

T. (Tessarastromma) HKL., 1887 [**T. democriti*]. Principal arms dissimilar. *Rec.*

Trigonastrum HKL., 1887 [**T. regulare*; SD herein]. Like *Chitonastrum* but has 3 forked arms and a patagium. *Rec.*

T. (Trigonastrum) [=*Trigonastrella* HKL., 1887 (obj.)]. Arms similar.——FIG. 41,*1*. **T. (T.) regulare*, Rec., ×100 (42).

T. (Trigonastromma) HKL., 1887 [**T. gegenbauri*; SD herein]. One arm different in size or form.

Subfamily ARCHIDISCINAE Haeckel, 1887
[as Archidiscida; emend. CAMPBELL, herein]

Single chambered girdle surrounds central chamber. *Jur.-Rec.*

Archidiscus HKL., 1887 [**A. dioniscus*; SD herein]. Shell margin smooth. *Jur.-Rec.*

A. (Archidiscus) [=*Dioniscus* HKL., 1887 (obj.)]. Ring with 2 chambers. *Jur.-Rec.*

A. (Hexoniscus) HKL., 1887 [**A. hexoniscus*; SD herein]. Ring with 6 chambers. *Rec.*

A. (Pentoniscus) HKL., 1887 [**A. pentoniscus*]. Ring with 5 chambers. *Rec.*

A. (Tetroniscus) HKL., 1887 [**A. stauroniscus*; SD herein]. Ring with 4 chambers. *Rec.*——FIG. 43,*3*. **A. stauroniscus*, Rec., ×400 (42).

A. (Trioniscus) HKL., 1887 [**A. trioniscus*; SD herein]. Ring with 3 chambers. *Rec.*

Axodiscus HKL., 1887 [**A. stylophorus*; SD herein]. Like *Archidiscus* but margin armed with spines. *Rec.*

Subfamily FLUSTRELLINAE Campbell, nom. nov.
[*pro* Trematodiscida HKL., 1862]

Central chamber has 2 or more (commonly 3 to 6) concentric chambered rings; shell margin without radial appendages. *Cam.-Rec.*

Flustrella Ehr., 1838 [*non* Gray, 1848, *nec* d'Orb., 1852] [**F. concentrica*] [=*Porodiscus* Hkl., 1882 (obj.)]. Shell margin simple; without equatorial girdle. *Cam.-Rec.*

F. (Flustrella) [=*Trematodiscus* Hkl., 1860 (obj.)]. Rings all concentric. *Cam.-Rec.*——Fig. 44,2c. *F. (F.) flustrella* Hkl., Rec., ×200 (42).

F. (Atactodiscus) Hkl., 1882 [**Atactodiscus liasicus* Rüst, 1885] [=*Perispongidium* Hkl., 1882 (obj.)]. Rings more or less irregular. *Jur.-Rec.*——Fig. 44,2a. *F. (A.) irregularis* Hkl., Rec., ×200 (42).

F. (Centrospira) Hkl., 1882 [**Porodiscus centrospira* Hkl., 1887]. Inner rings spiral; outer ones

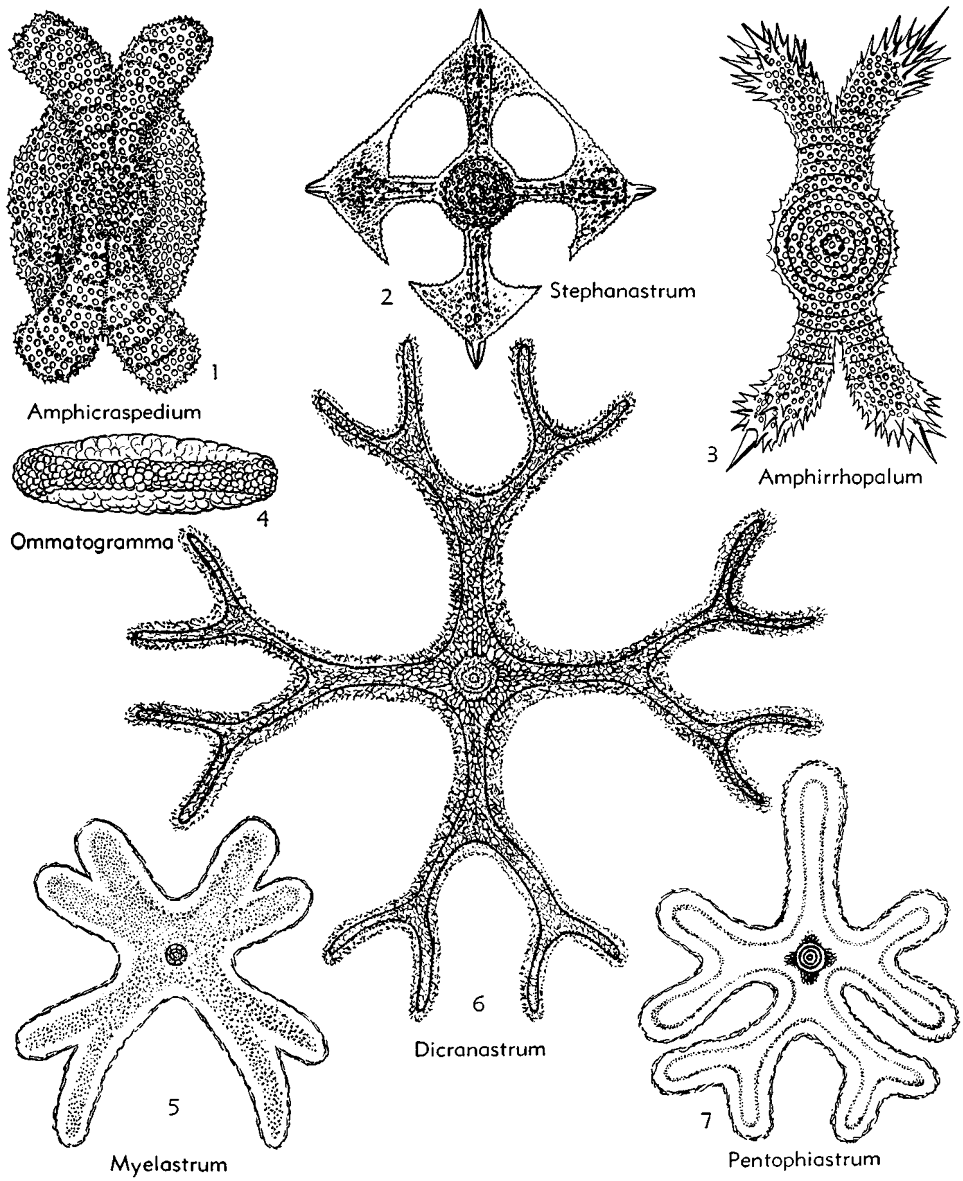


Fig. 42. Euchitoniidae (p. D86-D88).

concentric. *Rec.*——FIG. 44,2*b*. **F. (C.) centrospira,* Rec., ×200 (42).

F. (Discospira) HKL., 1862 [**Discospira helicoides;* SD herein]. All rings spiral. *Eoc.-Rec.* ——FIG. 44,2*e*. *F. (D.) semispiralis* HKL., Rec., ×200 (42).

F. (Perispira) HKL., 1882 [**Porodiscus perispira* HKL., 1887 (=*Perispira perispira* HKL., 1887)]. Inner rings concentric; outer ones spiral. *Rec.* ——FIG. 44,2*d*. **F. (P.) perispira,* Rec., ×200 (42).

Perichlamydium EHR., 1847 [**P. praetextum*].

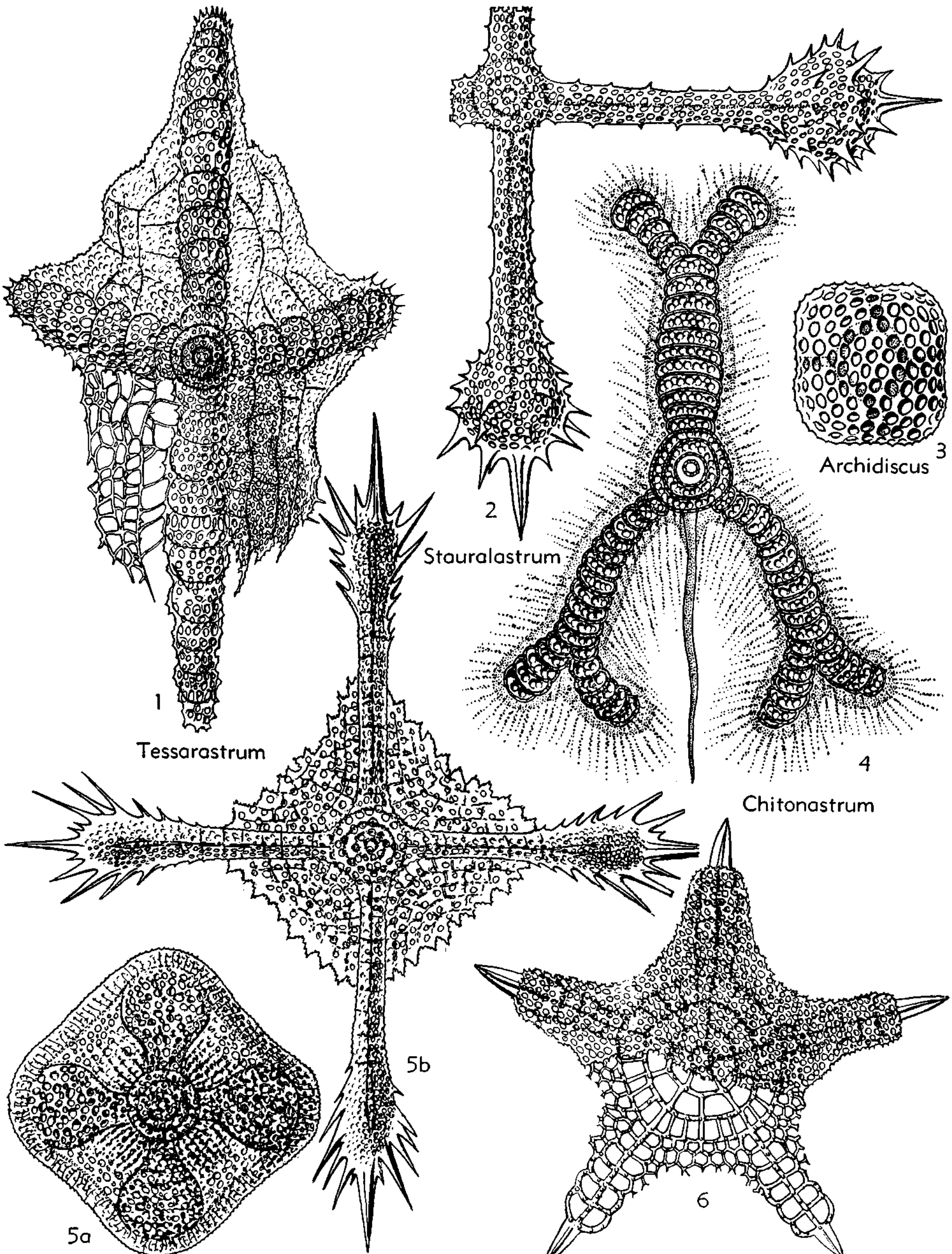


FIG. 43. Euchitoniidae (p. D86-D88).

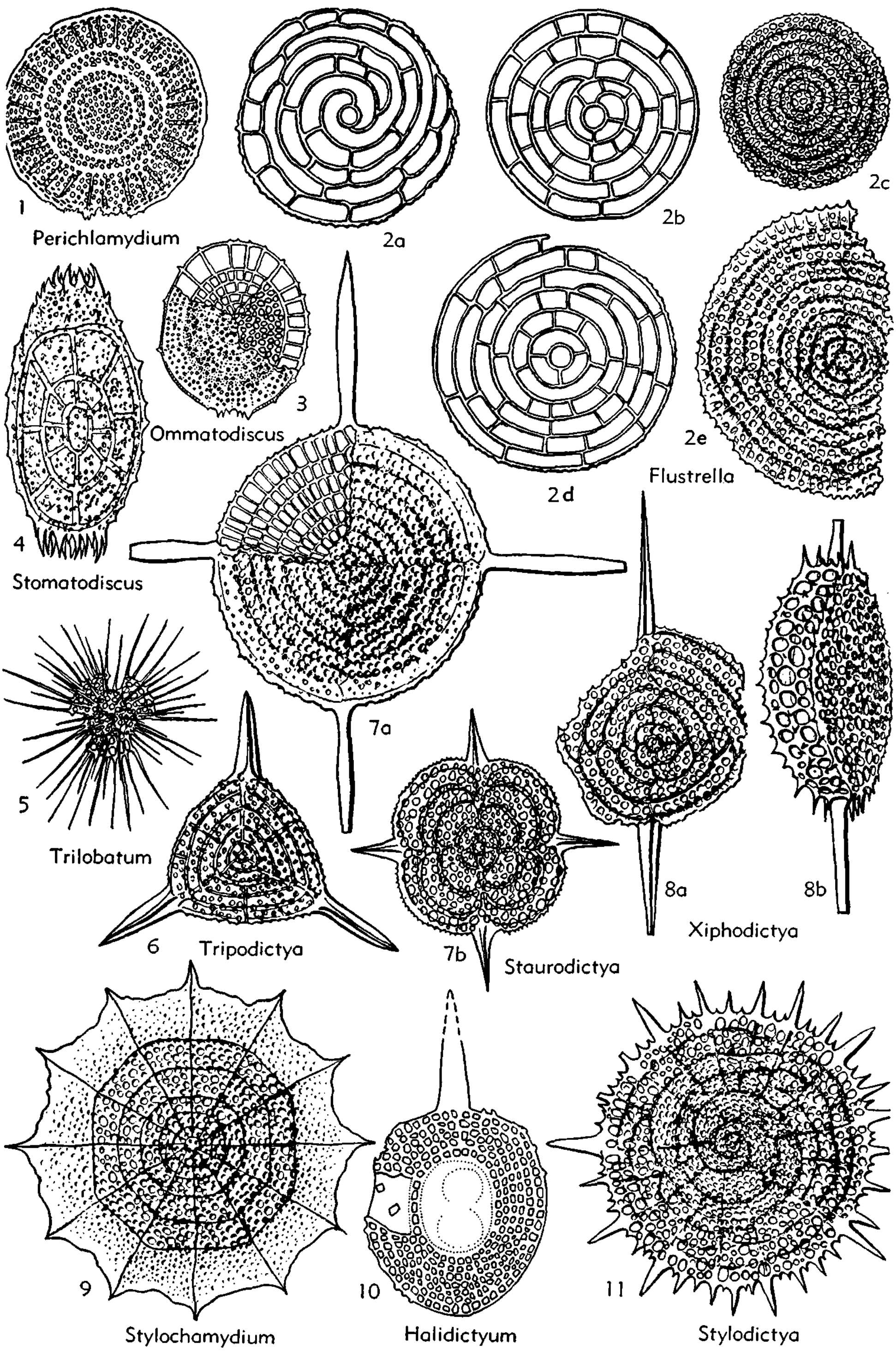


FIG. 44. Euchitoniidae (p. D89-D92).

Smooth shell margin with thin porous equatorial girdle. *Eoc.-Rec.*——FIG. 44,*1*. *P. scutaeforme* C.-CL., Mio., Calif., ×150 (35).

Subfamily OMMATODISCINAE Stöhr, 1880

[as Ommatodiscida; emend. CAMPBELL, herein]

Shell margin without chambered arms; with 1 or 2 large pylomes each armed with a spiny corona. *Paleoc.-Rec.*

Ommatodiscus STÖHR, 1880 [**O. haeckeli;* SD FRIZZELL, 1951]. Disc with 2 pylomes. *Paleoc.-Eoc.-Rec.*

O. (Ommatodiscus) [=*Ommatodisculus* HKL., 1887 (obj.)]. Disc elliptical. *Eoc.-Rec.*——FIG. 44,*3*. *O. (O.) fragilis* STÖHR, Mio., Sicily, ×150 (53).

O. (Ommatodiscinus) HKL., 1887 [**O. decipiens* STÖHR, 1880; SD herein]. Disc circular. *Eoc.-Rec.*

Stomatodiscus HKL., 1887 [**S. osculatus;* SD FRIZZELL, 1951]. Disc with 2 pylomes. *Paleoc.-Rec.*——FIG. 44,*4*. **S. osculatus,* Rec., ×300 (42).

Subfamily STYLODICTYINAE Haeckel, 1882

[as Stylodictyida; emend. CAMPBELL, herein]

Solid radial spines on shell margin. *Permo-Trias.-Rec.*

Stylodictya EHR., 1847 [**S. gracilis* EHR., 1854]. Five or more radial spines. *Jur.-Rec.*

S. (Stylodictya) [=*Stylodictyon* HKL., 1862 (obj.)]. All rings concentric. *Jur.-Rec.*

S. (Stylodictula) HKL., 1887 [**S. perispira;* SD herein]. Rings partly concentric and partly spiral or interrupted. *Eoc.-Rec.*——FIG. 44,*11*. *S. (S.) centrospira* HKL., Rec., ×200 (42).

S. (Stylospira) HKL., 1862 [**S. dujardinii*]. All rings convoluted in simple or double spiral. *Eoc.-Rec.*

Halidictyum ICHIKAWA, 1950 [**H. haeckeli*]. One single radial spine. *Permo-Trias.*——FIG. 44,*10*. **H. haeckeli,* Permo-Trias., Japan, ×75 (45).

Staurodictya HKL., 1882 [**S. beneckei* RÜST, 1885]. Four crossed radial spines. *Jur.-Rec.*

S. (Staurodictya) [=*Staurodictyon* HKL., 1887 (obj.)]. All rings concentric. *Jur.-Rec.*——FIG. 44,*7b*. *S. (S.) medusa* HKL., 1887, Rec., ×200 (42).

S. (Staurospira) HKL., 1887 [**S. cruciata;* SD herein]. Rings partly concentric; partly spiral. *Eoc.-Rec.*——FIG. 44,*7a*. **S. (S.) cruciata,* Rec., ×200 (42).

Stylochamydium HKL., 1882 [**S. asteriscus* HKL., 1887 (=*Perichlamydium asteriscus* HKL., 1887)]. Like *Stylodictya* but has thin porous equatorial girdle. *Eoc.-Rec.*

S. (Stylochlamydium) [=*Stylochlamys* HKL., 1887 (obj.)]. Rings all concentric. *Eoc.-Rec.*——FIG. 44,*9*. **S. (S.) asteriscus,* Rec., ×200 (42).

S. (Stylochlamyum) HKL., 1887 [**S. perispirale;* SD herein]. Rings partly concentric; partly spiral. *Eoc.-Rec.*

Trilobatum POP., 1911 [**T. tribrachium;* SD herein]. Central chamber tripartate-lobular. Rec.——FIG. 44,*5*. **T. tribrachium,* Rec., ×200 (45).

Tripodictya HKL., 1882 [**T. trigonaria* HKL., 1887]. Three equatorial radial spines. *Rec.*——44,*6*. **T. trigonaria,* Rec., ×200 (42).

Xiphodictya HKL., 1882 [**X. teretispinosa* RÜST, 1885]. Two opposite radial spines. *Jur.-Rec.*

X. (Xiphodictya) [=*Xiphodictyon* HKL., 1887 (obj.)]. All rings concentric. *Jur.-Rec.*——FIG. 44,*8b*. *X. (X.) amphibelone* HKL., Rec., ×200 (42).

X. (Xiphospira) HKL., 1887 [**X. staurospira;* SD herein]. All rings partly or completely spiral. *Rec.*——FIG. 44,*8a*. **X. (X.) staurospira,* Rec., ×200 (42).

Family PYLODISCIDAE Haeckel, 1887

[as Pylodiscida; emend. CAMPBELL, herein]
[=Pylonida HKL., 1882 *(partim)*]

Simple spherical central chamber surrounded by 1 or 2 concentric triradial girdles; each girdle with 3 gates separated by 3 simple arm-chambers; surface with 3 gates. *Eoc.-Rec.*

Subfamily PYLODISCINAE Haeckel, 1887

[as Pylodiscida *(partim)*; emend. CAMPBELL, herein]
[=Pylomorphida HKL., 1882 *(partim)*; Hexapylida HKL., 1887]

Six gates between 3 double arm-chambers; no chambered marginal girdle. *Rec.*

Pylodiscus HKL., 1887 [**P. triangularis;* SD herein]. Both faces of 3 outer gates; latticed equatorial girdle.——FIG. 45,*3*. **P. triangularis,* Rec., ×200 (42).

Hexapyle HKL., 1882 [**H. triangula* HKL., 1887]. Like *Pylodiscus* but both faces of 3 outer gates simple.——FIG. 45,*1*. *H. dodecantha* HKL., Rec., ×150 (42).

Pyolena HKL., 1887 [**P. armata;* SD herein]. Three outer gates open.——FIG. 45,*2*. **P. armata,* Rec., ×200 (42).

Subfamily TRIOPYLINAE Haeckel, 1887

[as Triopylida; emend. CAMPBELL, herein]

Three gates between 3 single arms. *Rec.*

Triopyle HKL., 1882 [**T. circulus* HKL., 1887]. Three gates barred by latticed equatorial girdle; gate-faces simple.——FIG. 45,*6*. *T. hexagona* HKL., Rec., ×400 (42).

Triodiscus HKL., 1887 [**T. spinosus;* SD herein]. Like *Triopyle* but gate-faces latticed.——FIG. 45.*7*. **T. spinosus,* Rec., ×400 (42).

Triolena HKL., 1887 [**T. primordialis;* SD herein]. Like *Triopyle* but gates open.——FIG. 45,*5*. **T. primordialis,* Rec., ×600 (42).

Subfamily DISCOPYLINAE Haeckel, 1887

[as Discopylida; emend. CAMPBELL, herein]

Six gates between 3 double arm-chambers; chambered marginal girdle. *Eoc.-Rec.*

Discopyle HKL., 1887 [**D. osculata;* SD herein]. With pylome. *Eoc.-Rec.*——FIG. 45,*4*. *D. elliptica* HKL., Rec., ×200 (42).

Discozonium HKL., 1887 [**D. hexagonium;* SD herein]. Without pylome. *Rec.*——FIG. 45,*8*. **D. hexagonium,* Rec., ×200 (42).

Family SPONGODISCIDAE Haeckel, 1882

[as Spongodiscida; emend. CAMPBELL, herein]

Simple central chamber surrounded by spongy framework; without porous sieve-plate. *Ord.-Rec.*

Subfamily SPONGODISCINAE Haeckel, 1882

[as Spongodiscida *(partim)*; emend. CAMPBELL, herein] [=Spongophacida HKL., 1882]

Simple circular disc without radial spines or chamberd arms. *Dev.-Rec.*

Spongodiscus EHR., 1845 [*non* ZITTEL, 1878] [**S. resurgens*]. Circular disc without equatorial girdle. *Dev.-Rec.*

S. (Spongodiscus) [=*Spongodisculus* HKL., 1887 (obj.)]. Spongy framework lacks spiral convolutions or rings. *Dev.-Rec.*

S. (Annulatospira) CL.-C., 1945 [**S. pulcher*]. Inner part spiral, outer part annular. *Eoc.*

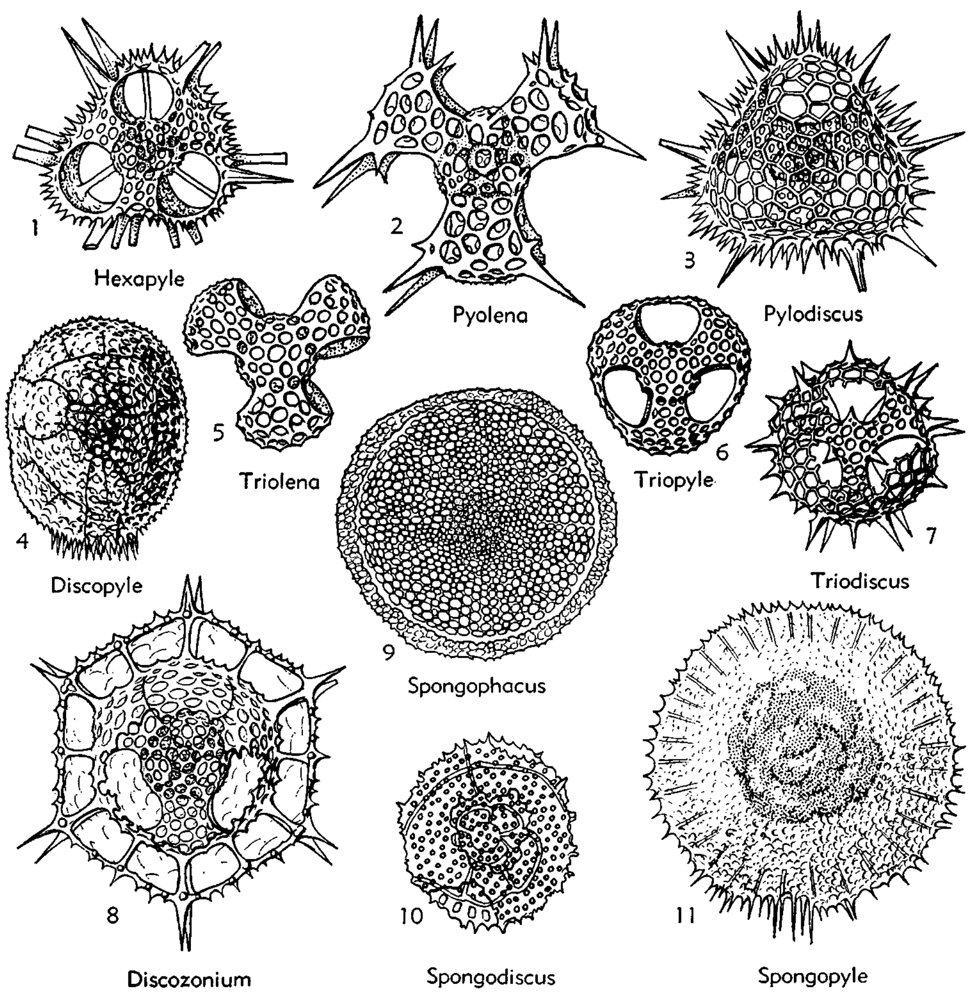


FIG. 45. Pylodiscidae, Spongodiscidae (p. D92-D94).

S. (Spongocyclia) HKL., 1862 [*S. *cycloides;* SD FRIZZELL, 1951]. Inner part with concentric rings, outer part irregular. *Eoc.-Rec.*

S. (Spongospira) STÖHR, 1880 [*S. *florealis*]. Inner part spiral, outer part irregular. *Eoc.-Rec.*——FIG. 45,*10*. *S. *(S.) florealis,* Mio., Sicily, ×150 (53).

Spongophacus HKL., 1882 [*S. *periphaena* HKL., 1887]. Spongy disc with solid or porous equatorial girdle. *Trias.-Rec.*——FIG. 45,*9*. *S. hantkeni* RÜST, Trias., Hungary, ×150 (51).

Subfamily SPONGOPYLINAE Dreyer, 1889

[as Spongopylida; emend. CAMPBELL, herein]

One or more pylomes. *Eoc.-Rec.*

Spongopyle DREYER, 1889 [*S. *setosa;* SD herein]. One pylome. *Eoc.-Rec.*

S. (Spongopyle) [=*Spongopylarium* DREYER, 1889 (obj.)]. Shell generally circular. *Eoc.-Rec.*——FIG. 45,*11*. *S. *setosa,* Rec., ×250 (40).

S. (Spongopylidium) DREYER, 1889 [*S. *ovata;* SD herein]. Shell elliptical or oval. *Rec.*

Subfamily SPONGOTROCHINAE Haeckel, 1882

[as Spongotrochida; emend. CAMPBELL, herein]

Spongy disc with radial spines. *Ord.-Rec.*

Spongotrochus HKL., 1860 [*S. *brevispinus* HKL., 1862]. Five or more (commonly 10) solid equatorial radial spines. *Ord.-Rec.*

S. (Spongotrochus) [=*Spongotrochiscus* HKL., 1862 (obj.)]. Spongy framework everywhere irregular. *Ord.-Rec.*

S. (Stylospongidium) HKL., 1882 [*S. *scutella* HKL., 1887]. Inner part with concentric rings, outer part irregular. *Eoc.-Rec.*——FIG. 46,*1*. *S. (S.) echinodiscus* CL.-C., U.Eoc., Calif., ×120 (39).

Dispongotripus SQUIN., 1903. [*D. *acutispina*]. Triangular shell with 6 radial spines. *Cret.*——FIG. 46,*5*. *D. *acutispina,* Cret., Italy, ×80 (52).

Spongolonche HKL., 1882 [*non Spongolonchis* HKL., 1887][*S. *conostyla* HKL., 1887]. Two opposite radial spines. *Dev.-Rec.*——FIG. 46,*7*. *S. lens* HINDE, Dev., Austral., ×150 (44).

Spongostaurus HKL., 1882 [*S. *cruciatus* HKL., 1887]. Four crossed radial spines. *Jur.-Rec.*——FIG. 46,*2*. *S. circulus* RÜST., L.Jur., Ilsede., ×100 (51).

Spongotripus HKL., 1882 [*S. *regularis* HKL., 1887]. Three radial spines. *Dev.-Rec.*

S. (Spongotripus) [=*Spongotripodiscus* HKL., 1887 (obj.)]. Radial spines similar. *Dev.-Rec.*——FIG. 46,*4*. *S. (S.) morenoensis* C.-CL., Cret., Calif., ×150 (35).

S. (Spongopodium) HKL., 1887 [*S. *ypsilon;* SD herein]. Radial spines dissimilar in size or distance. *Rec.*

Stylospongia HKL., 1862 [*S. *huxleyi*][=*Stylotrochus* HKL., 1862 (obj.), *non idem* SEGUENZA, 1876, *nec* FROMENTEL, 1887]. Like *Spongotrochus* but spines limited to shell margin. *Dev.-Rec.*

S. (Stylospongia). Inner part with concentric rings or spirals. *Cret.-Rec.*——FIG. 46,*3*. *S. (S.) polygonata* C.-CL., Cret., Calif., ×150 (35).

S. (Stylotrochiscus) HKL., 1887 [*Spongotrochus *arachnius* HKL., 1862]. Spongy framework everywhere irregular. *Dev.-Rec.*

Subfamily SPONGOBRACHIINAE Haeckel, 1882

[as Spongobrachida; emend. CAMPBELL, herein]

Spongy disc with spongy radial arms. *Jur.-Rec.*

Spongobrachium HKL., 1882 [*Spongodiscus *ellipticus* HKL., 1860]. Two spongy arms; with patagium. *Cret.-Rec.*——FIG. 46,*11*. *S. divergens* RÜST, Cret., Zilli., ×200 (51).

Dictyocoryne EHR., 1860 [*D. *profunda* EHR., 1872]. Three spongy arms; with patagium. *Jur.-Rec.*

D. (Dictyocoryne) [=*Dictyocorynula* HKL., 1887 (obj.)]. Arms similar. *Jur.-Rec.*——FIG. 46,*6*. *D. (D.) heimi* RÜST, Jur., Urshlau., ×150 (51).

D. (Dictyocorynium) HKL., 1887 [*Spongodiscus *charybdaeus* HKL., 1860]. Arms dissimilar. *Eoc.-Rec.*

Rhopalodictyum EHR., 1860 [*R. *abyssorum* EHR., 1872; SD HKL., 1887]. Like *Dictyocoryne* but lacks patagium. *Trias.-Rec.*

R. (Rhopalodictyum) [=*Rhopalodictya* HKL., 1887 (obj.)]. Three similar arms. *Eoc.-Rec.*——FIG. 46,*8*. *R. (R.) irvinense* C.-CL., Mio., Calif., ×150 (35).

R. (Triactinosphaera) DUNIKOWSKI, 1882 [*T. *zittelii*]. Three arms dissimilar in size or distance. *Trias.-Rec.*

Spongolena HKL., 1887 [*S. *rhopalura;* SD herein] [=*Spongolene* CL.-C., 1942 (obj.)]. Like *Spongobrachium* but lacks patagium. *Cret.-Rec.*——FIG. 46,*9*. *S. lataformis* CL.-C., U.Eoc., Calif., ×120 (39).

Spongaster EHR., 1860 [*S. *tetras* EHR., 1872]. Four spongy arms; with patagium. *Cret.-Rec.*

S. (Spongaster) [=*Spongastrella* HKL., 1887 (obj.)]. Cross of 4 arms regular. *Cret.-Rec.*——FIG. 46,*12*. *S. *(S.) tetras,* Rec., ×200 (41).

S. (Spongastromma) HKL., 1887 [*S. *orthogona;* SD herein]. Cross of 4 arms bilateral or irregular. *Rec.*

Spongasteriscus HKL., 1862 [*S. *quadricornis;* SD herein]. Like *Spongaster* but lacks patagium. *Jur.-Rec.*

S. (Spongasteriscus) [=*Spongasterisculus* HKL., 1887 (obj.)]. Cross of 4 arms bilateral or irregular. *Rec.*

S. (Spongasteriscinus) HKL., 1887 [*S. *ovatus;* SD herein]. Cross of 4 arms regular. *Jur.-Rec.*——FIG. 46,*10*. *S. (S.) cruciferus* CL.-C., U.Eoc., Calif., ×120 (39).

Superfamily LARACARIICAE Haeckel, 1887

[*ex* Laracarida; emend. CAMPBELL, herein]
[=Larcoidea HKL., 1887]

Lentelliptical fenestrated or spongy shell resulting from unequal growth in 3 axes. *Cam.-Rec.*

Family LARACARIIDAE Haeckel, 1887

[as Laracarida; emend. CAMPBELL, herein]

Shell without gates, domes or annular constrictions. *Eoc.-Rec.*

Subfamily LARACARIINAE Haeckel, 1887

[as Laracarida *(partim)*; emend. CAMPBELL, herein]
[=Cenolarcida HKL., 1887]

Cortical shell only. *Rec.*

Laracarium HKL., 1887 [**L. amphistylum;* SD herein]. Surface with radial spines.

Cenolarchus HKL., 1887 [**C. primordialis;* SD herein]. Surface without spines.——FIG. 47,*2*. **C. primordialis,* Rec., ×200 (42).

Subfamily COCCOLARCINAE Haeckel, 1887

[as Coccolarcida; emend. CAMPBELL, herein]

Single medullary shell. *Eoc.-Rec.*

Coccolarcus HKL., 1887 [**C. lentellipsis;* SD herein]. Surface smooth. *Eoc.-Rec.*——FIG. 47,*1*. *C. oviformis* CL.-C., U.Eoc., Calif., ×150 (39).

Larcidium HKL., 1887 [**L. dodecanthum;* SD herein]. Surface with radial spines. *Eoc.-Rec.*——FIG. 47,*4*. **L. dodecanthum,* Rec., ×200 (42).

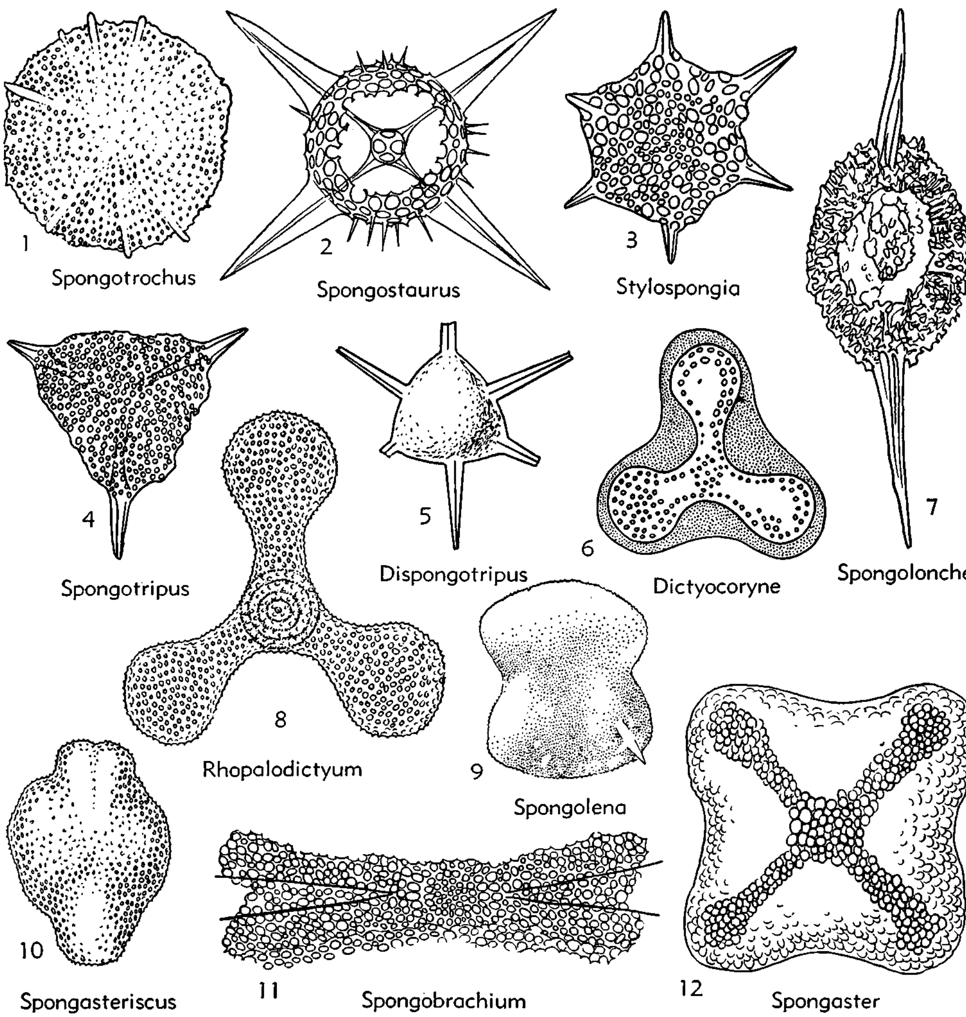


FIG. 46. Spongodiscidae (p. D94).

Subfamily SPONGOLARCINAE Haeckel, 1887
[as Spongolarcida; emend. CAMPBELL, herein]

Shell spongy. *Rec.*

Spongolarcus HKL., 1887 [**S. lentellipsis;* SD herein]. With internal cavity.
Stypolarcus HKL., 1887 [**S. spongiosus*]. Solid shell.

Subfamily LARCOPYLINAE Dreyer, 1889
[as Larcopylida; emend. CAMPBELL, herein]

With pylome. *Rec.*

Larcopyle DREYER, 1889 [**L. bütschlii*].——FIG. 47,*3*. **L. bütschlii,* Rec., ×250 (40).

Family LARNACILLIDAE Haeckel, 1887
[as Larnacillida; emend. CAMPBELL, herein]
[=Larnacida HKL., 1887]

Shell with open gates or annular constrictions; medullary shell trizonal. *Paleoc.-Rec.*

Subfamily LARNACILLINAE Haeckel, 1887
[as Larnacillida *(partim);* emend. CAMPBELL, herein]

Medullary shell single. *Rec.*

Larnacilla HKL., 1887 [**L. typus*]. Surface smooth. ——FIG. 47,*7*. **L. typus,* Rec., ×200 (42).
Larnacidium HKL., 1887 [**L. staurobelonium;* SD herein]. Surface spiny.

Subfamily LARNACALPIDINAE Haeckel, 1887
[as Larnacalpida; emend. CAMPBELL, herein]

Medullary shell double. *Paleoc.-Rec.*

Larnacalpis HKL., 1887 [**L. lentellipsis;* SD FRIZZELL, 1951]. Surface smooth. *Paleoc.-Rec.*——FIG. 47,*6*. **L. lentellipsis,* Rec., ×200 (42).
Larnacantha HKL., 1887 [**L. hexacantha;* SD herein]. Shell spiny. *Mio.-Rec.*——FIG. 47,*5*. **L. hexacantha,* Rec., ×200 (42).
Larnacoma HKL., 1887 [**L. lentellipticum;* SD herein]. Double cortical shell smooth. *Rec.*
Laracospongus HKL., 1887 [**L. larnacillifer;* SD herein]. Spongy cortical shell without spines. *Rec.*
Larnacostupa HKL., 1887 [**L. octacantha;* SD herein]. Spongy cortical shell with spines. *Rec.*

Subfamily CENOLARCOPYLINAE Campbell, nov.

One single pylome. *Plio.*

Cenolarcopyle TAN, 1931 [**C. fragilis*]. *Plio.,* Rotti.

Family PYLONIIDAE Haeckel, 1882
[as Pylonida; emend. CAMPBELL, herein]

Cortical shell latticed; with 2 to 4 or more symmetrically disposed gates. *Jur.-Rec.*

Subfamily PYLONIINAE Haeckel, 1882
[as Pylonida *(partim);* emend. CAMPBELL, herein]
[=Diplozonaria HKL., 1887]

Two systems of concentric girdles. *Rec.*

Pylonium HKL., 1882 [**P. circozonium* HKL., 1887]. Cortical shell with 3 perfect girdles.
P. (Pylonium) [=*Pylonissa* HKL., 1887 (obj.)]. Shell without large symmetrically disposed spines.
P. (Pylonura) HKL., 1887 [**P. quadricorne;* SD herein]. Shell arms with large spines.——FIG. 47,*14*. **P. (P.) quadricorne,* Rec., ×200 (42).
Amphipyle HKL., 1882 [**A. aceros* HKL., 1887]. Shell with only one perfect girdle.
A. (Amphipyle) [=*Amphipylissa* HKL., 1887 (obj.)]. Shell without large symmetrically disposed spines.
A. (Amphipylura) HKL., 1887 [**A. tetraceros;* SD herein]. Shell armed with large spines.——FIG. 47,*16*. **A. (A.) tetraceros,* Rec., ×200 (42).
Octopyle HKL., 1882 [**O. ovulina* HKL., 1887]. Shell with 2 perfect girdles; 4 gates bisected by sagittal septum.
O. (Octopyle) [=*Octopylissa* HKL., 1887 (obj.)]. Shell without large symmetrically disposed spines.
O. (Octopylura) HKL., 1887 [**O. stenozona;* SD herein]. Shell armed with large spines.——FIG. 47,*13*. *O. (O.) sexangulata* HKL., Rec., ×150 (42).
Tetrapyle MÜLLER, 1858 [**T. octacantha*][=*Schizomma* EHR., 1860 (obj.)]. Like *Octopyle* but gates simple.
T. (Tetrapyle) [=*Tetrapylura* HKL., 1887 (obj.)]. Shell armed with large symmetrically disposed spines.
T. (Tetrapylissa) HKL., 1887 [**T. circularis;* SD herein]. Shell without large spines.——FIG. 47,*15*. **T. (T.) circularis,* Rec., ×200 (42).

Subfamily MONOZONIINAE Campbell, nov.
[=Haplozonaria HKL., 1887]

One perfect system of girdles. *Jur.-Rec.*

Monozonium HKL., 1887 [**M. primordiale;* SD herein]. One transverse girdle. *Rec.*
M. (Monozonium) [=*Monozonaris* HKL., 1887 (obj.)]. Shell smooth.——FIG. 47,*9*. *M. (M.) alatum* HKL., Rec., ×300 (42).
M. (Monozonites) HKL., 1887 [**M. pleurostylum;* SD herein]. Shell with large spines.
Dizonium HKL., 1887 [**D. circulare;* SD herein]. Two crossed latticed girdles. *Jur.-Rec.*
D. (Dizonium) [=*Dizonaris* HKL., 1887 (obj.)]. Shell smooth. *Jur.-Rec.*
D. (Dizonites) HKL., 1887 [**D. pleuracanthum;* SD herein]. Shell with large spines. *Rec.*——FIG. 47,*11*. **D. (D.) pleuracanthum,* Rec., ×300 (42).
Echinosphaera HERTWIG, 1879 [**E. datura*][=*Trizonium* HKL., 1887 (obj.)]. Three girdles. *Rec.*
E. (Echinosphaera) [=*Trizonites* HKL., 1887 (obj.)]. Shell with large symmetrically disposed spines.
E. (Trizonaris) HKL., 1887 [**Trizonium tricinc-*

tum; SD herein]. Shell without large spines. ——FIG. 47,*8*. **E.* (*T.*) *tricincta,* Rec., ×300 (42).

Subfamily TETRAPYLONIINAE Campbell, nov. [=Triplozonaria HKL., 1887]

Three concentric systems of fenestrated girdles. *Jur.-Rec.*

Tetrapylonium HKL., 1887 [**T. pantellipticum;* SD herein]. Outer cortical shell with 3 perfect girdles. *Jur.-Rec.*——FIG. 47,*10*. *T. quadrangulare* HKL., Rec., ×150 (42).

Amphipylonium HKL., 1882 [**A. semilunare* HKL., 1887]. One perfect girdle. *Rec.*

Pylozonium HKL., 1887 [**P. octacanthum;* SD herein]. Three perfect girdles. *Rec.*——FIG. 47,*12*. **P. octacanthum,* Rec., ×150 (42).

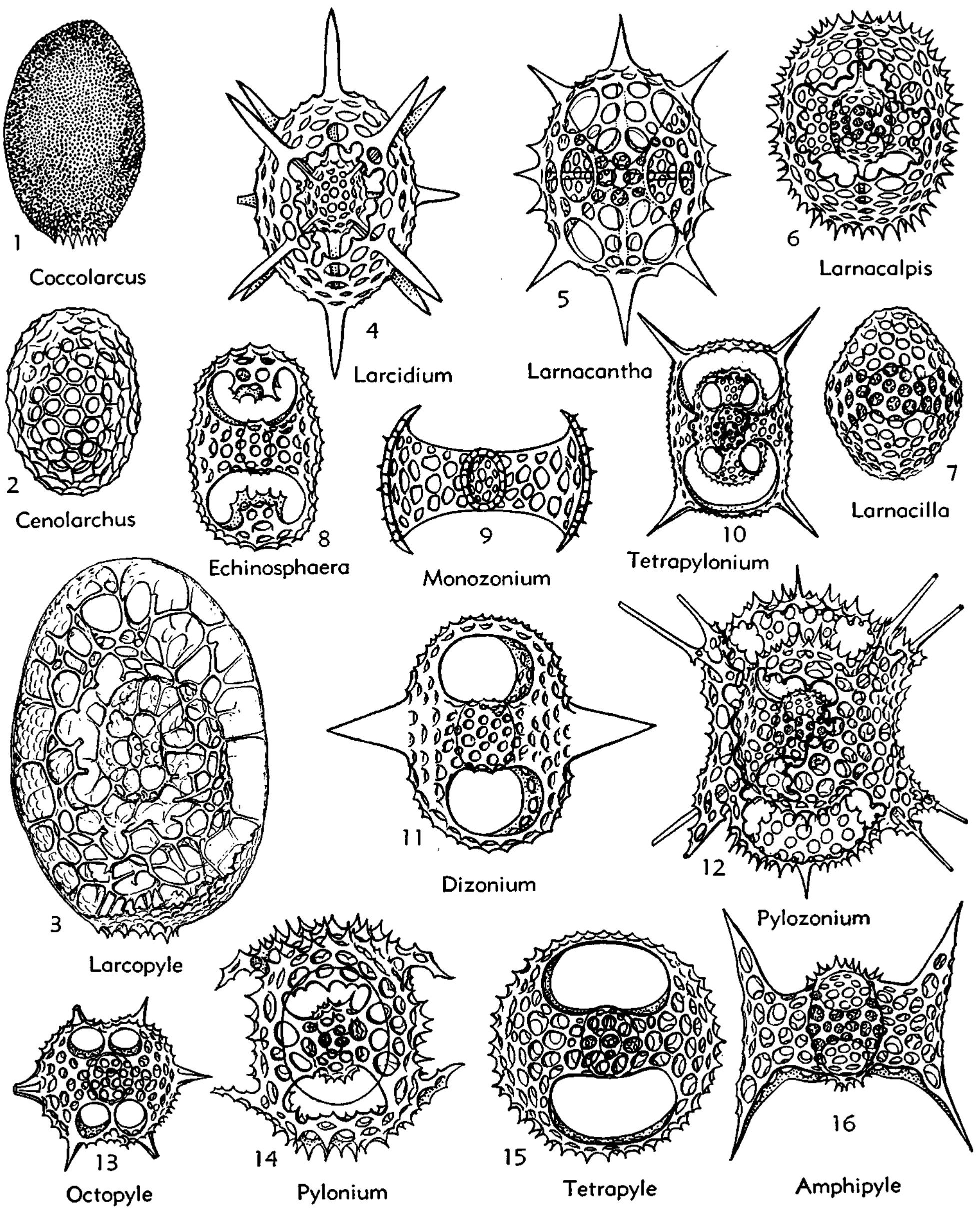


FIG. 47. Laracariidae, Pyloniidae (p. D95, D96).

Family THOLONIIDAE Haeckel, 1887

[as Tholonida; emend. CAMPBELL, herein]

Cortical shell with 2 to 4 or more annular constrictions separated by 3 to 6 or more cupolas; constrictions in diagonal planes, cupolas in dimensive axes. *Rec.*

Subfamily THOLONIINAE Haeckel, 1887

[as Tholonida *(partim)*; emend. CAMPBELL, herein] [=Cubotholida HKL., 1887]

Cupolas developed in direction of 3 axes. *Rec.*

Tholonium HKL., 1887 [**T. bicubicum;* SD herein]. Like *Tholocubus* but has 6 double cupolas.

T. (Tholonium) [=*Tholonetta* HKL., 1887 (obj.)]. Without radial spines or thorns.

T. (Tholonilla) HKL., 1887 [**T. hexonium;* SD herein]. With radial spines or thorns.——FIG. 48,*1*. **T. (T.) hexonium,* Rec., ×200 (42).

Cubotholus HKL., 1887 [**C. regularis;* SD herein]. Central chamber with medullary shell; 6 simple cupolas.

C. (Cubotholus) [=*Cubotholissa* HKL., 1887 (obj.)]. Without spines or thorns.——FIG. 48,*3*. **C. (C.) regularis,* Rec., ×200 (42).

C. (Cubotholura) HKL., 1887 [**C. octoceras*]. With radial spines or thorns.

Cubotholonium HKL., 1887 [**C. ellipsoides*] [=*Tholothauma* HKL., 1887 (obj.)]. Like *Cubotholus* but has 6 double cupolas.——FIG. 48,*4*. **C. ellipsoides,* Rec., ×150 (42).

Tholocubus HKL., 1887 [**T. tesselatus;* SD herein]. Without medullary shell; 6 simple cupolas.

T. (Tholocubus) [=*Tholocubulus* HKL., 1887 (obj.)]. Without radial spines or thorns.——FIG. 48,*2*. *T. (T.) tessellatus,* Rec., ×200 (42).

T. (Tholocubitus) HKL., 1887 [**T. tessaralis*]. With radial spines or thorns.

Subfamily AMPHITHOLINAE Haeckel, 1887

[as Amphitholida; emend. CAMPBELL, herein]

Cupolas developed only in direction of a single axis. *Rec.*

Amphitholus HKL., 1887 [**A. artiscus;* SD herein]. Central chamber with medullary shell; 2 simple cupolas.

A. (Amphitholus) [=*Amphitholissa* HKL., 1887 (obj.)]. Without radial spines or thorns.——FIG. 48,*9*. **A. (A.) artiscus,* Rec., ×200 (42).

A. (Amphitholura) HKL., 1887 [**A. acanthometra;* SD herein]. With radial spines or thorns.

Amphitholonium HKL., 1887 [**A. tricolonium;* SD herein]. Like *Amphitholus* but has 2 double cupolas.——FIG. 48,*6*. **A. tricolonium,* Rec., ×150 (42).

Tholartus HKL., 1887 [**T. tricolus;* SD herein]. Central chamber without medullary shell; 2 simple cupolas.

T. (Tholartus) [=*Tholartella* HKL., 1887 (obj.)]. Without radial spines.——FIG. 48,*7*. **T. (T.) tricolus,* Rec., ×200 (42).

T. (Tholartissa) HKL., 1887 [**T. tripanis;* SD herein]. With radial spines or thorns.

Tholodes HKL., 1887 [**T. cupola*]. Like *Tholartus* but has 2 double cupolas.——FIG. 48,*10*. **T. cupola,* Rec., ×250 (42).

Subfamily STAUROTHOLINAE Haeckel, 1887

[as Staurotholida; emend. CAMPBELL, herein]

Cupolas developed in direction of 2 axes. *Rec.*

Staurotholus HKL., 1887 [**S. quadratus;* SD herein]. Central chamber with medullary shell; 4 simple cupolas.

S. (Staurotholus) [=*Staurotholissa* HKL., 1887 (obj.)]. Without radial spines.

S. (Staurotholura) HKL., 1887 [**S. tetrastylus;* SD herein]. With radial spines.——FIG. 48,*8*. **S. (S.) tetrastylus,* Rec., ×200 (42).

Staurotholonium HKL., 1887 [**S. biquadratum;* SD herein]. Like *Staurotholus* but has 4 double cupolas.

S. (Staurotholonium) [=*Staurotholodes* HKL., 1887 (obj.)]. Without radial spines.

S. (Staurotholoma) HKL., 1887 [**S. octodoronium;* SD herein]. Surface spiny or thorny.——FIG. 48,*12*. **S. (S.) octodoronium,* Rec., ×150 (42).

Tholoma HKL., 1887 [**T. quadrigeminum;* SD herein]. Like *Tholostaurus* but has 4 double cupolas.

T. (Tholoma) [=*Tholomantha* HKL., 1887 (obj.)]. Without radial spines.——FIG. 48,*5*. **T. (T.) quadrigeminum,* Rec., ×200 (42).

T. (Tholomura) HKL., 1887 [**T. metallasson*]. With radial spines.

Tholostaurus HKL., 1887 [**T. quadrigatus;* SD herein]. Central chamber without medullary shell; 4 simple cupolas.

T. (Tholostaurus) [=*Tholostaurantha* HKL., 1887 (obj.)]. Without radial spines.

T. (Tholostauroma) HKL., 1887 [**T. tetrabelonis;* SD herein]. With radial spines or thorns.

Family ZONARIIDAE Haeckel, 1887

[as Zonarida; emend. CAMPBELL, herein]

Annular constrictions in dimensive axes 2 or more; cupolas in diagonal axes. *Rec.*

Zonarium HKL., 1887 [**Z. octangulum;* SD herein]. Two rings; 4 cupolas.—— FIG. 48,*11*. **Z. octangulum,* Rec., ×200 (42).

Zonidium HKL., 1887 [**Z. octotholium;* SD herein]. Four rings; 8 cupolas.——FIG. 48,*13*. **Z. octotholium,* Rec., ×200 (42).

Zoniscus HKL., 1887 [**Z. tetracanthus;* SD herein]. Three rings; 6 cupolas.——FIG. 48,*14*. **Z. tetracanthus,* Rec., ×200 (42).

Family LITHELIIDAE Haeckel, 1862

[as Lithelida; emend. CAMPBELL, herein]

Planispiral cortical shell. *Dev.-Rec.*

Subfamily LITHELIINAE Haeckel, 1862

[as Lithelida *(partim)*; emend. CAMPBELL, herein] [=Spireuma HKL., 1882; Spiremida HKL., 1887]

Medullary shell simple. *Dev.-Rec.*

Lithelius HKL., 1862 [**L. spiralis;* SD herein]. Branched or unbranched radial spines. *Dev.-Rec.*

L. (Lithelius) [=*Lithospira* HKL., 1887 (obj.)]. Simple spiral. *Dev.-Rec.*

L. (Drymospira) HKL., 1882 [**L. solaris* HKL., 1887]. Spiral double. *Rec.*——FIG. 49,*3*. *L. (D.) solaris*, Rec., ×200 (42).

Spireuma HKL., 1882 [**Spirema lentellipsis* HKL., 1887][=*Spirema* HKL., 1887 (obj.)]. Surface smooth or thorny; without radial spines. *Rec.*

S. (Spireuma) [=*Spiremarium* HKL., 1887 (obj.)]. Simple spiral.——FIG. 49,*1*. *S. (S.) melonia* HKL., Rec., ×200 (42).

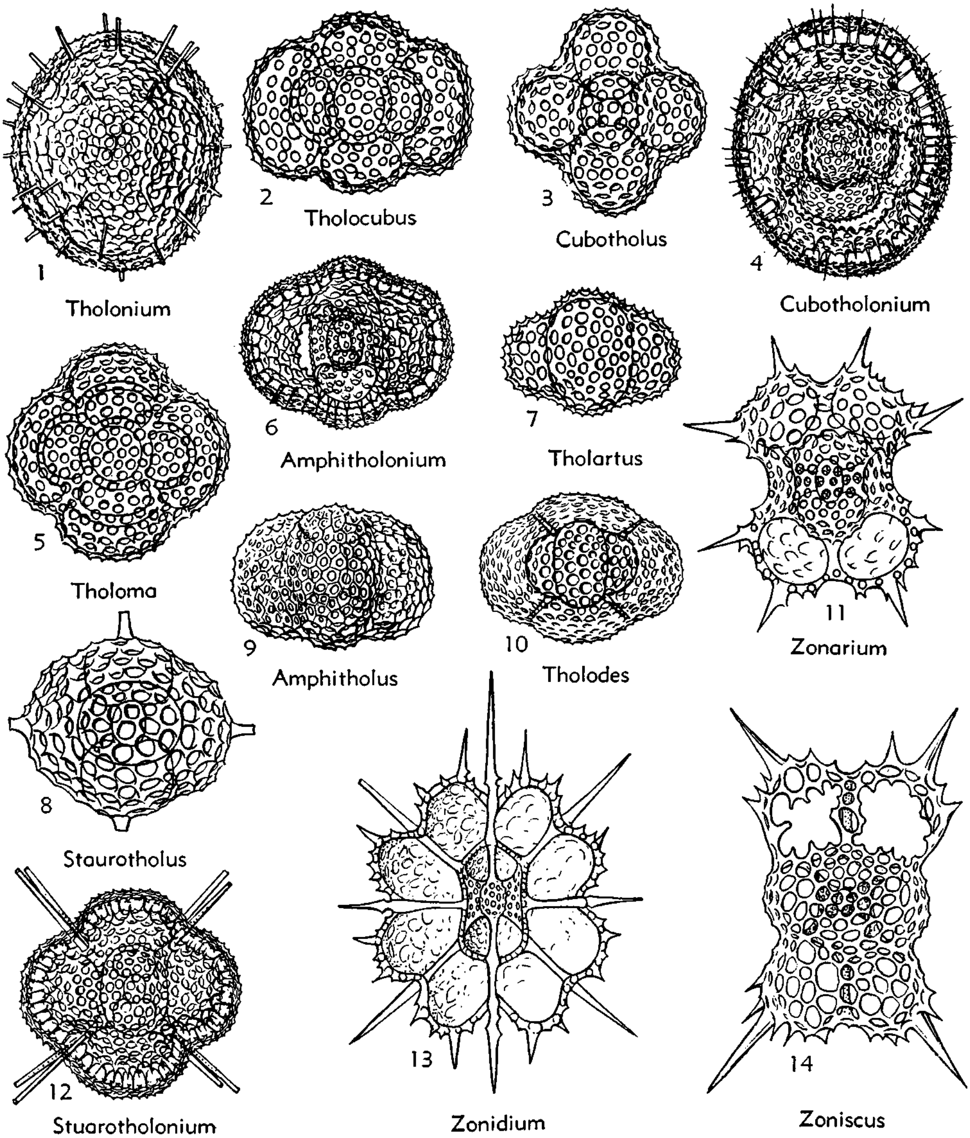


FIG. 48. Tholoniidae, Zonariidae (p. D98).

S. (Spiremidium) HKL., 1887 [*S. diplospira; SD herein]. Spiral double.

Subfamily LARCOSPIRINAE Haeckel, 1887

[as Larcospirida; emend. CAMPBELL, herein]

Medullary shell double. *Dev.-Rec.*

Larcospira HKL., 1887 [**L. quadrangula;* SD herein]. Transverse girdle turns around principal axis. *Rec.*

L. (Larcospira) [=*Larcospirema* HKL., 1887 (obj.)]. Spiral turns single.——FIG. 49,2. **L. quadrangula,* Rec., ×200 (42).

L. (Larcospironium) HKL., 1887 [**L. oliva*]. Spiral turns double.

Pylospira HKL., 1887 [**P. octopyle;* SD herein]. Lateral girdle turns around sagittal axis. *Rec.*

P. (Pylospira) [=*Pylospirema* HKL., 1887 (obj.)]. Spiral turns single.——FIG. 49,*10.* **P. (P.) octopyle,* Rec., ×300 (42).

P. (Pylospironium) HKL., 1887 [**P. cymbium*]. Spiral turns double.

Spironium HKL., 1887 [**S. octonium;* SD herein]. Both wings of transverse girdle turn around principal axis in an opposite diagonal direction. *Dev.-Rec.*

S. (Spironium) [=*Spironetta* HKL., 1887 obj.)]. Surface without radial spines; smooth or rough surface.——FIG. 49,*5.* **S. (S.) octonium,* Rec., ×150 (42).

S. (Spironilla) HKL., 1887 [**S. spinosum;* SD herein]. Surface covered by branched or unbranched radial spines.

Tholospira HKL., 1887 [**T. dendrophora* 1887; SD herein]. Sagittal girdle tturns around transverse axis. *Rec.*

T. (Tholospira) [=*Tholospirema* HKL., 1887 (obj.)]. Spiral turns simple.——FIG. 49,*4.* **T. (T.) dendrophora,* Rec., ×150 (42).

T. (Tholospironium) HKL., 1887 [**T. crevicornis;* SD herein]. Spiral turns double.

Family STREBLONIIDAE Haeckel, 1887

[as Streblonida; emend. CAMPBELL, herein]
[=Streblemida HKL., 1887]

Cortical shell helicoidal. *Rec.*

Subfamily STREBLONIINAE Haeckel, 1887

[as Streblonida *(partim);* emend. CAMPBELL, herein]
[=Streblacanthida HKL., 1887]

Primary chamber simple. *Rec.*

Streblonia HKL., 1887 [**S. globigerna;* SD herein]. Shell without radial spines.

Streblacantha HKL., 1887 [**S. siderolina;* SD herein]. Shell with radial spines.——FIG. 49,*11.* **S. siderolina,* Rec., ×200 (42).

Subfamily STREBLOPYLINAE Haeckel, 1887

[as Streblopylida; emend. CAMPBELL, herein]

Primary shell composed of 3 elliptical girdles surrounding single central chamber. *Rec.*

Streblopyle HKL., 1887 [**S. helicina;* SD herein]. Without radial spines.——FIG. 49,*12.* **S. helicina,* Rec., ×150 (42).

Family PHORTICIDAE Haeckel, 1882

[as Phorticida; emend. CAMPBELL, herein]

Cortical shell with single irregular chamber. *Cam.-Rec.*

Phorticum HKL., 1882 [**P. pylonium* HKL., 1887]. Cortical shell latticed. *Cam.-Rec.*

P. (Phorticum) [=*Phortopyle* HKL., 1887 (obj.)]. Lattice with large gates. *Cam.-Rec.*——FIG. 49,*7.* **P. (P.) pylonium,* Rec., ×150 (42).

P. (Phortolarcus) HKL., 1887 [**P. deforme;* SD herein]. Lattice complete. *Rec.*

Spongophortis HKL., 1882 [**S. spongiosa* HKL., 1887]. Spongy cortical shell. *Rec.*

S. (Spongophortis) [=*Stylophorticum* HKL., 1887 (obj.)]. Spongy shell immediately enclosing medullary shell.——FIG. 49,*6. S. (S.) larnacilla* HKL., Rec., ×200 (42).

S. (Spongophorticum) HKL., 1887 [**S. radiosa;* SD herein]. Spongy shell separated from medullary shell.

Family SOREUMATIDAE Haeckel, 1882

[as Soreumida; emend. CAMPBELL, herein]

Cortical shell composed of irregularly grouped chambers. *Rec.*

Soreuma HKL., 1882 [**S. irregulare* HKL., 1887]. Simple primary chamber.

S. (Soreuma) [=*Soreumium* HKL., 1887 (obj.)]. Without radial spines.——FIG. 49,*8. S. (S.) irregulare,* Rec., ×100 (42).

S. (Soreumidium) HKL., 1882 [**S. spinosum* HKL., 1887]. With radial spines.

Sorolarcus HKL., 1887 [**S. larnacillifer;* SD herein]. Primary chamber has elliptical girdle.

S. (Sorolarcus) [=*Sorolarcium* HKL., 1887 (obj.)]. Without radial spines.——FIG. 49,*9.* **S. (S.) larnacillifer,* Rec., ×150 (42).

S. (Sorolarcidium) HKL., 1887 [**S. terminalis*]. With radial spines.

Order OSCULOSIDA Haeckel, 1887

[as Osculosa; emend. CAMPBELL, herein]
[=Merotrypasta HKL., 1887]

Pores restricted to one pole or to tubular openings in the central capsule. *Cam.-Rec.*

Suborder NASSELLINA Ehrenberg, 1875

[as Nassellaria; emend. CAMPBELL, herein]
[=Monopylea HERTWIG, 1879; Cricoidea BÜTSCHLI, 1882; Monopylaria HKL., 1882; Polycystina DREYER, 1913 (*non* EHRENBERG, 1838) *(partim)*]

Central capsule perforated only at one pole; with a single membrane; skeleton a tripod, ring, or lattice shell; opposite poles of shell dissimilar; skeleton composed of opaline silica. *Cam.-Rec.*

MORPHOLOGICAL FEATURES

The Nassellina differ essentially from other suborders in the structure of the central capsule and of the skeleton. The thin-walled single membrane encloses a more or less egg-shaped central capsule with a truncated base. The convex part is completely devoid of pores, but the flat part, closed off by a thick **operculum,** is pierced by numerous tiny pores. Inside the central capsule, resting its base upon the operculum, is a stout obtuse cone termed the **podoconus.** Fine canals from the operculum pass

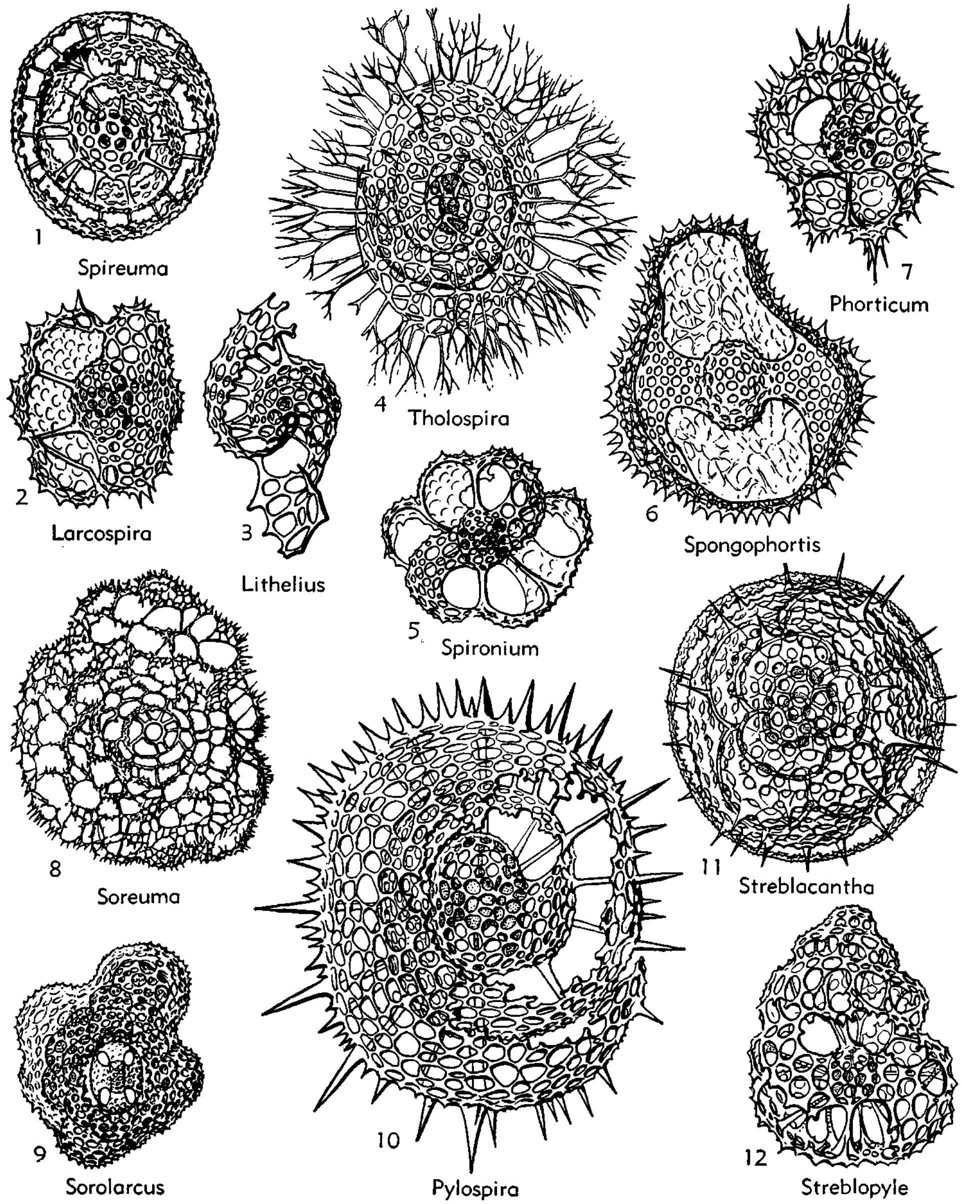


FIG. 49. Litheliidae, Strebloniidae, Phorticidae, Soreumatidae (p. D99, D100).

through the podoconus to the apex and thus allow communication between the extracapsular and intracapsular cytoplasm. The simple genus *Cystidium* of the Nassellina may be compared with *Procyttarium* of the Spumellina, from which it differs almost exclusively in the shape of the central capsule and in presence of a podoconus. These two genera represent probable ancestors of their respective suborders.

The peripherally generated nasselline skeleton is siliceous (opal), like that of the spumelline shell and unlike that found in the other 2 suborders. Three fundamental skeletal elements are found in this type of skeleton: (a) the **tripod** formed by divergent rods united at a common center and oriented in such a way that one leg is posterior and the other 2 are right and left antero-lateral; (b) the commonly conical or helmet-shaped **lattice shell,** fixed at the common center of the tripod; and (c) the great circle or **sagittal ring** which reinforces the latticed wall in the medial sagittal plane. Especially in Nasselina having a segmented lattice shell, the first division (nearest the center) is called the **cephalis.**

Great difficulty is presented by the fact that the 3 structural types mentioned are not constantly united, but each alone may constitute the skeleton by itself. In this respect there are 7 possible arrangements: (1) The skeleton is formed by the basal tripod alone, as in some Stephaniicae. (2) The skeleton is composed of a basal tripod alone *(Acanthometra)* or a tripod with a vertical apical spine rising from its center *(Plagoniscus),* and commonly with an irregular framework rising from the rods of the tripod but without trace of a latticed cephalis or sagittal ring, as in the Plagoniicae. (3) The skeleton is composed only of a latticed cephalis or single chamber and is without trace of sagittal ring or basal tripod, as in the Archicorythidae, some Cannobotrydicae, and many other Cyrtellari. (4) The skeleton is composed of a sagittal ring and basal tripod without a latticed cephalis, as in some Stephaniicae. (5) The skeleton is formed by a sagittal ring and latticed cephalis without a basal tripod, as among Cyrtellari, especially in some Triospyrididae, many Cannobotrydicae, and some complex Adelocyrtidinae, Theocorythidae, and Stichocorythidae. (6) The shell is composed of a basal tripod and latticed cephalis which may bear an apical cupola or dome but lacks any trace of sagittal ring, as among many Cyrtellari. (7) The shell is composed of a sagittal ring, basal tripod, and latticed cephalis, as in most Triospyridicae and Archipiliicae.

Among the Archipiliicae, subdivisions may be distinguished according to 3 different criteria: number of **joints** into which the shell is divided by transverse strictures; number of radial apophyses rising from the shell; and character of the basal shell mouth, which is open in most but closed off or **fenestrated** in some. The number of **segments into which the shell is divided by transverse strictures** serves to discriminate 4 subsuperfamilies—Archipiliilae (1 joint, no stricture), Sethopiliilae (2 joints, 1 stricture), Theopiliilae (3 joints, 2 strictures), and Triacartilae (4 or more joints, 3 or more strictures). The first 3 joints generally are very different from those which follow, so that the first is distinguished as the cephalis, the second as the **thorax,** and the third as the **abdomen.** Joints which may follow the abdomen are termed collectively **postabdomina.**

The radial appendages may consist of either solid or fenestrated **feet** projecting from the ultimate joint, or **wings** extending from the sides of the shell, but solid or latticed ribs may take the place of wings. Most shells have 3 radial appendages, although some have many more and others none.

The cephalis of the Archipiliicae is probably similar to that of the Triospyridicae and differs from it in the reduction of the sagittal stricture, so that the chamber is single instead of double. That of the Cannobotrydicae is lobulated into several, commonly irregular chambers, and appears to have arisen secondarily from the single-chamber cephalis of the Archipiliicae. The thorax of shells belonging to the Sethopiliilae, Theopiliilae, and Tricartilae is equivalent to that found in the Phormospyrididae, Androspyrididae, Pylobotrydidae, being developed from apophyses which arise from the base of the cephalis and become united by transverse branches to form a latticed cylinder, truncate cone, or pyramid. The thorax may be closed by a convex or flat fenestrated plate at its lower end. The abdomen, absent in the Archipiliicae and most Triospyridicae, occurs in most other Cyrtellari.

The horizontal plate at the base of the cephalis has basal or **collar pores** in the Triospyridicae, and some other Cyrtellari. They resemble those at the point of attachment of the ring and tripod in the Semantididae. **Strictures** between successive shell joints of the Cyrtellari generally are marked by a latticed girdle projecting into the shell cavity like a diaphragm; this diaphragm has the form of a solid horizontal annulus in many shells.

The lattice structure exhibits extraordinary variety and the different shell joints commonly are distinguished by modifications displayed by this lattice. The pores of the meshwork of the different joints are also varied in many ways and may serve to differentiate these joints externally.

The closing of the mouth by a transverse plate has different significance in the Archiperinae from that found in the many multijointed basally fenestrated genera. In the Archiperinae this plate is the original one formed by the cephalis of the Triospyridicae and developed from the beams which bound the regularly disposed collar pores of these forms. In multijointed genera, on the other hand, the plate originates by the central union of the convergent edges of the shell margin which grew inward toward the center; a central vertical spine, as in *Artoperina,* may project downward from this center, but in most basally fenestrated genera it is lacking. The basal plate may be flat, convex, or even inverted conical. The pores which occur in it are generally like those of the next superior joint.

The radial apophyses may be derived from the tripod found among the Plectellari, especially of the Stephaniicae and most Triospyridicae. The apical spine, or **apical horn**, is particularly important and bears relationship to the odd or posterior foot. An **internal columella** arises in many forms within the cephalis, or an ascending rib following the convex surface of the cephalis on the dorsal wall may develop in its place. This rib connects the base of the apical horn with the origin of the posterior foot; the columella or rib seems to be a remaining part of the sagittal ring found in some Plectellari. Accessory apical horns, either free or less commonly anastomosed, may be developed. In some hornless genera, the columella connecting with the posterior foot is preserved.

The characters of the Cyrtellari are such that all structures described above in connection with this division are combined with each other to produce the many genera and families. This group contains more than 1,000 species, and the majority of the fossil Nassellina are included in it. In many genera the number of species is large, but species belonging to the more complex genera are few.

The best account of the biology and ecology of the Nassellina may be found in HAECKEL (12).

Division PLECTELLARI Haeckel, 1887

[as Plectellaria; emend. CAMPBELL, herein]

Without complete skeleton. *Ord.-Rec.*

Superfamily CYSTIDIICAE Haeckel, 1883

[*ex* Cystidina; emend. CAMPBELL, herein]
[=Nassoidea, HKL., 1887]

Lacking skeleton. *Rec.*

Family CYSTIDIIDAE Haeckel, 1883

[as Cystidina; emend. CAMPBELL, herein]
[=Nassellida HKL., 1887]

Naked cells only. *Rec.*

Cystidium HERTWIG, 1879 [**C. inerme*]. Calymma hyaline, without alveoles.——FIG. 50,*1. C. princeps* HKL., Rec., ×200 (42).

Nassella HKL., 1887 [**N. thalassicola;* SD herein]. Calymma foamy, with large alveoles.

Superfamily PLAGONIICAE Haeckel, 1882

[*ex* Plagonida; emend. CAMPBELL, herein]
[=Plegmida HKL., 1878; Plagiacanthida HERTWIG, 1879 *(partim);* Plectida HKL., 1882; Plectoidea HKL., 1887]

Skeleton consists only of basal tripod. *Ord.-Rec.*

Family PLAGONIIDAE Haeckel, 1882

[as Plagonida; emend. CAMPBELL, herein]

Skeleton formed of radial spines united at a common center; without wickerwork. *Ord.-Rec.*

Subfamily PLAGONIINAE Haeckel, 1882

[as Plagonida *(partim);* emend. CAMPBELL, herein]
[=Hexaplagida HKL., 1887]

Six radial spines. *Ord.-Rec.*

Plagonium HKL., 1882 [**P. sphaerozoum* HKL., 1887]. Spines in 2 opposite groups from poles of common center. *Ord.-Rec.*——FIG. 50,*6*. **P. sphaerozoum*, Rec., ×100 (42).

Hexaplagia HKL., 1882 [**H. arctica* HKL., 1887] [=*Hexaplagidium* HKL., 1882]. Spines arise from one common center. *Rec.*

Subfamily TRIPLAGIINAE Haeckel, 1882
[as Triplagida; emend. CAMPBELL, herein]

Three radial spines. *Dev.-Rec.*

Triplagia HKL., 1882 [**T. primordialis* HKL., 1887]. Spines in one horizontal plane. *Rec.*——FIG. 50,*3*. **T. primordialis*, Rec., ×82 (42).

Acanthometra MÜLLER, 1855 [**A. arachnoides* CLAPARÈDE, 1855] [=*Plagiacantha* CLAPARÈDE, 1856 (obj.); *Triplagiacantha* SCHRÖDER, 1914]. Spines corresponding to edges of flat pyramid. *Dev.-Rec.*——FIG. 50,*2*. *A. australis* (HINDE), 2 spines and basal part of a third one, Dev., Austral., ×150 (44).

Subfamily TETRAPLAGIINAE Haeckel, 1887
[as Tetraplagida; emend. CAMPBELL, herein]
[=Tetraplectida HKL., 1882]

Four radial spines. *Ord.-Rec.*

Tetraplagia HKL., 1882 [**T. geometrica* HKL., 1887]. Equal spines arise from common center. *Rec.*——FIG. 50,*5*. *T. phaenaxonia* HKL., Rec., ×100 (42).

Plagiocarpa HKL., 1882 [**P. procortina* HKL., 1887]. Spines arise in 2 pairs from poles of common central rod; one apical spine opposed to 3 basal spines. *Rec.*——FIG. 50,*4*. **P. procortina*, Rec., ×100 (42).

Plagonidium HKL., 1882 [**P. bigeminum* HKL., 1887]. Like *Plagiocarpa* but all spines equal. *Rec.*

Plagoniscus HKL., 1887 [**P. tripodiscus;* SD herein]. Like *Tetraplagia* but spines unequal. *Ord.-Rec.*——FIG. 50,*7*. *P. cristatus* HINDE, Dev., Austral., ×150 (44).

Subfamily ENNEAPLAGIINAE Campbell, nov.

Radial spines 7 to 9 or more. *Rec.*

Enneaplagia HKL., 1882 [**Polyplagia septenaria* HKL., 1887][=*Enneaplagidium* HKL., 1882; *Polyplagia* HKL., 1887 (obj.)]. Spines arise from common central rod and lie in different planes.

Family PLECTANIIDAE Haeckel, 1882
[as Plectanida; emend. CAMPBELL, herein]

Skeleton formed of the united branches of radial spines. *Rec.*

Subfamily PLECTANIINAE Haeckel, 1882
[as Plectanida *(partim)*; emend. CAMPBELL, herein]
[=Polyplectida HKL., 1882 *(partim)*]

Six radial spines. *Rec.*

Plectanium HKL., 1882 [**P. trigeminum* HKL., 1887]. Spines arise in 2 opposite groups from poles of common central rod.——FIG. 50,*12*. **P. trigeminum*, Rec., ×200 (42).

Hexaplegma HKL., 1882 [**Hexaplecta triaxonia* HKL., 1887][=*Hexaplecta* HKL., 1887 (obj.)]. Spines arise from one common central point.

Verticellata POP., 1913 [**V. hexacantha*]. Spines surrounded by lattice.——FIG. 50,*13*. **V. hexacantha*, Rec., ×275 (48).

Subfamily TRIPLECTINAE Haeckel, 1882
[as Triplectida; emend. CAMPBELL, herein]

Three radial spines. *Rec.*

Triplecta HKL., 1882 [**T. triangulum* HKL., 1887]. Spines lie in one horizontal plane.——FIG. 50,*10*. *T. triactus* HKL., Rec., ×100 (42).

Campylacantha JÖRG., 1905 [**C. cladophora*]. Vertical spine simple, others basally forked with 3 free tips at ends.——FIG. 50,*8*. **C. cladophora*, Rec., ×300 (46).

Plectacantha JÖRG., 1905 [**P. oikiskos*]. Each spine has 2 paired forked branches.——FIG. 50,*9*. **P. oikiskos*, Rec., ×250 (46).

Plectophora HKL., 1882 [**P. triomma* HKL., 1887]. Spines correspond to edges of flat pyramid.

Protoscenium JÖRG., 1905 [**Plectanium simplex* CLEVE, 1899]. Each primary spine forked 4 times; primary spines connected by arches.——FIG. 50,*11*. **P. simplex* (CLEVE), Rec., ×400 (46).

Subfamily TETRAPLECTINAE Haeckel, 1882
[as Tetraplectida; emend. CAMPBELL, herein]

Four radial spines. *Rec.*

Tetraplecta HKL., 1882 [**T. tetrahedra* HKL., 1887][=*Amphiplecta* HKL., 1882]. Equal spines correspond to 4 axes of a tetrahedron.

Dumetium POP., 1909 [**D. rectum*]. Axial spine opposed to 2 basal spines one of which is terminally forked; repeated lateral anastomosed branches on spines.——FIG. 51,*2*. **D. rectum*, Rec., ×200 (48).

Gonosphaera JÖRG., 1905 [**G. primordialis*]. Two regular pentagons with a common side, long oblique spines at 4 corners and a connecting 3-jointed arch at 5th.——FIG. 51,*4*. **G. primordialis*, Rec., ×250 (46).

Obeliscus POP., 1913 [**O. pseudocuboïdes*]. Strong spines extend from ring united by arched beams; above ring a pyramidal spiny lattice.——FIG. 51,*1*. **O. pseudocuboïdes*, Rec., ×400 (48).

Periplecta HKL., 1882 [**P. cortina* HKL., 1887]. Spines in 2 pairs; one apical spine differs from 3 basal spines.——FIG. 51,*3*. **P. cortina*, Rec., ×100 (42).

Phormacantha JÖRG., 1905 [**Peridium hystrix* CLEVE, 1899]. Primary spines with 3 arches and a strong ventral sagittal spine.——FIG. 51,*7*. **P. hystrix* (CLEVE), Rec., ×300 (46).

Plectaniscus HKL., 1887 [**P. cortiniscus*]. Spines arise from common central point; apical spine differs from 3 basal spines.——FIG. 51,5. *P. *cortiniscus*, Rec., ×100 (42).

Subfamily ENNEAPLEGMATINAE Campbell, nov.

Radial spines 7 to 9 or more. *Rec.*

Enneaplegma HKL., 1882 [**Polyplecta heptacantha* HKL., 1887 (=*Heptaplegma heptacantha* HKL., 1887)] [=*Pentaplegma* (obj.), *Plegmatium* (obj.) HKL., 1882; *Polyplecta* (obj.), *Heptaplegma* (obj.) HKL., 1887]. Seven to 9 or more spines arise from central point and lie in different planes.——FIG. 51,6. **E. heptacantha* (HKL.), Rec., ×150 (42).

Superfamily STEPHANIICAE Haeckel, 1887

[*ex* Stephanida; emend. CAMPBELL, herein] [=Stephida HKL., 1882 *(partim)*; Stephoidea HKL., 1887; Orboidea POP., 1913 *(partim)*]

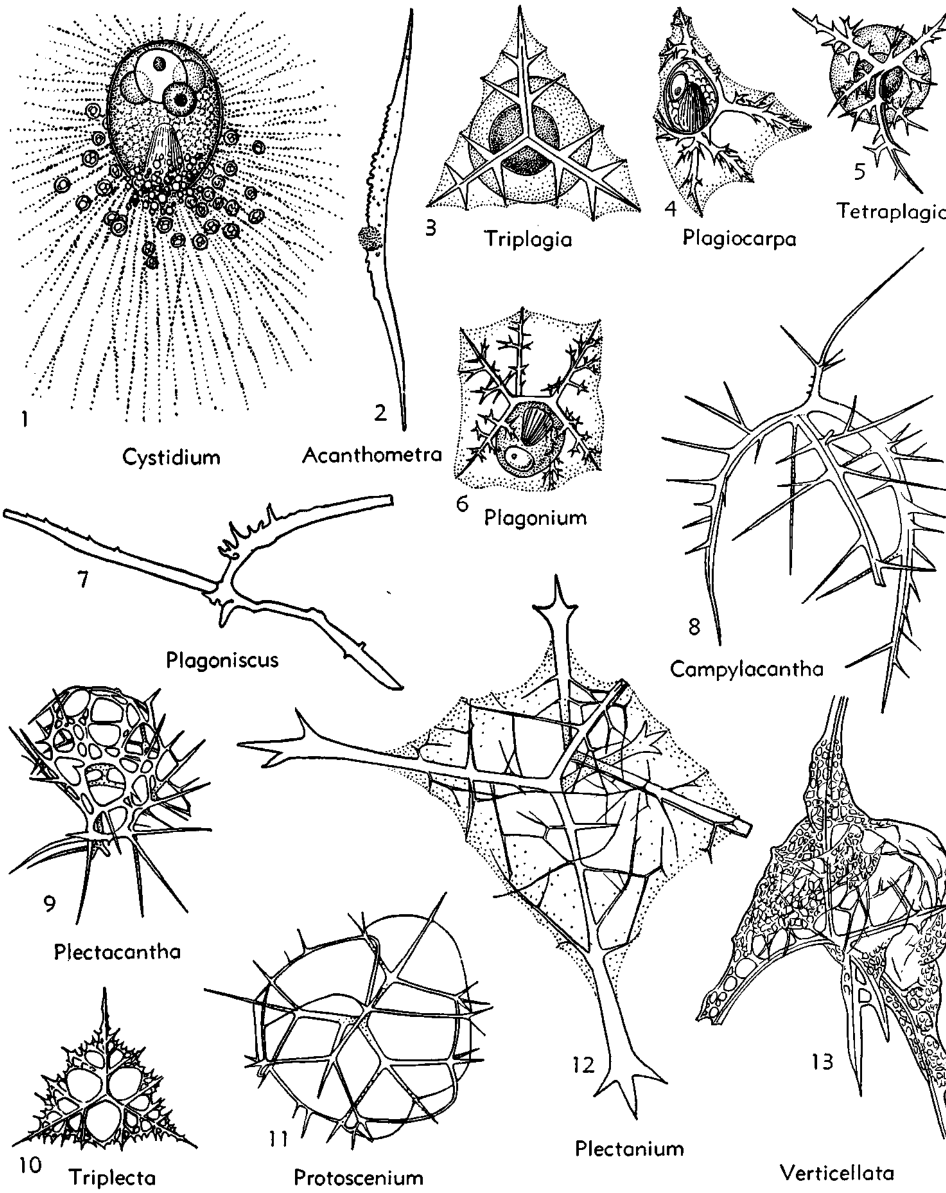


FIG. 50. Cystidiidae, Plagoniidae, Plectaniidae (p. D103, D104).

Skeleton formed of sagittal ring with or without basal tripod. *Trias.-Rec.*

Family STEPHANIIDAE Haeckel, 1887

[as Stephanida; emend. CAMPBELL, herein] [=Monostephida HKL., 1882 *(partim)*]

Skeleton composed of simple vertical sagittal ring, without secondary rings. *Trias.-Rec.*

Subfamily STEPHANIINAE Haeckel, 1887

[as Stephanida *(partim)*; emend. CAMPBELL, herein] [=Cortinida HKL., 1887]

Basal feet present. *Eoc.-Rec.*

Stephanium HKL., 1887 [**S. quadrupes;* SD herein]. Four basal feet. *Eoc.-Rec.*——FIG. 51,*8*. **S. quadrupes,* Rec., ×150 (42).

Cortina HKL., 1887 [**C. typus*]. Three basal feet. *Eoc.-Rec.*——FIG. 51,*12*. **C. typus,* Rec., ×100 (42).

Subfamily LITHOCIRCINAE Haeckel, 1887

[as Lithocircida; emend. CAMPBELL, herein]

Without typical basal feet. *Trias.-Rec.*

Lithocircus MÜLLER, 1856 [**L. annularis* MÜLLER, 1858]. Dorsal and ventral bows of ring similar; armed with branched spines. *Cret.-Rec.*——FIG. 51,*14*. *L. quadricornis* HKL., Rec., ×200 (42).

Acanthocircus SQUIN., 1903 [**A. irregularis;* SD herein]. Ring mostly elliptical; incomplete internal spine on each side of middle; thorns or spines simple. *Cret.*——FIG. 51,*9*. **A. irregularis,* Cret., Italy, ×60 (52).

Dendrocircus HKL., 1882 [**D. quadrangulus* HKL., 1887]. Dorsal and ventral bows of ring different, otherwise as *Lithocircus*. *Eoc.-Rec.*——FIG. 51,*11*. *D. arborescens* HKL., Rec., ×200 (42).

Monostephus HKL., 1882 [**Archicircus monostephus* HKL., 1887] Like *Lithocircus* but ring has no branched thorns or spines. *Trias.-Rec.*

M. (Monostephus). Ring without prominent corners. *Trias.-Rec.*——FIG. 51,*13b*. **M. (M.) monostephus,* Rec., ×300 (42).

M. (Archicircus) HKL., 1887 [**Archicircus primordialis* HKL., 1887] [=*Archistephus* HKL., 1887 (obj.)]. Ring polygonal. *Rec.*——FIG. 51, *13a*. **M. (A.) primordialis,* Rec., ×200 (42).

Zygocircus BÜTSCHLI, 1882 [**Lithocircus productus* HERTWIG, 1879]. Like *Dendrocircus* but spines branched. *Cret.-Rec.*——FIG. 51,*10*. **Z. pentagonus* HKL., Rec., ×200 (42).

Family CYRTOSTEPHANIDAE Popofsky, 1913

Sagittal ring latticed, or netlike fan of repeated anastomosed spines. *Rec.*

Cyrtostephanus POP., 1913 [**C. globus;* SD herein]. Ring incomplete.——FIG. 52,*1*. **C. globus,* Rec., ×400 (48).

Family SEMANTIDIDAE Haeckel, 1887

[as Semantida; emend. CAMPBELL, herein]

Skeleton composed of a vertical sagittal and a horizontal basal ring. *Jur.-Rec.*

Subfamily SEMANTIDINAE Haeckel, 1887

[as Semantida *(partim)*; emend. CAMPBELL, herein] [=Semantiscida HKL., 1887]

Lacking typical basal feet. *Jur.-Rec.*

Semantis HKL., 1887 [**S. biforis;* SD herein]. Two basal pores. *Jur.-Rec.*——FIG. 52,*4*. *S. triangularis* CL.-C., U.Eoc., Calif., ×870 (39).

Clathrocircus HKL., 1882 [**C. hexaporus* HKL., 1887] [=*Sphaerocircus* HKL., 1882]. Like *Semantis* but has dorsal and ventral pores along whole ring. *Rec.*——FIG. 52,*5*. *S. stapedius* HKL., Rec., ×200 (42).

Dictyocircus JÖRG., 1905 [**D. clathratus*]. Sagittal ring with 6 spines; 2 opposite lateral rings each with 2 short spines. *Rec.*——FIG. 52,*2*. **D. clathratus,* Rec., ×300 (46).

Neosemantis POP., 1913 [**N. distephanus;* SD herein]. Three fused rings united at 2 places. *Rec.*——FIG. 52,*3*. *N. distephanus,* Rec., ×400 (48).

Semantidium HKL., 1887 [**S. hexastoma;* SD herein]. Six basal pores, otherwise as *Semantis*. *Rec.*——FIG. 52,*6*. *S. signatorum* HKL., Rec., ×200 (42).

Semantrum HKL., 1887 [**S. quadrifore;* SD herein]. Four basal pores, otherwise as *Semantis*. *Eoc.-Rec.*——FIG. 52,*7*. **S. quadrifore,* Eoc., Barbados, ×200 (42).

Subfamily CORTINISCINAE Haeckel, 1887

[as Cortiniscida; emend. CAMPBELL, herein]

Basal ring with regularly disposed feet. *Eoc.-Rec.*

Cortiniscus HKL., 1887 [**C. typicus*]. One odd or caudal foot and 2 paired lateral feet. *Eoc.-Rec.*——FIG. 52,*8*. **C. typicus,* Rec., ×150 (42).

Semantiscus HKL., 1887 [**S. hexapylus;* SD herein]. Six basal feet. *Rec.*——FIG. 52,*10*. **S. hexapylus,* Rec., ×200 (42).

Stephaniscus HKL., 1887 [**S. quadrifurcus;* SD herein]. Like *Cortiniscus* but has 4 feet. *Eoc.-Rec.*——FIG. 52,*9*. **S. quadrifurcus,* Rec., ×150 (42).

Family ACANTHODESMIIDAE Hertwig, 1879

[as Acanthodesmida; emend. CAMPBELL, herein] [=Coronida HKL., 1887]

Skeleton formed by 2 crossed vertical meridional rings and commonly a horizontal basal ring. *Jur.-Rec.*

Subfamily ACANTHODESMIINAE Haeckel, 1882

[as Acanthodesmida *(partim)*; emend. CAMPBELL, herein]

Five large gates or openings between rings. *Rec.*

Acanthodesmia MÜLLER, 1858 [**Lithocircus vinculatus* MÜLLER, 1856]. Like *Coronidium* but gates partly latticed.——FIG. 52,*13*. *A. coronata* HKL., Rec., ×200 (42).

Coronidium HKL., 1882 [**C. dyostephanus* HKL., 1887]. Four open lateral gates.——FIG. 52,*15*. **C. dyostephanus*, Rec., ×200 (42).

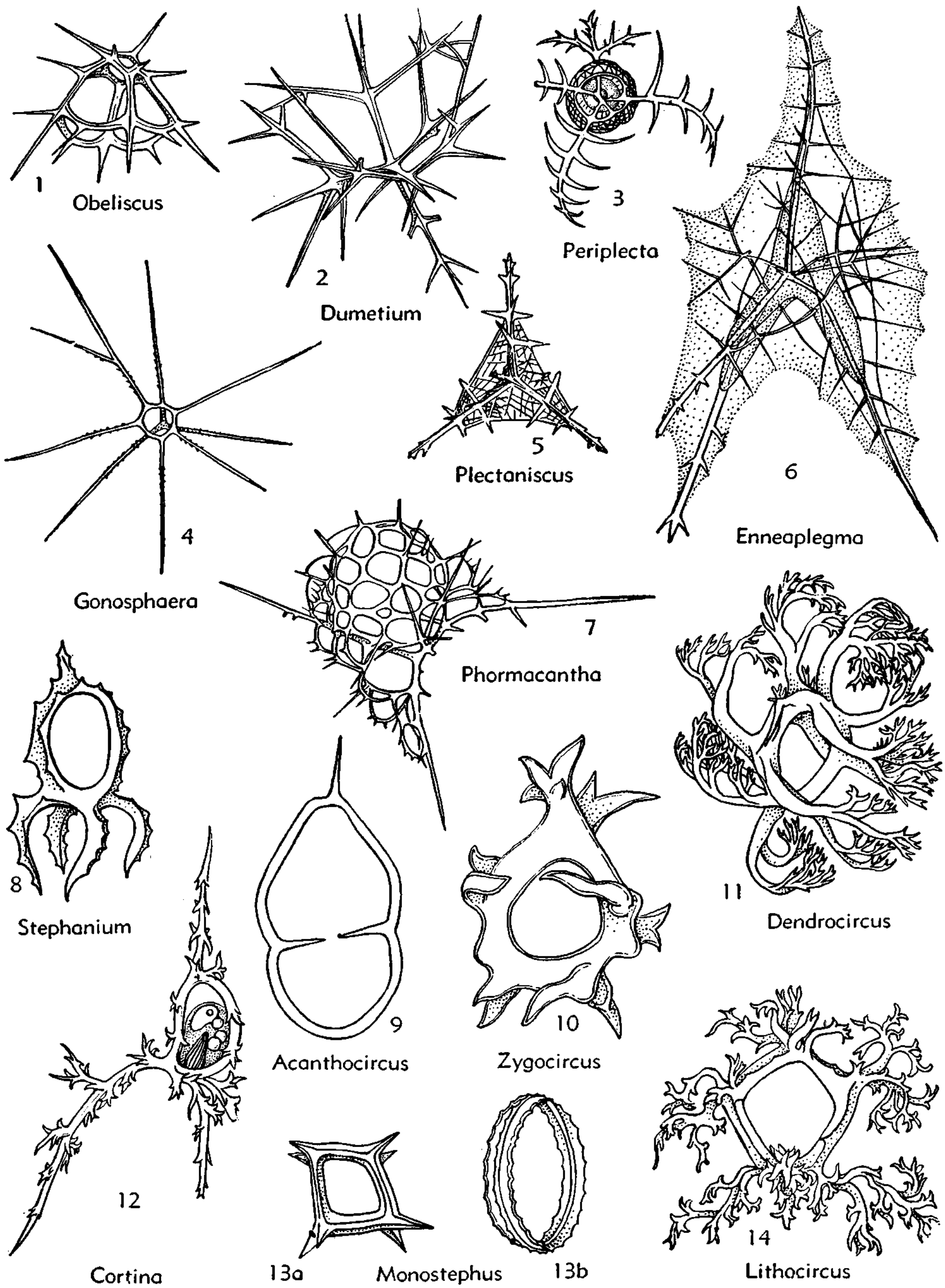


FIG. 51. Plectaniidae, Stephaniidae (p. D104-D106).

Subfamily ZYGOSTEPHANINAE Haeckel, 1882
[as Zygostephanida; emend. CAMPBELL, herein]

Four lateral gates. *Jur.-Rec.*

Zygostephanus HKL., 1862 [*Z. *mülleri*]. Gates simple. *Jur.-Rec.*

Z. (Zygostephanus) [=*Zygostephus* HKL., 1882 (obj.)]. Vertical ring without sagittal constriction. *Jur.-Rec.*——FIG. 52,*11*. *Z. (Z.) dissocircus* HKL., Rec., ×200 (42).

Z. (Zygostephaniscus) HKL., 1882 [*Z. *reniformis* HKL., 1887]. Sagittal constrictions present. *Rec.*

Zygostephanium HKL., 1882 [*Z. *dizonium* HKL., 1887 (=*Tympaniscus dizonius* HKL., 1887)]. Gates partly latticed. *Rec.*——FIG. 52,*12*. *Z. paradictyum* HKL., Rec., ×200 (42).

Subfamily EUCORONIDINAE Haeckel, 1882
[as Eucoronida; emend. CAMPBELL, herein]

Six large gates. *Eoc.-Rec.*

Eucoronis HKL., 1882 [*E. *perspicillum* HKL., 1887]. Lacking large basal feet; gates simple. *Rec.*

E. (Eucoronis) [=*Acrocoronis* HKL., 1882 (obj.)]. Armed with short thorns.——FIG. 52,*14*. *E. *(E.) perspicillum*, Rec., ×200 (42).

E. (Lithocoronis) HKL., 1882 [*E. *crevicornis* HKL., 1887]. Armed with arborescent spines.

Plectocoronis HKL., 1882 [*P. *anacantha* HKL., 1887]. Like *Eucoronis* but gates partly latticed. *Rec.*——FIG. 52,*19*. *P. *pentacantha* HKL., Rec., ×150 (42).

Podocoronis HKL., 1882 [*P. *dipodiscus* HKL., 1887]. Large regularly disposed basal feet and simple gates. *Eoc.-Rec.*

P. (Podocoronis) [=*Dipocoronis* HKL., 1882 (obj.)]. A right and left lateral foot. *Eoc.-Rec.*——FIG. 52,*18*. *P. (P.) toxarium* HKL., Rec., ×200 (42).

P. (Hexacoronis) HKL., 1887 [*P. *hexapodiscus*]. Six basal feet. *Rec.*

P. (Stylocoronis) HKL., 1887 [*P. *petalospyris;* SD herein]. Eight to 12 or more basal feet. *Eoc.-Rec.*

P. (Tetracoronis) HKL., 1882 [*P. *tetrapodiscus* HKL., 1887]. Four basal feet. *Rec.*

P. (Tripocoronis) HKL., 1882 [*P. *cortiniscus* HKL., 1887]. Three basal feet. *Eoc.-Rec.*

Subfamily TRISSOCYCLINAE Haeckel, 1882
[as Trissocyclida; emend. CAMPBELL, herein]

Eight large gates. *Rec.*

Trissocyclus HKL., 1882 [*T. *stauroporus* HKL., 1887]. Gates all similar, partly latticed.

T. (Trissocyclus) [=*Tricyclarium* HKL., 1887 (obj.)]. Sagittal ring smaller than others.

T. (Tricyclonium) HKL., 1887 [*T. *sphaeridium*]. All rings similar.——FIG. 52,*20*. *T. *(T.) sphaeridium*, Rec., ×200 (42).

Tricyclidium HKL., 1882 [*T. *dictyospyris* HKL., 1887]. Four upper gates larger than others; gates partly latticed.——FIG. 52,*16*. *T. *dictyospyris*, Rec., ×150 (42).

Trissocircus HKL., 1882 [*T. *lentellipsis* HKL., 1887]. Like *Trissocyclus* but gates all simple.

T. (Trissocircus) [=*Tricircarium* HKL., 1887 (obj.)]. Sagittal ring smaller than others.——FIG. 52,*17*. *T. *(T.) lentellipsis*, Rec., ×200 (42).

T. (Tricirconium) HKL., 1887 [*T. *globus;* SD herein]. Rings all alike.

Tristephanium HKL., 1882 [*T. *dimensivum* HKL., 1887]. Like *Tricyclidium* but gates all simple.

T. (Tristephanium) [=*Triostephus* HKL., 1882 (obj.)]. Sagittal and frontal rings of different size and form.——FIG. 52,*21*. *T. *(T.) dimensivum*, Rec., ×200 (42).

T. (Tristephaniscus) HKL., 1882 [*T. *quadricorne* HKL., 1887]. Sagittal and frontal rings alike.

Family PARATYMPANIDAE Haeckel, 1882
[as Paratympanida; emend. CAMPBELL, herein]
[=Parastephida HKL., 1882; Tympanida HKL., 1887]

Skeleton composed of 2 parallel horizontal rings conected by vertical sagittal ring. *Jur.-Rec.*

Subfamily PROTYMPANIINAE Haeckel, 1887
[as Protympanida; emend. CAMPBELL, herein]

Horizontal rings bisected by complete sagittal ring. *Cret.-Rec.*

Protympanium HKL., 1882 [*P. *primordiale* HKL., 1887]. Horizontal rings connected by 2 columellae; one complete sagittal ring. *Rec.*——FIG. 53, *13*. *P. amphipodium* HKL., Rec., ×200 (42).

Acrocubus HKL., 1882 [*A. *octopylus* HKL., 1887]. Like *Microcubus* but without equatorial ring or galear (upper) and thoracal bows. *Rec.*

A. (Acrocubus) [=*Apocubus* HKL., 1887 (obj.)]. Basal ring without feet.——FIG. 53,*8*. *A. *(A.) octopylus*, Rec., ×200 (42).

A. (Dipocubus) HKL., 1887 [*A. *arcuatus;* SD herein]. Two feet.

A. (Tetracubus) HKL., 1887 [*A. *tetrapodius;* SD herein]. Four feet.

A. (Tripocubus) HKL., 1887 [*A. *cortina;* SD herein]. Three feet.

Microcubus HKL., 1882 [*M. *dodecastoma* HKL., 1887]. Four columellae; complete equatorial ring. *Eoc.-Rec.*——FIG. 53.*5*. *M. *dodecastoma*, Rec., ×150 (42).

Octotympanum HKL., 1887 [*O. *octonarium;* SD herein]. Like *Microcubus* but equatorial ring incomplete. *Eoc.-Rec.*——FIG. 53,*10*. *O. *octonarium*, Rec., ×200 (42).

Toxarium HKL., 1887 [*T. *circospyris;* SD herein]. Like *Acrocubus* but has galear and thoracal bows. *Rec.*

T. (Toxarium) [=*Toxellium* HKL., 1887 (obj.)]. Bows simple.——FIG. 53,*11a*. *T. *(T.) circospyris*, Rec., ×200 (42).

T. (Toxidium) Hkl., 1887 [**T. cordatum;* SD herein]. Thoracal bow forked.

T. (Toxonium) Hkl., 1887 [**T. bifurcum;* SD herein]. Like *Tympanidium* but has 6 columellae. *Eoc.-Rec.*——Fig. 53,*11b*. **T. dipodiscus,* Rec., ×200 (42).

Tympanidium Hkl., 1882 [**T. foliosum* Hkl., 1887]. Horizontal rings connected by 8 columellae or rods. *Cret.-Rec.*

T. (Tympanidium) [=*Tympanura* Hkl., 1887 (obj.)]. Gates 12. *Cret.-Rec.*——Fig. 53,*15*. **T. (T.) foliosum,* Rec., ×150 (42).

T. (Tympanomma) Hkl., 1887 [**T. binoctonum* Hkl., 1887; SD herein]. Gates 16. *Rec.*

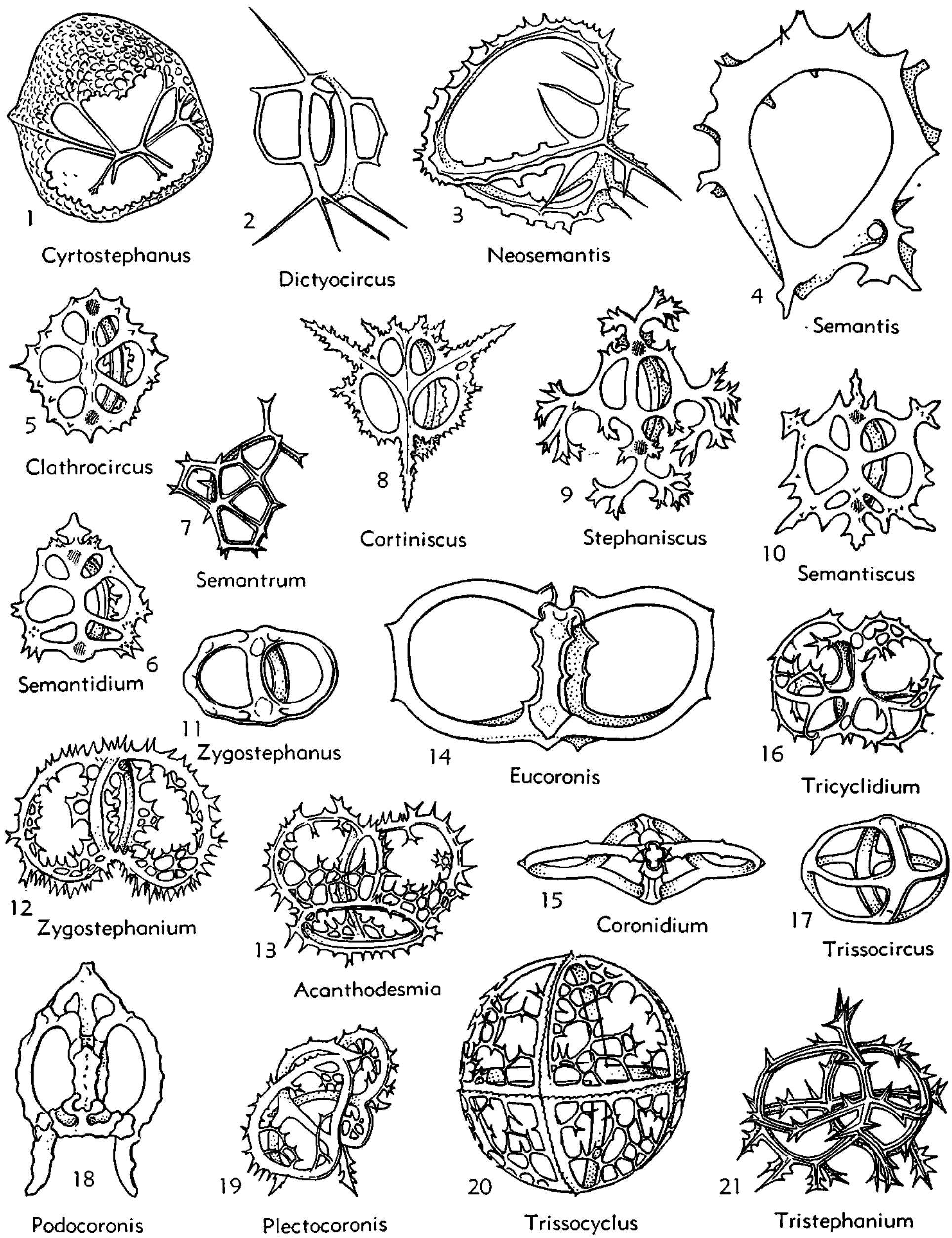


Fig. 52. Cyrtostephanidae, Semantididae, Acanthodesmiidae (p. D106-D108).

Subfamily PARATYMPANINAE Haeckel, 1882

[as Paratympanida *(partim)*; emend. CAMPBELL, herein]

Two horizontal fenestrated rings. *Rec.*

Paratympanum HKL., 1882 [**P. hexastylum* HKL., 1887]. Two horizontal rings unequal.——FIG. 53,*6*. *P. octostylum* HKL., Rec., ×200 (42).

Lithotympanum HKL., 1882 [**L. tuberosum* HKL., 1887]. Rings unequal.——FIG. 53,*14*. **L. tuberosum*, Rec., ×300 (42).

Subfamily DYSTYMPANIINAE Haeckel, 1887

[as Dystympanida; emend. CAMPBELL, herein]

Mitral or upper ring fenestrated, basal ring simple. *Jur.-Rec.*

Dystympanium HKL., 1887 [**D. dictyocha*; SD herein]. With characters of subfamily.——FIG. 53,*7*. **D. dictyocha*, Rec., ×200 (42).

Subfamily EUTYMPANIINAE Haeckel, 1887

[as Eutympanida; emend. CAMPBELL, herein]

Two simple horizontal rings; apical and basal parts of sagittal ring absent. *Jur.-Rec.*

Eutympanium HKL., 1882 [**E. musicantum* HKL., 1887]. Horizontal rings connected by 6 to 8 or more columellae; rings equal. *Rec.*——FIG. 53,*1*. **E. musicantum*, Rec., ×300 (42).

Circotympanum HKL., 1887 [**C. hexagonium*; SD herein]. Like *Eutympanium* but rings unequal. *Rec.*——FIG. 53,*9*. *C. octogonium* HKL., Rec., ×200 (42).

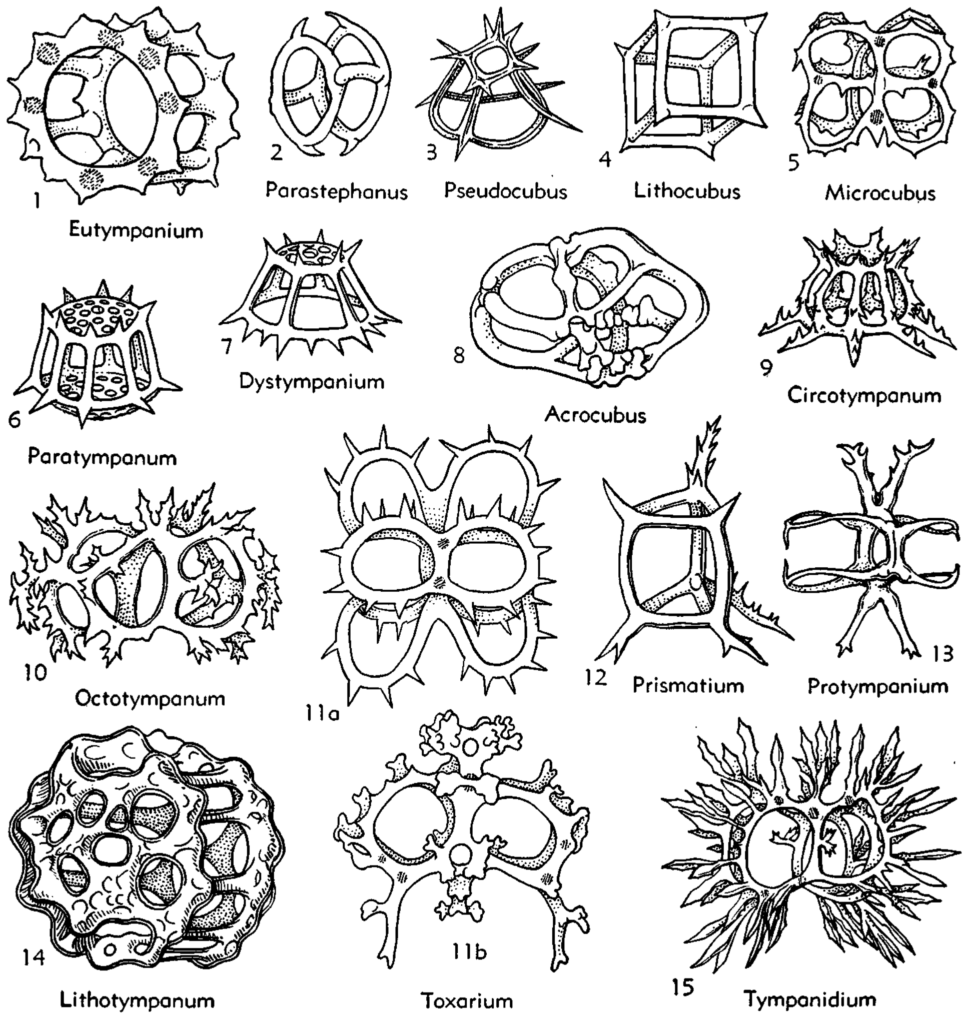


FIG. 53. Paratympanidae (p. D108-D111).

Lithocubus Hkl., 1882 [**L. geometricus* Hkl., 1887]. Four columellae; rings equal. *Rec.*——53,*4*. **L. geometricus,* Rec., ×200 (42).

Parastephanus Hkl., 1882 [**P. circularis* Hkl., 1887]. Two columellae. *Rec.*——Fig. 53,*2*. *P. quadrispinus* Hkl., Rec., ×200 (42).

Prismatium Hkl., 1882 [**Acanthodesmia prismatium* Hkl., 1860]. Three columellae. *Jur.-Rec.*——Fig. 53,*12*. *P. tripodium* Hkl., Rec., ×200 (42).

Pseudocubus Hkl., 1887 [**P. obeliscus;* SD herein]. Like *Lithocubus* but rings unequal. *Rec.*——Fig. 53,*3*. **P. obeliscus,* Rec., ×300 (42).

Division CYRTELLARI Haeckel, 1882

[as Cyrtellaria; emend. Campbell, herein]

Lattice shell complete. *Cam.-Rec.*

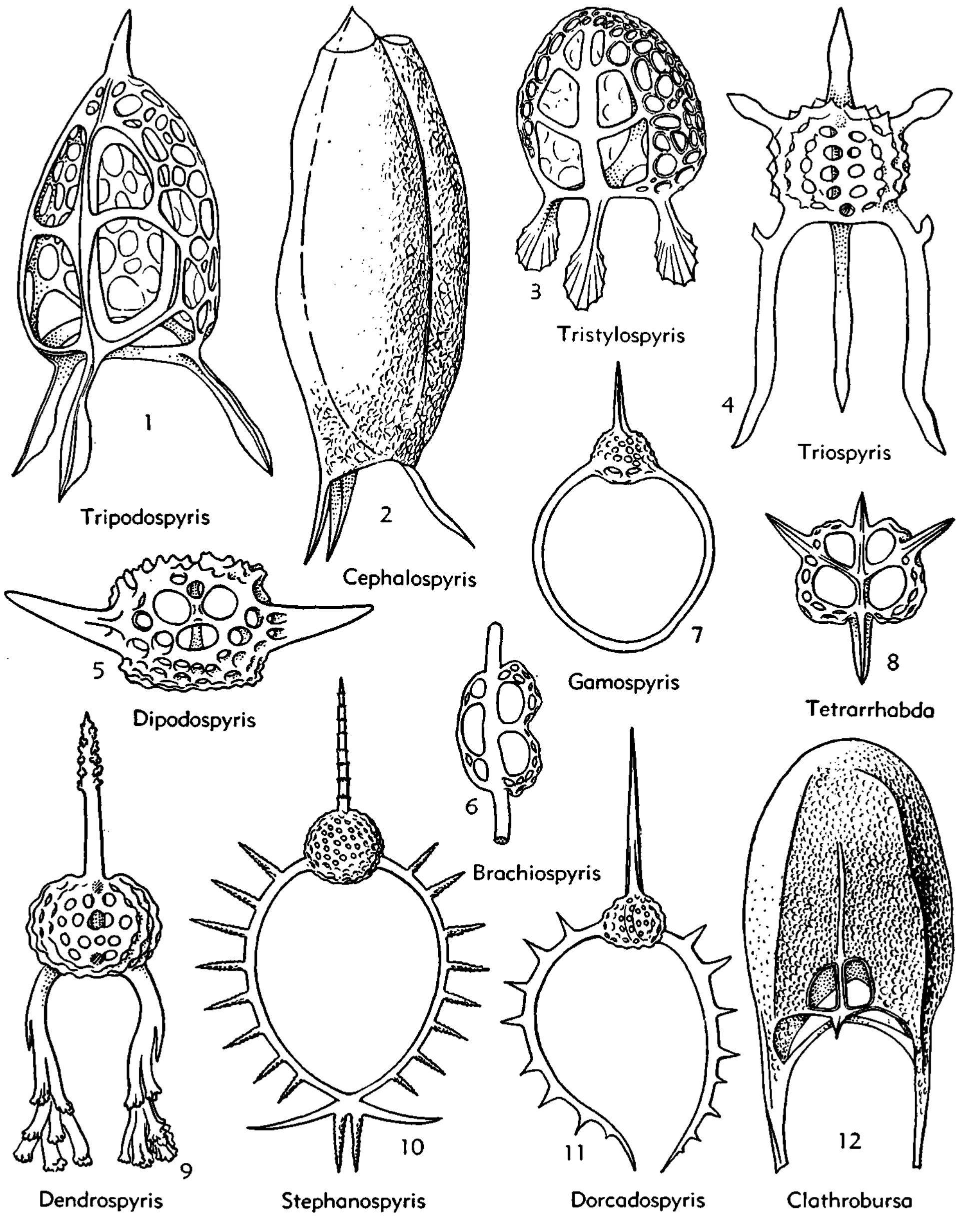


Fig. 54. Triospyrididae (p. D112).

Superfamily TRIOSPYRIDICAE Haeckel, 1882

[*ex* Triospyrida; emend. CAMPBELL, herein] [=Spyridina EHR., 1847 *(partim)*; Zygocyrtida HKL., 1862; Spyrida HKL., 1882; Orboidea POP., 1913 *(partim)*]

Bilocular cephalis with sagittal constriction. *Jur.-Rec.*

Family TRIOSPYRIDIDAE Haeckel, 1882

[as Triospyrida; emend. CAMPBELL, herein] [=Zygospyrida HKL., 1887]

Shell composed of cephalis and its apophyses; without apical cupola or dome or thorax. *Jur.-Rec.*

Subfamily TRIOSPYRIDINAE Haeckel, 1882

[as Triospyrida *(partim)*; emend. CAMPBELL, herein] [=Tripospyrida HKL., 1887]

Three basal feet. *Eoc.-Rec.*

Triospyris HKL., 1882 [**Triceraspyris tripodiscus* HKL., 1887][=*Triceraspyris* HKL., 1887 (obj.)]. Apex has 3 horns. *Rec.*

T. (Triospyris). Horns and feet unbranched.

T. (Triospyrium) HKL., 1887 [**Ceratospyris furcata* EHR., 1875; SD herein]. Horns simple; feet forked or branched.——FIG. 54,*4*. *T. (T.) giraffa* HKL., Rec., ×200 (42).

T. (Triospyridium) HKL., 1887 [**Triceraspyris damaecornis* HKL., 1887; SD herein]. Horns and feet forked or branched.

Cephalospyris HKL., 1882 [**C. cancellata* HKL., 1887]. Apex with a right and left apical hole; no horn. *Rec.*——FIG. 54,*2*. **C. cancellata*, Rec., ×200 (42).

Tripodospyris HKL., 1882 [**Tripospyris cortina* HKL., 1887][=*Tripospyris* HKL., 1887 (obj.)]. Apex with a single horn. *Eoc.-Rec.*

T. (Tripodospyris) [=*Tripospyrantha* HKL., 1887 (obj.)]. Basal plate with 2 large collar pores. *Rec.*——FIG. 54,*1*. *T. (T.) cortiniscus* HKL., Rec., ×300 (42).

T. (Tripospyrella) HKL., 1887 [**Tripospyris conifer* HKL., 1887; SD herein]. Basal plate with 3 large collar pores.

T. (Tripospyrissa) HKL., 1887 [**Tripospyris semantrum* HKL., 1887; SD herein]. Basal plate with 2 pairs of collar pores. *Eoc.-Rec.*

T. (Tripospyromma) HKL., 1887 [**Tripospyris hexomma* HKL., 1887; SD herein]. Basal plate with 6 or more collar pores. *Eoc.-Rec.*

Tristylospyris HKL., 1887 [**T. palmipes* HKL., 1887]. Apex without horn; no apical holes. *Eoc.-Rec.*

T. (Tristylospyris) [=*Tristylospyrula* HKL., 1887 (obj.)]. Feet unbranched. *Eoc.-Rec.*——FIG. 54,*3*. **T. (T.) palmipes*, Rec., ×200 (42).

T. (Tristylospyrium) HKL., 1887 [**T. ramosa*; SD herein]. Feet branched or forked. *Rec.*

Subfamily DIPODOSPYRIDINAE Haeckel, 1882

[as Dipodospyrida; emend. CAMPBELL, herein] [=Brachiospyrida HKL., 1882; Dipospyrida HKL., 1887]

Two lateral basal feet. *Eoc.-Rec.*

Dipodospyris HKL., 1882 [**Dipospyris bipes* HKL., 1887][=*Dipospyris* HKL., 1887 (obj.)]. Feet unbranched, with lateral spines; single apical horn. *Eoc.-Rec.*——FIG. 54,*5*. *D. cubus* HKL., Rec., ×200 (42).

Brachiospyris HKL., 1882 [**Ceratospyris ocellata* EHR., 1875]. Like *Dipodospyris* but without apical horn. *Paleoc.-Rec.*——FIG. 54,*6*. *B. diacantha* (EHR.), Rec., ×200 (42).

Dendrospyris HKL., 1882 [**Ceratospyris stylophora* EHR., 1875]. Feet branched like a tree; single apical horn. *Eoc.-Rec.*——FIG. 54,*9*. *D. arborescens* HKL., Rec., ×200 (42).

Dorcadospyris HKL., 1882 [**D. dentata* HKL., 1887]. Feet with lateral spines; single apical horn. *Mio.-Rec.*——FIG. 54,*11*. **D. dentata*, Rec., ×100 (42).

Gamospyris HKL., 1882 [**G. circulus* HKL., 1887]. Two unbranched feet grown together forming a ring; apex with single horn. *Rec.*——FIG. 54,*7*. **G. circulus*, Rec., ×100 (42).

Stephanospyris HKL., 1882 [**S. cordata* HKL., 1887]. Like *Gamospyris* but feet have lateral spines. *Rec.*——FIG. 54,*10*. *S. excellens* HKL., Rec., ×100 (42).

Subfamily TETRARRHABDINAE Campbell, nom. nov.

[*pro* Tetraspyrida HKL., 1887]

Two lateral and 2 sagittal feet. *Eoc.-Rec.*

Tetrarrhabda HKL., 1882 [**Tetraspyris stephanium* HKL., 1887][=*Tetraspyris* HKL., 1887 (obj.)]. With single apical horn. *Eoc.-Rec.*

T. (Tetrarrhabda). Feet unbranched. *Eoc.-Rec.*——FIG. 54,*8*. **T. (T.) stephanium*, Rec., ×150 (42).

T. (Tetracorethra) HKL., 1882 [**Tetraspyris tetracorethra* HKL., 1887 (=*Tetracorethra tetracorethra* HKL., 1887)]. Feet branched or forked. *Rec.*

Clathrobursa HKL., 1882 [**Tessarospyris clathrobursa* HKL., 1887 (=*Clathrobursa dictyopus* HKL., 1887, obj.)][=*Tessarospyris* HKL., 1887 (obj.)]. Without apical horn. *Rec.*——FIG. 54, *12*. **C. clathrobursa*, Rec., ×200 (42).

Subfamily PENTASPYRIDINAE Haeckel, 1882

[as Pentaspyrida; emend. CAMPBELL, herein]

Five basal feet. *Eoc.-Rec.*

Pentaspyris HKL., 1882 [**P. pentacantha* HKL., 1887]. Apex without horn. *Eoc.-Rec.*——FIG. 55,*8*. **P. pentacantha*, Rec., ×200 (42).

Aegospyris HKL., 1882 [**A. aequispina* HKL., 1887]. Apex with 3 horns. *Eoc.-Rec.*——FIG. 55,*1*. *A. aegoceras* HKL., Rec., ×200 (42).

Clathrospyris Hkl., 1882 [**C. camelopardalis* Hkl., 1887]. Apex with single horn. *Eoc.-Rec.*——Fig. 55,4. *C. pyramidalis* Hkl., Rec., ×200 (42).

Subfamily HEXASPYRIDINAE Haeckel, 1887
[as Hexaspyrida; emend. Campbell, herein]

Six basal feet. *Eoc.-Rec.*

Hexaspyris Hkl., 1887 [**H. alterna;* SD herein]. Apex with single horn. *Eoc.-Rec.*

H. (Hexaspyris) [=*Hexaspyridium* Hkl., 1887 (obj.)]. Feet unbranched. *Eoc.-Rec.*

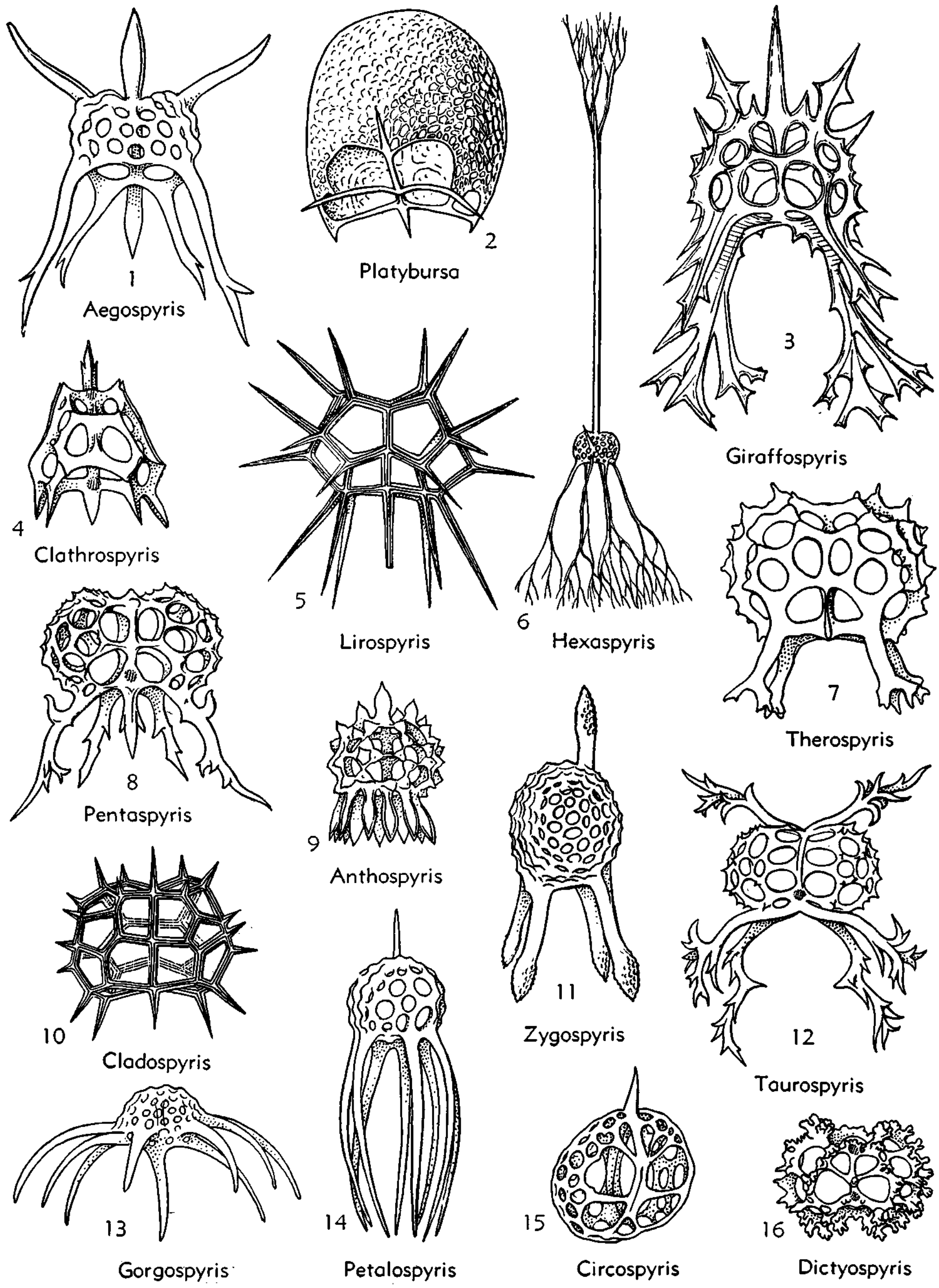


Fig. 55. Triospyrididae (p. D113, D114).

H. (**Hexacorethra**) Hkl., 1887 [**H. hexacorethra;* SD herein (=*Hexacorethra magica* Hkl., 1887; obj.)]. Feet forked or branched *Eoc.-Rec.*——Fig. 55,*6*. **H. (H.) hexacorethra,* Rec., ×100 (42).

Lirospyris Hkl., 1882 [**L. hexapoda* Hkl., 1887]. Three apical horns. *Eoc.-Rec.*——Fig. 55,*5*. **L. hexapoda,* Rec., ×200 (42).

Platybursa Hkl., 1882 [**Cantharospyris platybursa* Hkl., 1887 (=*Platybursa compressa* Hkl., 1887, obj.)][=*Cantharospyris* Hkl., 1887 (obj.)]. Lacks apical horn. *Eoc.-Rec.*——Fig. 55,*2*. **P. platybursa,* Rec., ×200 (42).

Subfamily THEROSPYRIDINAE Haeckel, 1882

[as Therospyrida; emend. Campbell, herein]

Four paired lateral basal feet. *Cret.-Rec.*

Therospyris Hkl., 1882 [**T. canis* Hkl., 1887]. Apex without apical horn. *Eoc.-Rec.*——Fig. 55, *7*. *T. felis* Hkl., Rec., ×200 (42).

Giraffospyris Hkl., 1882 [**Ceratospyris heptaceros* Ehr., 1875][=*Elaphospyris* Hkl., 1882 (obj.)]. Three apical horns. *Eoc.-Rec.*

G. (**Giraffospyris**). Feet unbranched. *Eoc.-Rec.*

G. (**Corythospyris**) Hkl., 1882 [**Elaphospyris damaecornis* Hkl., 1887]. Feet branched or forked. *Rec.*——Fig. 55,*3*. *G. (C.) crevicornis* Hkl., Rec., ×200 (42).

Taurospyris Hkl., 1882 [**T. cervina* Hkl., 1887]. Two lateral or frontal apical horns. *Rec.*——Fig. 55,*12*. **T. cervina,* Rec., ×200 (42).

Zygospyris Hkl., 1882 [**Z quadrupes* Hkl., 1887]. Apex with a single horn. *Cret.* (Calif.)-*Rec.*——Fig. 55,*11*. *Z. equis* Hkl., Rec., ×200 (42).

Subfamily PETALOSPYRIDINAE Campbell, nov.

Basal feet 7 to 12 or more. *Jur.-Rec.*

Petalospyris Ehr., 1847 [**D. foveolata* Ehr., 1854]. Single apical horn. *Jur.-Rec.*

P. (**Petalospyris**) [=*Petalospyrantha* Hkl., 1887 (obj.)]. Basal plate with 2 large collar pores. *Jur.-Rec.*

P. (**Petalospyrella**) Hkl., 1887 [**P. platyacantha* Ehr., 1875; SD herein]. Basal plate with 3 large collar pores. *Eoc.-Rec.*

P. (**Petalospyrissa**) Hkl., 1887 [**P. octopus;* SD herein]. Basal plate with 4 large collar pores. *Eoc.-Rec.*——Fig. 55,*14*. **P. (P.) octopus,* Rec., ×200 (42).

P. (**Petalospyromma**) Hkl., 1887 [**P. dictyocubus;* SD herein]. Basal plate with 6 or more large collar pores. *Eoc.-Rec.*

Anthospyris Hkl., 1882 [**A. mammillata* Hkl., 1887]. Three apical horns. *Eoc.-Rec.*——Fig. 55,*9*. **A. mammillata,* Rec., ×200 (42).

Cladospyris Ehr., 1847 [**C. ramosa*][=*Ceratospyris* Ehr., 1847 (obj.)]. Apex with numerous horns. *Eoc.-Rec.*

C. (**Cladospyris**). Spines forked or branched; meshes rounded or polygonal. *Eoc.-Rec.*

C. (**Lophospyris**) Hkl., 1882 [*non* Hkl., 1887] [**Ceratospyris polygona* Hkl., 1887]. Spines unbranched; meshes polygonal or within polygonal frames. *Eoc.-Rec.*——Fig. 55,*10*. *C. (L.) allmersii* Hkl., Rec., ×200 (42).

Gorgospyris Hkl., 1882 [**G. medusa* Hkl., 1887]. Lacks apical horns. *Eoc.-Rec.*

G. (**Gorgospyris**) [=*Gorgospyrium* Hkl., 1887 (obj.)]. Feet unbranched. *Eoc.-Rec.*——Fig. 55, *13*. **G. (G.) medusa,* Rec., ×150 (42).

G. (**Thamnospyris**) Hkl., 1882 [**G. schizopodia* Hkl., 1887]. Feet divided or branched. *Rec.*

Subfamily CIRCOSPYRIDINAE Haeckel, 1882

[as Circospyrida; emend. Campbell, herein]

Basal feet lacking. *Jur.-Rec.*

Circospyris Hkl., 1882 [**C. nucula* Hkl., 1887]. Single apical horn. *Rec.*——Fig. 55,*15*. **C. nucula,* Rec., ×200 (42).

Dictyospyris Ehr., 1847 [**D. ceratospyris*]. Lacks apical horn. *Jur.-Rec.*

D. (**Dictyospyris**) [=*Dictyospyrantha* Hkl., 1887 (obj.)]. Basal plate with 2 large collar pores. *Jur.-Rec.*——Fig. 55,*16*. *D. (D.) stalactites* Hkl., Rec., ×200 (42).

D. (**Dictyospyrella**) Hkl., 1887 [**D. triastoma* Ehr., 1875; SD herein]. Basal plate with 3 large collar pores. *Eoc.-Rec.*

D. (**Dictyospyrissa**) Hkl., 1887 [**D. fenestrata* Ehr., 1875; SD herein]. Basal plate with 4 large collar pores. *Eoc.-Rec.*

D. (**Dictyospyromma**) Hkl., 1887 [**D. hexastoma;* SD herein]. Basal plate with 6 or more large pores. *Eoc.-Rec.*

Family THOLOSPYRIDIDAE Haeckel, 1887

[as Tholospyrida; emend. Campbell, herein]

Cephalis with an apical cupola; without thorax. *Mio.-Rec.*

Subfamily THOLOSPYRIDINAE Haeckel, 1887

[as Tholospyrida *(partim);* emend. Campbell, herein]
[=Lophospyrida Hkl., 1887]

Basal feet 2 or 3; cupola with apical horn. *Mio.-Rec.*

Tholospyris Hkl., 1882 [**T. tripodiscus* Hkl., 1887]. Basal feet 3. *Mio.-Rec.*

T. (**Tholospyris**) [=*Tholospyrium* Hkl., 1887 (obj.)]. Feet unbranched. *Mio.-Rec.*——Fig. 56,*1*. *T. (T.) fenestrata* Hkl., Rec., ×200 (42).

T. (**Tholospyridium**) Hkl., 1887 [**T. ramosa;* SD herein]. Feet forked or branched. *Rec.*

Eulophospyris Campbell, 1951 [*pro Lophospyris* Hkl., 1887 (*non* 1882)][**Lophospyris diplodiscus* Hkl., 1887]. Two paired feet. *Rec.*——Fig. 56,*2*. **E. diplodiscus* (Hkl.), Rec., ×200 (42).

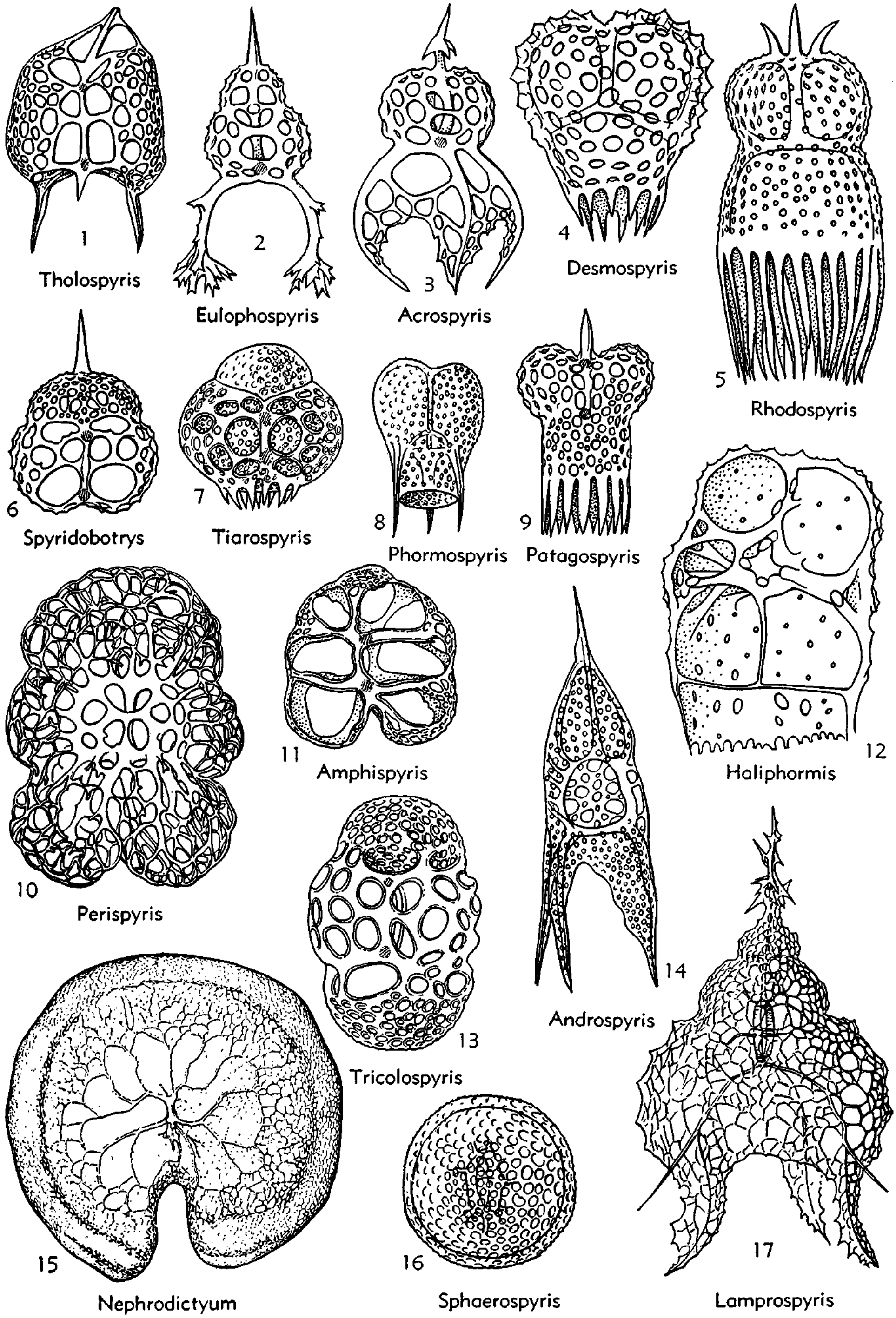


FIG. 56. Tholospyrididae, Phormospyrididae, Androspyrididae (p. D114, D116).

Subfamily TIAROSPYRIDINAE Haeckel, 1887

[as Tiarospyrida; emend. CAMPBELL, herein]

Basal feet 6 to 9 or more. *Rec.*

Tiarospyris HKL., 1882 [**T. pervia* HKL., 1887]. Lacking apical horn.——FIG. 56,*7*. *T. mitra* HKL., Rec., ×200 (42).

Sepalospyris HKL., 1882 [**S. platyphylla* HKL., 1887]. With apical horn.

Subfamily SPYRIDOBOTRYDINAE Campbell, nom. nov.

[*pro* Pylospyrida HKL., 1887]

Basal feet lacking. *Rec.*

Spyridobotrys HKL., 1862 [**S. trinacria*] [=*Pylospyris* HKL., 1882 (obj.)]. Cupola with apical horn.——FIG. 56,*6*. *S. canariensis* HKL., Rec., ×200.

Family PHORMOSPYRIDIDAE Haeckel, 1882

[as Phormospyrida; emend. CAMPBELL, herein]

Shell with thorax; without apical cupola. *Eoc.-Rec.*

Subfamily PHORMOSPYRIDINAE Haeckel, 1882

[as Phormospyrida *(partim)*; emend. CAMPBELL, herein] [=Acrospyrida HKL., 1882]

Basal feet 3. *Eoc.-Rec.*

Phormospyris HKL., 1882 [**P. tricostata* HKL., 1887]. Lacks apical horn. *Rec.*——FIG. 56,*8*. *P. tridentata* HKL., Rec., ×200 (42).

Acrospyris HKL., 1882 [**A. clathrocanium* HKL., 1887]. Single apical horn. *Eoc.-Rec.*——FIG. 56,*3*. **A. clathrocanium*, Rec., ×150 (42).

Subfamily RHODOSPYRIDINAE Haeckel, 1887

[as Rhodospyrida; emend. CAMPBELL, herein]

Basal feet 9 to 12 or more. *Eoc.-Rec.*

Rhodospyris HKL., 1882 [**R. tricornis* HKL., 1887]. Three apical horns. *Rec.*——FIG. 56,*5*. **R. tricornis*, Rec., ×300 (42).

Desmospyris HKL., 1882 [**D. mammillata* HKL., 1887]. Lacks apical horn. *Eoc.-Rec.*——FIG. 56,*4*. **D. mammillata*, Rec., ×300 (42).

Haliphormis EHR., 1847 [*non* HKL., 1887 (=*Haliphormartidium* CAMPBELL, 1951)] [**H. calva* EHR., 1854] [=*Saccospyris* HAECKER, 1908]. Lacks apical horn; has corona of minute serrations around basal shell mouth. *Rec.*——FIG. 56,*12*. *H. antarctica* (HAECKER), Rec., ×400 (43).

Patagospyris HKL., 1882 [**Petalospyris confluens* EHR., 1875]. Has apical horn. *Eoc.-Rec.*——FIG. 56,*9*. *P. anthocyrtis* HKL., Rec., ×200 (42).

Family ANDROSPYRIDIDAE Haeckel, 1887

[as Androspyrida; emend. CAMPBELL, herein]

Has thorax and cephalis with apical cupola. *Eoc.-Rec.*

Subfamily ANDROSPYRIDINAE Haeckel, 1887

[as Androspyrida *(partim)*; emend. CAMPBELL, herein] [=Lamprospyrida HKL., 1887]

Basal feet 3. *Rec.*

Androspyris HKL., 1887 [**A. pithicus;* SD herein]. Lattice simple; apical horn usually not fenestrated.——FIG. 56,*14*. **A. pithicus*, Rec., ×300 (42).

Lamprospyris HKL., 1882 [**L. darwinii* HKL., 1887]. Shell wholly or partly spongy; apical horn always fenestrated.——FIG. 56,*17*. **L. darwinii*, Rec., ×150 (42).

Subfamily PERISPYRIDINAE Haeckel, 1882

[as Perispyrida; emend. CAMPBELL, herein]

Shell 3-jointed; without basal feet. *Rec.*

Perispyris HKL., 1882 [**P. bicincta* HKL., 1887]. Shell with 2 transverse strictures; lattice double or spongy.——FIG. 56,*10*. **P. bicincta*, Rec., ×200 (42).

Amphispyris HKL., 1882 [**A. thorax* HKL., 1887]. Like *Perispyris* but lattice complete only in frontal ring.

A. (Amphispyris) [=*Amphispyrium* HKL., 1887 (obj.)]. On each side of ring-plane 3 pairs of large annular meshes.——FIG. 56,*11*. **A. (A.) thorax*, Rec., ×150 (42).

A. (Amphispyridium) HKL., 1887 [**A. sternalis;* SD herein]. On each side of ring-plane 4 pairs of large meshes.

Tricolospyris HKL., 1882 [**T. kantiana* HKL., 1887]. Lattice complete on all sides, otherwise like *Perispyris*.——FIG. 56,*13*. **T. kantiana*, Rec., ×300 (42).

Subfamily PARADICTYINAE Haeckel, 1882

[as Paradictyida; emend. CAMPBELL, herein] [=Nephrospyrida HKL., 1887]

Shell discoidal or spherical; without basal feet. *Eoc.-Rec.*

Nephrodictyum HKL., [**Nephrospyris renilla* HKL., 1887][=*Nephrospyris* HKL., 1887 (obj.)]. Shell discoidal, subcircular or bean-shaped. *Rec.*

N. (Nephrodictyum). Simple network.

N. (Paradictyum) HKL., 1882 [**Nephrospyris paradictyum* HKL., 1887 (=*Paradictyum paradoxum* HKL., 1887, obj.)]. Double network, space between filled with weblike meshes.——FIG. 56,*15*. **N. (P.) paradictyum*, Rec., ×100 (42).

Sphaerospyris HKL., 1887 [**Dictyospyris sphaera* BÜTSCHLI, 1882]. Shell spherical. *Eoc.-Rec.*——FIG. 56,*16*. *S. globosa* HKL., Rec., ×200 (42).

Superfamily ARCHIPILIICAE Haeckel, 1882

[*ex* Archipilida; emend. CAMPBELL, herein] [=Cyrtida HKL., 1862; Cyrtoidea HKL., 1887]

Cephalis neither bilocular nor lobate. *Cam.-Rec.*

Subsuperfamily ARCHIPILIILAE Haeckel, 1882

[*ex* Archipilida; emend. CAMPBELL, herein] [=Monocyrtida HKL., 1862]

Shell lacking joints or strictures. *Cam.-Rec.*

Family ARCHIPILIIDAE Haeckel, 1882

[as Archipilida; emend. CAMPBELL, herein] [Tripocalpida HKL., 1887]

Three radial apophyses. *Cam.-Rec.*

Subfamily ARCHIPILIINAE Haeckel, 1882

[as Archipilida *(partim)*; emend. CAMPBELL, herein]

Basal shell mouth open. *Cam.-Rec.*

Archipilium HKL., 1882 [**A. orthopterum* HKL., 1887]. Without feet or apical horn. *Rec.*——FIG. 57,*2*. **A. orthopterum,* Rec., ×200 (42).

Tripocalpis HKL., 1882 [**T. plectaniscus* HKL., 1887]. Three unbranched solid feet; with apical horn. *Cam.-Rec.*——FIG. 57,*1*. *T. cortinaris* HKL., Rec., ×200 (42).

Bisphaerocephalus POP., 1909 [**B. minutus*]. Cephalis incompletely divided by stricture. *Rec.*——FIG. 57,*9*. **B. minutus,* Rec., ×500 (48).

Tripodictyopus HERTWIG, 1879 [**T. elegans*]. Three shovel-shaped latticed feet; with apical horn. *Rec.*——FIG. 57,*11*. *T. vatillum* HKL., Rec., ×200 (42).

Tripilidium HKL., 1882 [**T. nanum* RÜST, 1885]. Like *Tripodiscium* but lacks apical horn. *Cam.-Rec.*

T. (Tripilidium) [=*Tristylocorys* HKL., 1887 (obj.)]. Feet unbranched. *Cam.-Rec.*——FIG. 57,*10*. *T. (T.) costatum* HKL., Rec., ×200 (42).

T. (Tripodocorys) HKL., 1882 [**T. fischeri* RÜST, 1885]. Feet forked or branched. *Jur.-Rec.*

Tripodiscium HKL., 1882 [**T. tristylospyris* HKL., 1887]. Like *Tripocalpis* but has 3 lateral ribs in wall, and lacks apical horn. *Cam.-Rec.*

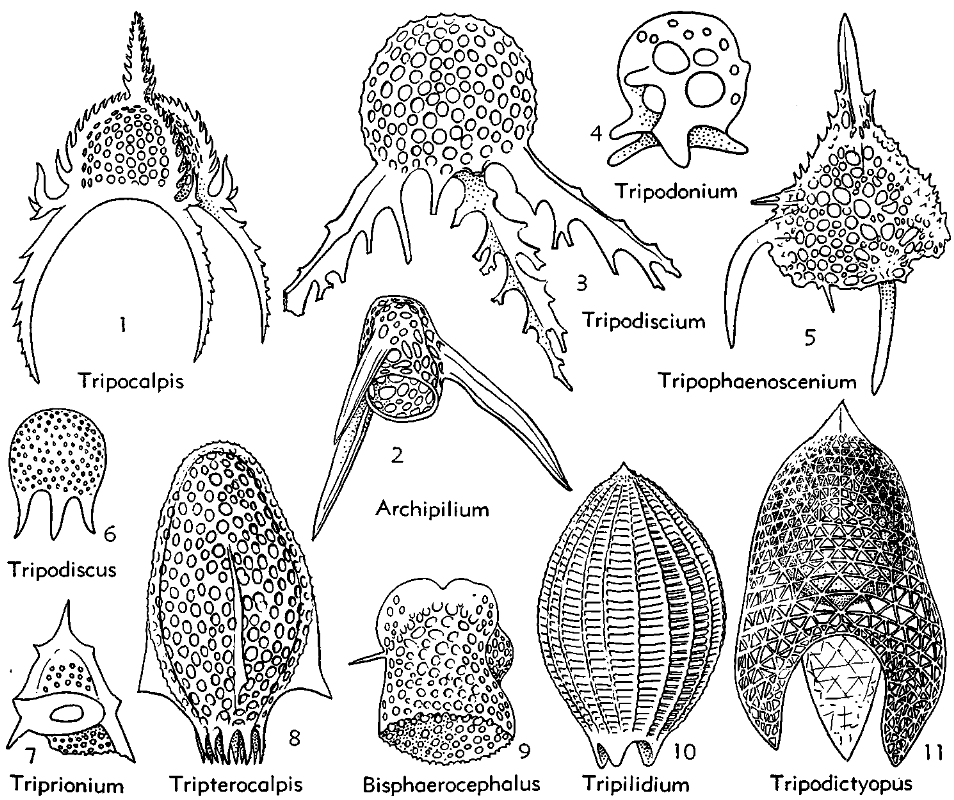


FIG. 57. Archipiliidae (p. D117, D118).

T. (Tripodiscium) [=*Tripodiscinus* Hkl., 1887 (obj.)]. Feet unbranched. *Cam.-Rec.*

T. (Tripodisculus) Hkl., 1887 [**T. sphaerocephalum;* SD herein]. Feet branched or forked. *Rec.*——Fig. 57,*3*. **T. (T.) sphaerocephalum,* Rec., ×300 (42).

Tripodiscus Hkl., 1882 [**T. modestus* Rüst, 1885]. Shell globular; 3 short stout feet. *Jur.*——Fig. 57,*6*. **T. modestus,* Jur., Ger., ×150 (51).

Tripodonium Hkl., 1882 [**T. campanulatum* Hkl., 1887]. Like *Tripocalpis* but lacks apical horn. *Mio.-Rec.*——Fig. 57,*4*. *T. caputmortis* Vinassa, Mio., Italy, ×400 (55).

Tripophaenoscenium C.-Cl. [**T. laimingi*]. Three unbranched feet; 3 lateral subapical spikes; internal columella. *Mio.*——Fig. 57,*5*. **T. laimingi,* Mio., Calif., ×120 (35).

Triprionium Hkl., 1882 [**T. montisrigi* Rüst, 1885]. Three forked feet; with apical horn; lateral ribs in wall. *Jur.*——Fig. 57,*7*. **T. montisrigi,* Jur., Ger., ×75 (51).

Tripterocalpis Hkl., 1882 [**T. phylloptera* Hkl., 1887]. Six to 9 terminal feet; without apical horn; 3 lateral wings. *Rec.*——Fig. 57,*8*. **T. phylloptera,* Rec., ×200 (42).

Trissopilium Hkl., 1882 [**T. tetraplecta* Hkl., 1887]. Like *Archipilium* but has apical horn. *Plio.-Rec.*

Subfamily ARCHIPERINAE Haeckel, 1882

[as Archiperida; emend. Campbell, herein]

Basal shell mouth fenestrated. *Rec.*

Archipera Hkl., 1882 [**A. cortiniscus* Hkl., 1887]. Without internal columella; 3 basal feet; 2 or more apical horns.——Fig. 58,*1*. **A. cortiniscus,* Rec., ×200 (42).

Archibursa Hkl., 1882 [**A. tripodiscus* Hkl., 1887]. Like *Archipera* but lacks apical horn.——Fig. 58,*3*. **A. tripodiscus,* Rec., ×200 (42).

Archiscenium Hkl., 1882 [**A. quadrispinum* Hkl., 1887]. Unbranched internal columella; 3 latticed wings connecting feet and horn.——Fig. 58,*5*. **A. quadrispinum,* Rec., ×300 (42).

Cladoscenium Hkl., 1882 [**C. fulcratum* Hkl., 1887]. Three free feet; no latticed wings; branched columella.——Fig. 58,*6*. *C. ancoratum* Hkl., Rec., ×300 (42).

Euscenium Hkl., 1887 [**E. plectaniscus;* SD herein]. Like *Cladoscenium* but columella unbranched.

E. (Euscenium) [=*Euscenarium* Hkl., 1887 (obj.)]. Feet unbranched.——Fig. 58,*4*. *E. (E.) tricolpium* Hkl., Rec., ×300 (42).

E. (Euscenidium) Hkl., 1887 [**E. furcatum;* SD herein]. Feet branched or forked.

Peridium Hkl., 1882 [**P. lasanum* Hkl., 1887]. Like *Archipera* but has only single horn.

P. (Peridium) [=*Peridarium* Hkl., 1887 (obj.)]. Feet unbranched.

P. (Archiperidium) Hkl., 1887 [**P. spinipes;* SD herein]. Feet spiny or branched.——Fig. 58,*2*. **P. (P.) spinipes,* Rec., ×300 (42).

Pteroscenium Hkl., 1882 [**P. arcuatum* Hkl., 1887]. Like *Archiscenium* but has branched columella.——Fig. 58,*7*. *P. pinatum* Hkl., Rec., ×300 (42).

Family ARCHIPHORMIDIDAE Haeckel, 1882

[as Archiphormida; emend. Campbell, herein]
[=Phaenocalpida Hkl., 1887]

Radial apophyses 4 to 9 or more. *Ord.-Rec.*

Subfamily ARCHIPHORMIDINAE Haeckel, 1882

[as Archiphormida *(partim);* emend. Campbell, herein]
[=Acropyramida Hkl., 1882]

Basal shell mouth open. *Ord.-Rec.*

Archiphormis Hkl., 1882 [**Halicalyptra cancellata* Ehr., 1854]. Bell-shaped or urnlike shell with radial ribs; mouth with corona of spines; without apical horn. *Rec.*——Fig. 59,*1*. *A. urceolata* Hkl., Rec., ×150 (42).

Arachnocalpis Hkl., 1882 [**A. ellipsoides,* Hkl., 1887]. Without radial ribs; free terminal feet; double shell with external mantle; without apical horn. *Rec.*——Fig. 59,*11*. **A. ellipsoides,* Rec., ×150 (42).

Bathrocalpis Cl.-C., 1942 [**B. campanula*]. Without radial feet; internal columella. *Eoc.*——Fig. 59,*4*. **B. campanula,* U.Eoc., Calif., ×150 (39).

Bathropyramis Hkl., 1882 [**B. acephala* Hkl., 1887]. Pyramidal shell with simple lattice; without apical horn. *Cret.-Rec.*

B. (Bathropyramis) [=*Acropyramis* Hkl., 1882 (obj.)]. Without surface spines. *Cret.-Rec.*——Fig. 59,*3b*. *B. (B.) quadrata,* Hkl., Rec., ×200 (42).

B. (Cladopyramis) Hkl., 1882 [**B. spinosa* Hkl., 1887]. With prominent unbranched or branched spines on surface. *Mio.-Rec.*——Fig. 59,*3a*. *B. (C.) ramosa* Hkl., Rec., ×150 (42).

Cinclopyramis Hkl., 1882 [**C. cribellum* Hkl., 1887]. Like *Bathropyramis* but has double network. *Eoc.-Rec.*——Fig. 59,*12*. *C. infundibulum* Hkl., Rec., ×150 (42).

Cladarachnium Hkl., 1882 [**C. ramosum* Hkl., 1887]. Bell-shaped shell with branched radial ribs. *Rec.*——Fig. 59,*7*. **C. ramosum,* Rec., ×100 (42).

Cystophormis Hkl., 1887 [**C. pila;* SD herein]. Shell with radial ribs; ovate or urn-shaped to bell-shaped shell; mouth constricted; without radial feet or apical horn. *Rec.*——Fig. 59,*8*. **C. pila,* Rec., ×200 (42).

Halicalyptra Ehr., 1847 [**H. virginica* Ehr., 1854]. Like *Lithocarpium* but has apical horn. *Ord.-Rec.*

H. (Halicalyptra) [=*Acrocalpis* HKL., 1882 (obj.)]. Surface without spines or thorns. *Ord.-Rec.*——FIG. 59,*9*. *H. (H.) petalospyris* HKL., Rec., ×200 (42).

H. (Echinocalpis) HKL., 1882 [**H. spinosa* HKL., 1887]. Surface spiny or thorny. *Rec.*

Haliphormartidium CAMPBELL, 1951 [*pro Haliphormis* HKL., 1887 (*non* EHR., 1847)][**Haliphormis lagena* HKL., 1887]. Like *Archiphormis* but has apical horn. *Rec.*——FIG. 59,*10*. **H. lagena* (HKL.), Rec., ×100 (42).

Lithocarpium STÖHR, 1880 [**L. pyriforme*] [=*Carpocanistrum* HKL., 1887 (obj.)]. Without radial ribs; with corona of free feet; without mantle or apical horn. *Eoc.-Rec.*——FIG. 59,*5*. *L. flosculum* (HKL.), Rec., ×300 (42).

Litharachnium HKL., 1860 [**L. arachnoides* HKL., 1862; SD herein]. Like *Cladarachnium* but has unbranched radial ribs. *Rec.*

L. (Litharachnium) [=*Litharachnidium* HKL., 1887 (obj.)]. Apex with 3 pores.——FIG. 59,*6*. *L. araneosum* HKL., Rec., ×150 (42).

L. (Litharachnoma) HKL., 1887 [**L. pilidium;* SD herein]. Apex with 4 pores.

Peripyramis HKL., 1882 [**P. circumtexta* HKL., 1887]. Like *Bathropyramis* but has outer mantle. *Rec.*——FIG. 59,*2*. **P. circumtexta,* Rec., ×150 (42).

Subfamily ARCHIPHATNINAE Haeckel, 1882

[as Archiphatnida (*partim*); emend. CAMPBELL, herein]

Basal shell mouth fenestrated. *Jur.-Rec.*

Archiphatna HKL., 1882 [**Archiphaena gorgospyris* HKL., 1887][=*Archiphaena* HKL., 1887 (obj.)]. Without columella or apical horn. *Rec.*

A. (Archiphatna) [=*Coronophatna* HKL., 1882 (obj.); *Coronophaena* HKL., 1887 (obj.)]. Feet unbranched.——FIG. 60,*7*. **A. (A.) gorgospyris,* Rec., ×200 (42).

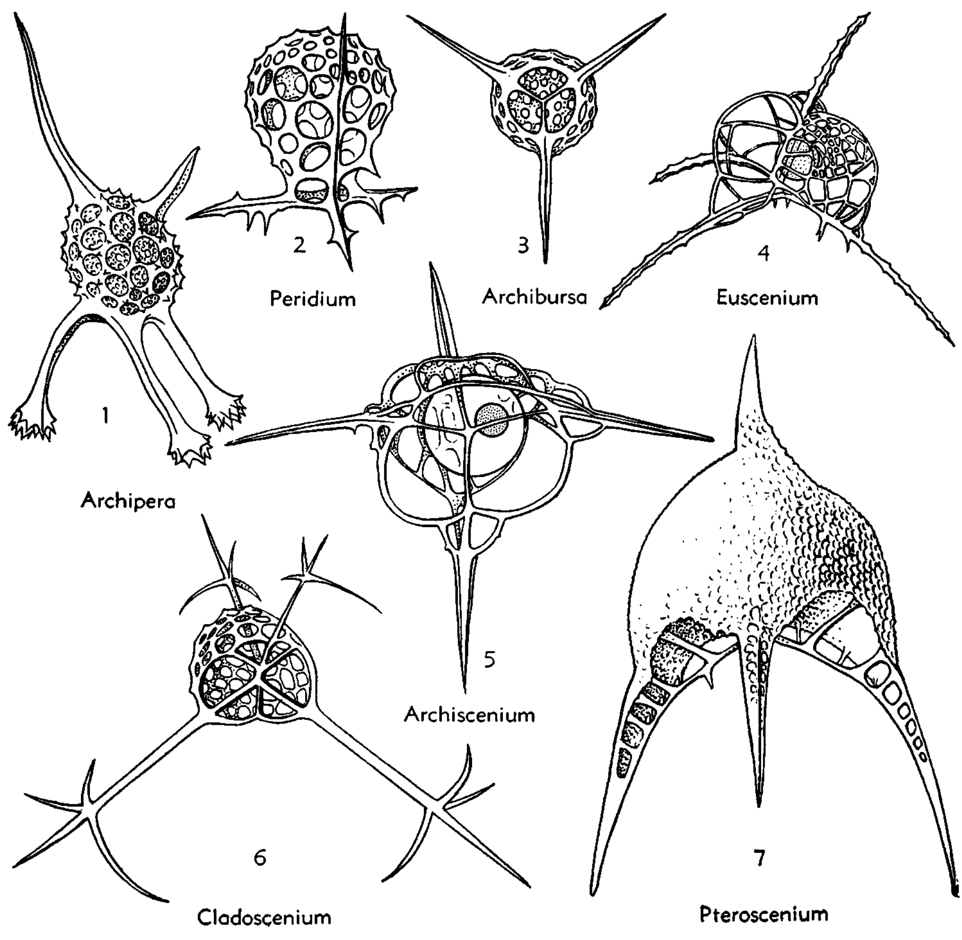


FIG. 58. Archipiliidae (p. D118).

A. (Stephanophatna) Hkl., 1882 [**Archiphaena stephanoma* Hkl., 1887][=*Stephanophaena* Hkl., 1887 (obj.)]. Feet branched or forked.

Acrocorona Hkl., 1882 [**Calopophaena tetrarrhabda* Hkl., 1887][=*Tetrapteroma* Hkl., 1882; *Calopophaena* Hkl., 1887 (obj.)]. Like *Archiphatna* but has apical horn. *Rec.*

A. (Acrocorona). Unbranched feet.——Fig. 60,*8*. *A. (A.) hexarrhabda* Hkl., Rec., ×200 (42).

A. (Cladocorona) Hkl., 1882 [**Calopophaena tetracorethra* Hkl., 1887]. Feet branched or forked.

Phaenocalpis Hkl., 1887 [**P. petalospyris;* SD herein]. Unbranched free columella. *Eoc.-Rec.*——Fig. 60,*11*. **P. petalospyris,* Rec., ×200 (42).

Phaenoscenium Hkl., 1887 [**P. hexapodium;* SD herein]. Like *Phaenocalpis* but has branched columella. *Jur.-Rec.*——Fig. 60,*12*. **P. hexapodium,* Rec., ×150 (42).

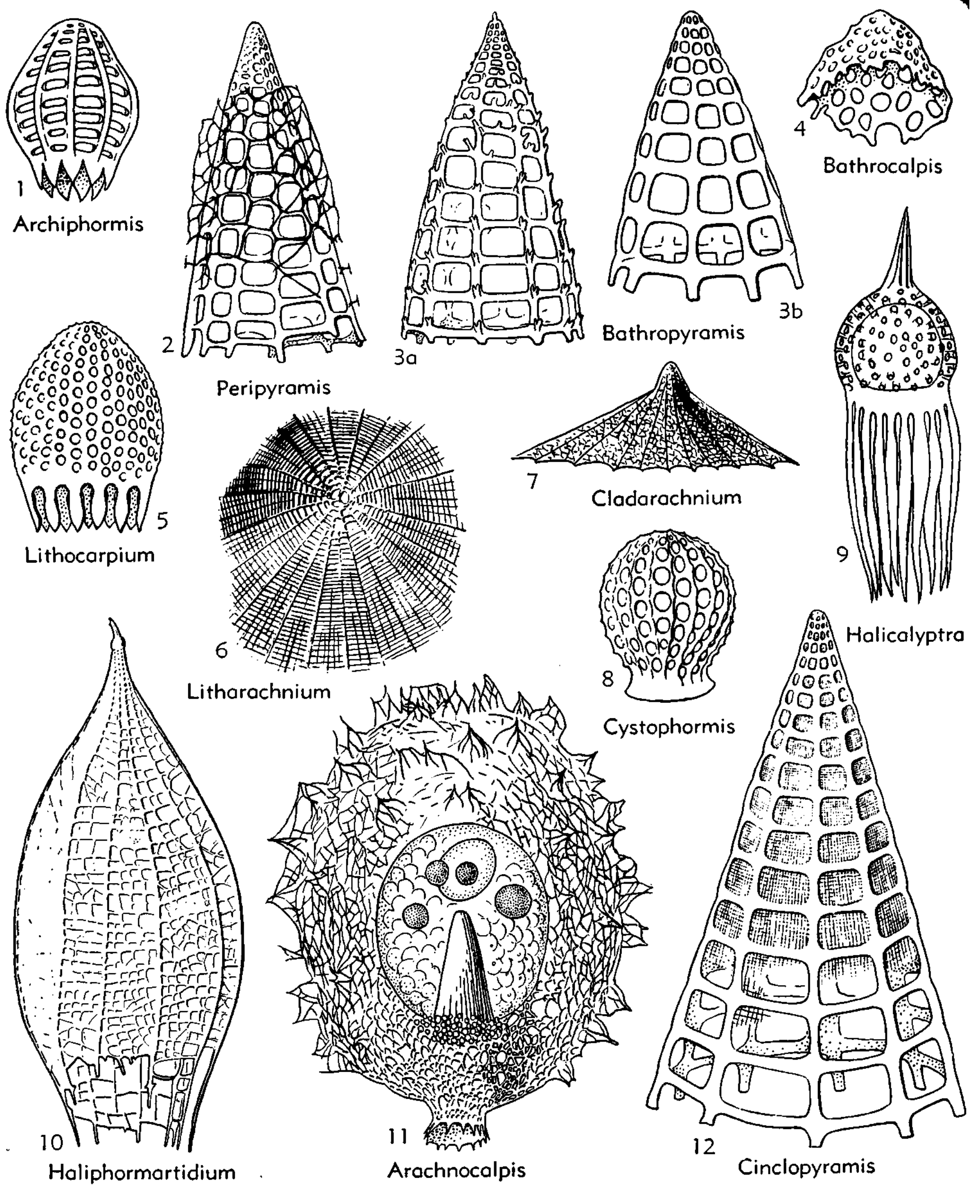


Fig. 59. Archiphormididae (p. D118, D119).

Family ARCHICORYTHIDAE Haeckel, 1887

[as Archicorida; emend. CAMPBELL, herein] [=Cyrtocalpida HKL., 1887]

Without radial apophyses. *Cam.-Rec.*

Subfamily ARCHICORYTHINAE Haeckel, 1882

[as Archicorida *(partim)*; emend. CAMPBELL, herein]

Basal shell mouth open. *Cam.-Rec.*

Archicorys HKL., 1882 [**A. galea* HKL., 1887]. Like *Cyrtocalpis* but has apical horn. *Cam.-Rec.* ——FIG. 60,*1*. *A. ovata* HKL., Rec., ×200 (42).

Cornutanna HKL., 1882 [**C. orthoconus* HKL., 1887]. Conical shell with simple lattice; without apical horn. *Jur.-Rec.*

C. (Cornutanna) [=*Orthocornutanna* CL.-C., 1945 (obj.)]. Shell axis straight. *Jur.-Rec.*——FIG. 60,*5*. *C. (C.) charlestownensis* CL.-C., U.Eoc., Calif., ×200 (39).

C. (Heterocornutanna) CL.-C., 1945 [**C. cyrtoconus* HKL., 1887]. Shell axis curved. *Jur.-Rec.*

Cornutella EHR., 1838 [**C. clathrata* EHR., 1884]. Like *Cornutanna* but has distinct apical horn. *Jur.-Rec.*

C. (Cornutella) [=*Cornutissa* HKL., 1882 (obj.)]. Shell axis straight; pores round and without polygonal frames. *Eoc.-Rec.*——FIG. 60,*3a*. *C. (C.) paloverdensis* CL.-C., Mio., Calif. (common), ×150 (39).

C. (Cornutellium) HKL., 1882 [*non* 1887][**C. limbatum* RÜST, 1885]. Shell axis straight; pores polygonal or within polygonal frames. *Jur.-Rec.* ——FIG. 60,*3b*. *C. (C.) hexagona* HKL., Rec., ×400 (42).

C. (Cornutosa) HKL., 1882 [**C. curvata* HKL., 1887] [=*Cornutura* HKL., 1882]. Shell axis curved; pores circular. *Eoc.-Rec.*

Cyrtocalpis HKL., 1860 [**C. amphora* HKL., 1862; SD herein][=*Cyrtolepis* RÜST, 1885 (obj.)]. Ovate or urn-shaped shell with simple lattice; constricted mouth; without apical horn. *Cam.-Rec.*——FIG. 60,*6*. *C. urceolatus* HKL., Rec., ×200 (42).

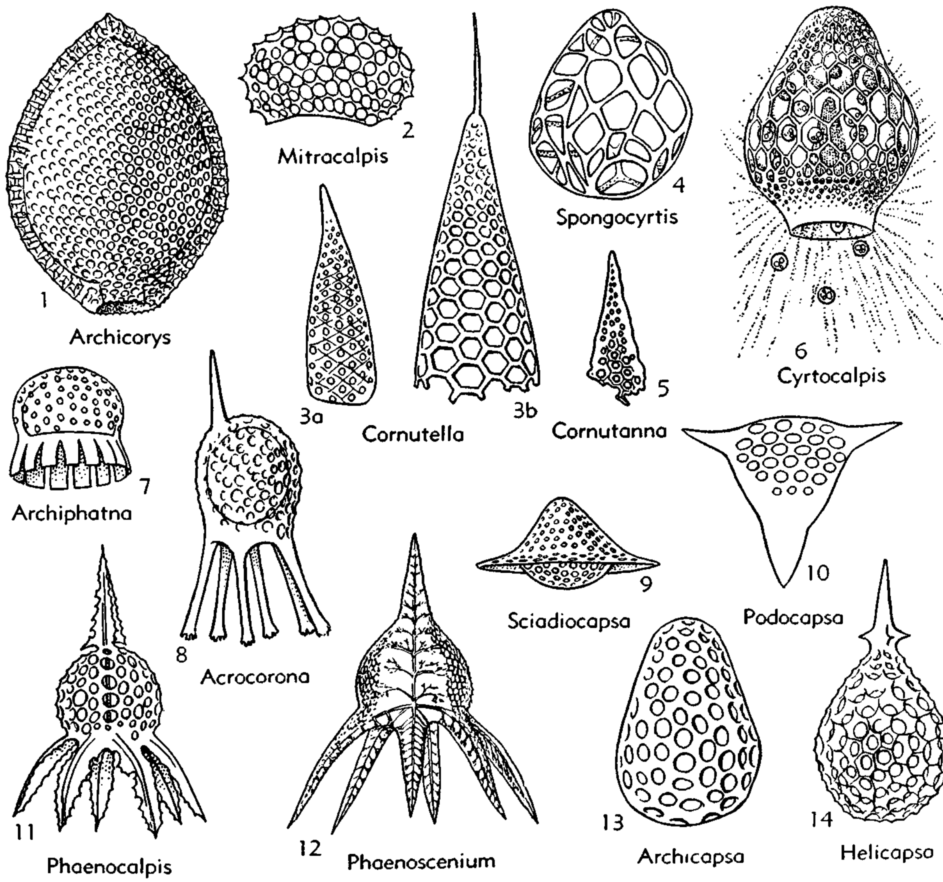


FIG. 60. Archiphormididae, Archicorythidae (p. D119-D122).

Mitracalpis Hkl., 1882 [**M. palliata* Hkl., 1887]. Ovate shell with outer mantle. *Cret.-Rec.*——Fig. 60,*2*. *M. depressa* Rüst, Cret., C.Eur., ×300 (51).

Spongocyrtis Dunikowski, 1882 [**S. montisovis*]. Like *Mitracalpis* but has spongy lattice. *Carb.-Jur.*——Fig. 60,*4*. *S. eurydictyum* Rüst, Carb., Harz Mts., ×100 (51).

Subfamily ARCHICAPSINAE Haeckel, 1882

[as Archicapsida; emend. Campbell, herein]

Basal shell mouth fenestrated. *Perm.-Rec.*

Archicapsa Hkl., 1882 [**A. pyriformis* Rüst, 1885]. Lacks apical horn. *Perm.-Rec.*——Fig. 60,*13*. *A. triforis* Hkl., Rec., ×300 (42).

Halicapsa Hkl., 1882 [**H. pulex* Rüst, 1885]. Like *Archicapsa* but has apical horn. *Cret.-Rec.*

H. (Halicapsa) [=*Calpocapsa* Hkl., 1887 (obj.)]. Surface not spiny. *Cret.-Rec.*——Fig. 60,*14*. *H. (H.) trigochin* Hkl., Rec., ×200 (42).

H. (Echinocapsa) Hkl., 1882 [**H. papillata* Hkl., 1887]. Surface spiny, thorny, or papillate. *Cret.-Rec.*

Podocapsa Rüst, 1885 [**P. guembelii*]. Three or more fenestrated appendages. *Jur.*——Fig. 60,*10*. **P. guembelii,* Jur., Switz., ×150 (51).

Sciadiocapsa Squin., 1904 [**S. euganea*]. Peripheral flange surrounds fenestrate mouth plate of lenslike shell; without apical spine. *Cret.*——Fig. 60,*9*. **S. euganea,* Cret., Italy, ×150 (52).

Subsuperfamily SETHOPILIILAE Haeckel, 1882

[*ex* Sethopilida; emend. Campbell, herein]
[=Dicyrtida Hkl., 1862]

Shell divided by transverse stricture into cephalis and thorax. *Cam.-Rec.*

Family SETHOPILIIDAE Haeckel, 1882

[as Sethopilida; emend. Campbell, herein]
[=Tripocyrtida Hkl., 1887]

Shell bears 3 radial apophyses. *Jur.-Rec.*

Subfamily SETHOPILIINAE Haeckel, 1882

[as Sethopilida *(partim)*; emend. Campbell, herein]

Basal shell mouth open. *Jur.-Rec.*

Sethopilium Hkl., 1882 [**S. orthopus* Hkl., 1887]. Like *Dictyophimus* but without cephalic horn and lacks septum between shell joints. *Eoc.-Rec.*——Fig. 61,*7*. *S. macropus* Hkl., Rec., ×150 (42).

Acerocanium Vinassa, 1900 [**A. globosum*]. Thorax without radial ribs; solid straight feet; lacks apical horn. *Mio.*——Fig. 61,*15*. **A. globosum,* Mio., Italy, ×200 (55).

Amphiplecta Hkl., 1882 [**A. amphistoma* Hkl., 1887][=*Amphicryphalus* Hkl., 1887 (obj.); *Trisulcus* Pop., 1913]. Like *Eucecryphalus* but ribs inside thorax; cephalis with large apical hole. *Rec.*——Fig. 61,*14*. *A. acrostoma* Hkl., Rec., ×200 (42).

Callimitra Hkl., 1882 [**C. carolatae* Hkl., 1887]. Thorax completely latticed; thoracic ribs connected by latticed vertical wings to cephalis; with 4 cephalic spines. *Rec.*——Fig. 61,*9*. **C. carolatae,* Rec., ×300 (42).

Clathrocanium Ehr., 1860 [**C. squarrosum* Ehr., 1872; SD herein]. Three prominent lateral ribs in thorax; without latticed wings; ribs alternated with 3 large thoracic holes; with apical horn. *Rec.*

C. (Clathrocanium) [=*Clathrocanidium* Hkl., 1887 (obj.)]. Apical horn not fenestrated; basal shell mouth smooth.——Fig. 61,*11*. *C. (C.) sphaerocephalum* Hkl., Rec., ×300 (42).

C. (Clathrocorona) Hkl., 1882 [**C. diadema* Hkl., 1887]. Apical horn fenestrated; basal shell mouth with spiny corona.

Clathrocorys Hkl., 1882 [**C. murrayi* Hkl., 1887]. Three prominent lateral thoracic ribs alternated with 3 large thoracic holes; ribs connected with apical horn by latticed wings. *Rec.*——Fig. 61,*4*. **C. murrayi,* Rec., ×300 (42).

Clathromitra Hkl., 1882 [**C. pterophormis* Hkl., 1887]. Like *Callimitra* but has 5 cephalic spines. *Rec.*——Fig. 61,*6*. **C. pterophormis,* Rec., X200 (42).

Dictyophimus Ehr., 1847 [**D. lucerna* Ehr., 1854; SD herein]. Three complete thoracic ribs prolonged as solid divergent feet; cephalis with apical horn; without latticed wings. *Jur.-Rec.*

D. (Dictyophimus) [=*Dictyophimium* Hkl., 1887 (obj.)]. Without prominent spines on edges of ribs. *Jur.-Rec.*——Fig. 61,*12*. *D. (D.) babylonis* Cl.-C., U.Eoc., Calif., ×150 (39).

D. (Lamprotripus) Hkl., 1882 [**D. triserratus* Hkl., 1887]. Prominent spines on edge of thoracic ribs. *Rec.*

Eucecryphalus Hkl., 1860 [*E. gegenbauri* Hkl., 1862]. Three free wings or solid spines outside thorax; without apical hole; with apical spine. *Eoc.-Rec.*

E. (Eucecryphalus) [=*Eucecryphalium* Hkl., 1887 (obj.)]. Shell mouth with corona of spines. *Eoc.-Rec.*

E. (Eucyrtomphalus) Hkl., 1882 [**E. corocalyptra* Hkl., 1887]. Shell mouth devoid of spines. *Rec.*——Fig. 61,*8*. *E. (E.) campanella* (Ehr.), Rec., ×200 (42).

Lamprodiscus Ehr., 1860 [**L. monoceros* Ehr., 1872; SD herein]. Three divergent lateral ribs in wall of flat, conical, discoidal or pyramidal thorax; with apical horn; shell mouth devoid of spines. *Rec.*

Lampromitra Hkl., 1882 [**L. coronata* Hkl., 1887]. Like *Lamprodiscus* but mouth has prominent spiny corona. *Rec.*——Fig. 61,*13*. *L. huxleyi* Hkl., Rec., ×200 (42).

Lithomelissa Ehr., 1847 [**L. tartari* Ehr., 1854]. Thoracic ribs prolonged as lateral wings or spines; thorax latticed; without terminal feet; with one or more apical horns. *Eoc.-Rec.*

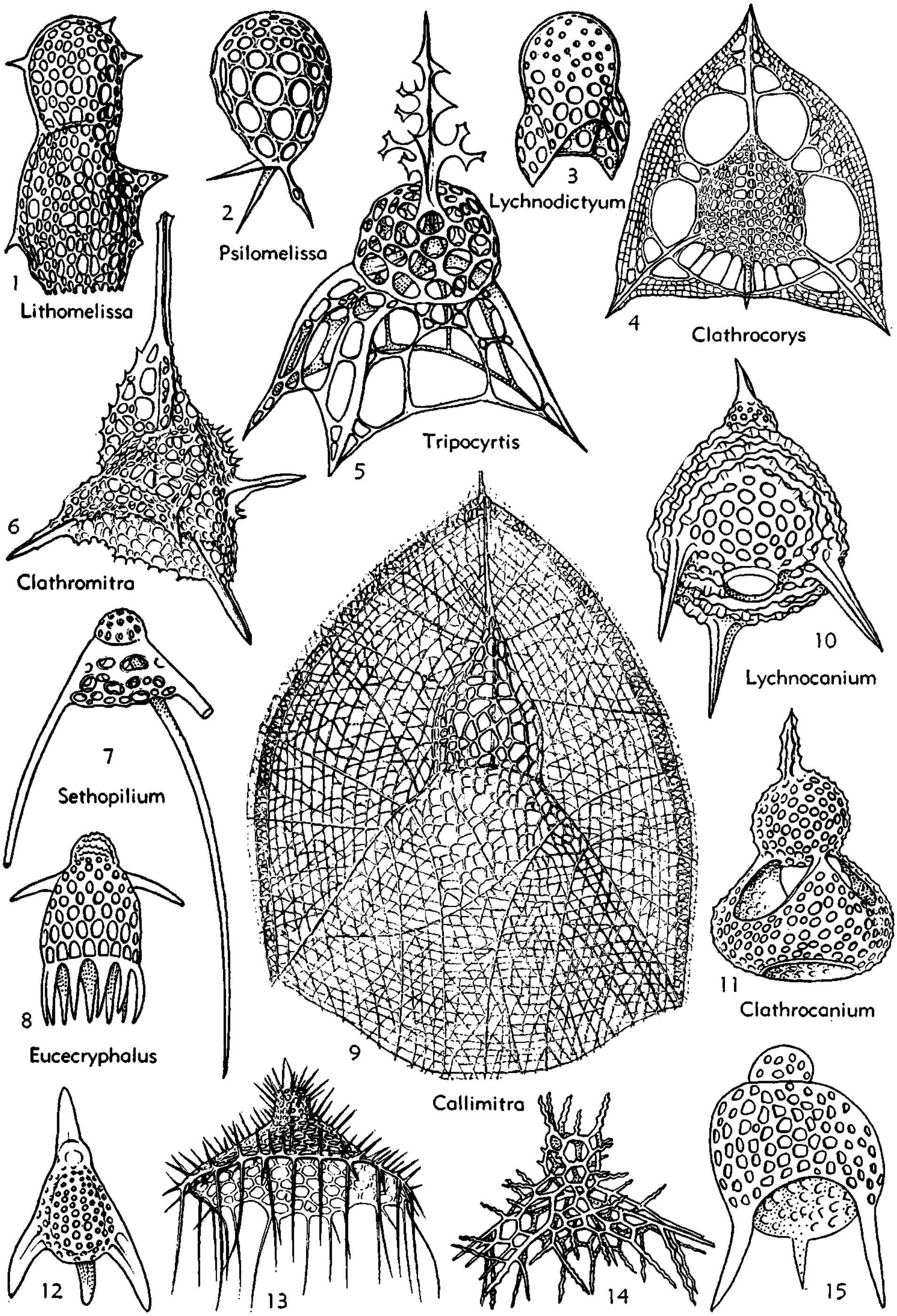


FIG. 61. Sethopiliidae (p. D122-D124).

L. (Lithomelissa) [=*Acromelissa* HKL., 1882 (obj.)]. Single occipital horn. *Eoc.-Rec.*

L. (Corythomelissa) CAMPBELL, 1951 [*pro Sethomelissa* HKL., 1887 (12, p. 1207; *non* p. 1237)] [**L. corythium* EHR., 1875]. Three or more horns. *Eoc.-Rec.*

L. (Dimelissa) CAMPBELL, 1951 [*pro Micromelissa* HKL., 1882 (12, p. 1205; *non* p. 1235)] [**L. thoracites* HKL., 1862]. Two divergent apical horns. *Rec.*——FIG. 61,*1*. *L. (D.) bütschlii* HKL., Rec., ×300 (42).

Lychnocanium EHR., 1847 [**L. falciferum* EHR., 1854; SD herein][=*Lichnocanium* VINASSA, 1900 (obj.); *Fenestracantha* BERTOLINI, 1935]. Three solid terminal feet on shell mouth; without thoracic ribs. *Cret.-Rec.*

L. (Lychnocanium) [=*Lychnocanissa* HKL., 1887 (obj.)]. Feet divergent, more or less curved. *Cret.-Rec.*

L. (Lychnocanella) HKL., 1887 [**L. lanterna;* SD herein]. Feet divergent, more or less straight. *Eoc.-Rec.*——FIG. 61,*10*. *L. (L.) pyriforme* HKL., Rec., ×200 (42).

L. (Lychnocanoma) HKL., 1887 [**L. clavigerum;* SD herein]. Feet parallel, straight or curved. *Eoc.-Rec.*

Lychnodictyum HKL., 1882 [**Dictyophimus challengeri* HKL., 1878]. Like *Lychnocanium* but feet latticed. *Mio.-Rec.*——FIG. 61,*3*. *L. scaphopodium* HKL., Rec., ×300 (42).

Psilomelissa HKL., 1882 [**Dictyocephalus galeatus* EHR., 1872]. Like *Lithomelissa* but without apical horn. *Rec.*——FIG. 61,*2*. *P. calvata* HKL., Rec., ×300 (42).

Spongomelissa HKL., 1887 [**Lithomelissa spongiosa* BÜTSCHLI, 1882]. Like *Lithomelissa* but has spongy shell. *Eoc.*

Tripocyrtis HKL., 1887 [**T. plagoniscus;* SD herein]. Three radial ribs in thorax prolonged into solid feet; without latticed wings; with apical horn. *Eoc.-Rec.*——FIG. 61,*5*. **T. plagoniscus,* Rec., ×300 (42).

Subfamily SETHOPERINAE Haeckel, 1882

[as Sethoperida; emend. CAMPBELL, herein]

Basal shell mouth fenestrated. *Jur.-Rec.*

Sethopera HKL., 1882 [**S. tricostata* HKL., 1887]. Three ribs enclosed in latticed thorax; with apical horn. *Jur.-Rec.*——FIG. 62,*4*. **S. tricostata,* Rec., ×200 (42).

Acerahedrina VINASSA, 1900 [**A. hirta*]. Like *Sethopera* but lacks apical horn. *Mio.*——FIG. 62,*9*. **A. hirta,* Mio. Italy, ×150 (55).

Clathrolychnus HKL., 1882 [**C. araneosus* HKL., 1887]. Three free latticed feet; with weblike mantle. *Rec.*——FIG. 62,*2*. **C. araneosus,* Rec., ×300 (42).

Helotholus JÖRG., 1905 [**H. histricola*]. Without apical horn; shell spiny. *Eoc.* (Ger.)-*Rec.*——FIG. 62,*8*. **H. histricola,* Rec., ×300 (46).

Lithopera EHR., 1847 [**L. bacca* EHR., 1872]. Like *Sethopera* but has 3 internal rods in thorax. *Rec.*——FIG. 62,*7*. *L. ananassa* HKL., Rec., ×300 (42).

Micromelissa HKL., 1882 [*non* HKL., 1887][**M. bombus* HKL., 1887]. Three solid divergent lateral spines; wtih apical horn. *Cret.-Rec.*——FIG. 62,*5*. **M. bombus,* Rec., ×200 (42).

Peromelissa HKL., 1882 [**P. phalacra* HKL., 1887]. Like *Micromelissa* but lacks apical horn. *Plio.-Rec.*——FIG. 62,*1*. *P. calva* HKL., Rec., ×300 (42).

Sethochytris HKL., 1882 [**S. triconiscus* HKL., 1887]. Three latticed feet; with apical horn. *Eoc.-Rec.*——FIG. 62,*3*. **S. triconiscus,* Rec., ×200 (42).

Sethomelissa HKL., 1882 [*non* HKL., 1887][**S. hymenoptera* HKL., 1887]. Like *Micromelissa* but has latticed wings and a horn or bunch of horns. *Rec.*

Tetrahedrina HKL., 1882 [**T. pyramidalis* HKL., 1887]. Like *Sethomelissa* but has 3 solid feet. *Cret.-Rec.*——FIG. 62,*6*. *T. megapora* RÜST, Cret., Zilli., ×60 (51).

Family SETHOPHORMIDIDAE Haeckel, 1882

[as Sethophormida; emend. CAMPBELL, herein] [=Anthocyrtida HKL., 1887; Plectopyramididae *(partim);* Sethophormidae FRIZZELL, 1951]

Radial apophyses 4 to 9 or more. *Cam.-Rec.*

Subfamily SETHOPHORMIDINAE Haeckel, 1887

[as Sethophormida *(partim);* emend. CAMPBELL, herein] [=Sethophorminae FRIZZELL, 1951]

Basal shell mouth open. *Cam.-Rec.*

Tetraphormis HKL., 1882 [**Sethophormis cruciata* HKL., 1887] [=*Sethophormis* HKL., 1887]. Numerous radial ribs in flat and broad bell-shaped or nearly discoidal thorax; cap-shaped cephalis lacks apical horn. *Cret.-Rec.*

T. (Tetraphormis). Thorax with 4 radial ribs. *Cret.-Rec.*

T. (Astrophormis) HKL., 1887 [**Sethophormis aurelia* HKL., 1887 (=*Leptarachnium aurelia* HKL., 1887)][=*Leptarachnium* HKL., 1887 (obj.)]. Radial ribs 12 to 20 or more. *Rec.*——FIG. 63,*1c*. *T. (A.) dodecaster* HKL., Rec., ×200 (42).

T. (Enneaphormis) HKL., 1882 [**Sethophormis rotula* HKL., 1887 (=*Enneaphormis rotula* HKL., 1887)][=*Craspedilium* HKL., 1887 (obj.)]. Thorax with 9 radial ribs. *Rec.*——FIG. 63,*1b*. **T. (E.) rotula,* Rec., ×200 (42).

T. (Hexaphormis) HKL., 1882 [**Sethophormis hexalactis* HKL., 1887 (=*Heptaphormis hexalactis* HKL., 1887)][=*Heptaphormis* HKL., 1887 (obj.)]. Thorax with 6 radial ribs. *Rec.*——FIG. 63,*1a*. **T. (H.) hexalactis,* Rec., ×200 (42).

T. **(Octophormis)** HKL., 1887 [**Sethophormis octalactis*]. Thorax with 8 radial ribs. *Rec.*

T. **(Pentaphormis)** HKL., 1882 [**Sethophormis pentalactis* HKL., 1887]. Thorax with 5 radial ribs. *Rec.*——FIG. 63,*1d*. **T. (P.) pentalactis*, Rec., ×200 (42).

Acanthocorys HKL., 1882 [**A. hexapodia* HKL., 1887]. Numerous radial ribs in wall of pyramidal thorax prolonged into divergent feet; simple network; cephalis often has apical horns. *Cret.-Rec.*

A. **(Acanthocorys)** [=*Acanthocorallium* HKL., 1887 (obj.)]. Thorax with 6 ribs. *Cret.-Rec.*

A. **(Acanthocoronium)** HKL., 1887 [**Arachnocorys umbellifera* HKL., 1862]. Thorax with 9 ribs. *Rec.* ——FIG. 63,*6*. *A. (A.) macroceras* HKL., Rec., ×100 (42).

A. **(Acanthocorythium)** HKL., 1887 [**A. dodecaster;* SD herein]. Thorax with 20 or more ribs. *Rec.*

Anthocyrtidium HKL., 1882 [**A. cineraria* HKL., 1887]. Like *Anthocyrtis* but feet are outside of constricted mouth. *Eoc.-Rec.*——FIG. 63,*4*. **A. cineraria*, Rec., ×200 (42).

Anthocyrtium HKL., 1887 [**A. chrysanthemum;* SD herein]. Like *Anthocyrtis* but has 12 or more feet. *Eoc.-Rec.*

A. **(Anthocyrtium)** [=*Anthocyrtarium* HKL., 1887 (obj.)]. Feet divergent. *Eoc.-Rec.*——FIG. 63,*2*. *A. (A.) adonis* HKL., Rec., ×300.

A. **(Anthocyrtonium)** HKL., 1887 [**A. campanula;* SD herein]. Feet parallel. *Eoc.-Rec.*

A. **(Anthocyrturium)** HKL., 1887 [**A. pyrum;* SD herein]. Feet convergent. *Eoc.-Rec.*

Anthocyrtoma HKL., 1887 [**Anthocyrtis serrulata* EHR., 1875; SD FRIZZELL, 1951]. Without thoracic ribs; 9 feet; free cephalis with apical horn. *Paleoc.-Rec.*

Anthocyrtis EHR., 1847 [**A. mespilus* EHR., 1854; SD herein]. Like *Anthocyrtoma* but has only 6 feet; feet inside mouth unlike *Anthocyrtidium*. *Cam.-Rec.*

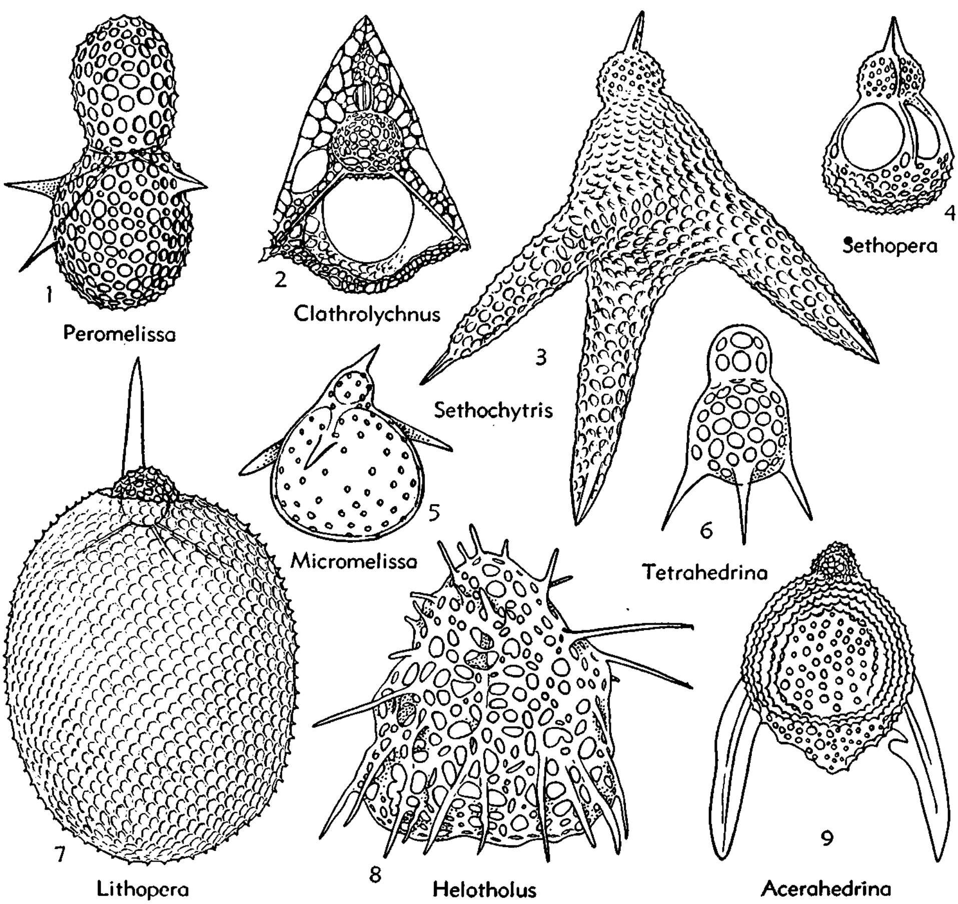


FIG. 62. Sethopiliidae (p. D124).

A. (Anthocyrtis) [=*Anthocyrtella* Hkl., 1887 (obj.)]. Feet divergent. *Cam.-Rec.*

A. (Anthocyrtissa) Hkl., 1887 [**A. ophirensis* Ehr., 1872; SD herein]. Feet parallel. *Rec.*

A. (Anthocyrtura) Hkl., 1887 [**A. ovata* Hkl., 1887]. Feet convergent. *Rec.*——Fig. 63,*3*. **A. (A.) ovata,* Rec., ×200 (42).

Arachnocorys Hkl., 1860 [**A. circumtextum* Hkl., 1862]. Like *Acanthocorys* but shell enveloped by weblike network. *Rec.*

A. (Arachnocorys) [=*Arachnocoronium* Hkl., 1887 (obj.)]. Thorax with 9 ribs.——Fig. 63,*7*. **A. (A.) araneosa* Hkl., Rec., ×200 (42).

A. (Arachnocorallium) Hkl., 1887 [**A. hexaptera;* SD herein]. Thorax with 6 ribs.

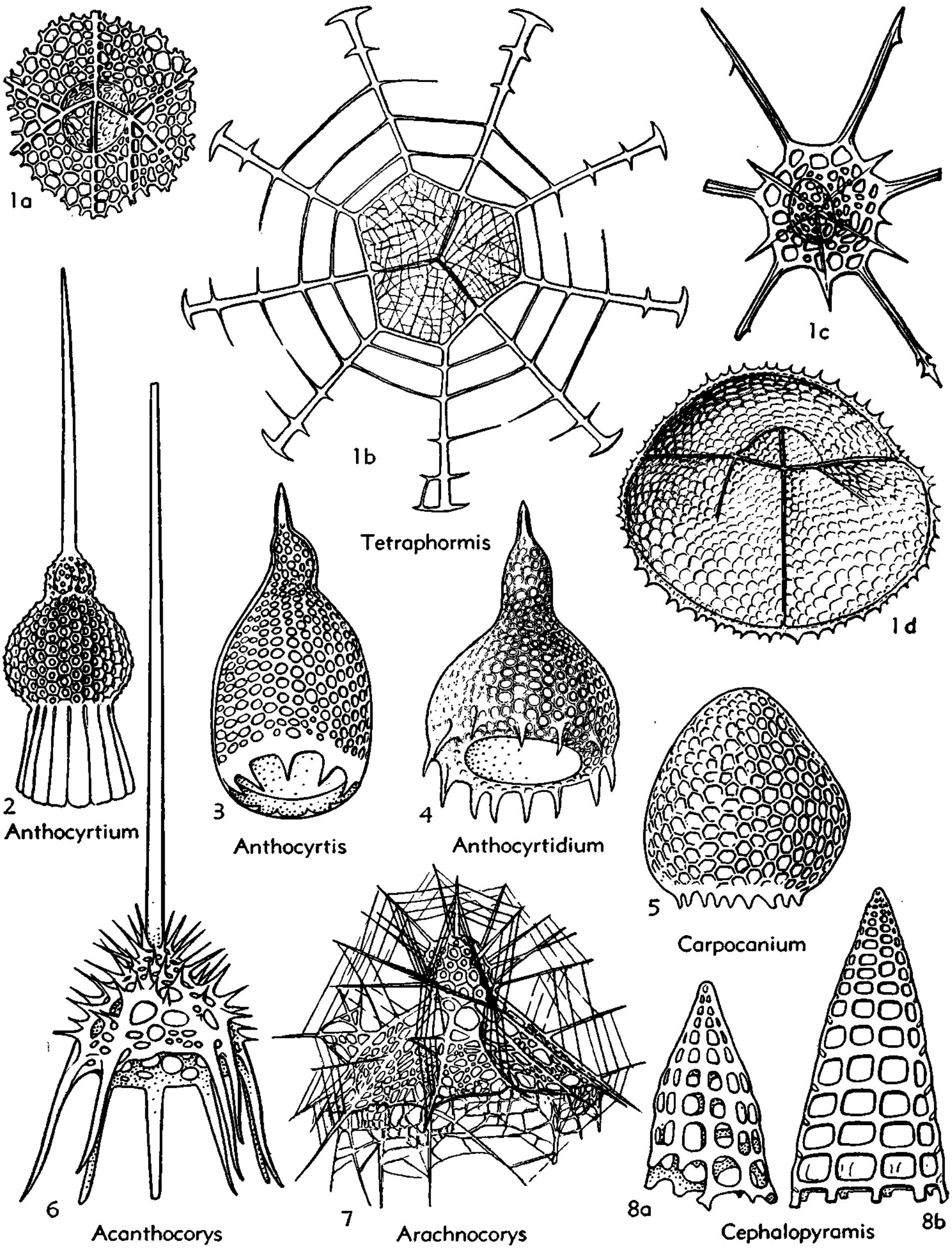


Fig. 63. Sethophormididae (p. D124-D127).

A. (Arachnocorythium) Hkl., 1887 [*A. polyptera]. Thorax with 12 to 20 or more ribs.

Carpocanium Ehr., 1847 [*Lithocampe solitaria Ehr., 1874]. Without thoracic ribs; with 6 to 12 or more feet; hornless cephalis hidden within thorax. *Eoc.-Rec.*

C. (Carpocanium) [=*Carpocanidium* Hkl., 1887 (obj.)]. With corona of 9 feet. *Eoc.-Rec.*

C. (Carpocanarium) Hkl., 1887 [*C. calycodes* Stöhr, 1880]. With corona of 6 feet. *Eoc.-Rec.*

C. (Carpocanobium) Hkl., 1887 [*C. trepanium; SD herein]. With corona of 12 or more feet. *Rec.*——Fig. 63,5. *C. (C.) hexagonale* Hkl., Rec., ×300 (42).

Cephalopyramis Hkl., 1882 [*Sethopyramis enneactis Hkl., 1887][=*Sethopyramis* Hkl., 1882 (obj.); *Sethophormis (Enneaphormis) eupilium* Hkl., 1887 =*Craspedelium eupilium* Hkl., 1887 (12, p. 1247) (obj.)]. Pyramidal shell with straight ribs and simple fenestration. *Eoc.-Rec.*

C. (Cephalopyramis). Nine radial ribs in thorax. *Eoc.-Rec.*——Fig. 63,8a. *C. (C.) magnifica* (Cl.-C.), U.Eoc., Calif., ×200 (39).

C. (Actinopyramis) Hkl., 1887 [*Sethopyramis dodecalactis; SD herein]. Twelve or more radial ribs in thorax. *Rec.*

C. (Sestropyramis) Hkl., 1882 [*Cornutella scalaris Ehr., 1875]. Six radial ribs in thorax. *Eoc.-Rec.*——Fig. 63,8b. *C. (S.) quadrata* Hkl., Rec., ×200 (42).

Craterocyclas Haecker, 1908 [*C. robusta]. Craterlike shell without ribs; with toothed corona. *Rec.*——Fig. 64,1. *C. robusta, Rec., ×200 (43).

Cryptocephalus Hkl., 1882 [*C. exiguus Rüst, 1885][=*Sethamphora* Hkl., 1887 (obj.)]. Like *Tetraphormis* but has ovate shell and constricted mouth. *Jur.-Rec.*

C. (Cryptocephalus). Cephalis hidden within thorax. *Jur.-Rec.*——Fig. 64,4. *C. (C.) favosa* Hkl., Rec., ×300 (42).

C. (Dictyoprora) Hkl., 1882 [*Sethamphora hexapleura Hkl., 1887]. Cephalis free. *Eoc.-Rec.*

Dicorys Pop., 1913 [*D. architypus]. Shell open at both ends; 4 or more thoracic ribs extended as feet; commonly with 2 apical horns. *Rec.*——Fig. 64,2. *D. architypus, Rec., ×400 (48).

Platycryphalus Hkl., 1882 [*P. pumilus Rüst,

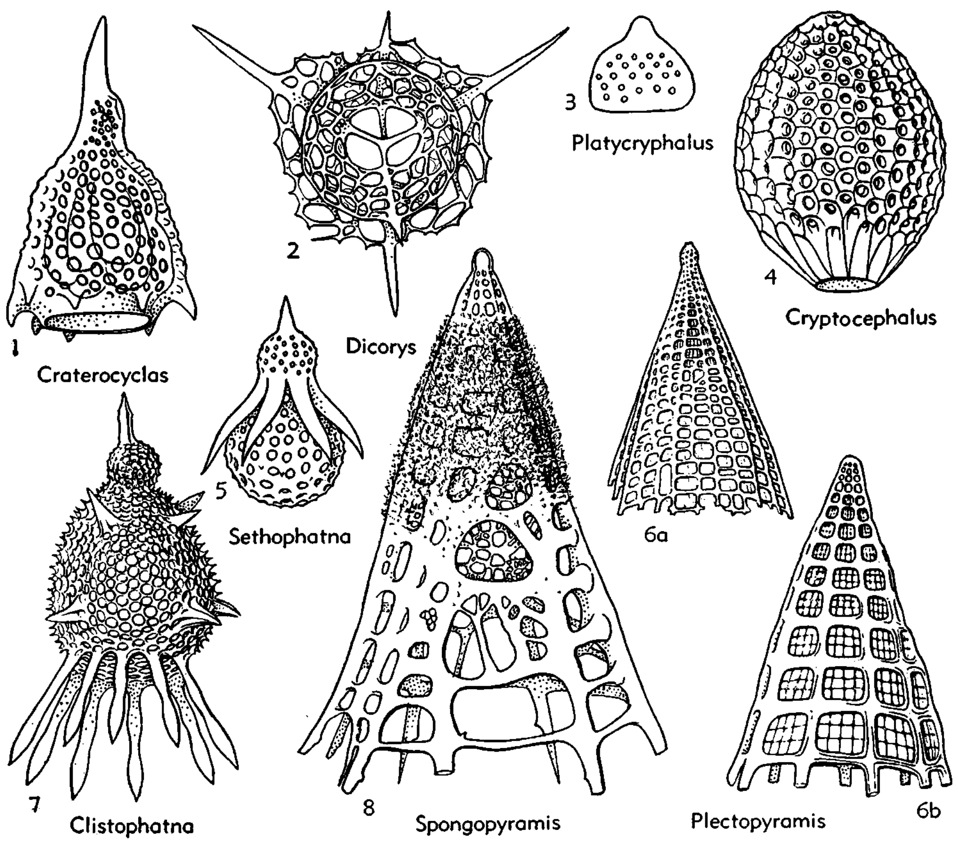


Fig. 64. Sethophormididae (p. D127, D128).

1885][=*Sethocephalus* Hkl., 1887 (obj.)]. Large cephalis without apical horn; flat expanded discoidal thorax. *Jur.-Rec.*——Fig. 64,*3*. **P. pumilus*, Jur., Rigi, ×150 (51).

Plectopyramis Hkl., 1882 [**P. magnifica* Hkl., 1887 (=*Polycystina magnifica* Hkl., 1887 (12, p. 1257))][=*Pyramis* (obj.), *Polycystina* (obj.) Hkl., 1887]. Slender pyramidal shell with straight ribs, meshes fenestrated by secondary lattice. *Eoc.-Rec.*

P. (Plectopyramis) [=*Hexapleuris* Hkl., 1887 (obj.)]. Six (5-7) main radial beams. *Eoc.-Rec.*

P. (Enneapleuris) Hkl., 1887 [**P. dodecomma* Hkl., 1887; SD herein]. Nine (8-10) radial beams. *Eoc.-Rec.*——Fig. 64,*6b*. **P. (E.) dodecomma*, Rec., ×200 (42).

P. (Polypleuris) Hkl., 1887 [**P. polypleura;* SD herein]. Twelve (12-20) or more radial beams. *Rec.*——Fig. 64,*6a*. **P. (P.) polypleura*, Rec., ×200 (42).

Spongopyramis Hkl., 1887 [**S. spongiosa;* SD herein (=*Plectopyramis spongiosa* Hkl., 1887)]. Like *Plectopyramis* but meshes closed by spongy framework. *Rec.*——Fig. 64,*8*. **S. spongiosa*, Rec., ×200 (42).

Velicucullus Riedel & Campbell, 1952 [**Soreuma magnificum* Cl.-C., 1942]. Spongy or platelike velum on oral surface of broadly bell-shaped or discoidal thorax; cephalis with several lobes. *Eoc.*, Calif., core samples off New York.

Subfamily SETHOPHATNINAE Haeckel, 1882

[as Sethophatnida; emend. Campbell, herein]
[=Sethophaenida Hkl., 1887]

Basal shell mouth fenestrated. *Rec.*

Sethophatna Hkl., 1882 [**Sethophaena tetraptera* Hkl., 1887] [=*Sethophaena* Hkl., 1887 (*non* 1882) (obj.)]. Apophyses lateral; cephalis without horn.——Fig. 64,*5*. *S. hexaptera* (Hkl.), Rec., ×200 (42).

Clistophatna Hkl., 1882 [**Clistophaena rüstiana* Hkl., 1887][=*Clistophaena* Hkl., 1887 (*non* 1882) (obj.)]. Apophyses terminal; with apical horn.——Fig. 64,*7*. *C. armata* Hkl., Rec., ×150 (42).

Family LOPHOPHAENIDAE Haeckel, 1882

[as Lophophaenida; emend. Campbell, herein]
[=Sethocorida Hkl., 1882 *(partim);* Sethocyrtida Hkl., 1887]

Without radial apophyses. *Cam.-Rec.*

Subfamily LOPHOPHAENINAE Haeckel, 1882

[as Lophophaenida *(partim);* emend. Campbell, herein]

Basal shell mouth open. *Cam.-Rec.*

Lophophaena Ehr., 1847 [**L. galea* Ehr., 1854]. Like *Dictyocephalus* but has a bunch of large cephalic horns. *Eoc.-Rec.*

L. (Lophophaena) [=*Lophophaenula* Hkl., 1887 (obj.)]. Horns without anastomosis. *Eoc.-Rec.*——Fig. 65,*2*. *L. (L.) auriculaleporis* Cl.-C., U.Eoc., Calif., ×200 (39).

L. (Lophophaenoma) Hkl., 1887 [**L. circumtexta*]. Horns anastomosed. *Eoc.-Rec.*

Asecta Pop., 1913 [**A. prunoides*]. Thorax ovate, without constricted throat; cephalis hidden within thorax; without apical spine. *Rec.* ——Fig. 65,*8*. **A. prunoides*, Rec., ×400 (48).

Conarachnium Hkl., 1882 [**Eucyrtidium trochus* Ehr., 1872][=*Sethoconus* Hkl., 1887 (*non* 1882) (obj.)]. Conical or bell-shaped thorax; wide open mouth; with one or more apical horns. *Cret.-Rec.*

C. (Conarachnium) [=*Ceratocyrtis* Bütschli, 1882 (obj.)]. Large cephalis; distinct collar septum; thorax smooth. *Cret.-Rec.*

C. (Cerataracbnium) Hkl., 1887 [*pro Cornuellium* Hkl., 1882 (*non* 1887)][**Sethoconus hexagonalis* Hkl., 1887]. Small cephalis; feeble collar septum; thorax smooth. *Eoc.-Rec.*

C. (Phlebarachnium) Hkl., 1882 [**Sethoconus facetus* Hkl., 1887] [=*Cladarachnium* Hkl., 1882 (obj.)]. Small cephalis; internal collar septum; spiny or thorny thorax. *Rec.*——Fig. 65,*3*. **C. (P.) facetus* (Hkl.), Rec., ×200 (42).

Dictyocephalus Ehr., 1860 [**D. obtusus* Ehr., 1860; SD herein]. Like *Sethocyrtis* but mouth may be simply truncated or with collar; apical horn lacking. *Cam.-Rec.*

D. (Dictyocephalus) [=*Dictyocryphalus* Hkl., 1882 (obj.)]. Mouth without collar. *Cam.-Rec.*

D. (Streptodelus) Campbell, 1953 [*pro Dictyoprora* Hkl., 1887 (*non* Hkl., 1882)][**D. amphora* Hkl., 1887]. Mouth with collar. *Cret.-Rec.*——Fig. 65,*12*. *D. (S.) obesus* Cl.-C., U.Eoc., Calif., ×200 (39).

Lithocampana Cl.-C., 1942 [**L. lithoconella*]. Bell-shaped, without apical horn or lateral appendages. *Eoc.*——Fig. 65,*4*. **L. lithoconella*, U.Eoc., Calif., ×200 (39).

Periarachnium Hkl., 1882 [**P. periplectum* Hkl., 1887]. Like *Conarachnium* but has webbed mantle. *Rec.*——Fig. 65,*13*. **P. periplectum*, Rec., ×300 (42).

Sethocorys Hkl., 1882 [**S. achillus* Hkl., 1887]. Like *Sethocyrtis* but has tubular collar. *Jur.-Rec.* ——Fig. 65,*14*. **S. achillus*, Rec., ×300 (42).

Sethocyrtis Hkl., 1887 [**S. oxycephalus;* SD herein]. Thorax ovate or cylindrical; constricted mouth without collar; single apical horn. *Jur.-Rec.*——Fig. 65,*11*. **S. oxycephalus*, Rec., ×300 (42).

Sethodiscus Hkl., 1882 [*non* Hkl., 1887][**S. tholus* Rüst, 1885]. Small cephalis with minute apical spine; smooth inflated thorax. *Jur.*——Fig. 65,*1*. **S. tholus*, Rüst, Jur., Rigi, ×150 (51).

Subfamily ADELOCYRTIDINAE Campbell, nom. nov.

[*pro* Sethocapsida Hkl., 1882]

Basal shell mouth fenestrated. *Cam.-Rec.*

Adelocyrtis Pantanelli, 1880 [**A. pala;* SD herein] [=*Sethocapsa* Hkl., 1882 (obj.)]. Greatly inflated thorax; single apical horn. *Cam.-Rec.*——Fig. 65,*5*. *A. pyriformis* (Hkl.), Rec., ×300 (42).

Cryptocapsa Hkl., 1882 [**C. tricyclia* Rüst, 1885]. Cephalis hidden within thorax; without apical horn. *Jur.-Rec.*——Fig. 65,*10*. **C. tricyclia* Rüst, Jur., Switz., ×150 (51).

Diacanthocapsa Squin., 1903 [**D. eugenea*]. Cephalis with 2 horns. *Cret.*——Fig. 65,*15*. **D. eugenea,* Cret., Italy, ×150 (52).

Dicolocapsa Hkl., 1882 [**D. murina* Rüst, 1885]. Cephalis without apical horn. *Cam.-Rec.*——Fig. 65,*6*. *D. microcephalia* Hkl., Rec., ×300 (42).

Salpingocapsa Rüst, 1885 [**S. mira*]. Cephalis with single horn; thorax fenestrated only in basal part. *Jur.*——Fig. 65,*9*. **S. mira,* Jur., Rigi, ×100 (51).

Stylocapsa Principi, 1909 [**S. exagonata*]. Small globular cephalis with strong horn partly hidden within swollen, ovate thorax. *Mio.-Plio.,* Rotti.——Fig. 65,*7*. **S. exogonata,* Mio., Italy, ×230 (49).

Subsuperfamily THEOPILIILAE Haeckel, 1882

[*ex* Theopilida; emend. Campbell, herein]
[=Tricyrtida Hkl., 1882]

Shell divided by 2 transverse strictures into cephalis, thorax and abdomen. *Cam.-Rec.*

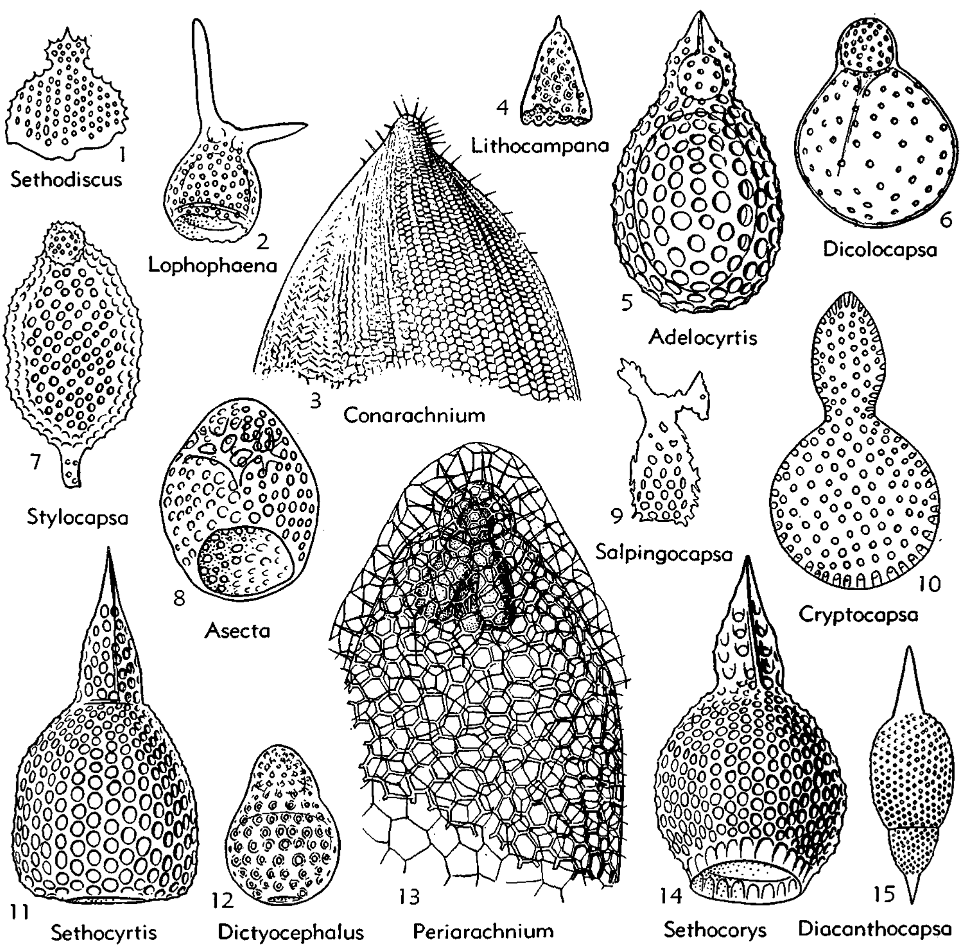


Fig. 65. Lophophaenidae (p. D128, D129).

Family THEOPILIIDAE Haeckel, 1882

[as Theopilida; emend. CAMPBELL, herein]
[=Podocyrtida HKL., 1887]

Three radial apophyses. *Jur.-Rec.*

Subfamily THEOPILIINAE Haeckel, 1882

[as Theopilida *(partim)*; emend. CAMPBELL, herein]

Basal shell mouth open. *Jur.-Rec.*

Theopilium HKL., 1882 [**T. tricostatum* HKL., 1887]. Without wings or feet; 3 lateral ribs enclosed in thorax. *Rec.*——FIG. 66,*1*. **T. tricostatum*, Rec., ×200 (42).

Corocalyptra HKL., 1887 [**C. agnesae;* SD herein]. Hat-shaped shell with 3 solid free thoracic wings arising from collar stricture. *Cret.-Rec.*——FIG. 66,*2*. **C. agnesae*, Rec., ×200 (42).

Dictyoceras HKL., 1862 [**Lithornithium dictyoceras* HKL., 1860]. Three latticed thoracic wings not extended into cephalis; without terminal feet. *Rec.*——FIG. 66,*3*. *D. insectum* HKL., Rec., ×300 (42).

Dictyocodon HKL., 1882 [**D. annasethe* HKL., 1887]. Three free latticed wings; numerous terminal feet. *Rec.*

D. (Dictyocodon) [=*Dictyocodella* HKL., 1887 (obj.)]. Latticed wings arise from thorax alone. ——FIG. 66,*4*. **D. (D.) annasethe*, Rec., ×300 (42).

D. (Dictyocodoma) HKL., 1887 [**D. pallidius;* SD herein]. Latticed wings prolonged to abdomen.

Dictyopodium EHR., 1847 [**D. eurylophus* EHR., 1875]. Like *Podocyrtis* but has 3 latticed terminal feet. *Eoc.-Rec.*——FIG. 66,*7*. *D. scaphopodium* HKL., Rec., ×200 (42).

Lithopilium POP., 1913 [**L. macroceras;* SD herein]. Three ribs extended from thorax as free feet connected internally with apical horn and with transverse collar beams. *Rec.*——FIG. 66,*5*. **L. macroceras*, Rec., ×400 (48).

Pleuropodium HKL., 1882 [**Podocyrtis charybdea* MÜLLER, 1856]. Abdomen with 3 ribs and 3 simple feet; no thoracic ribs. *Rec.*

Podocyrtis EHR., 1847 [**P. papalis* EHR., 1854]. Solid unbranched abdominal feet; abdomen without ribs. *Cret.-Rec.*

P. (Podocyrtis) [=*Podocyrtidium* HKL., 1887 (obj.)]. Feet convergent; thoracic and abdominal pores nearly similar. *Cret.-Rec.*——FIG. 66, *8a*. *P. (P.) fasciata* CL.-C., U.Eoc., Calif., ×150 (39).

P. (Podocyrtarium) HKL., 1887 [**P. tripodiscus;* SD herein]. Feet divergent; thoracic and abdominal pores nearly similar. *Eoc.-Rec.*——FIG. 66, *8b*. **P. (P.) tripodiscus*, Rec., ×200 (42).

P. (Podocyrtecium) HKL., 1887 [**P. prismatica;* SD herein]. Feet divergent; thoracic and abdominal pores dissimilar. *Eoc.-Rec.*——FIG. 66,*8d*. **P. (P.) prismatica*, Rec., ×200 (42).

P. (Podocyrtonium) HKL., 1887 [**P. pedicellaria;* SD herein]. Feet convergent; thoracic and abdominal pores dissimilar. *Eoc.-Rec.*——FIG. 66,*8c*. **P. (P.) pedicellaria*. Rec., ×150 (42).

Pterocanium EHR., 1847 [**P. proserpinae* EHR., 1858]. Three latticed ribs prolonged into latticed feet, otherwise like *Theopodium*. *Jur.-Rec.*

P. (Pterocanium) [=*Pterocanarium* HKL., 1887 (obj.)]. Abdominal edges concave. *Jur.-Rec.*——FIG. 66,*6*. *P. (P.) gravidum* HKL., Rec., ×200 (42).

P. (Pterocanidium) HKL., 1887 [**P. eucolpum;* SD herein (=*Dictyopodium eucolpum* HKL., 1887)]. Basal abdominal edges convex. *Rec.*

Pterocodon EHR., 1847 [**P. campana* EHR., 1854] [=*Androcyclas* JÖRG., 1905]. Like *Pterocorys* but has numerous terminal feet. *Eoc.-Rec.*——FIG. 67,*11*. *P. ornatus* HKL., Rec., ×200 (42).

Pterocorys HKL., 1882 [**P. campanula* HKL., 1887]. Three solid thoracic wings; without terminal feet. *Eoc.-Rec.*

P. (Pterocorys) [=*Pterocyrtidium* BÜTSCHLI, 1882 (obj.)]. Single apical horn; abdomen not prolonged as a tube. *Eoc.-Rec.*——FIG. 67,*10a*. **P. (P.) campanula*, Rec., ×300 (42).

P. (Pterosyringium) HKL., 1887 [**Pterosyringium tubulosum* HKL., 1887; SD herein]. Single apical horn; abdomen prolonged into a tube. *Rec.*——FIG. 67,*10b*. **P. (P.) tubulosa*, Rec., ×200 (42).

P. (Pterocorythium) HKL., 1887 [**P. rhinoceras;* SD herein]. Two or more apical horns; abdomen not prolonged into tube. *Eoc.-Rec.*

Pteropilium HKL., 1882 [**P. stratiodes* HKL., 1887]. Like *Dictyoceras* but wings not prolonged into cephalis. *Rec.*

P. (Pteropilium) [=*Clathropilium* HKL., 1882 (obj.)]. Thorax completely latticed.——FIG. 67, *9*. **P. (P.) stratiodes*, Rec., ×200 (42).

P. (Arachnopilium) HKL., 1882 [**P. clathrocanium* HKL., 1887]. Thorax with 3 large lateral holes between latticed wings.

Rhopalosyringium C.-CL., 1944 [**R. magnificum*]. Terminal spine at open end of abdomen longer than apical horn. *Cret.*——FIG. 67,*2*. **R. magnificum*, Cret., Calif., ×150 (35).

Theopodium HKL., 1882 [**T. macropus* RÜST, 1885]. Like *Pterocanium* but ribs and feet solid. *Jur.-Rec.*——FIG. 67,*5*. **T. macropus* RÜST, Rec., ×200 (42).

Thyrsocyrtis EHR., 1847 [**T. rhizodon* EHR., 1875]. Like *Podocyrtis* but has branched solid feet. *Eoc.-Rec.*——FIG. 67,*7*. *T. arborescens* HKL., Rec., ×300 (42).

Subfamily THEOPERINAE Haeckel, 1882

[as Theoperida; emend. CAMPBELL, herein]

Basal shell mouth fenestrated. *Jur.-Rec.*

Theopera HKL., 1882 [**Rhopalocanium prismaticum* HKL., 1887]. Three lateral thoracic wings

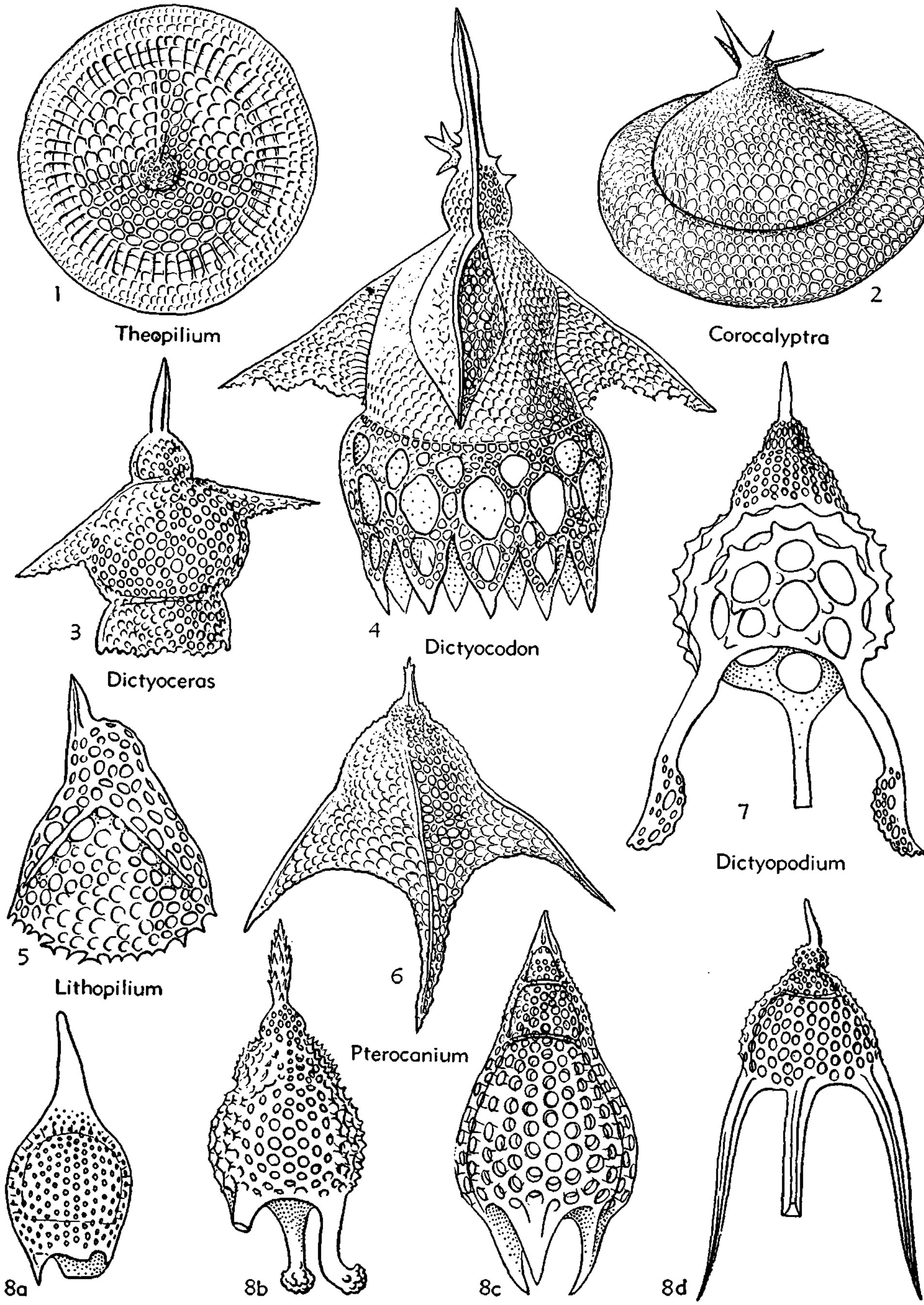


FIG. 66. Theopiliidae (p. D130).

prolonged into abdomen. *Eoc.-Rec.*——FIG. 67,*8*. **T. prismatica* (HKL.), Rec., ×300 (42).

Lithochytris EHR., 1847 [**L. vespertilio* EHR., 1875]. Stout regular tetrahedral shell with external apophysis at each of 3 basal corners; with apical horn. *Jur.-Rec.*

L. (Lithochytris) [=*Lithochytridium* HKL., 1887 (obj.)]. Apophyses latticed. *Eoc.-Rec.*——FIG. 67,*3b*. *L. (L.) cheopsis* CL.-C., U.Eoc., Calif., ×150 (39).

L. (Lithochytrodes) HKL., 1887 [**L. pyriformis*; SD herein]. Apophyses solid. *Jur.-Rec.*——FIG. 67,*3a*. **L. (L.) pyriformis*, Rec., ×300 (42).

Lithornithium EHR., 1847 [**Lithocampe hirundo* EHR., 1844]. Three solid lateral wings on thorax. *Jur.-Rec.*——FIG. 67,*1*. *L. falco* HKL., Rec., ×300 (42).

Rhopalatractus HKL., 1882 [**R. pentacanthus* HKL., 1887][=*Dictyatractus* HKL., 1882 (obj.)]. Fenestrated basal pole of shell with spine, otherwise like *Rhopalocanium*. *Rec.*——FIG. 67,*6*. *R. fenestratus* HKL., Rec., ×150 (42).

Rhopalocanium EHR., 1847 [**R. ornatum* EHR., 1854]. Three lateral wings on conical abdomen; without basal spine. *Eoc.-Rec.*——FIG. 67,*4*. *R. lasanum* HKL., Rec., ×200 (42).

Sethornithium HKL., 1882 [**S. dictyopterum* HKL., 1887]. Like *Lithornithium* but has latticed wings. *Rec.*

Family THEOPHORMIDIDAE Haeckel, 1887

[as Theophormida; emend. CAMPBELL, herein] [=Phormocyrtida HKL., 1887; Lamprocycladidae HAECKER, 1908 *(partim)*]

Four to 9 or more radial apophyses. *Jur.-Rec.*

Subfamily THEOPHORMIDINAE Haeckel, 1882

[as Theophormida *(partim)*; emend. CAMPBELL, herein]

Basal shell mouth open. *Jur.-Rec.*

Theophormis HKL., 1882 [**T. callipilium* HKL., 1887]. Flat dilated abdomen with wide open mouth and numerous radial ribs. *Cret.-Rec.*——FIG. 68,*2*. **T. callipilium*, Rec., ×150 (42).

Calocyclas EHR., 1847 [**C. turris* EHR., 1875]. Like *Clathrocyclas* but has cylindrical or ovate, not dilated abdomen. *Cret.-Rec.*

C. (Calocyclas) [=*Calocyclissa* HKL., 1887 (obj.)]. Thorax spiny or thorny; abdomen smooth. *Cret.-Rec.*——FIG. 68,*1b*. *C. (C.) advena* CL.-C., U.Eoc., Calif., ×150 (39).

C. (Calocycletta) HKL., 1887 [**C. veneris*; SD herein]. Thorax and abdomen smooth. *Eoc.-Rec.*——FIG. 68,*1c*. *C. (C.) semipolita* CL.-C., U.Eoc., Calif., ×150 (39).

C. (Calocycloma) HKL., 1887 [**C. casta*; SD herein]. Thorax smooth; abdomen spiny or thorny. *Rec.*——FIG. 68,*1a*. **C. (C.) casta*, Rec., ×200 (42).

C. (Calocyclura) HKL., 1887 [**C. monumentum*; SD herein][=*Calocycloma* HKL., 1887 (obj.); *Calompterium* CL.-C., 1942 (obj.)]. Thorax and abdomen spiny or thorny. *Eoc.-Rec.*——FIG. 68, *1d*. **C. (C.) monumentum*, Rec., ×200 (42).

Clathrocyclas HKL., 1882 [**C. principessa* HKL., 1887]. Lacks radial ribs; single terminal corona of feet; abdomen dilated, truncate, conical or discoidal. *Jur.-Rec.*

C. (Clathrocyclas) [=*Clathrocyclia* HKL., 1887 (obj.)]. Conical shell with single apical horn. *Jur.-Rec.*

C. (Clathrocycloma) HKL., 1887 [**C. alcmenae*; SD herein]. Flattened shell; cephalis with 2 or more horns. *Mio.-Rec.*——FIG. 68,*3*. *C. (C.) cabrilloensis* C.-CL., Mio., Calif., ×150 (35).

Cryptoprora EHR., 1860 [**C. fundicola*][=*Alacorys* HKL., 1887 (obj.)]. Ribs limited to abdomen but continued as free feet. *Eoc.-Rec.*

C. (Cryptoprora) [=*Polyalacorys* HKL., 1887 (obj.)]. Feet 10 to 20 or more. *Eoc.-Rec.*

C. (Ennealacorys) HKL., 1887 [**Alacorys enneacantha*; SD herein]. Nine feet. *Eoc.-Rec.*

C. (Hexalacorys) HKL., 1882 [**Alacorys friderici* HKL., 1887]. Six feet. *Eoc.-Rec.*——FIG. 68,*7*. **C. (H.) friderici* (HKL.), Rec., ×200 (42).

C. (Octalacorys) HKL., 1887 [**Podocyrtis aculeata* EHR., 1875]. Eight feet. *Eoc.-Rec.*

C. (Pentalacorys) HKL., 1882 [**Podocyrtis pentacantha* EHR., 1875]. Five feet. *Eoc.-Rec.*

C. (Tetralacorys) HKL., 1882 [**Alacorys lutheri* HKL., 1887]. Four feet. *Eoc.-Rec.*

Cycladophora EHR., 1847 [**C. stiligera* EHR., 1875] [=*Lanterna* HKL., 1887 (obj.)]. Like *Cryptoprora* but lacks terminal feet. *Eoc.-Rec.*

C. (Cycladophora) [=*Cyclamptidium* HKL., 1887 (obj.)]. Abdomen nearly cylindrical or prismatic; 10 to 20 strong straight, vertical, parallel ribs; mouth wide open. *Eoc.-Rec.*

C. (Cyclampterium) HKL., 1887 [**C. pantheon*; SD herein]. Abdomen bell-shaped with 10 to 20 or more ribs and wide open mouth. *Eoc.-Rec.*

C. (Lampterium) HKL., 1882 [**C. goetheana* HKL., 1887]. Abdomen with 4 ribs, opposite in 2 pairs. *Rec.*——FIG. 68,*8*. **C. (L.) goetheana*, Rec., ×200 (42).

C. (Lamptidium) HKL., 1887 [**C. hexapleura*; SD herein]. Abdomen with 6 ribs. *Eoc.-Rec.*

C. (Lamptonium) HKL., 1887 [**C. enneapleura*; SD herein]. Abdomen with 9 ribs. *Rec.*

Diplocyclas HKL., 1882 [**D. bicorona* HKL., 1887]. Has one corona of teeth between thorax and abdomen and a second corona around mouth of abdomen. *Rec.*——FIG. 68,*6*. **D. bicorona*, Rec., ×300 (42).

Lamprocyclas HKL., 1882 [**L. nuptialis* HKL., 1887]. Like *Diplocyclas* but both coronas of teeth are terminal. *Rec.*

L. (Lamprocyclas) [=*Lamprocyclia* HKL., 1887 (obj.)]. Feet of both coronas unbranched.——

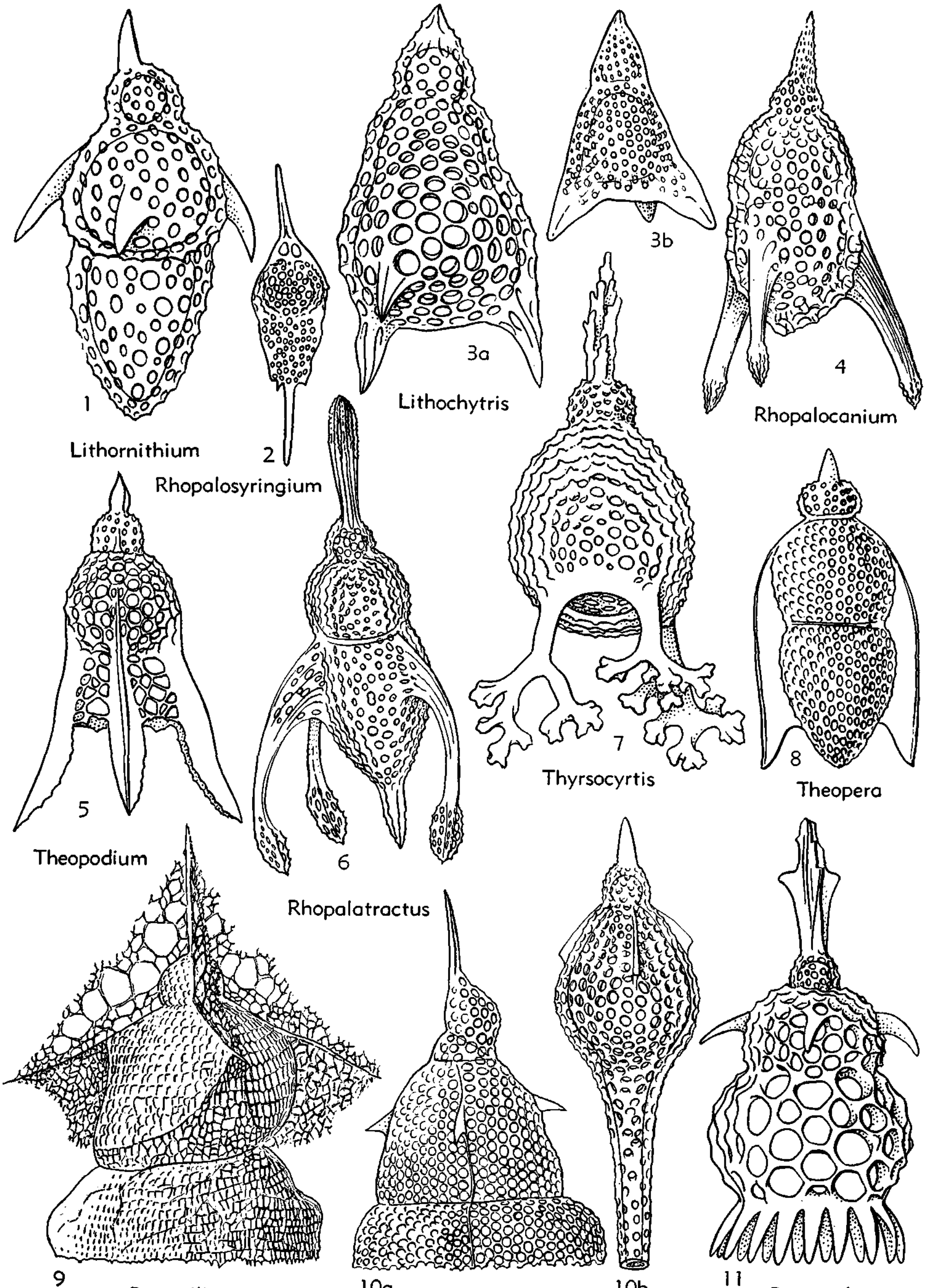


FIG. 67. Theopiliidae (p. D130-D132).

FIG. 68,*4*. **L. (L.) nuptialis,* Rec., ×200 (42).

L. (Lamprocycloma) HKL., 1887 [**L. bajaderae*]. Feet branched or forked.

Phormocyrtis HKL., 1887 [**Theocorys longicornis* HKL., 1887; SD herein]. Like *Theophormis* but has ovate or cylindrical abdomen and constricted mouth. *Jur.-Rec.*——FIG. 68,*5*. **P. longicornis* (HKL.), Rec., ×200 (42).

Subfamily THEOPHATNINAE Haeckel, 1882

[as Theophatnida; emend. CAMPBELL, herein] [=Theophaenida HKL., 1887]

Basal shell mouth fenestrated. *Rec.*

Theophatna HKL., 1882 [**Theophaena corona* HKL., 1887][=*Theophaena* HKL., 1887 (obj.), *non* HKL., 1882]. Nine lateral abdominal wings. ——FIG. 69,*1*. **T. corona* (HKL.), Rec., ×150 (42).

Hexalodus HAECKER, 1908 [**H. dendrophorus*]. Six teeth on abdomen.——FIG. 69,*3*. **H. dendrophorus*]. Six teeth on abdomen.——FIG. 69,*3*. **H. dendrophorus,* Rec., ×200 (43).

Theophaena HKL., 1882 [*non* HKL., 1887][**Hexalatractus sexalatus* HKL., 1887][=*Hexalatractus* HKL., 1887 (obj.)]. Six lateral abdominal wings. ——FIG. 69,*2*. *T. fusiformis* (HKL.), Rec., ×200 (42).

Family THEOCORYTHIDAE Haeckel, 1882

[as Theocorida; emend. CAMPBELL, herein] [=Theocyrtida HKL., 1887; Theocoridae FRIZZELL, 1951]

Without basal apophyses. *Cam.-Rec.*

Subfamily THEOCORYTHINAE Haeckel, 1882

[as Theocorida *(partim)*; emend. CAMPBELL, herein]

Basal shell mouth open. *Cam.-Rec.*

Theocorys HKL., 1882 [**T. morchellula* RÜST, 1885]. Swollen abdomen ovate; mouth constricted; cephalis with single apical horn. *Cret.-Rec.*

T. (Theocorys) [=*Theocoronium* HKL., 1887 (obj.)]. Thoracic and abdominal pores similar. *Cret.-Rec.*——FIG. 69,*5*. *T. (T.) adamsi* CL.-C., Mio., Calif., ×200 (39).

T. (Theocorythium) HKL., 1887 [**T. dianae;* SD herein]. Thoracic and abdominal pores dissimilar. *Eoc.-Rec.*

Axocorys HKL., 1882 [**A. macroceros* HKL., 1887]. Like *Theocorys* but has internal axial columella. *Jur.-Rec.*——FIG. 69,*17*. **A. macroceros,* Rec., ×200 (42).

Cecryphalium HKL., 1882 [**C. lamprodiscus* HKL., 1887]. Like *Theocalyptra* but lacks apical horn. *Perm.-Rec.*——FIG. 69,*16*. **C. lamprodiscus,* Rec., ×200 (42).

Lophoconus HKL., 1887 [**Eucyrtidium antilope* EHR., 1872; SD FRIZZELL, 1951]. Abdomen conical; with 2 or more apical horns. *Paleoc.-Rec.*——FIG. 69,*4*. *L. titanothericeraos* CL.-C., U.Eoc., Calif., ×200 (39).

Lophocorys HKL., 1882 [**L. cribosa* RÜST, 1885]. Like *Theocorys* but has 2 apical horns or a bunch of horns. *Jur.-Rec.*——FIG. 69,*11*. *L. astrocephalia* HKL., Rec., ×200 (42).

Lophocyrtis HKL., 1887 [**Eucyrtidium stephanophorum* EHR., 1875; SD herein]. Like *Theocyrtis* but has 2 apical horns, or a bunch of cephalic horns. *Jur.-Rec.*

Theocalyptra HKL., 1882 [**T. veneris* HKL., 1887]. Abdomen discoidal; with one or 2 apical horns. *Cret.-Rec.*

Theocampe HKL., 1887 [**Dictyomitra ehrenbergii* ZITTEL, 1876; SD herein]. Like *Theocorys* but without apical horn. *Cam.-Rec.*

T. (Theocampe) [=*Theocampula* HKL., 1887 (obj.)]. Thoracic and abdominal pores similar. *Cam.-Rec.*——FIG. 69,*6*. *T. (T.) stenostoma* HKL., Rec., ×200 (42).

T. (Theocamptra) HKL., 1887 [**T. collaris;* SD herein]. Thoracic and abdominal pores dissimilar. *Eoc.-Rec.*

Theoconus HKL., 1887 [**Eucyrtidium zancleum* MÜLLER, 1858; SD herein]. Like *Lophocorys* but has single apical horn. *Cret.-Rec.*

T. (Theoconus) [=*Theocorax* HKL., 1887 (obj.)]. Thoracic and abdominal pores similar. *Cret.-Rec.*

T. (Theocorbis) HKL., 1887 [**T. jovis;* SD herein]. Thoracic and abdominal pores dissimilar. *Eoc.-Rec.*——FIG. 69,*10*. **T. (T.) jovis,* Rec., ×200 (42).

Theocyrtis HKL., 1887 [**Eucyrtidium barbadense* EHR., 1875; SD herein]. Cylindrical abdomen; thorax and abdomen of nearly similar breadth; with single apical horn. *Cret.-Rec.*

T. (Theocyrtis) [=*Theocorypha* HKL., 1887 (obj.)]. Thoracic and abdominal pores similar. *Cret.-Rec.*

T. (Theocorusa) HKL., 1887 [**T. macroceros;* SD herein]. Thoracic and abdominal pores dissimilar. *Eoc.-Rec.*——FIG. 69,*15*. **T. (T.) macroceros,* Rec., ×200 (42).

Tricolocampe HKL., 1882 [**T. clypsydra* RÜST, 1885]. Abdomen cylindrical; without apical horn. *Jur.-Rec.*

T. (Tricolocampe) [=*Tricolocampium* HKL., 1887 (obj.)]. Thoracic and abdominal pores similar. *Jur.-Rec.*——FIG. 69,*7*. *T. (T.) cylindrica* HKL., Rec., ×200 (42).

T. (Tricolocamptra) HKL., 1887 [**T. urnula;* SD herein]. Thoracic and abdominal pores dissimilar. *Eoc.-Rec.*

Urocyrtis PANTANELLI, 1880 [**U. amaliae;* SD herein] [=*Theosyringium* HKL., 1882 (obj.)]. Slender tubular abdomen; inflated thorax; with single apical horn. *Jur.-Rec.*——FIG. 69,*9*. *U. tibia* (HKL.), Rec., ×200 (42).

Subfamily THEOCAPSINAE Haeckel, 1882
[as Theocapsida; emend. CAMPBELL, herein]

Basal shell mouth fenestrated. *Dev.-Rec.*

Theocapsa HKL., 1882 [**T. gratiosa* RÜST, 1885]. Without latticed septum between thorax and abdomen; with single apical horn. *Dev.-Rec.*

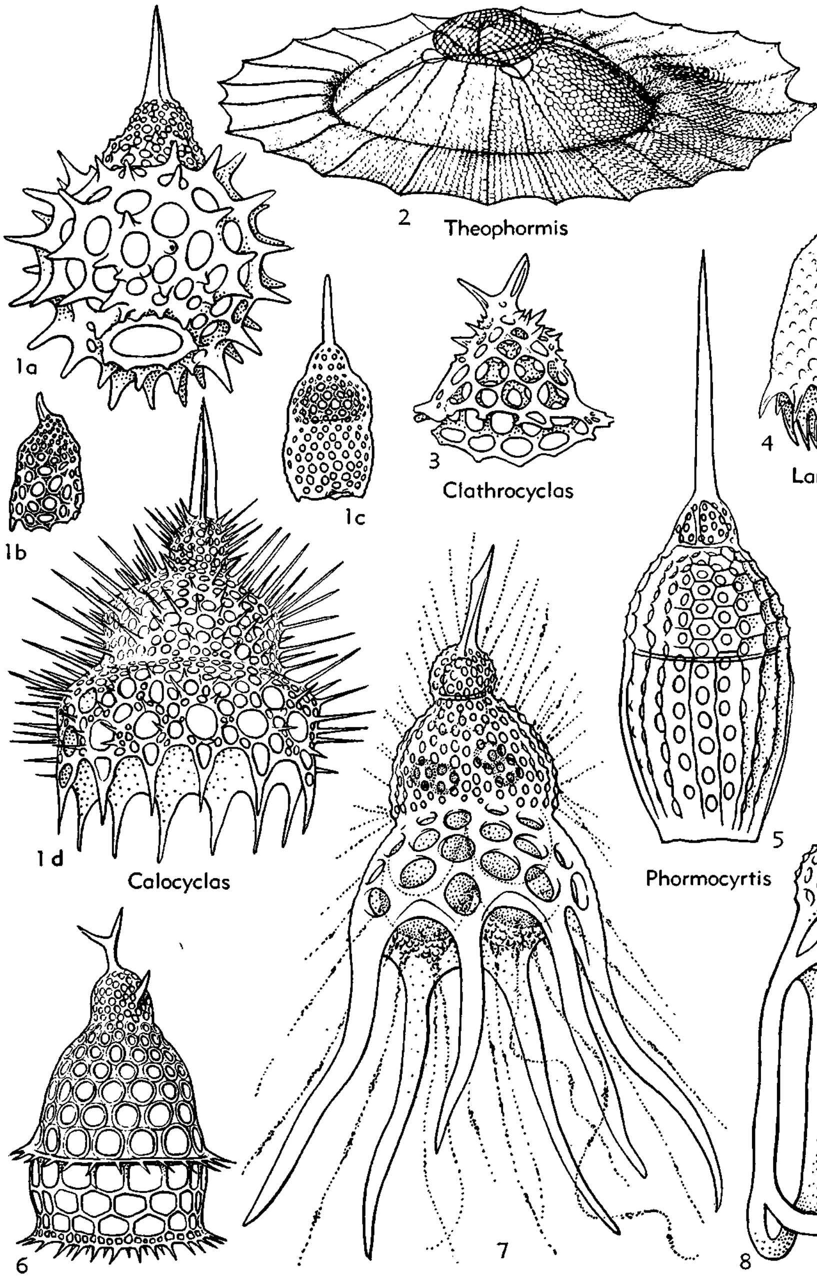


FIG. 68. Theophormididae (p. D132-D134).

T. (Theocapsa) [=*Theocapsetta* HKL., 1887 (obj.)]. Thorax and abdomen of nearly the same size; thoracic and abdominal pores similar. *Jur.-Rec.*——FIG. 69,*18*. *T. (T.) aristotelis* HKL., Rec., ×200 (42).

T. (Theocapsilla) HKL., 1887 [**T. wottonis;* SD herein]. Thorax and abdomen of about the same size; thoracic and abdominal pores dissimilar. *Rec.*

T. (Theocapsomma) HKL., 1887 [**T. linnaei;* SD herein]. Thorax much smaller than abdomen; thoracic and abdominal pores similar. *Rec.*

T. (Theocapsura) HKL., 1887 [**T. lamarckii;* SD herein]. Thorax much smaller than abdomen; thoracic and abdominal pores dissimilar. *Eoc.-Rec.*

Distylocapsa SQUIN., 1904 [**D. nova;* SD herein]. Single abdominal spine and 2 unequal apical horns. *Cret.*——FIG. 69,*13*. **D. nova,* Cret., Italy, ×133 (52).

Hemicryptocapsa TAN, 1927 [**H. capita*]. Cephalis hidden within thorax; with single apical horn. *Pre-Cret.*——FIG. 69,*12*. *H. pilula* (HINDE) Tan, Pre-Cret., Borneo, ×200 (43).

Holocryptocapsa TAN, 1927 [**H. fallax*]. Like *Hemicryptocapsa* but without apical horn. *Trias.-Plio.*

Phrenocodon HKL., 1887 [**P. clathrostomium;* SD herein]. Like *Theocapsa* but has lattice plate between thorax and abdomen. *Rec.*——FIG. 69,*8*. **P. clathrostomium,* Rec., ×300 (42).

Stylocryptocapsa TAN, 1927 [**S. verbeeki*]. Both cephalis and thorax hidden within abdomen; with apical horn. *U.Cret.-Plio.,* E.Indies.

Tricolocapsa HKL., 1887 [**T. theophrasti;* SD herein]. Like *Theocapsa* but lacks apical horn. *Jur.-Rec.*

T. (Tricolocapsa) [=*Tricolocapsula* HKL., 1887 (obj.)]. Thorax as large as abdomen or larger. *Jur.-Rec.*

T. (Tricolocapsium) HKL., 1887 [**T. schleidenii;* SD herein]. Thorax much smaller than abdomen. *Cret.-Rec.*——FIG. 69,*14*. *T. (T.) granti* C.-CL., Cret., Calif., ×150 (35).

Subsuperfamily TRIACARTILAE Campbell, nom. nov.

[*pro* Stichopilida HKL., 1882]
[=Tetracyrtida, Stichocyrtida, HKL., 1882]

Shell divided by 3 or more strictures into cephalis, thorax, abdomen, and post-abdominal segments. *Ord.-Rec.*

Family TRIACARTIDAE Campbell, nom. nov.

[*pro* Stichopilida HKL., 1882]
[=Podocampida HKL., 1887; Stichopiliidae FRIZZELL, 1951]

Three radial apophyses. *Perm.-Rec.*

Subfamily TRIACARTINAE Campbell, nom. nov.

[*pro* Stichopilida HKL., 1882 *(partim)*]
[=Stichopiliinae FRIZZELL, 1851]

Basal shell mouth open. *Perm.-Rec.*

Triacartus HKL., 1882 [**Stichopilium cortina* HKL., 1887][=*Stichopilium* HKL., 1882 (obj.)]. Three solid lateral ribs or wings; without basal feet; with apical horn. *Cret.-Rec.*

T. (Triacartus). Shell with 2 annular strictures. *Eoc.-Rec.*——FIG. 70,*1a*. *T. (T.) bicornis* HKL., Rec., ×300 (42).

T. (Stichopilidium) HKL., 1887 [**Stichopilium macropterum* HKL., 1887; SD herein (=*Rhopalocanium varietas* HKL., 1887, obj.)]. Shell with 4 or more annular strictures. *Cret.-Rec.*——FIG. 70,*1b*, *T. (S.) teslaensis* C.-CL., U.-Cret., Calif., ×120 (35).

Podocampe HKL., 1882 [**P. tripodiscus* HKL., 1887]. Three solid basal feet; without lateral ribs or wings; with apical horn. *Rec.*——FIG. 70,*2*. *P. trictenota* HKL., Rec., ×200 (42).

Pteropilium HKL., 1887 [**Pterocanium sphinx* EHR., 1875]. Like *Triacartus* but lacks apical horn. *Rec.*

Stichocampe HKL., 1882 [**S. divergens* HKL., 1887]. Three solid radial ribs or wings prolonged as solid basal feet; with apical horn. *Rec.*

Stichopodium HKL., 1882 [**S. dictyopodium* HKL., 1887]. Like *Podocampe* but has 3 latticed basal feet. *Rec.*——FIG. 70,*3*. **S. dictyopodium,* Rec., ×300 (42).

Stichopterium HKL., 1882 [**S. pterocanium* HKL., 1887]. Like *Stichocampe* has 3 latticed feet. *Rec.*

Trictenartus HKL., 1882 [**Artopilium elegans* HKL., 1887][=*Artopilium* (obj.), *Pterocorythium* (obj.) HKL., 1882]. Like *Triacartus* but has latticed lateral ribs or wings. *Rec.*

T. (Trictenartus). Shell with 3 annular strictures. ——FIG. 70,*4b*. *T. (T.) longicornis* HKL., Rec., ×300 (42).

T. (Stichopterygium) HKL., 1882 [**Artopilium trifenestra* HKL., 1887 (=*Clathropyrgus trifenestra* HKL., 1887)][=*Clathropyrgus* HKL., 1882 (obj.)]. Shell with 4 or more annular strictures. ——FIG. 70,*4a*. **T. (S.) trifenestra,* Rec., ×300 (42).

Subfamily STICHOPERINAE Haeckel, 1882

[as Stichoperida; emend. CAMPBELL, herein]

Basal shell mouth fenestrated. *Perm.-Rec.*

Stichopera HKL., 1882 [**S. ovata* HKL., 1887]. Three solid lateral ribs or 3 lateral rows of spiny combs; with apical horn. *Perm.-Rec.*

S. (Stichopera) [=*Stichoperina* HKL., 1887 (obj.)]. Three solid lateral ribs or longitudinal rows of dentate crests. *Perm.-Rec.*

S. (Sticholagena) HKL., 1887 [**S. pectinata;* SD herein]. Three radial spiny combs or longitud-

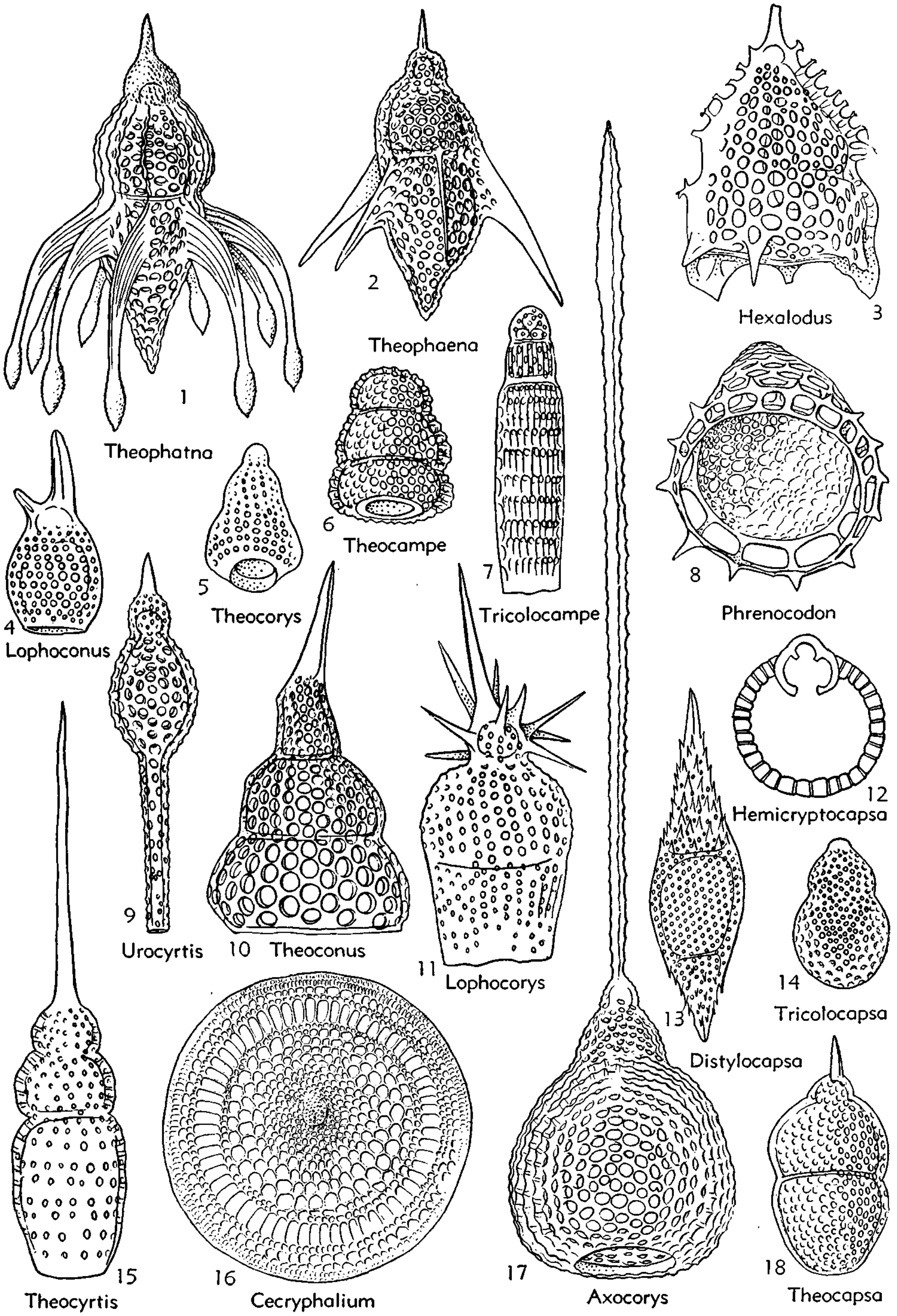


FIG. 69. Theophormididae, Theocorythidae (p. D134-D136).

inal rows of isolated spines. *Rec.*——Fig. 70,6. **S. (S.) pectinata,* Rec., ×300 (42).

Artoperina Campbell, 1951 [*pro Artopera* Hkl., 1887 (*non* 1882)][**Lithornithium loxia* Ehr., 1854]. Like *Stichopera* but has vertical spine on abdomen. *Eoc.-Rec.*——Fig. 70,7. **A. loxia* (Ehr.), U.Eoc., Barbados, ×200 (41).

Cytopera Hkl., 1882 [**C. thoracoptera* Hkl., 1887]. Like *Stichopera* but has latticed ribs or wings. *Rec.*

C. (Cyrtopera) [=*Artopera* Hkl., 1882 (*non* 1887)]. Three annular strictures.——Fig. 70,5. **C. (C.) thoracoptera,* Rec., ×200 (42).

C. (Cyrtolagena) Hkl., 1887 [*non* 1879] [**C. laguncula* Hkl., 1887]. Four or more annular strictures.

Family ARTOPHORMIDIDAE Haeckel, 1882

[as Artophormida; emend. Campbell, herein]
[=Artophaenida Hkl., 1882; Phormocampida Hkl., 1887]

Four to 9 or more radial apophyses. *Jur.-Rec.*

Subfamily ARTOPHORMIDINAE Haeckel, 1882

[as Artophormida *(partim)*; emend. Campbell, herein]
[=Stichophormida Hkl., 1882]

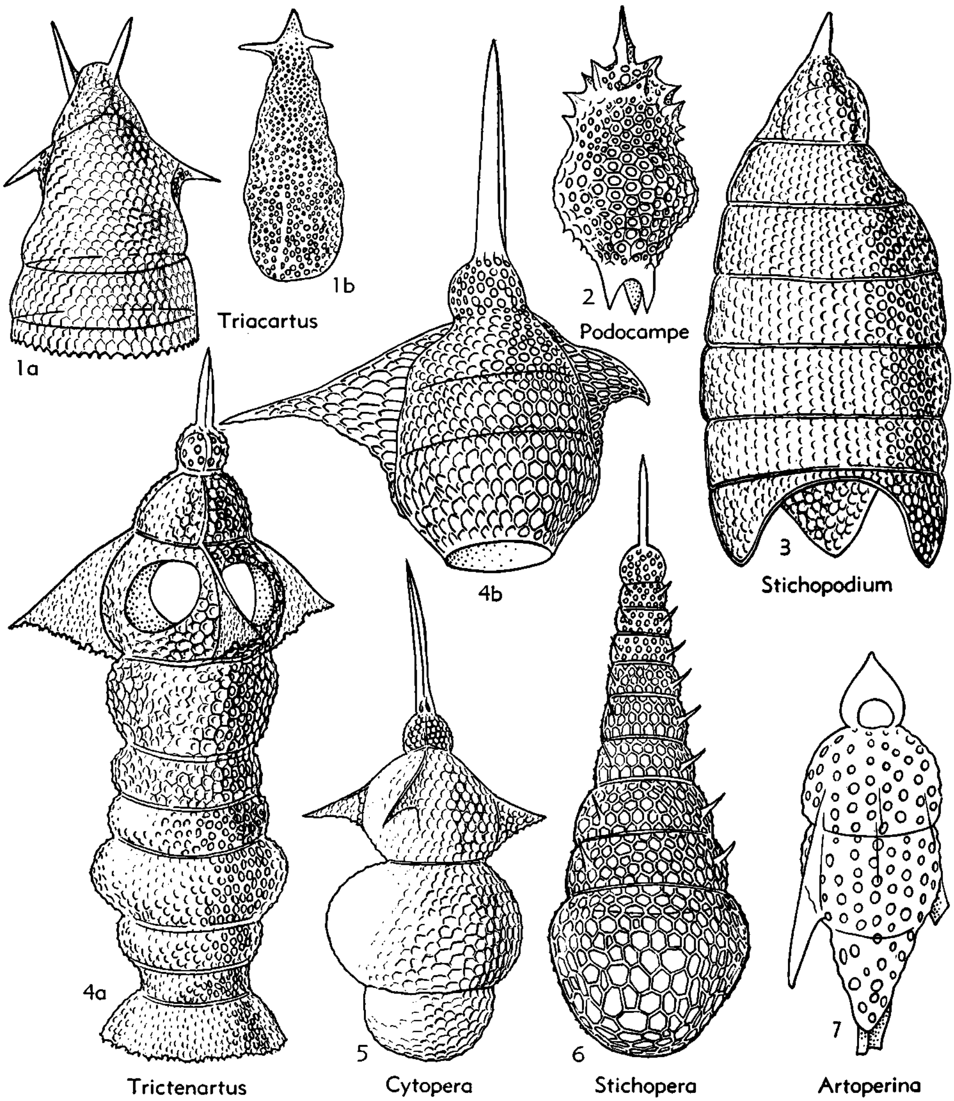


Fig. 70. Triacartidae (p. D136-D138).

Basal shell mouth open. *Jur.-Rec.*

Artophormis Hkl., 1882 [*A. *horrida* Hkl., 1887]. Oval or spindle-shaped shell; radial ribs prolonged into feet; mouth constricted. *Rec.*——Fig. 71,*1*. **A. horrida*, Rec., ×200 (42).

Anthocorys Hkl., 1882 [*A. *regularis* Rüst, 1885] [=*Phormocampe* Hkl., 1887 (obj.)]. Conical or pyramidal shell; without lateral ribs; with corona of feet. *Jur.-Rec.*

A. (Anthocorys). Three annular strictures. *Jur.-Rec.*——Fig. 71,*3*. *A. (A.) campanula*, Rec., ×300 (42).

A. (Cyrtocorys) Hkl., 1882 [**Phormocampe mitra* Hkl., 1887]. Four or more annular strictures. *Rec.*

Cyrtophormis Hkl., 1887 [*non Cystophormis* Hkl., 1887][**C. armata;* SD herein]. Like *Artophormis* but lacks lateral ribs. *Cret.-Rec.*

C. (Cyrtophormis) [=*Cyrtophormium* Hkl., 1887 (obj.)]. Six (5 to 7) feet. *Cret.-Rec.*——Fig. 71,*7a*. **C. (C.) armata*, Rec. ×300 (42).

C. (Cyrtophormiscus) Hkl., 1887 [**C. cingulata*, SD herein]. Nine (8 to 10) feet. *Eoc.-Rec.*——Fig. 71,*7b*. **C. (C.) cingulata*, Rec., ×300 (42).

C. (Phormostichoartus) Campbell, 1951 [*pro Acanthocyrtis* Hkl., 1887 (*non* 1882)][**C. cylindrica* Hkl., 1887]. Feet 12 to 20 or more. *Cret.-Rec.*——Fig. 71,*7c*. *C. (P.) grandis* C.-Cl., Cret., Calif., ×100 (35).

Stichophormis Hkl., 1882 [**S. pyramidalis* Hkl.,

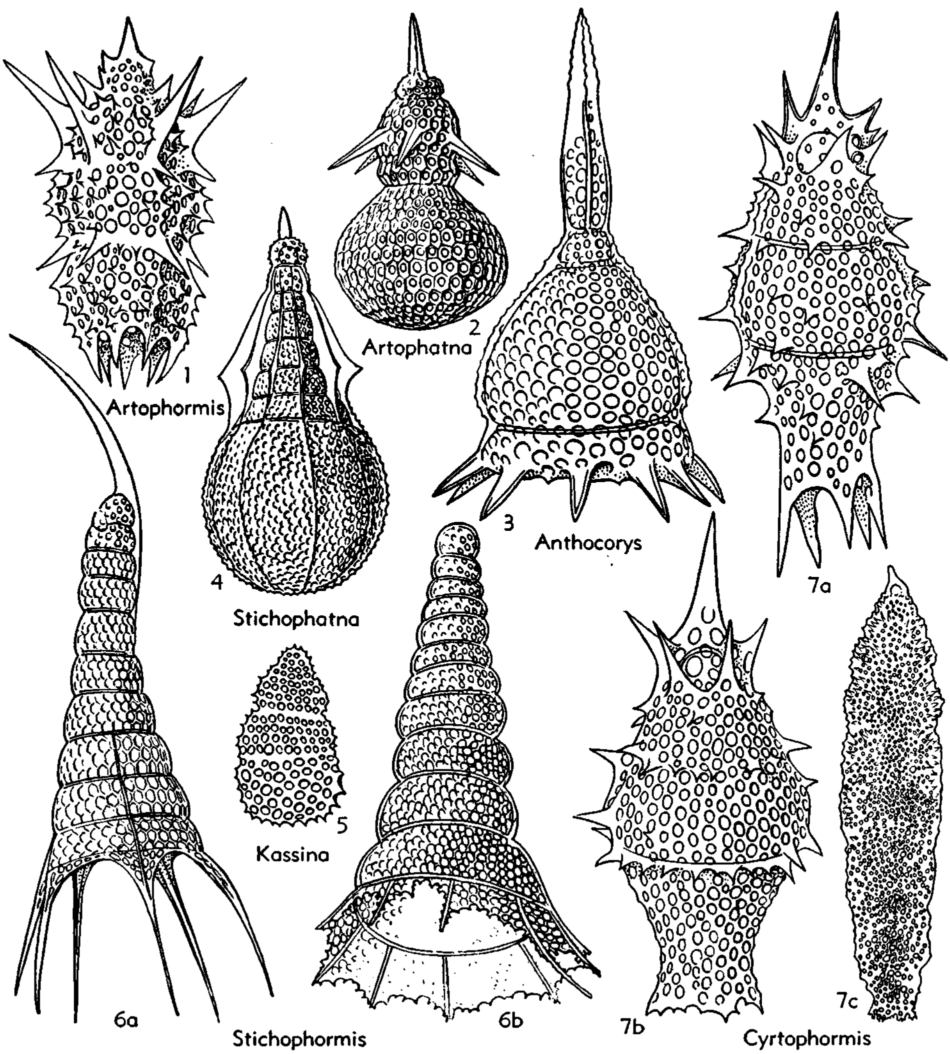


Fig. 71. Artophormididae (p. D139, D140).

1887]. Like *Anthocorys* but lateral ribs are prolonged into feet. *Jur.-Rec.*

S. (Stichophormis) [=*Stichophormium* HKL., 1887 (obj.)]. Six prominent ribs. *Jur.-Rec.*——FIG. 71,6*a*. *S. (S.) cornutella* HKL., Rec., ×300 (42).

S. (Stichophormiscus) HKL., 1887 [**S. novena;* SD herein]. Nine prominent ribs. *Rec.*——FIG. 71, 6*b*. **S. (S.) novena,* Rec., ×300 (42).

Subfamily STICHOPHATNINAE Haeckel, 1882

[as Stichophatnida; emend. CAMPBELL, herein] [=Stichophaenida HKL., 1887]

Basal shell mouth fenestrated. *Cret.-Rec.*

Stichophatna HKL., 1882 [**Stichophaena ritteriana* HKL., 1887][=*Stichophaena* HKL., 1887 (obj.)]. Nine prominent ribs or wings. *Rec.*

S. (Stichophatna) [=*Stichophaenidium* HKL., 1887 (obj.)]. Last joint rounded; without basal spine.——FIG. 71,*4*. **S. (S.) ritteriana,* Rec., ×200 (42).

S. (Stichophaenoma) HKL., 1887 [**Stichophaena nonaria;* SD herein]. Last joint pointed; with basal spine.

Artophatna HKL., 1882 [**Arthophaena aerostatica* HKL., 1887][=*Artophaena* HKL., 1887 (obj.)]. Six radial ribs or wings. *Rec.*——FIG. 71,*2*. **A. aerostatica,* Rec., ×200 (42).

Kassina CHABAKOV, 1937 [**K. kassini*]. Tower-shaped shell; with 3 to 5 or more chambers. *Cret.*——FIG. 71,*5*. **K. kassini,* Cret., Russ., ×130 (38).

Tetracapsa HKL., 1882 [**T. pilula* RÜST, 1885]. Three lateral ribs. *Jur.*

Family STICHOCORYTHIDAE Haeckel, 1882

[as Stichocorida; emend. CAMPBELL, herein] [=Lithocampida HKL., 1887; Stichocoridae FRIZZELL, 1951]

With radial apophyses. *Ord.-Rec.*

Subfamily STICHOCORYTHINAE Haeckel, 1882

[as Stichocorida *(partim)*; emend. CAMPBELL, herein] [=Artocorida HKL., 1882; Stichocorinae FRIZZELL, 1951]

Basal shell mouth open. *Ord.-Rec.*

Stichocorys HKL., 1882 [**S. wolffi* HKL., 1887]. Shell constricted in middle; upper 0.5 conical, lower 0.5 cylindrical; mouth truncate; cephalis with apical horn. *Trias.-Rec.*——FIG. 72,*1*. **S. wolffi,* Rec., ×300 (42).

Acotripus HKL., 1882 [**A. urceolus* RÜST, 1885]. Small superior joints annular; without apical horn; 3 prolongations of last joint. *Jur.*

Artostrobus HKL., 1887 [**Cornutella annulata* BAILEY, 1856]. Shell cylindrical; rounded cephalis with apical horn; mouth truncated. *Eoc.-Rec.*

A. (Artostrobus) [=*Artostrobulus* HKL., 1887 (obj.)]. Single transverse row of small round pores on each joint. *Eoc.-Rec.*

A. (Artostrobium) HKL., 1887 [**A. auritus;* SD herein]. Several rows of small pores on each joint. *Eoc.-Rec.*——FIG. 72,*3*. *A. (A.) articulatus* HKL., Rec., ×300 (42).

Dictyomitra ZITTEL, 1876 [**D. multicostata;* SD herein][=*Polysticha* PANTANELLI, 1880 (obj.); *Stichomitra* CAYEUX, 1897; *Poramphora* JÖRG., 1905; *Lithocorys* ICHIKAWA, 1950]. Shell conical; without apical horn. *Dev.-Rec.*

D. (Dictyomitra) [=*Dictyomitroma* HKL., 1887 (obj.)]. Shell with longitudinal ribs and furrows; joints of dissimilar length. *Dev.-Rec.*——FIG. 72,*2*. **D. (D.) multicostata,* U.Cret., Calif., ×150 (35).

D. (Dictyomitrella) HKL., 1887 [**Eucyrtidium articulatum* EHR., 1875; SD herein]. Smooth shell; joints of nearly similar length. *Eoc.-Rec.*

D. (Dictyomitrissa) HKL., 1887 [**D. polypora* ZITTEL, 1876; SD herein]. Shell smooth; joints of dissimilar length. *Cret.-Rec.*

Diplostrobus SQUIN., 1903 [**D. crassispina*]. Tubular post-abdomen has narrow mouth; 5 chambers form upper conical part of shell; with apical horn. *Cret.*——FIG. 72,*5*. **D. crassispina,* Cret., Italy, ×80 (52).

Eucyrtidium EHR., 1847 [**Lithocampe acuminata* EHR., 1844; SD FRIZZELL, 1951]. Like *Lithocampe* but has solid apical horn. *Jur.-Rec.*

E. (Eucyrtidium) [=*Eucyrtis* HKL., 1882 (obj.)]. All joints of nearly similar length. *Jur.-Rec.*——FIG. 72,*7a*. *E. (E.) hexagonatum* HKL., Rec. ×300 (42).

E. (Acanthocyrtis) HKL., 1882 [*non* 1887][**E. tricinctum* HKL., 1887]. Joints of dissimilar length; surface spiny. *Rec.*——FIG. 72,*7b*. *E. (A.) armatum* HKL., Rec., ×200 (42).

E. (Artocyrtis) HKL., 1887 [**E. profundissimum* EHR., 1872; SD herein]. Joints of dissimilar length; surface smooth. *Paleoc.-Rec.*——FIG. 72, *7c*. *E. (A.) hertwigi* HKL., Rec., ×300 (42).

E. (Stichocyrtis) HKL., 1882 [**E. spinosum* HKL., 1887]. Joints of nearly similar length; surface spiny. *Rec.*

Eusyringium HKL., 1882 [**E. conosiphon* HKL., 1887]. Like *Eucyrtidium* but last shell joint is a long narrow cylinder. *Trias.-Rec.*

E. (Eusyringium) [=*Eusyringartus* HKL., 1887 (obj.)]. Shell with 3 strictures. *Trias.-Rec.*——72,*8a*. *E. (E.) conosiphon,* Rec., ×200 (42).

E. (Eusyringoma) HKL., 1887 [**E. lagenoides* STÖHR, 1880; SD FRIZZELL, 1951]. Shell has 4 or more strictures. *Paleoc.-Rec.*——FIG. 72,*8b*. *E. (E.) siphonostoma* HKL., Rec., ×300 (42).

Lithamphora POP., 1909 [**L. furcaspiculata*]. Internal radial beams connect apical horn but are not extended as apophyses; mouth open (?). *Rec.*——FIG. 72,*4*. **L. furcaspiculata,* Rec., ×300 (48).

Lithocampe EHR., 1838 [**L. radicula;* SD herein]. Ovate or spindle-shaped shell; with constricted but not tubular mouth; cephalis without apical horn. *Ord.-Rec.*

L. (Lithocampe) [=*Lithocampula* HKL., 1887 (obj.)]. All shell joints nearly of similar length. *Ord.-Rec.*

L. (Lithocampium) HKL., 1882 [**L. stabile* RÜST, 1885]. Shell joints of dissimilar length. *Eoc.-Rec.*——FIG. 73,*1*. *L. (L.) diploconus* HKL., Rec., ×350 (42).

Lithomitra BÜTSCHLI, 1882 [**Eucyrtidium pachyderma* EHR., 1875; SD herein]. Like *Artostrobus* but lacks apical horn. *Trias.-Rec.*

L. (Lithomitra) [=*Lithomitrella* HKL., 1887 (obj.)]. Single row of small round pores on each joint. *Trias.-Rec.*——FIG. 72,*6*. *L. (L.) nodosaria* HKL., Rec., ×400 (42).

L. (Lithomitrissa) HKL., 1887 [**L. infundibulum;* SD herein]. Several rows of pores on each joint. *Eoc.-Rec.*

Lithostrobus BÜTSCHLI, 1882 [**Eucyrtidium argus* EHR., 1875; SD herein]. Like *Dictyomitra* but has apical horn. *Perm.-Rec.*

L. (Lithostrobus) [=*Cyrtostrobus* HKL., 1887 (obj.)]. Conical shell with straight axis; dissimilar joints. *Perm.-Rec.*——FIG. 73,*4*. *L. (L.) conulus* HKL., Rec., ×300 (42).

L. (Botryostrobus) HKL., 1887 [**L. botryocyrtis;* SD herein]. Cephalis lobulate. *Rec.*

L. (Conostrobus) HKL., 1887 [**L. hexastichus;* SD herein]. Conical shell with straight axis; similar joints. *Rec.*

L. (Cornustrobus) HKL., 1887 [**L. caloceras;* SD herein]. Horn-shaped shell; similar joints. *Rec.*

Siphocampium HKL., 1882 [**S. accrescens* RÜST, 1885][=*Siphocampe* HKL., 1887 (obj.)]. Like *Eucyrtidium* but has hollow cylindrical cephalic tube in place of a solid apical horn. *Jur.-Rec.*

S. (Siphocampium). Shell joints of dissimilar length. *Jur.-Rec.*——FIG. 73,*9b*. *S. (S.) spiralis* HKL., Rec., ×300 (42).

S. (Siphocampula) HKL., 1887 [**Siphocampe tubulosa;* SD herein]. Joints of nearly similar

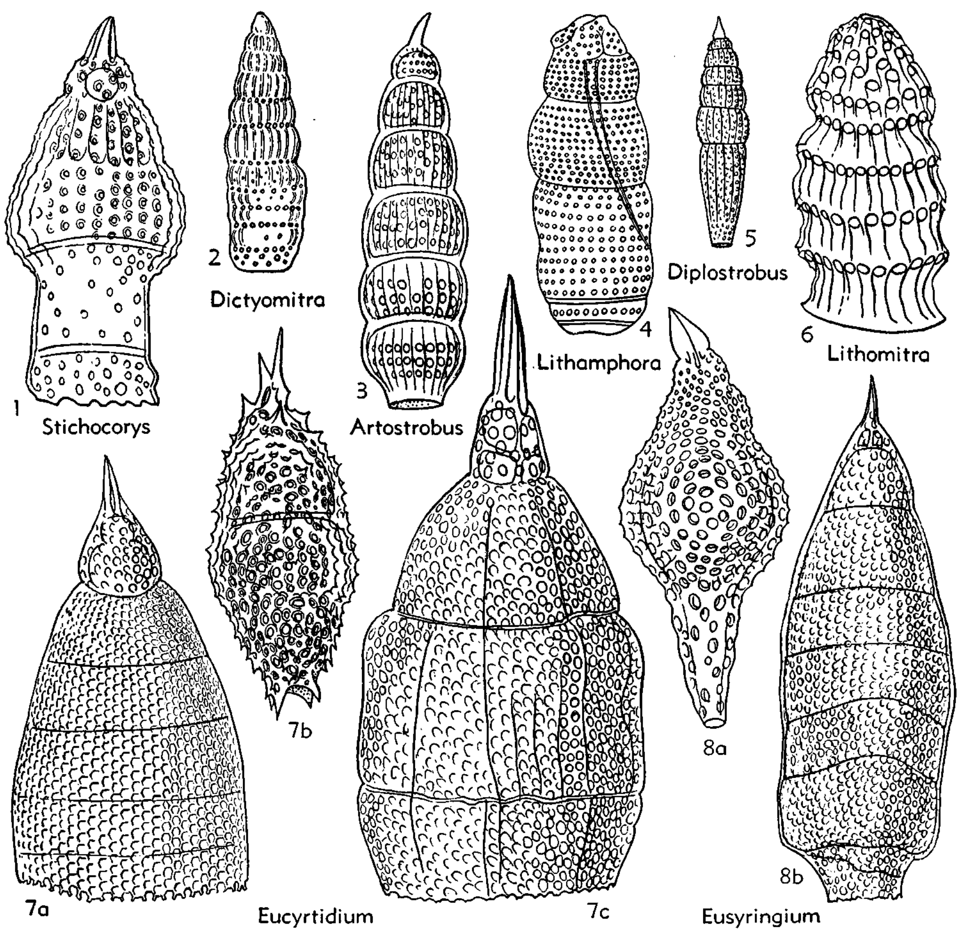


FIG. 72. Stichocorythidae (p. D140, D141).

length. *Rec.*——FIG. 73,*9a*. *S. (S.) annulosa* HKL., Rec., ×300 (42).

Spirocampe HKL., 1882 [**S. callispira* HKL., 1887]. Strictures spirally disposed; without apical horn. *Mio.*,Calif.-*Rec.*——FIG. 73,*3*. **S. callispira*, Rec., ×300 (42).

Spirocyrtis HKL., 1882 [**S. scalaris* HKL., 1887]. Like *Spirocampe* but has apical horn. *Cret.-Rec.*

S. (Spirocyrtis) [=*Spirocyrtidium* HKL., 1887 (obj.)]. Shell conical. *Cret.-Rec.*——FIG. 73,*10*. **S. scalaris*, Rec., ×350 (42).

S. (Spirocyrtoma) HKL., 1887 [**S. holospira*; SD herein]. Ovate shell, some spindle-shaped. *Rec.*

Syringium PRINCIPI, 1909 [**S. vinassai*]. Like *Eusyringium* but cephalis hidden within thorax. *Mio.-Plio.*——FIG. 73,*5*. **S. vinassai*, Mio., Italy, ×230 (49).

Trisyringium VINASSA 1900 [**T. capellinii*]. Three gradually dilated joints; without apical horn. *Cret.*——FIG. 73,*2*. **T. capellinii*, Cret., Karpathos., ×200 (55).

Subfamily STICHOCAPSINAE Haeckel, 1882

[as Stichocapsida; emend. CAMPBELL, herein]
[=Artocapsida, HKL., 1882]

Basal shell mouth fenestrated. *Dev.-Rec.*

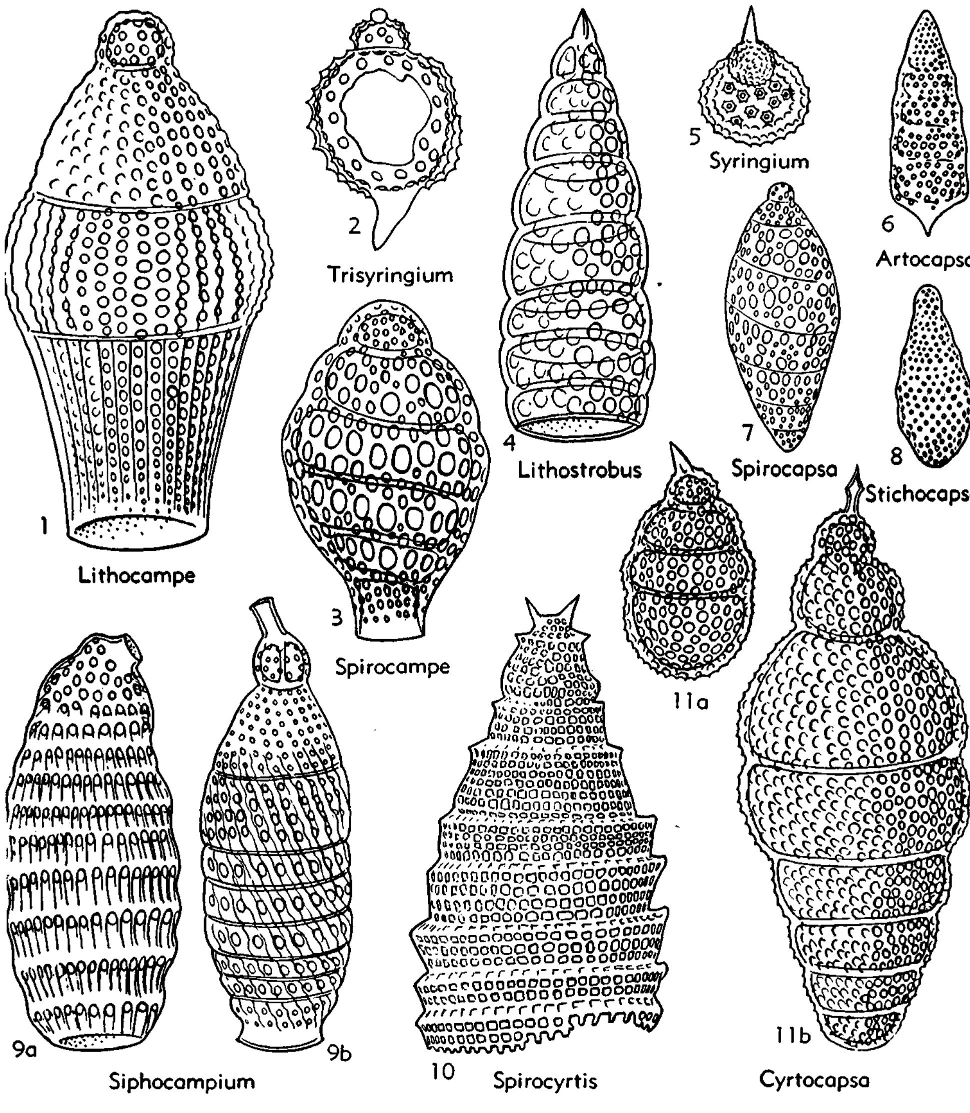


FIG. 73. Stichocorythidae (p. D141-D143).

Stichocapsa HKL., 1882 [**S. jaspidea* RÜST, 1885]. Last joint rounded but without basal spine or apical horn. *Dev.-Rec.*——FIG. 73,*8*. *S. megalocephalia* C.-CL., U.Cret., Calif., ×150 (35).

Artocapsa HKL., 1882 [**A. fusiformis* HKL., 1887]. Last joint pointed, conical, with basal spine and apical horn. *Cret.-Rec.*——FIG. 73,*6*. *A. livermorensis* C.-CL., U.Cret., Calif., ×150 (35).

Cyrtocapsa HKL., 1882 [**C. ovalis* RÜST, 1885]. Like *Stichocapsa* but has apical horn. *Jur.-Rec.*

C. (Cyrtocapsa) [=*Cyrtocapsoma* HKL., 1887 (obj.)]. Four or more annular strictures. *Jur.-Rec.*——FIG. 73,*11a*. *C. (C.) tetracapsa* HKL., Rec., ×200 (42).

C. (Cyrtocapsella) HKL., 1887 [**C. tetrapera;* SD herein]. Three annular strictures. *Rec.*——FIG. 73,*11b*. *C. (C.) chrysalidium* HKL., Rec., ×300 (42).

Spirocapsa RÜST, 1892 [**S. singularis*]. Shell composed of spiral lamina with 8 or more turns; with apical horn. *Jur.*——FIG. 73,*7*. **S. singularis,* Jur., Sicily, ×150 (51).

Superfamily CANNOBOTRYDICAE Haeckel, 1882

[*ex* Cannobotryida; emend. CAMPBELL, herein]
[=Botryodea HKL., 1882]

Cephalis lobulated. *Jur.-Rec.*

Family CANNOBOTRYDIDAE Haeckel, 1882

[as Cannobotryida; emend. CAMPBELL, herein]

Shell formed of a single chamber. *Jur.-Rec.*

Cannobotrys HKL., 1882 [**C. monacanna* HKL., 1887]. Has tubules. *Jur.-Rec.*——FIG. 74,*2*. *C. tricanna* HKL., Rec., ×200 (42).

Acanthobotrys POP., 1913 [**A. multispina*]. Two lobes; surface spiny. *Rec.*——FIG. 74,*1*. **A. multispina,* Rec., ×300 (48).

Lithobotrys EHR., 1844 [**L. quadriloba*][=*Lithocorythium* EHR., 1873; *Botryopera* HKL., 1887 (obj.)]. Lacks tubules. *Eoc.,*(Va.)*-Rec.*——FIG. 74,*3*. *L. cyrtoloba* (HKL.), Rec., ×300 (42).

Family GLYCOBOTRYDIDAE Campbell, nov.

[=emend. Lithobotryida HKL., 1887]
[=Neobotrydidae POP., 1913]

Shell formed of cephalis and thorax. *Eoc.-Rec.*

Glycobotrys CAMPBELL, 1951 [*pro Lithobotrys* HKL., 1887 (*non* EHR., 1844)]. [**Lithobotrys*

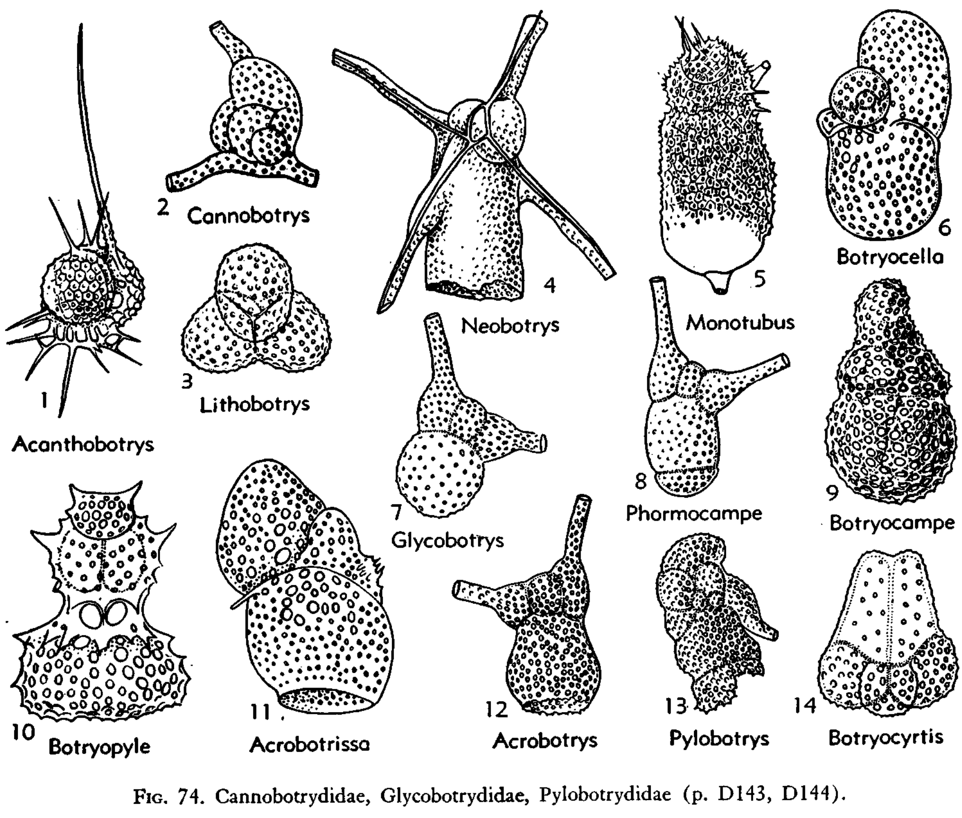


FIG. 74. Cannobotrydidae, Glycobotrydidae, Pylobotrydidae (p. D143, D144).

geminata EHR., 1875]. Cephalis has tubules; thorax fenestrated. *Eoc.-Rec.*——FIG. 74,*7*. *G. sphaerothorax* (HKL.), Rec., ×200 (42).

Acrobotrissa POP., 1913 [**A. cribosa*]. Lacks tubules and surface spines. *Rec.*——FIG. 74,*11*. **A. cribosa*, Rec., ×400 (48).

Acrobotrys HKL., 1882 [**A. monosolenia* HKL., 1887]. Has cephalic tubules; thorax open. *Rec.* ——FIG. 74,*12*. *A. disolenia* HKL., Rec., ×200 (42).

Botryocella HKL., 1882 [**Lithobotrys nucula* EHR., 1875]. Lacks cephalic tubules; thorax fenestrated. *Eoc.-Rec.*——FIG. 74,*6*. *B. multicellularis* HKL., Rec., ×300 (42).

Botryopyle HKL., 1882 [**B. sethocorys* HKL., 1887]. Lacks cephalic tubules; thorax open. *Eoc.-Rec.*——74,*10*. **B. sethocorys*, ×300 (42).

Monotubus POP., 1913. [**M. microporus*]. Single vertical-lateral cephalic tubule. *Rec.*——FIG. 74, *5*. **M. microporus*, Rec., ×400 (48).

Neobotrys POP., 1913 [**N. quadrituberosa*]. Has inner trellis consisting of sagittal ring and appended spines. *Rec.*——FIG. 74,*4*. **N. quadrituberosa*, Rec., ×400 (48).

Family PYLOBOTRYDIDAE Haeckel, 1882

[as Pylobotryida; emend CAMPBELL, herein]

Shell formed of cephalis, thorax, and abdomen. *Eoc.-Rec.*

Subfamily PYLOBOTRYDINAE Haeckel, 1882

[as Pylobotryida *(partim)*; emend. CAMPBELL, herein] [=Botryocyrtida HKL., 1887]

Basal shell mouth open. *Rec.*

Pylobotrys HKL., 1882 [**P. putealis* HKL., 1887]. Cephalis has variable number of tubules.——FIG. 74,*13*. **P. putealis*, Rec., ×200 (42).

Botryocyrtis EHR., 1860 [**B. serpentis* EHR., 1872; SD herein]. Cephalis without tubules.——FIG. 74,*14*. *B. cerebellum* HKL., Rec., ×300 (42).

Subfamily BOTRYOCAMPINAE Haeckel, 1887

[as Botryocampida; emend. CAMPBELL, herein]

Basal shell mouth fenestrated. *Eoc.-Rec.*

Botryocampe EHR., 1860 [**Lithobotrys inflata* BAILEY, 1856]. Lacks cephalic tubules. *Eoc.-Rec.* ——FIG. 74,*9*. *B. camerata* HKL., Rec., ×200 (42).

Phormocampe HKL., 1882 [**P. trithalmia* HKL., 1887]. Has cephalic tubules. *Rec.*——FIG. 74,*8*. *P. cannothalmia* HKL., Rec., ×200 (42).

Suborder PHAEODARINA Haeckel, 1879

[as Phaeodaria; emend. CAMPBELL, herein] [=Pansolenia HKL., 1878; Tripylea HERTWIG, 1879; Cannopylea HKL., 1882]

Central capsule with double membrane, bearing at one pole a tubular main opening **(astropyle)** in the center of a conical radiate operculum. Accessory openings common on opposite pole of the main axis; extracapsular cytoplasm with voluminous aggregate or dark pigmented bodies (phaeodium); skeleton composed of silica-carbonate in the form of hollow or solid tubules or rods or a lattice. *Cret.-Rec.*

MORPHOLOGICAL FEATURES

The Phaeodarina differ from other suborders of the Radiolaria in structure of the central capsule, presence of cytoplasmic inclusions and nature of the skeleton. The capsule generally is very large and oblately spherical, being depressed in the direction of the main axis. The main axis is vertical and distinctly marked by the commonly ventral position of the inverted conical **astropyle.** It has a double membrane, unlike the capsule of other suborders. These membranes differ in thickness, the outer one being thicker than the delicate inner one. In the living animal these membranes are in contact with each other. The walls of the capsule are continuous and devoid of the many pores which distinguish the capsular wall of Acantharina and Spumellina. The astropyle is a single aperture invariably placed at the oral end of the main axis, forming an inverted conical or caplike elevation, the center of which extends into a short cylindrical tube. This tube is termed the **proboscis**, and the conical part forms the **operculum**, but this operculum does not resemble the similarly termed plate of the oral pole of the central capsule of the Nassellina. In the Phaeodarina it is radially ribbed and no podoconus exists. Accessory apertures **(parapylae)** are variable in number and position, but generally there are 2 of them.

The **phaeodium**, composed of dark pigmented globules, is a unique possession in the cytoplasm of the Phaeodarina and is the structure from which the group derives its name. Invariable features of the phaeodium are its excentric location in the oral part of the calymma, its relation to the astropyle, constant volume (generally larger than the central capsule), and similar physical and chemical appearance. The most striking character is its position. The granules **(phaeodellae)** may be symbiotic algae, comparable to the zooanthellae of other Radiolaria; pigmented eye-spots comparable to those found in many flagellates; metabolic agents of a special sort.

The siliceous bars which compose the peripherally generated skeleton of the Phaeodarina are mostly hollow tubules filled with living cytoplasm. These cylindrical structures may be simple spicules in the Cannorrhaphididae and Aulacanthidae or articulated legs or spines containing regularly placed transverse septa in the Medusettidae and Atlanticellidae. The transverse plates somewhat resemble the septa of *Nautilus* and, like them, are pierced by a median aperture. In the Aulosphaeridae, Cannosphaeridae, Circoporidae, and Tuscadoridae, the tubules have a delicate wire-like thread of silica in the main axis which connects by horizontal branches to the inner wall of the tubule. Although hollow bars are most common, solid rods occur among the Sagosphaeridae, Castanellidae, and Conchariidae.

The substance of the shell of most Phaeodarina is homogeneous, but the Challengeriidae have a tracery of extremely fine, regular hexagonal meshes, which closely resembles the similar structure of the diatom frustule. The Tuscadoridae and Circoporidae possess porcelaneous texture, the walls being composed of silica cement and numerous fine needles enclosed in the matrix. In the Caementellidae and *Miracella* of the Atlanticellidae, the skeleton is formed of siliceous cement to which foreign particles are attached. These radiolarians are analogous to the arenaceous Foraminifera. Tabulate, paneled, or dimpled shells composed of polygonal plates or without plates, occur in the Circoporidae. These structures resemble similar ones found in complex Acantharina.

The meshwork of the lattice shell of some Castanellidae exhibits **rosettes** or flower-shaped buttons within hexagonal frames, especially located near the radial spines.

Among the families of Phaeodarina, the Phaeodinidae differ mostly from *Cystidium* (Nassellina) and *Procyttarium* (Spumellina) in the character of the central capsule and presence of the phaeodium. Other members of the Phaeodinicae have skeletal elements in the form of spicules or of incrusted foreign matter. The **spicules** are mostly cylindrical or spindle-shaped, and less commonly hemispheres or cap-shaped bodies. They may be unbranched or branched in different ways; many have terminal or lateral teeth (denticles). HAECKEL (20) associated these spiculate forms with those lacking skeletal structures, and called them Phaeocystina. The remaining Phaeodarina, with lattice shells, were included in a section termed Phaeocoscina. These last differ among themselves with respect to the shape of the shell and in other characters.

The Aulosphaericae include Phaeodarina with 1 or 2 spherical **lattice shells**, which may have pyramidal elevations or tents on the surface and **radial spines** projecting from the surface. The pyramidal elevations may have an axial rod running lengthwise of the pyramid and this rod bears lateral branches. Spongy spherical shells also occur among the Aulosphaericae. Some Cannosphaeridae have solid internal shells with closed pore frames on the surface.

The Challengeriicae, none of which have a bivalved form, are mostly characterized by shells with a prominent mouth at the free end of a projecting collar at one pole of the main axis. The mouth commonly is provided with **oral teeth**. In the Pharyngellinae an internal tube **(pharynx)** occurs inside the shell. Many genera of the Challengeriidae have marginal spines on the sharp edge of the shell or are provided with **apical horns.** These structures vary in number, position, and development in different genera and subgenera. The Medusettidae and Atlanticellidae have articulated legs or spines, described as ascending or descending, according to curvature of the spines upward toward the apex or downward around the mouth. Some Medusettidae, Castanellidae, and Tuscadoridae superficially resemble various Nassellina in manner well illustrating evolutionary convergence.

The Conchariicae have a bivalved shell composed of 2 completely separate thick hemispherical, cap- or boat-shaped dorsal and ventral valves, thus bearing likeness to brachiopods. These valves may be smooth or have dentate edges. A few bear a sagittal keel or median vertical superstructure. The valves may be unequal in size and may bear horns in various positions.

The Coelodendricae have a thin, delicate bivalved shell with a conical process **(galea)** which may bear branched tubes attached to each valve.

The 2 families included in this superfamily differ in presence or absence of structures termed **rhinocanna** and **frenulum.** The rhinocanna (nasal tube) is a curved cylinder or 3-sided prismatic tube which embraces the central capsule on one side and the galea on the other. It lies in the sagittal plane of the valve with its open end directed toward the proboscis of the central capsule. The frenulum (nasal suspensorium) is a small cylinder which connects the nasal mouth with the internal part of the nasal tube of the style near its base on the galea. **Styles** are long, generally dichotomously branched tubes which extend outside the shell margin. They anastomose with each other in some genera so as to form an outer lattice shell mantle. Commonly they have lateral and terminal branches. Numerous **dendrites (brushes)** may arise from the galea. Structures having importance in determination of the species of Coelodendricae are illustrated in Fig. 75.

The majority of the Phaeodarina are inhabitants of deep seas, mainly in the southern hemisphere; they are so common in some places that thousands of well-preserved individuals have been obtained in a single sample. A smaller number is found near the surface of the sea, widely distributed in most oceans. Most Phaeodarina have a diameter of 1 or 2 mm. They are thus 10 to 20 times the size of other Radiolaria. A few gigantic forms are 20 to 30

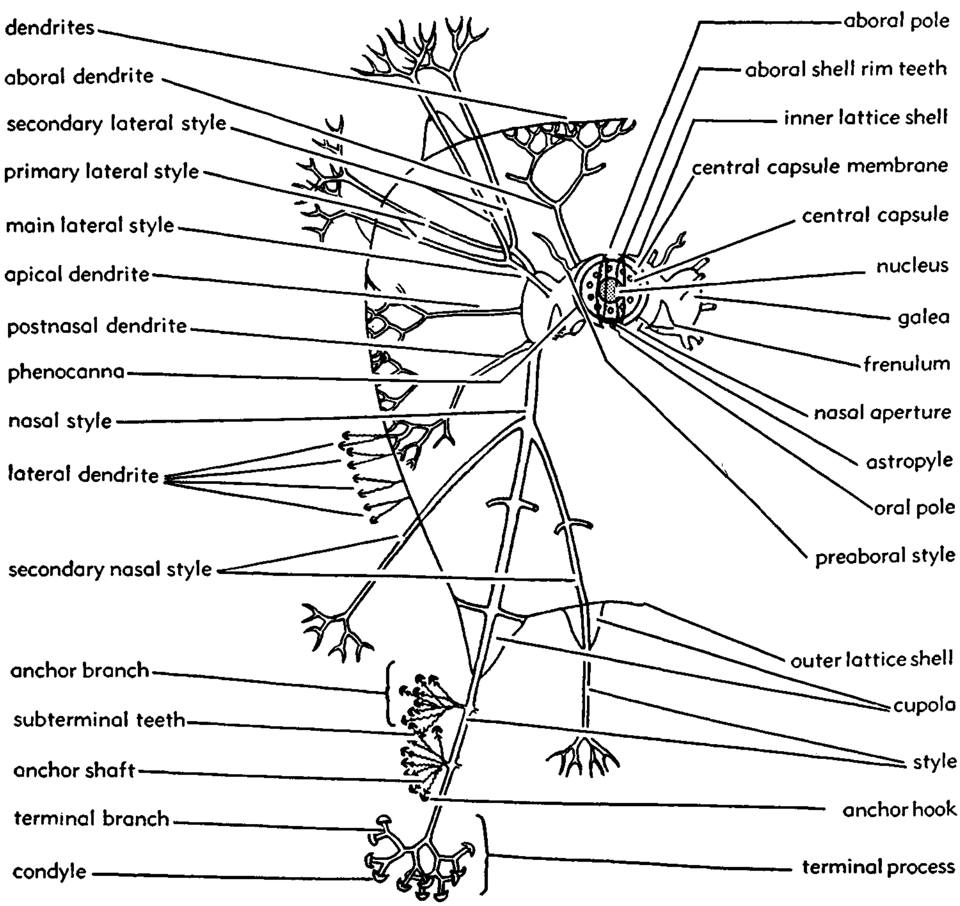


FIG. 75. Morphological features of phaeodarine radiolarians belonging to the superfamily Coelodendricae.

mm. in diameter, but a very few *(Cadium)* are extremely tiny.

Important accounts of the biology, reproduction, and ecology of the Phaeodarina are given by HAECKEL (12), HAECKER (13), and POPOFSKY (20). HAECKER, especially, gives an elaborate description of the reproduction and ecology of the members of this suborder found by the "Valdivia" in the central and south Atlantic, the Antarctic, and the Indian oceans.

Superfamily PHAEODINICAE Haeckel, 1879

[*ex* Phaeodinida; emend. CAMPBELL, herein] [=Phaeocystida HKL., 1879]

Lacking lattice shell; either naked cells or with isolated cytoplasmic spicules. *Rec.*

Family PHAEODINIDAE Haeckel, 1879

[as Phaeodinida; emend. CAMPBELL, herein]

Naked cells without spicules. *Rec.*

Phaeodina HKL., 1879 [**P. tripylea* HKL., 1887]. Central capsule with 3 openings.

Phaecolla HKL., 1879 [**P. primordialis* HKL., 1887]. Central capsule with single opening.——FIG. 76,*1*. **P. primordialis,* Rec., ×200 (42).

Family CAEMENTELLIDAE Borgert, 1909

Skeleton formed of incrusted siliceous foreign matter. *Rec.*

Caementella BORGERT, 1909 [**C. loricata*]. Central capsule with 3 openings.

Family CANNORRHAPHIDIDAE Haeckel, 1879

[as Cannorrhaphida; emend. CAMPBELL, herein]

Skeleton composed of scattered spicules. *Rec.*

Subfamily CANNORRHAPHIDINAE Haeckel, 1879

[as Cannorrhaphida *(partim)*; emend. CAMPBELL, herein] [=Cannobelida HKL., 1887]

Hollow tangential spicules cylindrical or spindle-shaped. *Rec.*

Cannorrhaphis HKL., 1879 [**C. spinulosa* HKL., 1887]. Tubules spiny or branched.——FIG. 76,*3*. **C. spinulosa,* Rec., ×50 (42).

Thalassoplancta HKL., 1862 [*non* HKL., 1887 (=*Thalassorrhaphis* CAMPBELL, 1951)] [**Thalassicolla calvispicula* HKL., 1860] [=*Cannobelos* HKL., 1887 (obj.)]. Smooth unbranched tubules.

Subfamily CATINULINAE Haeckel, 1887

[as Catinulida; emend. CAMPBELL, herein]

Spicules hemispherical or caplike. *Rec.*

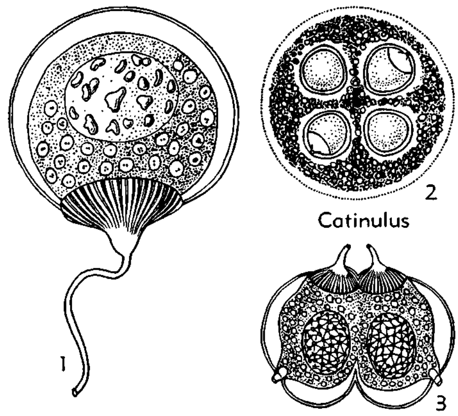


FIG. 76. Phaeodinidae, Cannorrhaphididae (p. D147).

Catinulus HKL., 1887 [**C. quadrifidus;* SD herein]. Spicules with radiate margins and circular openings.——FIG. 76,*2*. **C. quadrifidus,* Rec., ×200 (42).

Family AULACANTHIDAE Haeckel, 1862

[as Aulacanthida; emend. CAMPBELL, herein]

Skeleton formed of numerous hollow radial tubules the proximal ends of which touch the surface of the central capsule. *Rec.*

Subfamily AULACANTHINAE Haeckel, 1862

[as Aulacanthida *(partim)*; emend. CAMPBELL, herein] [=Aulographida HKL., 1887]

External veil of interwoven, numerous, thin and hollow tangential needles entirely covering surface of calymma. *Rec.*

Aulacantha HKL., 1860 [**A. scolymantha* HKL., 1862]. Unbranched radial tubules.

Auloceros HKL., 1887 [**A. furcosus;* SD herein]. Like *Aulographis* but terminal branches of radial tubules are forked and again ramified.

- **A. (Auloceros)** [=*Auloceraea* HKL., 1887 (obj.)]. Terminal branches without corona of radiate denticles.——FIG. 77,*2*. *A. (A.) elegans* HKL., Rec., ×40 (42).
- **A. (Auloceratium)** HKL., 1887 [**A. dicranaster;* SD herein]. Distal ends of terminal branches with small coronas of recurved radiate teeth.

Aulodendron HKL., 1887 [**A. pacificum;* SD herein]. Lateral and terminal branches irregularly scattered along length of radial tubules.——FIG. 77,*4*. *A. indicum* HKL., Rec., ×75 (42).

Aulographis HKL., 1879 [**A. pandora* HKL., 1887] [=*Aulographium, Aulancora* HKL., 1879]. Radial tubules with distal verticels of simple terminal branches.

A. (Aulographis) [=*Aulographantha* HKL., 1887 (obj.)]. No lateral teeth on tubules.

A. (Aulocoryne) FOWLER, 1898 [**A. zetesios*]. Terminal branches swollen, knoblike, with 100 to 150 or more threadlike branches and small coronas of radiate denticles.

A. (Aulographella) HKL., 1887 [**A. flosculus;* SD herein]. [=*Aulokleptes* IMMERMANN, 1904]. Without coronas of radiate denticles; lateral teeth or secondary spines commonly stout and club-shaped.

A. (Aulographidium) HKL., 1887 [**A. tetrancistra;* SD herein]. Terminal branches armed with whorls of small radial teeth; without lateral denticles.

A. (Aulographonium) HKL., 1887 [**A. candelabrum;* SD herein]. Terminal branches armed with lateral teeth and terminal whorls of small radial teeth.——FIG. 77,*1*. *A. (A.) candelabrum,* Rec., ×40 (42).

A. (Aulophyton) IMMERMANN, 1904 [**A. tetronyx*]. Terminal branches with 4 distal branches ending in recurved hooks.

Aulopetasus HAECKER, 1908 [**A. charoides*]. Terminal tubules with 4 to 5 lateral branches which have secondary terminal branches and minute coronas of radiate teeth.

Aulospathis HKL., 1887 [**A. bifurca;* SD herein]. Radial tubules bear a distal and proximal verticel of lateral branches.

A. (Aulospathis) [=*Aulospathessa* HKL., 1887 (obj.)]. Radial tubules distally inflated.——FIG. 77,*5*. **A. (A.) bifurca,* Rec., ×20 (42).

A. (Aulospathilla) HKL., 1887 [**A. triodon;* SD herein]. Radial tubules not inflated.

Subfamily AULACTINIINAE Haeckel, 1887

[as Aulactinida; emend. CAMPBELL, herein]

Lacking external veil of needles. *Rec.*

Aulactinium HKL., 1887 [**A. actinastrum;* SD herein]. Surface of calymma naked.——FIG. 77, *3a*. *A. spinosum* HKL., distal end of a tubule, ×100 (42).——FIG. 77,*3b*. **A. actinastrum,* Rec., ×50 (42).

Family ASTRACANTHIDAE Haecker, 1908

Distal ends of hollow radial tubules variously developed; proximal ends touch hollow central sphere. *Rec.*

Astracantha HAECKER, 1908 [**A. paradoxa;* SD herein].——FIG. 78,*2*. *A. umbellifera* HAECKER, Rec., ×25 (43).

Superfamily AULOSPHAERICAE Haeckel, 1862

[*ex* Aulosphaerida; emend. CAMPBELL, herein]
[=Phaeosphaeria HKL., 1879 *(partim)*]

Single or double, usually spherical lattice shell; without mouth and not bivalved. *Cret.-Rec.*

Family SAGOSPHAERIDAE Haeckel, 1887

[as Sagosphaerida; emend. CAMPBELL, herein]

Delicate network of subregular triangular meshes and thin filiform solid rods. *Rec.*

Subfamily SAGOSPHAERINAE Haeckel, 1887

[as Sagosphaerida *(partim)*; emend. CAMPBELL, herein]
[=Sagenida HKL., 1887]

Simple lattice sphere with or without pyramidal elevations or tents. *Rec.*

Sagosphaera HKL., 1887 [**S. penicella; SD herein*]. Like *Sagena* but with radial spines at nodal points of meshes.——FIG. 78,*1*. **S. penicella,* a nodal point and its radial spines. Rec., ×150 (42).

Sagena HKL., 1887 [**S. ternaria;* SD herein]. Surface smooth, without pyramidal elevations or radial spines.——FIG. 78,*4*. **S. ternaria,* Rec., ×100 (42).

Sagenoarium BORGERT, 1891 [**S. chuni*]. Double lattice shell; numerous pyramidal elevations without axial rods and with radial spines.

Sagenoscena HKL., 1887 [**S. stellata;* SD herein]. Like *Sagoscena* but pyramids have internal axial rods.——FIG. 78,*6*. **S. stellata,* top and axial rod of a pyramidal tent prolonged into a crowned radial spine, Rec., ×100 (42).

Sagoscena HKL., 1887 [**S. castra;* SD herein]. Pyramidal tents or elevations without internal axial rods.——FIG. 78,*5*. **S. castra,* Rec., ×25 (42).

Subfamily SAGMARIINAE Haeckel, 1887

[as Sagmarida; emend. CAMPBELL, herein]

Thick shell composed of spongy wickerwork. *Rec.*

Sagmarium HKL., 1887 [**S. spongodictyum;* SD herein]. Smooth surface.——FIG. 78,*7*. **S. spongodictyum,* Rec., ×25 (42).

Sagmidium HKL., 1887 [**S. crucicorne;* SD herein]. Spiny surface.——FIG. 78,*3*. **S. crucicorne,* single nodal point with 3 radial spines, Rec., ×150 (42).

Sagoplegma HKL., 1887 [**S. scenophora;* SD herein]. Like *Sagmidium* but has numerous pyramidal elevations.——FIG. 78,*8*. **S. scenophora,* tops of 3 pyramids, ×150 (42).

Family AULOSPHAERIDAE Haeckel, 1862

[as Aulosphaerida; emend. CAMPBELL, herein]

Single shell composed of hollow tangential cylindrical tubules separated by starlike (astral) septa in nodal points. *Rec.*

Subfamily AULOSPHAERINAE Haeckel, 1862
[as Aulosphaerida *(partim)*; emend. CAMPBELL, herein]
[=Aularida HKL., 1887]

Triangular meshwork. *Rec.*

Aulosphaera HKL., 1860 [**A. trigonopa* HKL., 1862]. Spherical shell with simple network; without radial tubules.

A. (Aulosphaera) [=*Aulosphaerantha* HKL., 1887

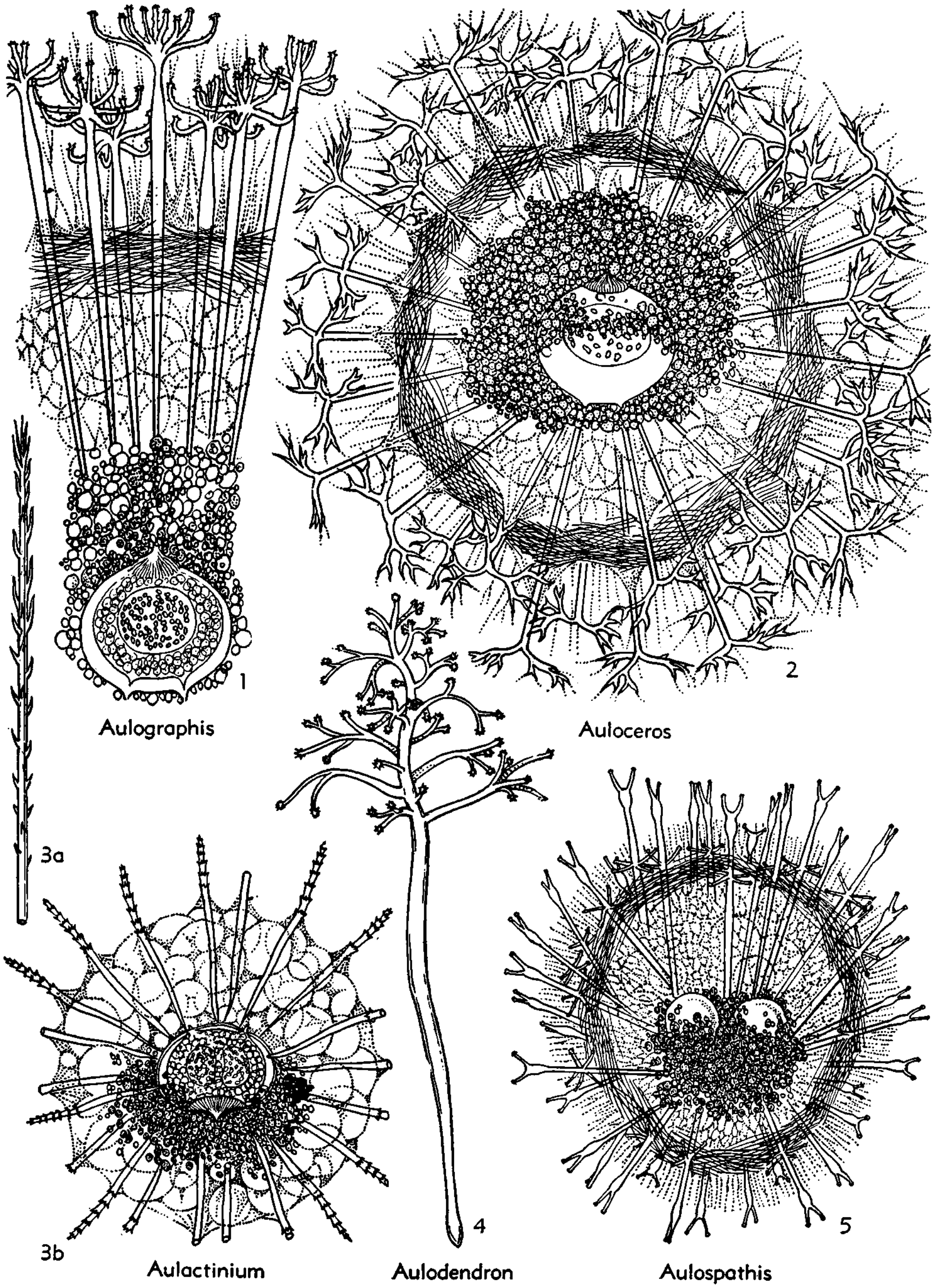


FIG. 77. Aulacanthidae (p. D147, D148).

(obj.)]. Radial tubules smooth; without teeth.

A. (Aulosphaerella) Hkl., 1887 [**A. triodon;* SD herein]. Radial tubules smooth; armed with a verticel of distal teeth.

A. (Aulosphaerissa) Hkl., 1887 [**A. spathillata;* SD herein]. Radial tubules with variable number of regular verticels of lateral branches.——Fig. 79,2. *A. (A.) dendrophora* Hkl., Rec., ×25 (42).

A. (Aulosphaeromma) Hkl., 1887 [**A. trifurca;* SD herein]. Radial tubules spiny or thorny; irregular lateral branches.

Aularia Hkl., 1887 [**A. ternaria;* SD herein]. Like *Aulosphaera* but lacks radial tubules.——Fig. 79,6. **A. ternaria,* group of 6 triangular meshes with 7 nodal points of tubules, ×150 (42).

Aulatractus Hkl., 1887 [**A. fusiformis;* SD herein]. Single shell spindle-shaped; radial tubules at nodal points.——Fig. 79,1. **A. fusiformis,* Rec., ×5 (42).

Aulophacus Hkl., 1887 [**A. amphidiscus;* SD herein]. Like *Aulatractus* but shell lenticular.——Fig. 79,3. *A. lenticularis* Hkl., single radial spine, ×150 (42).

Auloplegma Hkl., 1879 [**A. perplexum* Hkl., 1887]. Spongy spherical shell with radial tubules.——Fig. 79,5. **A. perplexum,* Rec., ×20 (42).

Auloscena Hkl., 1887 [**A. mirabilis;* SD herein]. Spherical shell with pyramidal elevations or tents with radial tubule on top.

A. (Auloscena) [=*Auloscenium* Hkl., 1887 (obj.)]. Radial tubules smooth.——Fig. 79,9. **A. (A.) mirabilis,* Rec., ×20 (42).

A. (Auloscenidium) Hkl., 1887 [**A. tentorium;* SD herein]. Radial tubules spiny or thorny.

Subfamily AULONIINAE Haeckel, 1887

[as Aulonida; emend. Campbell, herein]

Polygonal meshes. *Rec.*

Aulonia Hkl., 1887 [**A. hexagonia;* SD herein]. Spherical shell with simple network; without radial tubules.——Fig. 79,7. **A. hexagonia,* Rec., ×20 (42).

Aulastrum Hkl., 1887 [**A. dendroceros;* SD herein]. Like *Aulonia* but has radial tubules in nodes of network.——Fig. 79,8. **A. dendroceros,* 3 radial spines, ×150 (42).

Aulodictyum Hkl., 1879 [**A. hydrodictyum* Hkl., 1887]. Spongy spherical shell without radial tubules.

Family CANNOSPHAERIDAE Haeckel, 1879

[as Cannosphaerida; emend. Campbell, herein]

Two concentric shells. *Cret.-Rec.*

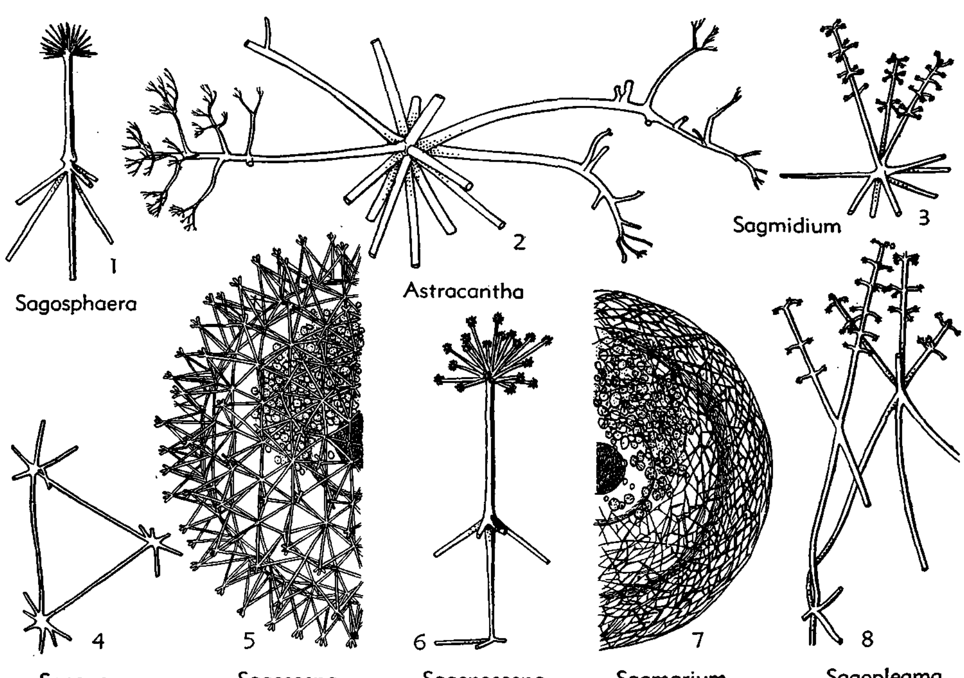


Fig. 78. Astracanthidae, Sagosphaeridae (p. D148).

Cannosphaera Hkl., 1879 [**C. atlantica* Hkl., 1887]. Internal shell without open pores. *Rec.*——Fig. 79,*4*. *C. antarctia* Hkl., Rec., ×20 (42).

Cannosphaeropsis Wetzel, 1933 [**C. utinensis*]. Like *Cannosphaera* but external shell has polygonal meshwork. *Cret.,* C.Eur.

Coelacantha Hertwig, 1879 [**C. ancorata*]. Internal shell latticed. *Rec.*

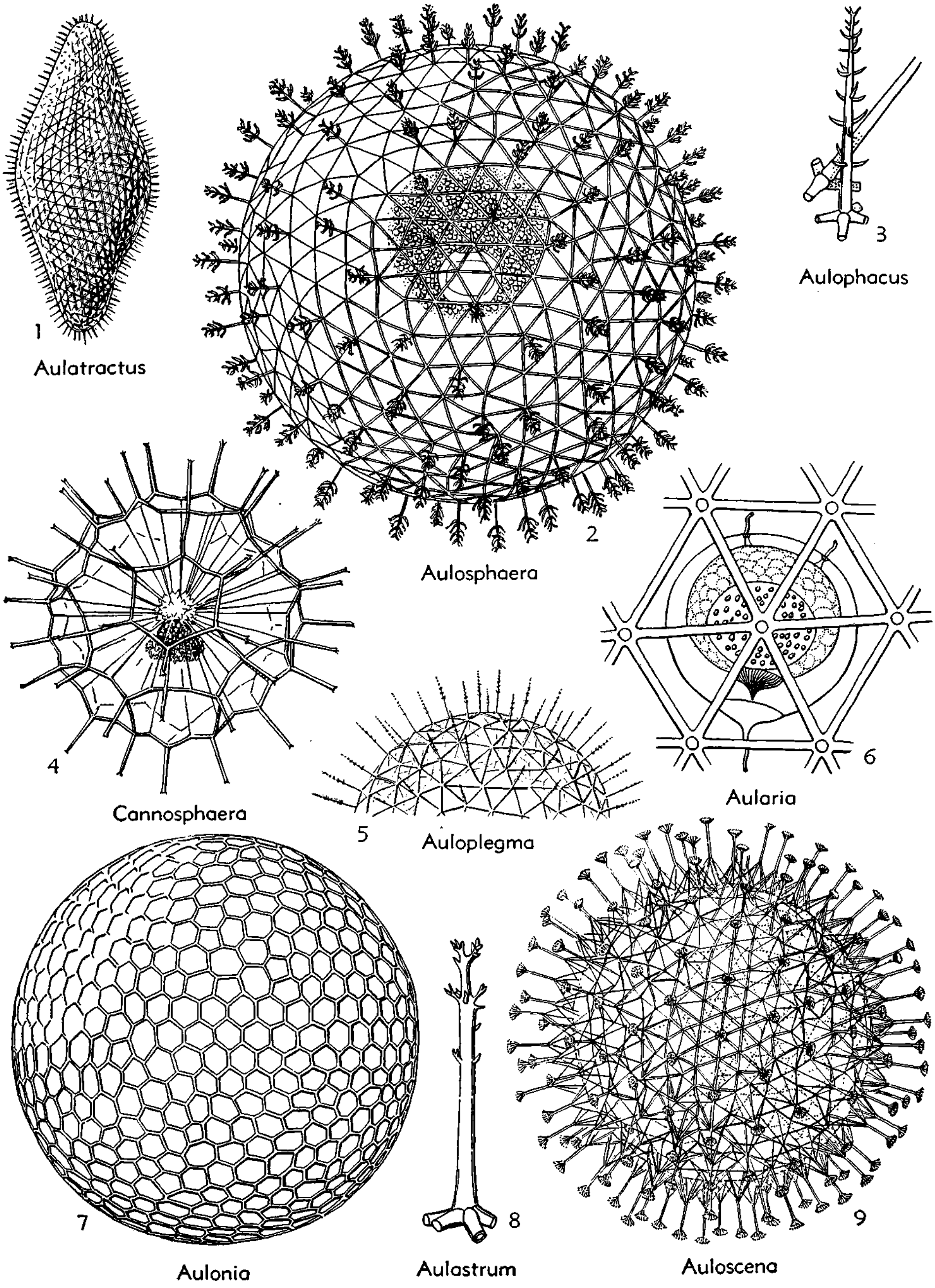


Fig. 79. Aulosphaeridae, Cannosphaeridae (p. D150, D151).

Superfamily CHALLENGERIICAE Murray, 1876

[*ex* Challengerida; emend. CAMPBELL, herein] [=Phaeogromia HKL., 1879]

Shell provided with mouth; not bivalved. *Rec.*

Family CHALLENGERIIDAE Murray, 1876

[as Challengerida; emend. CAMPBELL, herein]

Ovate or lens-shaped shell with fine regular hexagonal mesh (diatom-structure); with open mouth and commonly teeth; without articulated legs. *Rec.*

Subfamily CHALLENGERIINAE Murray, 1876

[as Challengerida *(partim)*; emend. CAMPBELL, herein] [=Lithogromida HKL., 1887]

Mouth simple. *Rec.*

Challengeria MURRAY, 1876 [**C. naresii*]. Shell with oral teeth, without marginal spines.

C. (Challengeria) [=*Challengerantha* HKL., 1887 (obj.)]. Single undivided tooth.——FIG. 80,*5*. *C. (C.) tritonis* HKL., Rec., ×100 (42).

C. (Challengeretta) HKL., 1887 [**C. slogettii;* SD herein]. Forked or bifid tooth, or 2 parallel teeth.

C. (Challengerilla) HKL., 1887 [**C. trifida;* SD herein]. Three teeth separate, or single tooth trifid.

C. (Challengeromma) HKL., 1887 [**C. bromleyi;* SD herein]. Four to 6 or more teeth.

Challengeron MURRAY, 1879 [**C. bethelli;* SD herein]. Like *Challengeria* but has spines on sharp marginal edge of shell.

C. (Challengeron) [=*Challengerosium* HKL., 1887 (obj.)]. Margin dentate or serrate in continuous series.——FIG. 80,*1*. *C. (C.) wyvillei* HKL., Rec., ×150 (42).

C. (Challengeranium) HKL., 1887 [**Challengeria swirei* MURRAY, 1879]. Single apical spine.

C. (Challengerebium) HKL., 1887 [**C. richardsii;* SD herein]. Two widely distant marginal spines.

C. (Challengeridium) HKL., 1887 [**C. crosbiei;* SD herein]. Large spines 3 to 5 or more, or a bunch of spines on shell margin; middle spine larger than others.

C. (Heliochallengeron) HAECKER, 1908 [**C. channeri* MURRAY, 1879]. Shell margin with 20 or more elongated spines in a single series.

Lithogromia HKL., 1879 [**L. silicea* HKL., 1879]. Like *Challengeria* but has smooth shell without either marginal spines or oral teeth.——FIG. 80,*2*. **L. silicea,* Rec., ×75 (42).

Protocystis WALLICH, 1869 [**P. aurita*]. Like *Lithogromia* but has one or more oral teeth.

Subfamily PHARYNGELLINAE Haeckel, 1887

[as Pharyngellida; emend. CAMPBELL, herein]

Shell has prominent inner tube or pharynx. *Rec.*

Pharyngella HKL., 1887 [**P. gastrula;* SD herein]. Shell has oral teeth but lacks marginal spines.——FIG. 80,*4*. **P. gastrula,* Rec., ×150 (42).

Entocannula HKL., 1879 [**E. circularis* HKL., 1887][=*Trichogromia* HKL., 1887 (obj.)]. Shell without marginal spines and oral teeth.——FIG. 80,*6*. *E. infundibulum* HKL., Rec., ×75 (42).

Porcupinia HKL., 1879 [**P. aculeata* HKL., 1887]. Shell with oral teeth and marginal spines.——FIG. 80,*3*. *P. cordiformis* HKL., Rec., ×100 (42).

Family CADIIDAE Borgert, 1901

Minute, ovoidal, elliptical, lemon- or melon-shaped shell with bent neck and subterminal opening; surface with longitudinal striae; apex with or without apical spine, or with an elliptical ring connecting apex and lower part of aperture. *Rec.*

Cadium BAILEY, 1856 [**C. marinum*] [=*Beroetta* CLEVE, 1899; *Cadimella* STAND, 1928].——FIG. 80,*12*. *C. inauris* BORGERT, Rec., ×1,000 (34).

Family MEDUSETTIDAE Haeckel, 1887

[as Medusettida; emend. CAMPBELL, herein]

Ovate, hemispherical or caplike shell of alveolated texture; hollow articulated legs surround wide open mouth. *Rec.*

Subfamily MEDUSETTINAE Haeckel, 1887

[as Medusettida *(partim)*; emend. CAMPBELL, herein] [=Euphysettida HKL., 1887]

Three or 4 legs; apex usually with horn. *Rec.*

Medusetta HKL., 1887 [**M. codonium;* SD herein]. Four equal legs.——FIG. 80,*9*. *M. quadrigata* HKL., Rec., ×200 (42).

Cortinetta HKL., 1887 [**C. tripodiscus;* SD herein]. Three equal legs.——FIG. 80,*7*. **C. tripodiscus,* Rec., ×150 (42).

Euphysetta HKL., 1887 [**E. staurocodon;* SD herein]. One large and 3 small legs.——FIG. 80,*10*. *E. amphicodon* HKL., Rec., ×150 (42).

Subfamily GAZELLETTINAE Haeckel, 1887

[as Gazellettida; emend. CAMPBELL, herein]

Six to 12 or more legs; apex usually without horn. *Rec.*

Gazelletta HKL., 1887 [*non* MURRAY, 1876 MSS] [**G. hexanema;* SD herein]. Six descending legs.

G. (Gazelletta) [=*Gazellarium* HKL., 1887 (obj.)]. Smooth unbranched legs.——FIG. 80,*8*. **G. (G.) hexanema,* Rec., ×200 (42).

G. (Gazellettidium) HKL., 1887 [**G. bifurca;* SD herein]. Legs distally branched or with a bunch of terminal spines.

G. (Gazellonium) HKL., 1887 [**G. studeri;* SD herein]. Legs with unbranched or branched lateral spines.

G. (Gazellusium) HKL., 1887 [**G. dendronema;* SD herein]. Spiny legs armed with large terminal branches.

Gorgonetta HKL., 1887 [**G. mirabilis;* SD herein]. Six descending and 6 ascending legs.——FIG. 80, *11. *G. mirabilis,* Rec., ×40 (42).

Nationaletta BORGERT, 1905 [**Gazelletta fragilis* BORGERT, 1902]. Spindle-, cudgel-, or bag-shaped shell with 10 to 13 chambered radial spines around mouth, each with terminal spines.

Planktonetta BORGERT, 1902 [**Gazelletta atlantica* BORGERT, 1901]. Like *Nationaletta* but has 8 to 10 distally branched descending legs.

Polypetta HKL., 1887 [**P. polynema;* SD herein]. Ten to 20 or more descending legs.

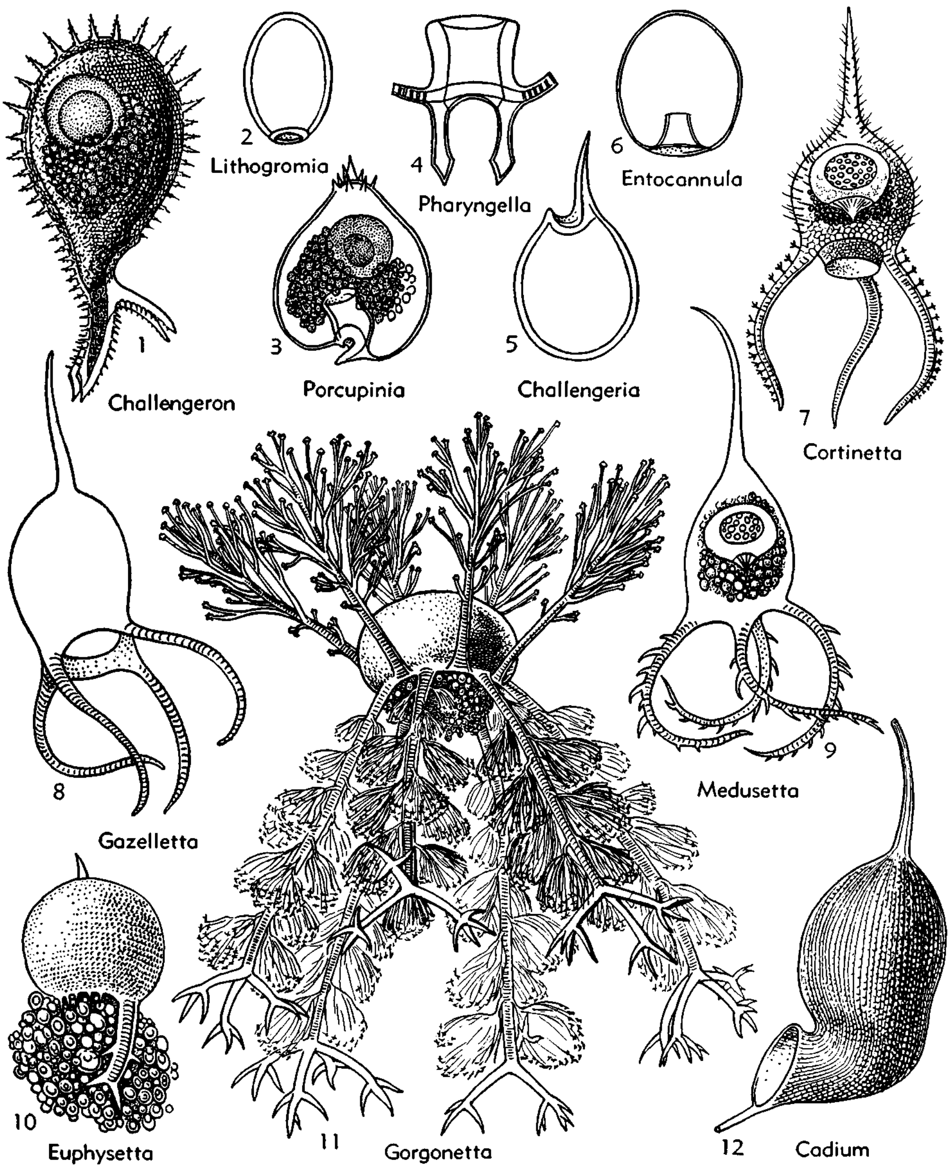


FIG. 80. Challengeriidae, Cadiidae, Medusettidae (p. D152, D153).

Family POROSPATHIDIDAE Borgert, 1901

[as Porospathida; emend. CAMPBELL, herein]

Shell covered by paneled or tabulated surface or covered by trizonal meshwork; radial spines on all sides. *Rec.*

Porospathis HKL., 1879 [**P. tabulata;* SD herein]. ——FIG. 81,*9*. **P. tabulata,* Rec., ×250 (42).

Family ATLANTICELLIDAE Borgert, 1906

Without skeleton or with skeleton appended to bladder-like central capsule forming a ring with 4 paired hollow articulated vertical descending divergent spines from each of which arise greatly elongated recurved ascending branches. *Rec.*

Atlanticella BORGERT, 1906 [**A. planktonica;* SD herein]. Central capsule tomato-shaped; usually with skeleton.——FIG. 81,*8*. *A. bicornis* HAECKER, Rec., ×70 (42).

Cornucella BORGERT, 1907 [**C. maya*]. Central capsule with cylindrical arms.

Globicella BORGERT, 1907 [**G. pila*]. Central capsule globular.

Halocella BORGERT, 1907 [**H. gemma*]. Skeleton formed of spongy basket-like piece and 2 small winglike rods.

Lobocella BORGERT, 1907 [**L. proteus*]. Saccular central capsule with finger-like processes.

Miracella BORGERT, 1911 [**M. ovulum*]. Skeleton formed of adherent foreign matter.

Family CASTANELLIDAE Haeckel, 1879

[as Castanellida; emend. CAMPBELL, herein]

Generally spherical shell with ordinary lattice and round pores; radial spines lacking circles of basal pores; large mouth armed with teeth. *Rec.*

Subfamily CASTANELLINAE Haeckel, 1879

[as Castanellida *(partim);* emend. CAMPBELL, herein]
[=Eucastanellinae HAECKER, 1908]

Pores without rosettes around main radial spines. *Rec.*

Castanella HKL., 1879 [**C. wyvillei* HKL., 1887]. Dentate mouth; without main radial spines.——FIG. 81,*5*. **C. wyvillei,* Rec., ×40 (42).

Castanarium HKL., 1879 [**C. darwini* HKL., 1887]. Like *Castanella* but has smooth mouth.

Castanea HAECKER, 1906 [**C. amphora*]. Large solid shell; feeble main radial spines; small smooth mouth.——FIG. 81,*4*. **C. amphora,* Rec., ×75 (43).

Castanidium HKL., 1879 [**C. willemoesi* HKL., 1887]. Large unbranched radial main spines scattered between short bristles; smooth mouth. ——FIG. 81,*2*. *C. murrayi* HKL., Rec., ×40 (42).

Castanissa HKL., 1879 [**C. challengeri* HKL., 1887]. Like *Castanidium* but has dentate mouth. ——FIG. 81,*1*. **C. challengeri,* Rec., ×40 (42).

Castanopsis HKL., 1879 [**C. naresi* HKL., 1887]. Main radial spines branched.——FIG. 81,*3*. **C. naresi,* Rec., ×40 (42).

Castanura HKL., 1879 [**C. tizardi* HKL., 1887]. Like *Castanopsis* but has dentate mouth.——FIG. 81,*7*. **C. tizardi,* Rec., ×40 (42).

Subfamily CIRCOCASTANEINAE Haecker, 1908

Pore frames near bases of main radial spines solid; with rosettes within them. *Rec.*

Circocastanea HAECKER, 1906 [**C. margarita*]. Mouth toothed; with corona of 4 to 7 (5 to 8) rosettes.——FIG. 81,*6*. **C. margarita,* Rec., ×75 (43).

Family CIRCOPORIDAE Haeckel, 1879

[as Circoporida; emend. CAMPBELL, herein]

Spherical or polyhedral shell exhibiting solid porcelaneous structure and tabulate, paneled or dimpled surface; stellate circle of radial pores around base of hollow radial spines. *Rec.*

Subfamily CIRCOPORINAE Haeckel, 1879

[as Circoporida *(partim);* emend. CAMPBELL, herein]
[=Circogonida HKL., 1887]

Paneled shell composed of polygonal plates; radial spines branched. *Rec.*

Circoporus HKL., 1879 [**C. sexfurcus* HKL., 1887]. Spherical shell with 6 radial spines.——FIG. 82,*3*. **C. sexfurcus,* Rec., ×40 (42).

Circogonia HKL., 1887 [**C. icosahedra;* SD herein]. Icosahedral shell with 12 radial spines. ——FIG. 82,*5*. **C. icosahedra,* Rec., ×40 (42).

Circoporetta HAECKER, 1908 [**Circoporus octahedrus* HKL., 1887]. Octahedral shell with trigonal plates; star-shaped pylome.——FIG. 82,*6*. **C. octahedrus* (HKL.), Rec., ×150 (42).

Circospathis HKL., 1879 [**C. furcata* HKL., 1887]. Tetradecahedral shell with 9 radial spines.——FIG. 82,*4*. **C. furcata,* Rec., ×40 (42).

Circostephanus HKL., 1879 [**C. coronarius* HKL., 1887]. Polyhedral shell with 24 to 40 or more radial spines.——FIG. 82,*2*. **C. coronarius,* Rec., ×50 (42).

Circorrhegma HKL., 1887 [**C. dodecahedra*]. Dodecahedral shell with 20 radial spines.——FIG. 82,*7*. **C. dodecahedra,* Rec., ×40 (42).

Subfamily HAECKELIANINAE Campbell, nov.

[=Haeckelinida HKL., 1887]

Dimpled spherical shell without polygonal plates; unbranched radial spines. *Rec.*

Haeckeliana Hkl., 1887 [*non* Murray MSS, 1879] [*non Haeckeliania* Giarult, 1912, *nec Haeckelina* Bessels, 1875] [**H. porcellana;* SD herein]. Radial spines variable in number.——Fig. 82,*1. H. darwiniana* Hkl., Rec., ×100 (42).

Family TUSCADORIDAE Haeckel, 1887

[as Tuscarorida; emend. Campbell, herein]

Ovate or spindle-shaped smooth or spiny shell with solid porcelaneous texture; not

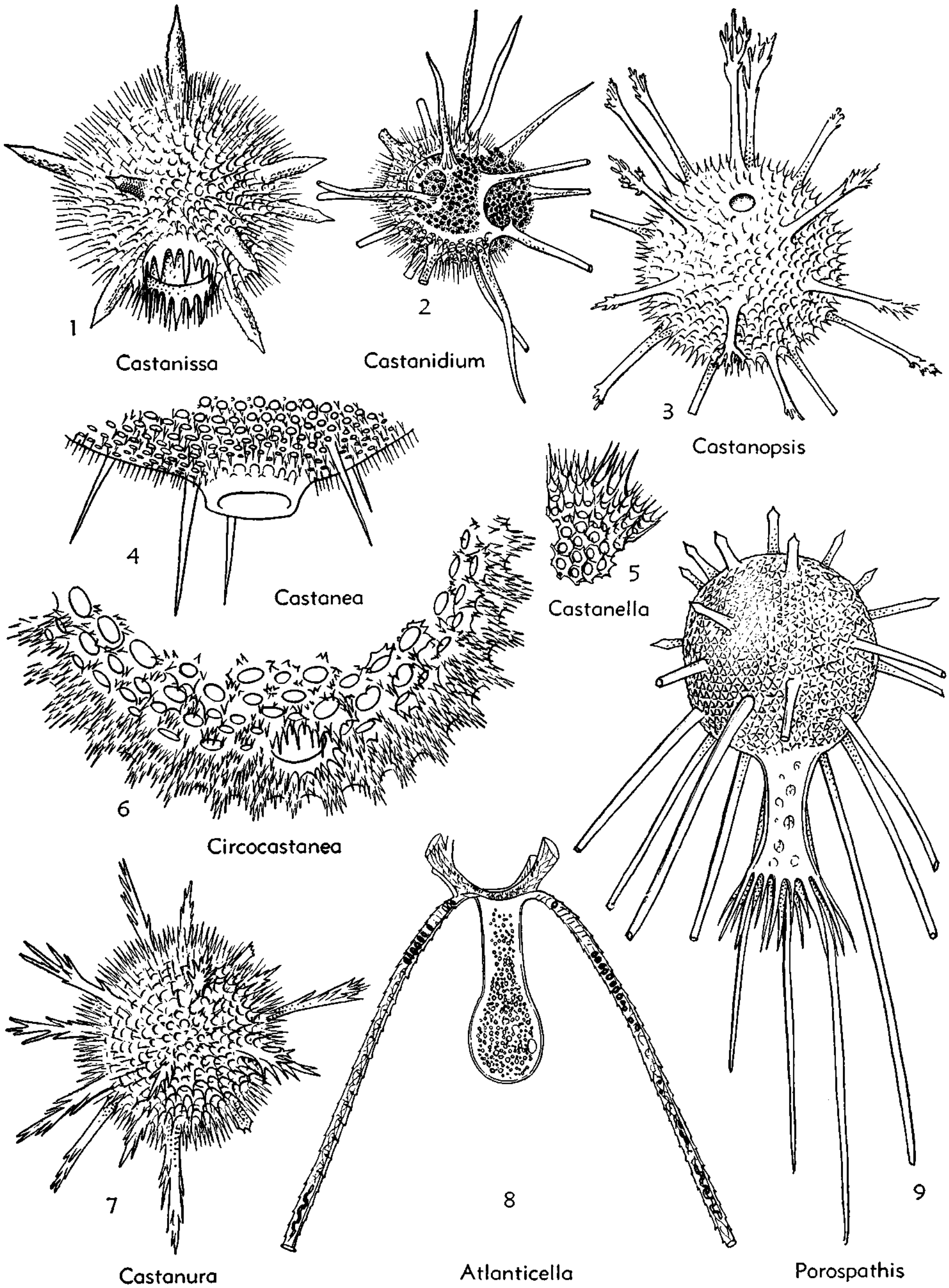


Fig. 81. Porospathididae, Atlanticellidae, Castanellidae (p. D154).

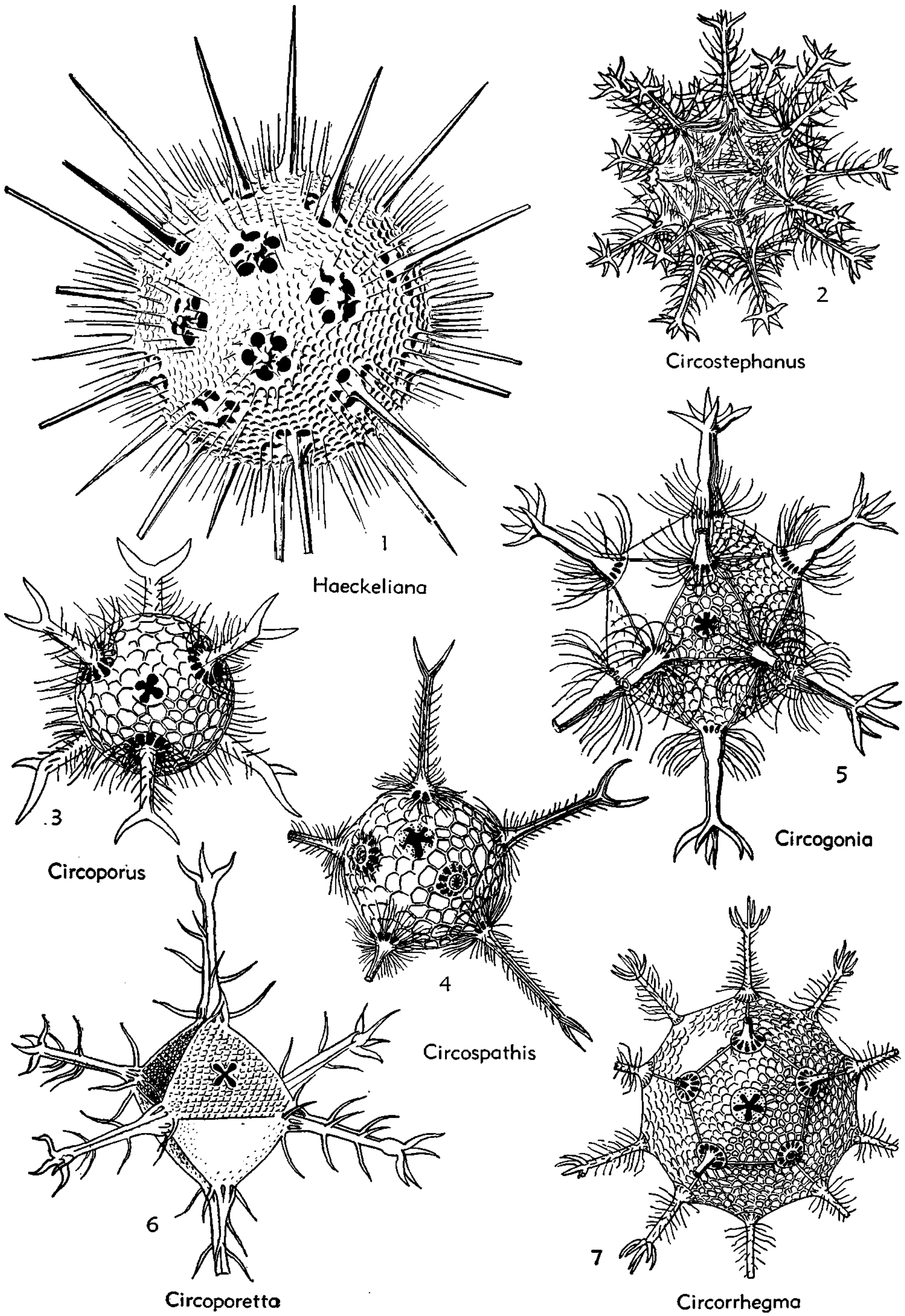


FIG. 82. Circoporidae (p. D154, D155).

paneled or tabulate; few pores around hollow radial legs. *Rec.*

Tuscadora Hkl., 1879 [**Tuscarora bisternaris* Murray, 1879] [=*Tuscarora* Hkl., 1882]. Three equidistant radial legs.

T. (Tuscadora) [=*Tuscarantha* Hkl., 1887 (obj.)]. Three oral teeth.——Fig. 83,*10*. *T.* (*T.*) *murrayi* (Hkl.), Rec., ×10 (42).

T. (Tuscaretta) Hkl., 1887 [**Tuscarora tubulosa* Murray, 1879; SD herein]. Two oral teeth.

T. (Tuscarilla) Hkl., 1887 [**Tuscarora bellknapii* Murray, 1879]. Four crossed teeth.

Tuscaridium Hkl., 1887 [**T. lithornithium;* SD herein]. Only one single leg.——Fig. 83,*11*. **T. lithornithium*, Rec., ×10 (42).

Tuscarusa Hkl., 1887 [**T. medusa*]. Four legs.——Fig. 83,*9*. **T. medusa*, Rec., ×10 (42).

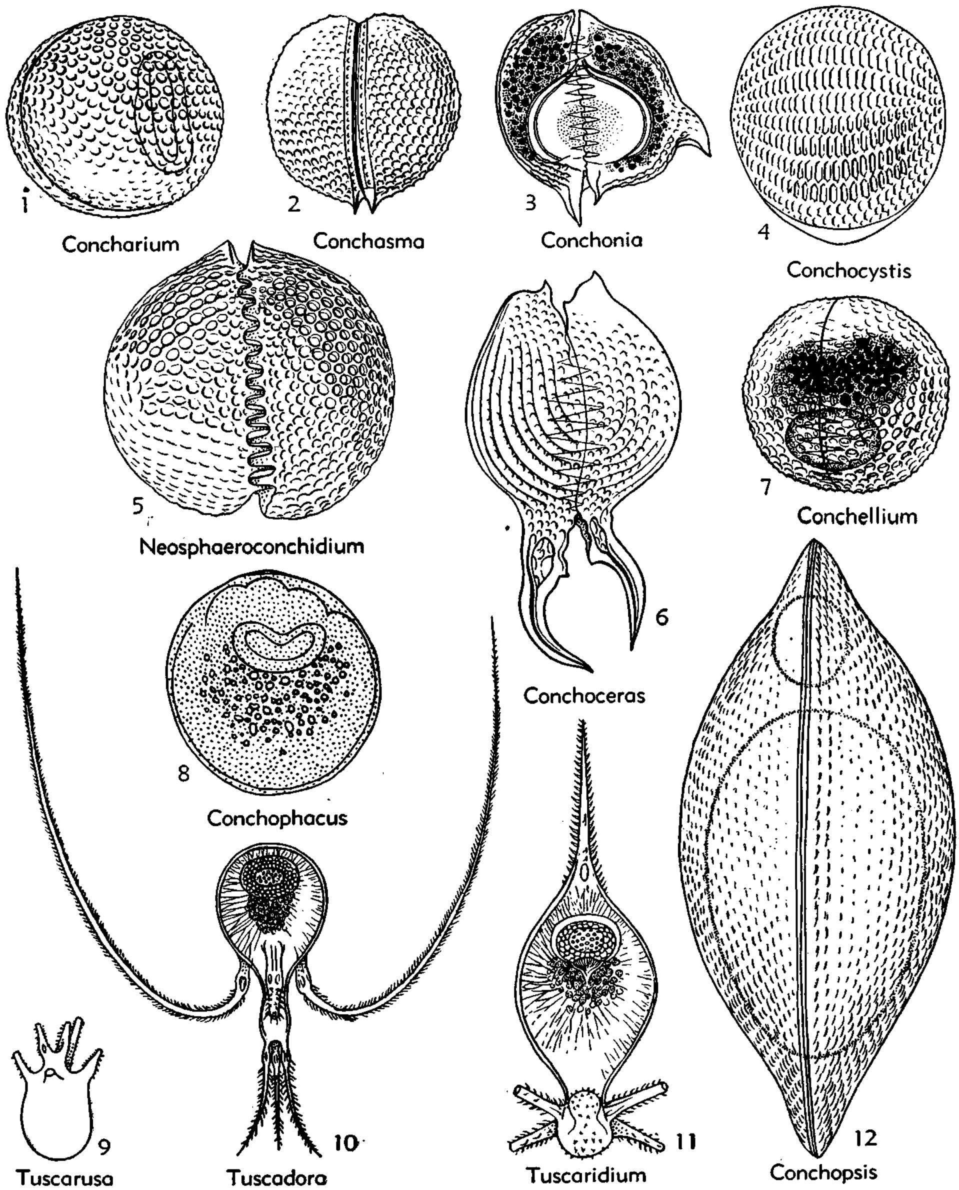


Fig. 83. Tuscadoridae, Conchariidae (p. D157, D158).

Superfamily CONCHARIICAE Haeckel, 1879

[*ex* Concharida; emend. CAMPBELL, herein] [=Phaeoconchia HKL., 1879 *(partim)*]

Two thick-walled valves perforated by rounded or slitlike pores. *Rec.*

Family CONCHARIIDAE Haeckel, 1879

[as Concharida; emend. CAMPBELL, herein]

Valves equal or unequal; boat-shaped. *Rec.*

Subfamily CONCHARIINAE Haeckel, 1879

[as Concharida *(partim)*; emend. CAMPBELL, herein] [=Conchasmida HKL., 1887]

Lateral edges of valves smooth. *Rec.*

Concharium HKL., 1879 [**C. bivalvum* HKL., 1887]. Aboral hinge lacks horn.——FIG. 83,*1*. **C. bivalvum*, Rec., ×75 (42).

Conchasma HKL., 1887 [**C. radiolites;* SD herein]. Aboral hinge with single horn.——FIG. 83,*2*. *C. sphaerulites* HKL., Rec., ×150 (42).

Subfamily NEOSPHAEROCONCHIDIINAE Campbell, nov.

[=emend. Conchidiinae HAECKER, 1908]

Lateral margin of valves dentate. *Rec.*

Neosphaeroconchidium CAMPBELL, 1952 [*pro Conchidium* HKL., 1879 (*non* LINNÉ, 1768, *nec* HISINGER, 1799)][**Conchidium terebratula* HKL., 1887]. Valves with 2 aboral horns on hinge; without apical horn.——FIG. 83,*5*. **N. terebratula* (HKL.), Rec., ×200 (42).

Conchellium HKL., 1887 [**C. tridacna;* SD herein]. Like *Neosphaeroconchidium* but lacks aboral horns. ——FIG. 83,*7*. **C. tridacna*, Rec., ×75 (42).

Conchocystis HAECKER, 1908 [**Conchellium lenticula* BORGERT, 1904]. Lens-shaped; diatom-like texture.——FIG. 83,*4*. **C. lenticula* (BORGERT), Rec., ×150 (43).

Conchonia HKL., 1887 [**C. diodon;* SD herein] [=*Conchura* HKL., 1887 (obj.)]. Apical horn on poles of sagittal axis; 2 caudal horns on hinge.——FIG. 83,*3*. **C. diodon*, Rec., ×100 (42).

Conchophacus HAECKER, 1908 [**Concharium diatomeum* HKL., 1887]. Like *Conchocystis* but pores are slitlike.——FIG. 83,*8*. **C. diatomeus* (HKL.), Rec., ×150 (43).

Subfamily CONCHOPSIDINAE Haeckel, 1887

[as Conchopsida; emend. CAMPBELL, herein] [=Conchidiinae HAECKER, 1908]

Shell compressed; with sharp sagittal keel. *Rec.*

Conchopsis HKL., 1879 [**C. orbicularis* HKL., 1887]. Aboral hinge without horns.——FIG. 83, *12*. *C. compressa* HKL., Rec., ×100 (42).

Conchoceras HKL., 1879 [**C. caudatum* HKL., 1887]. One horn on each valve.——FIG. 83,*6*. *C. cornutum* HKL., Rec., ×100 (42).

Superfamily COELODENDRICAE Haeckel, 1862

[*ex* Coelodendrida; emend. CAMPBELL, herein] [=Phaeoconchia HKL., 1879; Phaeodendria HAECKER, 1908]

Two thin-walled valves each with a conical process (galea) from which divergent branched tubes originate. *Rec.*

Family COELODENDRIDAE Haeckel, 1862

[as Coelodendrida; emend. CAMPBELL, herein]

Rhinocanna and frenula lacking. *Rec.*

Subfamily COELODENDRINAE Haeckel, 1862

[as Coelodendrida *(partim)*; emend. CAMPBELL, herein] [=Coelodorida HKL., 1887]

Without external mantle. *Rec.*

Coelodendrum HKL., 1860 [**C. ramosissimum* HERTWIG, 1879]. Forked or dichotomous nasal tubes.

C. (Coelodendrum) [=*Coelodendridium* HKL., 1887 (obj.)]. Terminal ramules of last branches equal.——FIG. 84,*1*. *C. furcatissimum* HKL., Rec., ×20 (42).

C. (Coelodendronium) HKL., 1887 [**C. cervicorne;* SD herein]. Terminal ramules of last branches unequal.

Coelodoras HKL., 1887 [**C. hexagraphis;* SD herein]. Nasal tubes unbranched.

Subfamily COELODRYMINAE Haeckel, 1887

[as Coelodrymida; emend. CAMPBELL, herein]

External bivalved mantle produced by anastomoses of branched hollow tubes. *Rec.*

Coelodrymus HKL., 1879 [**C. ancoratus* HKL., 1887]. Lattice mantle not spongy.——FIG. 84,*2*. **C. ancoratus*, Rec., ×20 (42).

Coelodasea HKL., 1887 [**C. spongiosa;* SD herein]. Mantle spongy.

Family COELOGRAPHIDIDAE Haeckel, 1887

[as Coelographida; emend. CAMPBELL, herein] [=Coelodendridae HAECKER, 1908]

Rhinocanna and single or double frenulum present. *Rec.*

Subfamily COELOGRAPHIDINAE Haeckel, 1887

[as Coelographida *(partim)*; emend. CAMPBELL, herein] [=Coeloplegmida HKL., 1887; Coeloplegminae, HAECKER, 1908]

Rhinocanna of each valve with odd sagittal frenulum; with external mantle. *Rec.*

Coelographis HKL., 1887 [**C. regina;* SD herein]. Styles 6.——FIG. 84,*3*. **C. regina*, Rec., ×10 (42).

Coelathemum HAECKER, 1907 [**C. auloceroides*]. Styles 28.——FIG. 84,5. **C. auloceroides*, Rec., ×40 (43).

Coelodecas HKL., 1887 [**C. sagittaria;* SD herein]. Styles 10.——FIG. 85,4. **C. sagittaria*, Rec., ×10 (42).

Coelogalma HKL., 1887 [**C. mirabile*]. Styles 16. ——FIG. 85,6. **C. mirabile*, Rec., ×10 (42).

Coeloplegma HKL., 1887 [**C. murrayanum;* SD herein]. Styles 14.——FIG. 85,1. **C. murrayanum*, Rec., ×20 (42).

Coelospathis HKL., 1887 [**C. ancorata; SD* herein]. Styles 8.——FIG. 84,4. **C. ancorata*, Rec., ×20 (42).

Coelostylus HKL., 1887 [**C. bisenarius;* SD herein]. Styles 12.——FIG. 85,3. **C. bisenarius*, Rec., ×10 (42).

Subfamily COELOTHYRINAE Haecker, 1908

Without nasal styles. *Rec.*

Coelothyrus HAECKER, 1907 [**C. cypripedium*]. Without lattice mantle.——FIG. 85,5. **C. cypripedium*, Rec., ×15 (43).

Coelopodium POP., 1926 [**C. borgerti*]. Mantle present.——FIG. 85,2. **C. borgerti*, anchor branches and side branches, ×80 (48).

Subfamily COELOTETRACERADINAE Campbell, nov.

Galea exaggerated. *Rec.*

Coelotetraceras HAECKER, 1907 [**C. xanthacanthium*]. Galea with high wide nasal opening.——FIG. 86,4. **C. xanthacanthium*, nasal side and 2 main spines, ×20 (43).

Coelechinus HAECKER, 1904 [**C. wapiticornis*]. Tubes and dendrites similar.——FIG. 86,5. **C. wapiticornis*, Rec., ×50 (43).

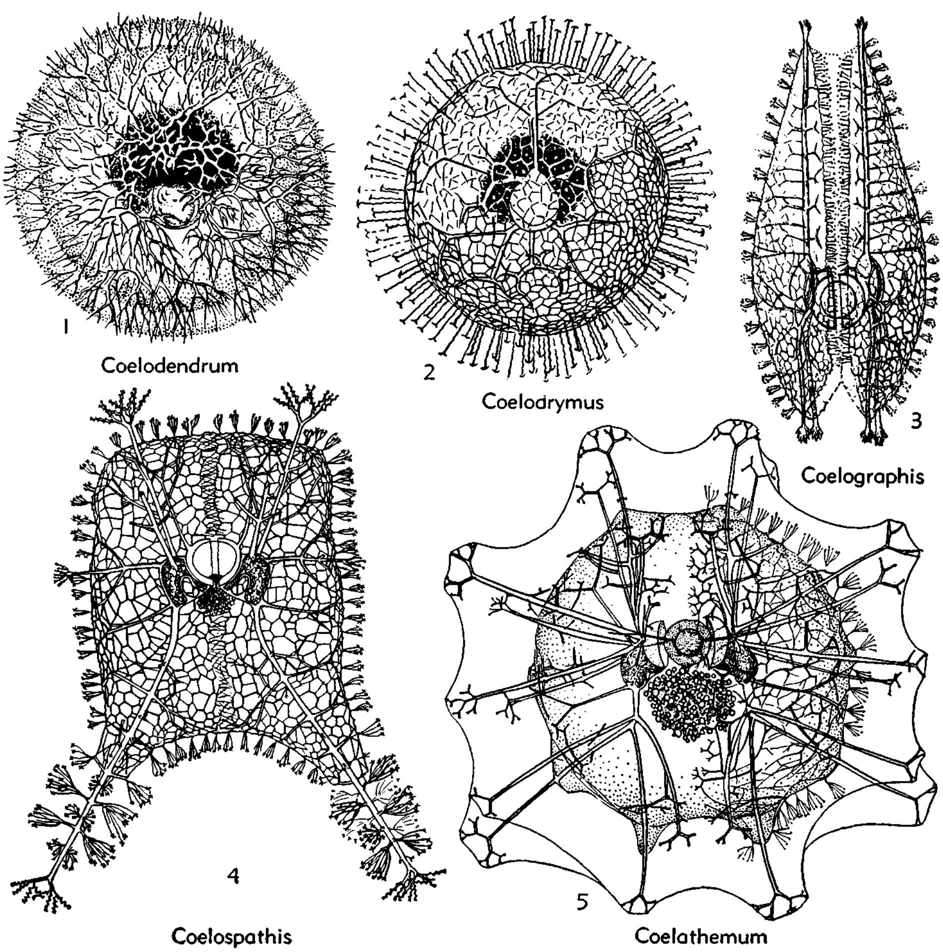


FIG. 84. Coelodendridae, Coelographididae (p. D158, D159).

Coelodiceras HAECKER, 1907 [**C. macropylum*]. Nasal tubes developed like styles.——FIG. 86,*6*. *C. spinosum* HAECKER, Rec., ×50 (43).

Subfamily COELOTHOLINAE Haeckel, 1887

[as Coelotholida; emend. CAMPBELL, herein]

Two paired lateral frenula on each galea; without lattice mantle. *Rec.*

Coelotholus HKL., 1887 [**C. octonus;* SD herein]. Paired styles 8.——FIG. 86,*2*. **C. octonus,* Rec., ×10 (42).

Coelothauma HKL., 1879 [**C. duodenum* HKL., 1887]. Paired styles 12.——FIG. 86,*1*. **C. duodenum,* Rec., ×10 (42).

Coelothamnus HKL., 1879 [**C. davidoffi* BÜTSCHLI, 1882]. Paired styles 16.——FIG. 86,*3*. *C. bivalvis,* Rec., ×10 (42).

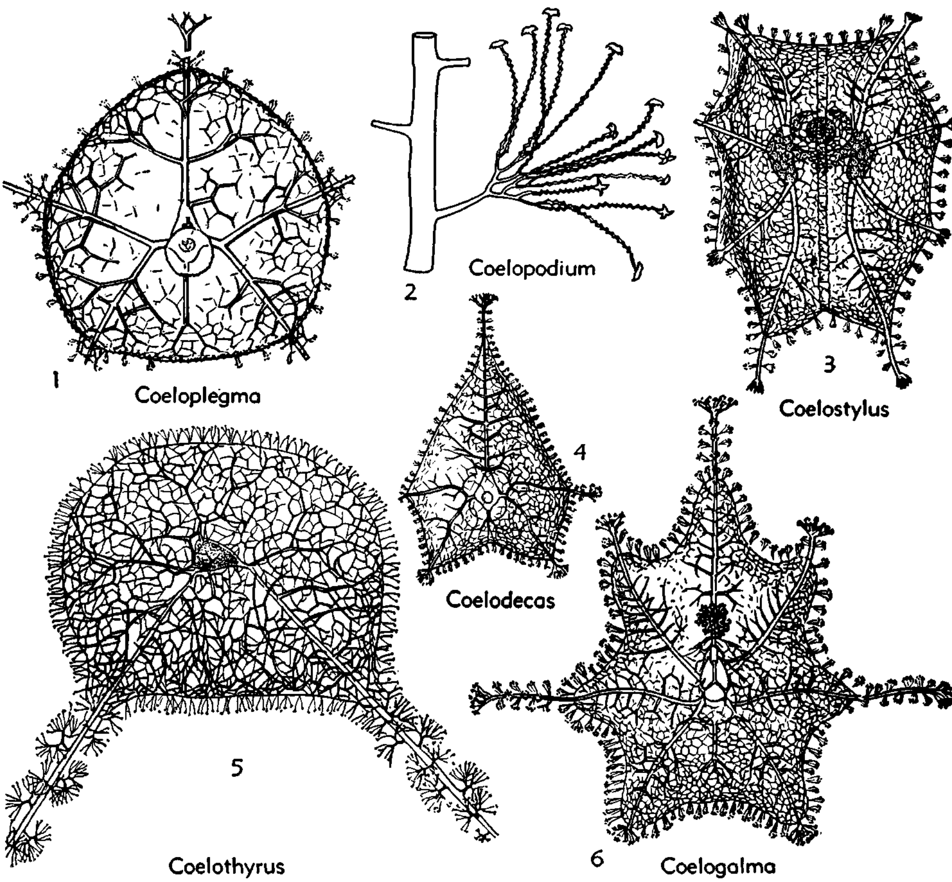


FIG. 85. Coelographididae (p. D159).

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The following references have been chosen with special regard to inclusion of larger monographs and shorter papers of special importance which have appeared since HAECKEL's "Challenger" contribution in 1887; this monograph contains a bibliography to the year 1884. Nearly all titles herein incorporated contain more or less extensive, pertinent bibliographical sections. The selected references are drawn from a list of approximately 500 titles.

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(1) 1940, *Radiolarian fauna of the Caballos formation, Marathon Basin, Texas;* Jour. Paleont., vol. 14, p. 127-139, pl. 20-21, fig. 1-2.

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(2) 1905-13, *Die Tripyleen Radiolarien der Plankton-Expedition:* Ergebnisse der Plankton-Expedition der Humboldt-Stiftung, (Kiel und

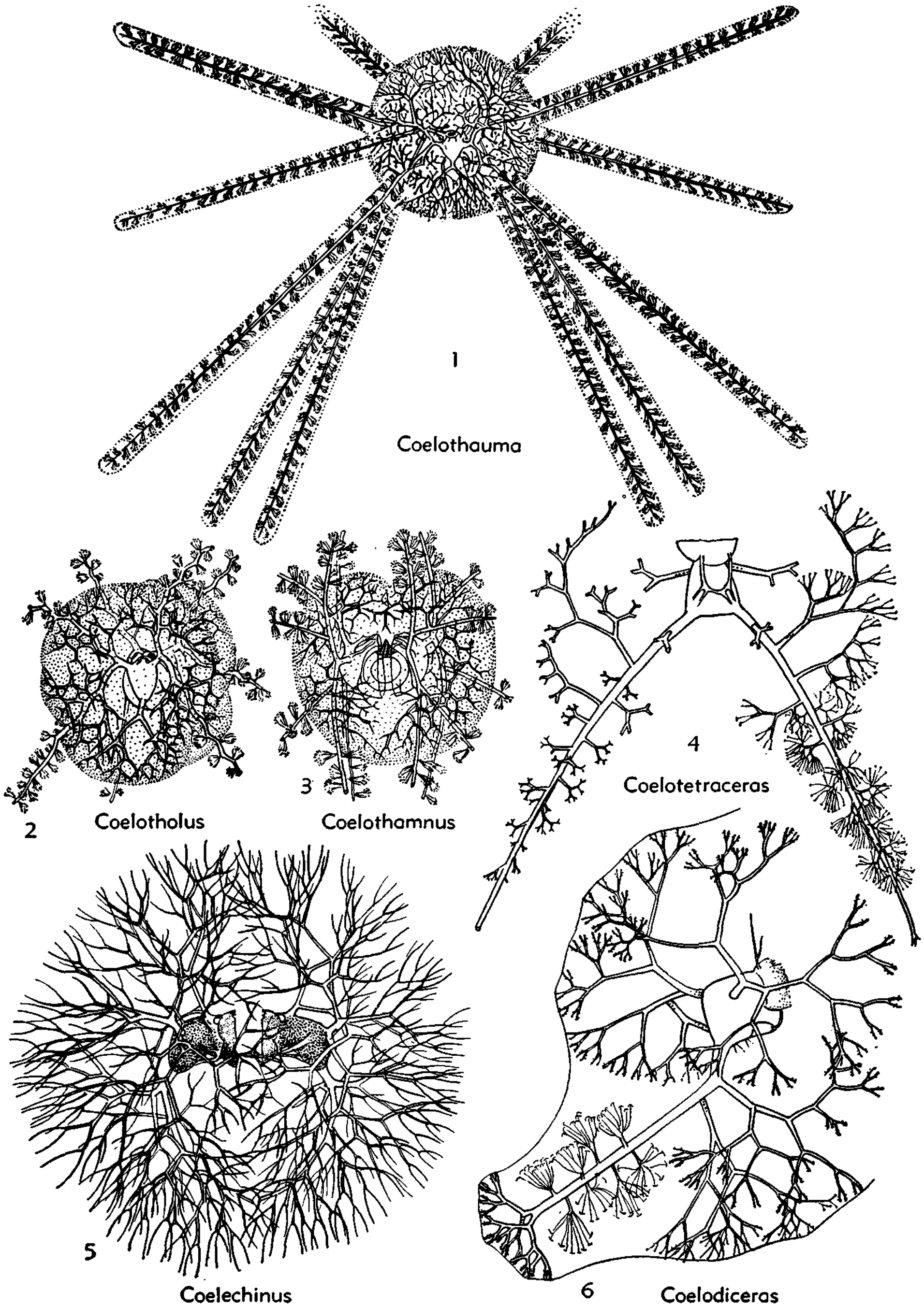

FIG. 86. Coelographididae (p. D159, D160).

Leipzig), Bd. 3 (1905) *Tuscaroiden*, Heft 2, p. 95-112, pl. 1, text fig. 1-2; (1905) *Atlanticellidae*, Heft 3, p. 117-128, pl. 1; (1906) *Medusettidae*, Heft 4, p. 133-190, pl. 1-4; (1907) *Conchariden*, Heft 5, p. 195-230, pl. 1-3; (1909) *Phaeodinidae, Caementellidae, und Cannorraphidae*, Heft 7, p. 285-315, pl. 1-2; (1909) *Cannosphaeridae*, Heft 8, p. 355-413, pl. 1-2; (1909) *Circosphaeridae*, Heft 9, p. 319-350, pl. 1; (1910) *Porospathidae und Cadiidae*, Heft 10, p. 384-414, pl. 1-2; (1911) *Challengeridae*, Heft 11, p. 419-536, pl. 1-5, text fig. 1-22; (1913) *Atlanticellidae*, Heft 12, p. 540-610, pl. 1-8, text fig. 1-22.

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SPOROZOA AND CILIOPHORA

By Raymond C. Moore

INTRODUCTION

Although the subphyla of protozoans termed Sporozoa and Ciliophora now are known to be represented among fossils only by some species classified as belonging to the suborder Tintinnina, an assemblage of ciliophorans, it is desirable to include in the *Treatise* a statement of the divisions missing from the paleontological record to show placement of the tintinnines sufficiently. The general relationships and distinctive peculiarities of the group having interest to paleontologists are then more readily apprehended.

SPOROZOANS

The sporozoans are exclusively parasitic, soft-bodied members of the phylum Protozoa which may have great paleontological importance of an indirect, unappraisable sort. This is because they are such widely distributed carriers of many infective diseases, although numerous kinds of sporozoan parasites do little harm to their hosts. They thrive in the bodies of nearly all invertebrate phyla as well as those of all main groups of vertebrates, and what is true of the present must be equally so of geological past time. It is certain that susceptibility and resistance of host animals to the parasitism of Sporozoa has influenced evolution of both hosts and parasites, and doubtless it has contributed to the extinction of many species both among hosts and parasites. Proof, however, is lacking, for even malformation of hard parts and lesions affecting them, well known in paleontology, are not acceptable as evidence.

The Sporozoa have a complicated life cycle which in many species includes an alternation of asexual and sexual reproduction and commonly depends on more than a single kind of host. Part of the life cycle consists of existence as a spore, which is a cell or group of cells surrounded by a membrane that adapts it to withstand adverse conditions. Classification is based mainly on the characters of these spores.

CILIOPHORANS

The subphylum Ciliophora contains very numerous kinds of protozoans which have in common the character of possessing cilia. Each cilium is a short hairlike appendage consisting of a sheath that surrounds a fibrillar axoneme. It is readily bent in different directions and the combined rhythmic motions of adjacent groups of cilia provide a mechanism (organelle) for locomotion. Some ciliophorans are equipped with several thousand cilia arranged in spiral or longitudinal rows; others have relatively few cilia which are localized in position, as around the cell mouth. The group called Suctoria bear cilia only in early stages of their development.

Nearly all ciliophorans (subclass Protociliata of the class Ciliata excepted) have two types of nuclei; so-called macronuclei of relatively large size, and one or several very small micronuclei. Both of these types normally divide during fission of the cell in reproduction.

Representative types of each main group of ciliophorans are illustrated in Fig. 87.

SYSTEMATIC DESCRIPTIONS

Subphylum SPOROZOA Leuckart, 1879

Parasitic, spore-bearing protozoans which (except as gametes) have neither flagella nor cilia; life cycle complex; skeletal parts lacking. *Rec.*

Subphylum CILIOPHORA Doflein, 1901

Protozoans equipped with cilia as organelles of locomotion, present throughout life or at least in young stages of growth; some provided with a moderately resistant test (lorica) consisting of a complex organic compound. *U.Jur.-Rec.*

Class CILIATA Perty, 1852

Cilia present throughout life, generally abundant. *U.Jur.-Rec.*

Subclass PROTOCILIATA Metcalf, 1918

Body covered uniformly by cilia of equal length; cytostome lacking; nuclei 2 to many, of similar type; mostly parasites of amphibians. *Rec.*

FIG. 87,*1*. *Opalina ranarum* EHR., ×250.

Subclass EUCILIATA Metcalf, 1918

Cilia uniformly distributed or developed in special fields and in many fused together in rows (cirri, membranelles); with macronuclei and micronuclei; sexual reproduction by conjugation. *U. Jur.-Rec.*

Order HOLOTRICHIDA Stein, 1859

[as Holotricha; emend. JAHN & JAHN, 1949]

Cilia uniformly distributed over entire body surface, generally with cytostome; adoral membranelles lacking. *Rec.*

FIG. 87,*2*. *Platophrya spumacola* KAHL, ×450.

Order PERITRICHIDA Stein, 1859

[as Peritricha; emend. JAHN & JAHN, 1949]

Adoral zone of fused cilia (membranelles) winding counter-clockwise through the cytostome into the pharynx; generally attached. *Rec.*

FIG. 87,*3*. *Carchesium polypinum* (DOFLEIN), ×400.

Order CHONOTRICHIDA Wallengren, 1896

[as Chonotricha; emend. JAHN & JAHN, 1949]

Cilia confined to peristomial region which is produced like a funnel. *Rec.*

FIG. 87,*9*. *Heliochona sessilis* PLATE, ×450.

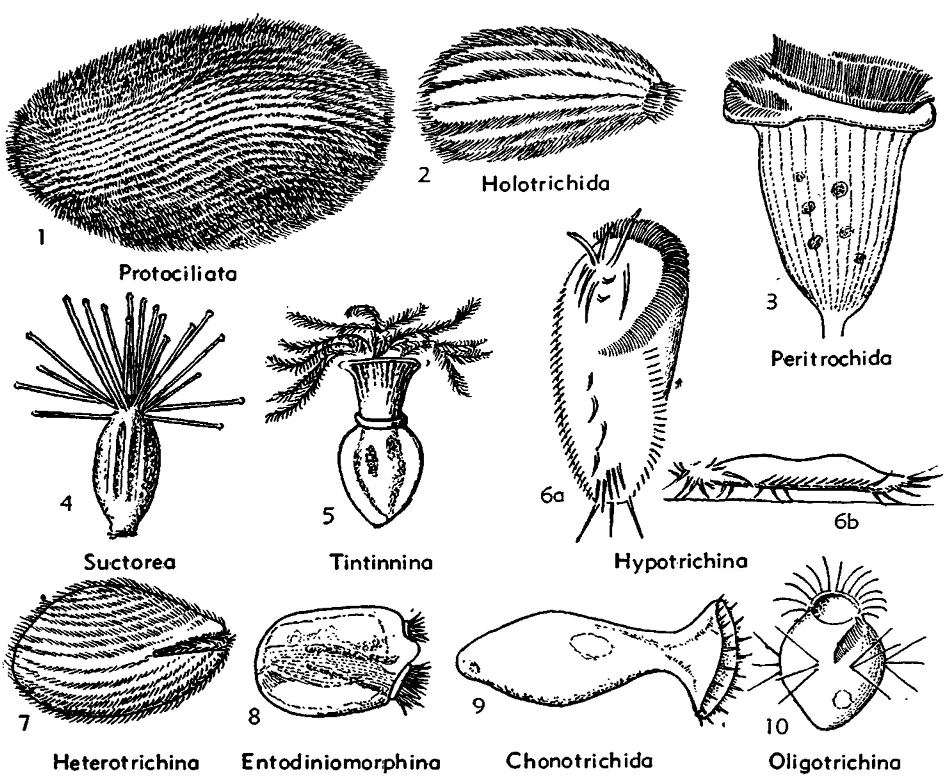

FIG. 87. Representative types of ciliophorans (p. D165, D166). For Fig. 87,*3* read "Peritrichida."

Order SPIROTRICHIDA Bütschli, 1889

[as Spirotricha; emend. JAHN & JAHN, 1949]

Adoral membranelles and cirri winding spirally clockwise to cytostome; peristome not extended beyond general body surface. *U. Jur.-Rec.*

Suborder HETEROTRICHINA Stein, 1859

[as Heterotricha; emend. JAHN & JAHN, 1949]

Short cilia distributed over most of body but restricted in some. *Rec.*

FIG. 87,*7*. *Balantidium coli* (WENYON), ×500.

Suborder OLIGOTRICHINA Bütschli, 1887

[as Oligotricha; emend. JAHN & JAHN, 1949]

Cilia lacking in adoral region adjacent to membranelles and weakly developed on other parts of body. *Rec.*

FIG. 87,*10*. *Halteria grandinella* (KAHL), ×500.

Suborder TINTINNINA Claparède & Lachmann, 1858

Conical or trumpet-shaped body with lorica; adoral membranelles spirally arranged on the flattened oral end (detailed descriptions by A. S. CAMPBELL in following section). *U. Jur.-Rec.*

FIG. 87,*5*. *Stenosemella* sp., ×240.

Suborder ENTODINIOMORPHINA Reichenow, 1929

Cilia restricted to adoral zone or with additional groups of membranelles. *Rec.*

FIG. 87,*8*. *Metadinium medium* AWERINZEW & MUTAFOWA, ×125.

Suborder HYPOTRICHINA Stein, 1859

Cilia confined to ventral side, generally fused as cirri. *Rec.*

FIG. 87,*6a,b*. *Stylonychia mytilus* (STEIN), ventral and side views, ×200.

Suborder CTENOSTOMINA Lauterborn, 1932

[as Ctenostomata; emend. JAHN & JAHN, 1949]

Laterally compressed, wedge-shaped, with sparse cilia. *Rec.*

Class SUCTORIA Claparède & Lachmann, 1858

Cilia present only in youthful growth stage; bearing tentacles but lacking cytostome; mostly sessile. *Rec.*

FIG. 87,*4*. *Anarma multiruga* (GOODRICH & JAHN), ×150.

TINTINNINA

By ARTHUR SHACKLETON CAMPBELL

INTRODUCTION

Tintinnina are one of the major subdivisions of ciliate protozoans, comprising about 40 per cent (some 800 species) of all known marine and fresh-water infusorians. Freedom of movement, coupled with availability of food supply, has led to very wide geographic distribution of these creatures, for no large water body lacks representatives of the suborder. They abound especially in the light-penetrated upper levels of warm seas. The study of modern tintinnines has value to paleontology because fossils belonging to the group have been found in Jurassic and younger rocks in various parts of the world, and knowledge of living forms aids in understanding morphological features and classificatory relationships of the fossils. Likewise, investigation of the ecology of Recent Tintinnina should contribute to correct interpretation of the mode of origin of tintinnine-bearing strata in the rock column.

This contribution in the *Treatise* is founded mainly on work undertaken by the late Prof. C. A. KOFOID and me during the years 1924 to 1942; this led to publication of 9 papers, including some monographs, on Recent Tintinnina. The present article brings together for the first time all known taxonomic units of generic and higher rank representing both fossil and living forms. Illustrations of 60 leading genera are given, including all known as fossils. The systematic text is believed to be complete to January, 1953.

MORPHOLOGY

SOFT PARTS

The Tintinnina are characterized by a conical or trumpet-shaped extensile body which is attached by its inverted apex to the base of an enclosing delicate test, termed the **lorica.** Except at the point of fixation, the soft body is separated from the lorica by an open space, and in this respect the tintinnines differ obviously from other protozoans provided with hard parts, such as the Foraminifera and Radiolaria.

A somewhat broad end of the body that projects outward from the mouth of the lorica bears a crown of 12 to 24 complex motile organs called **membranelles** (Fig. 88). These have a bladelike form and terminate distally in a row of lamellae, each of which consists of a thin hyaline sheet joined to a dense rodlet. A membranous covering (pellicular envelope) of the lamella encloses protoplasmic substance which surrounds 6 fibrils in the outer blunt denser part and a single fibril in hyaline material on the convex side of the lamella, which has a sickle-shaped cross section. Basal granules connect with the fibrils which lead to a granular spindle-shaped structure, termed **neuromotorium,** located well below the circle of membranelles. The neuromotorium is the dynamic center of the animal, serving as center of co-ordination in locomotion and other body activities, as well as directing agent in development of the lorica after binary fission. Of the fibrils extending from the neuromotorium, the most important (adoral fiber) leads to the membranelles. The whole arrangement of membranelles and rows of cilia on the outer side of the body has a left-twisted spiral form (Fig. 88). Several morphological features which are pertinent in detailed study of the soft parts are not described here, although some are indicated in Fig. 88. A line of unusually large strong cilia (ciliary membrane) extends part way down the side of the body defined as ventral, but this is known only in some genera.

The substance within the body commonly is green, especially in near-surface marine species; the coloring matter probably consists of chlorophyll derived from food or from zoochlorellae comparable to those existing in some species of *Paramecium.* Coccoliths, diatoms, and other food bodies commonly are seen in the interior of tintinnines.

HARD PARTS

The skeleton of Tintinnina consists of the lorica. It is composed of moderately hard, resistant complex organic substance which may be combined with foreign particles. Generally cuplike in form, it has a single large circular opening (oral aperture), that in some species is accompanied by an inflected rim (**collar**, Fig. 88). Morphological features of the lorica which have chief diagnostic value include: (1) wall structure, fine parts of which may be laminar, prismatic, alveolar, or hyaline; (2) inclusions, consisting commonly of coccoliths, diatoms, and bits of organic or inorganic detritus; (3) shape, including position and breadth of the widest part; (4) differentiation of circumoral from other parts, including nature of mouth margin, collar, teeth, bands, rings, ledges, interpolated collars, and other structures; (5) aboral structures such as apophyses, pedicel, knob, lance, skirt, and nature of the aboral opening, if present; and (6) surface markings such as ribs, ridges, plications, flutings, shelves, reticulations, fenestrae, and lacunae, as well as the number, spacing, direction, distribution and special patterns of these elements. Many of these characters are fairly constant in different species, but actual dimensions seem to be correlated with conditions of environment rather than taxonomic distinctions. Known species range from about 45 to 1,000 μ in length.

Morphological terms used in description of the tintinnines are listed alphabetically with definitions, as follows.

GLOSSARY OF MORPHOLOGICAL TERMS APPLIED TO TINTINNINA

accessory comb. Line of large cilia within preoral cavity.
adoral fiber. Large fibril leading from neuromotorium to edge of peristome.
anal pore. Small vent in part of aboral wall for ejection of faecal matter.
basal granule. Dotlike body forming part of neuromotor system.
body cilia. Small hairlike projections of the body surface.
ciliary lines. Rows of cilia on body surface joined with each other and neuromotorium.
ciliary membrane. Line of strong adherent cilia at side of body near peristome.
cytoplasm. Non-nuclear protoplasm in cell body.
ectoplasm. External layer of cytoplasm.
endoplasm. Internal matrix of cytoplasm.
fenestra. Open or closed window in wall of lorica.
fibril. Thread of tissue in cytoplasm comprising part of neuromotor system.
infundibulum. Apertural part of animal.
lacuna. Space on lorica lacking reticulation or other surface marking.
lamella. Continuous thin layer in membranelle.
lamina. Uniform thin sheet of wall substance in lorica.
lorica. Skeleton of Tintinnina.
macronucleus. Large vegetative nucleus in body.
marginal granule. Dotlike body in lamella.
membranelle. Bladelike organelle of locomotion fringed with lamellae.
micronucleus. Small reproductive nucleus in body.
neuromotorium. Ganglion-like granular body forming dynamic center of ciliates.
oral membrane. Sheet of cilia in gullet.
pedicel. Attachment of soft parts to lorica.
pellicular envelope. Delicate outer covering of soft parts.
peristome. Frontal depression above mouth.
piston organelle. Moundlike structure rising from floor of peristome.
preoral cavity. Depression above gullet.
primary structure. Fine alveoles in wall of lorica.
schizont. Daughter cell, produced by binary fission.
secondary structure. Coarse wall structure, commonly between distinct laminae.
sphaeroplast. Lorica-forming granule, part of shieldlike mass formed during binary fission.
spiral lamina. Coiled or winding part of lorica.
tertiary structure. Very coarsely irregular shell material.
triangular organelle. Small sensory structure near peristome.
zoochlorella. Green symbiont within cytoplasm.

BIOLOGY

REPRODUCTION

Tintinnines reproduce by conjugation and by binary fission, but details of the former process are undetermined. During binary fission sphaeroplasts accumulate in the deeper part of the cell below the gullet, forming a shieldlike mass around the laterally differentiating budlike schizont. After this daughter cell has reached nearly full growth, the granules are discharged and make up the daughter lorica, which test becomes inhabited by the posterior cell derived from the lateral bud while the original shell is retained by the anterior schizont.

MODE OF LIFE

The function and utility of the lorica are associated clearly with the pelagic mode of life of the tintinnines rather than with protection of soft parts. So delicate a structure hardly could safeguard the animal from active hunters provided with effective mouth structures. Generalized feeders like salpas capture large numbers of small-to-medium-sized Tintinnina. Dimensions of the lorica serve as protection only against appendicularians and similar animals which sift out smaller organisms of the finest plankton (nannoplankton).

The evolutionary development of this essentially pelagic group suggests that the lorica may have utility as an organ of flotation, even though its slight excess weight calls for added expenditure of energy by the tintinnine. The surface area of the lorica is considerably greater than that of the soft parts and this adds appreciably to resistance in locomotion, but even so, the lorica may aid in directed locomotion. Tintinnines usually move, like squids, with the oral end directed backwards.

It is essential that Tintinnina keep within the illuminated zone where concentration of food organisms is greatest. The elongate lorica and spiral structures of the tintinnines seem to be adaptations which aid these pelagic ciliates to move about at suitable levels in the sea. The lorica tends to retard sinking and thus impedes descent below the level of optimum food supply.

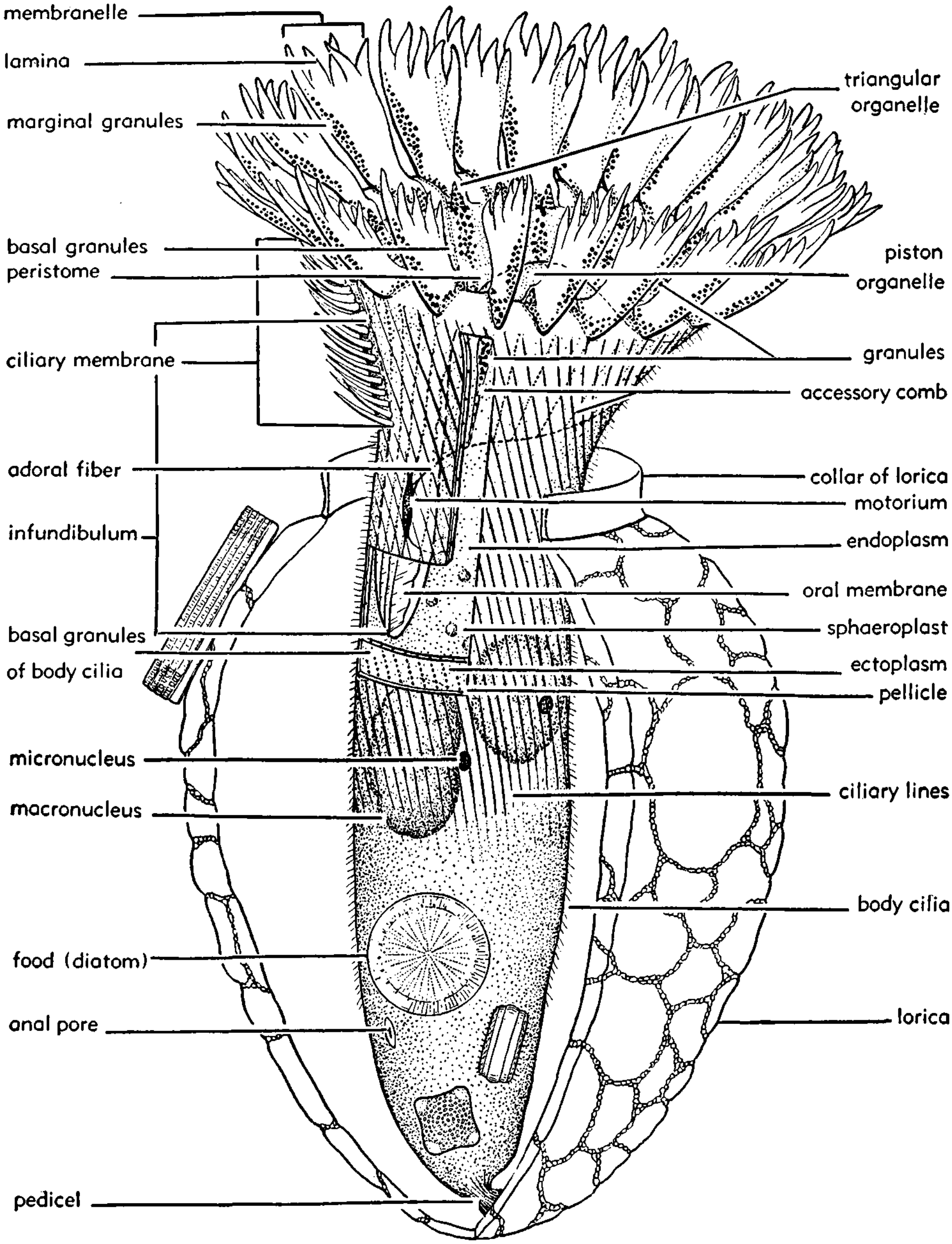

FIG. 88. Morphological features of a typical modern tintinnine, *Stenosemella nivalis* (MEUNIER), from shallow waters of the Pacific near La Jolla, Calif. Part of the lorica is cut away in order to show soft parts of the organism inside; terminology is illustrated (original preparation, ×1,000).

ECOLOGY

RECENT FORMS

Tintinnina are primarily marine protozoans, since less than 2 per cent of known species occur in fresh waters. They are almost exclusively free-swimming pelagic animals which occur at all latitudes, in all seas, and predominantly above the light floor. They feed on bacteria, algae, minute flagellates (especially Coccolithophorida), dinoflagellates, and small ciliates of the nannoplankton. Selective feeding is indicated by skeletons of food organisms in the body.

Most species have cosmopolitan distribution, and oceanic regions having like temperature and currents have faunas containing similar tintinnines (1, 3). The fauna of the northern Pacific resembles that of the northern Atlantic and the assemblage in Pacific equatorial regions is like that in Atlantic equatorial regions. Tintinnines from Arctic and Antarctic waters, however, are different; for example, *Parafavella* and *Ptychocylis* belong to the Arctic region, whereas *Cymatocylis, Protocymatocylis,* and *Laackmanniella* are confined to the Antarctic area. Better-known genera occur in all seas. A few genera, including *Tintinnopsis, Stenosemella,* and *Favella,* are mostly restricted to near-shore areas. The seeming exceptions in cosmopolitan distribution of species probably express incompleteness of exploration.

The fact that species belonging to a given genus of Tintinnina generally are more abundant in tropical waters than polar seas suggests that evolutionary differentiation is accelerated by higher temperatures. The ratio of cold-water to warm-water species corresponds closely to that of velocity in chemical reactions under varying temperature conditions as expressed by the law of VAN T'HOFF.

Areas of abundant tintinnines generally are large. Almost no highly localized swarms of these protozoans have been recorded, even though a few species are mainly restricted to certain ocean currents, as *Epicranella* spp. in the Humboldt current and *Petalotricha foli* in the Mexican current and Pacific currents moving toward Hawaii. Most species are widely distributed but occur in small numbers. The suggestion that planktonic organisms carried by currents into new regions may serve as guides to the source of such currents is not confirmed by evidence derived from tintinnines, for they do not seem to be carried far from their areas of abundance. Wide distribution of some species associated with relatively small number of individuals is interpreted to signify an indigenous population, rather than one spread by currents. The distances to which the loricas of tintinnines may be carried without dissolution doubtless vary according to the nature of the test, for some last longer than others.

FOSSIL FORMS

A unique biostratigraphic sequence of fossil Tintinnina is found in Majorca, in the Mediterranean area. In this intensively studied sequence (2), Tintinnina appear first in deep-water sediments of the Upper Jurassic (lower Tithonian) of this part of the Tethys basin. They are found in fine-grained limestones which alternate with pseudobreccias, although a few occur within the latter. The pseudobreccias are also fine-grained deposits composed of organic detritus containing Radiolaria. The matrix consists of powder-fine calcite formed, at least in part, of huge quantities of coccoliths. As these sediments were deposited, they were profoundly disturbed by currents which produced the brecciated structure. Higher in the Tithonian, somewhat different fine-grained limestones of high purity are found. Some of these contain pelagic Foraminifera, such as *Globigerina,* but others are composed largely of *Nannoconus* (a fossil of uncertain relationships believed to be a unicellular chlorophyll-bearing alga) and other microfossils which distinguish the upper Tithonian, Neocomian, and Barremian strata, continuing to the base of the Aptian-Albian. The Lower Cretaceous rocks of this succession consist of fine sublithographic limestone with some intercalated marl beds. The limestones are of pelagic origin, quite free of terrigenous influences. The fossils found within them are planktonic Radiolaria, Tintinnina, and *Nannoconus*. The Lower Cretaceous rock dissolves readily in acid, leaving little residue. Some silica of organic derivation occurs, and calcium phosphate grains, granules of glauconite, rare biotite flakes, and quartz grains or rutile crystals are found. Noteworthy is the fact that in these sediments the presence of Radiolaria seems generally to be correlated with absence of Tintinnina, and the same is true in Recent faunas. Overlying strata (Valanginian, Hauterivian, Barremian) exhibit abyssal characters. They carry a rich *Phylloceras*-fauna containing practically no remains of coastal organisms. The physical conditions must have resembled those in parts of Recent seas where Tintinnina are especially abundant. Fossil Tintinnina of this Mediterranean sequence belong to 10 genera distributed in 5 families, all having equivalents in modern warm seas.

Tintinnina and *Nannoconus* vanished suddenly in the Mediterranean at the end of Barremian time. This disappearance corresponds with a change in sedimentation reflecting the different conditions of the Aptian; in general, they indicate shoaling of the sea in which argillaceous and other detrital matter was laid down instead of the fine-grained limestone of earlier times.

It is well known that surface water of warm seas is heavily charged with $CaCO_3$ and that cooler subsurface water is undersaturated with this salt. Also, if deeper water rises, the surface becomes richer in lime content. An important consequence may be precipitation of calcareous mud. It is possible under conditions indicated that Tintinnina, abundant in the surface waters, may be deposited in the soft ooze and preserved. The delicate loricae of these protozoans may be replaced rapidly by calcite in the favorable environment. It is not likely that *Nannoconus* contributed so extensively to the matrix as did the inorganic precipitate.

GEOLOGICAL DISTRIBUTION

Fossil Tintinnina have a restricted geological distribution. The oldest known forms occur in limestones of Late Jurassic age in the Alps. Others are found in Spain, Italy, the Balearic Islands, North Africa (Algeria, Morocco), Corsica, the Carpathians of Rumania, the Crimea, and in the Caucasus and Himalayas, as well as other parts of the Tethys sea. All these occurrences are in limestones ranging from Kimmeridgian (Upper Jurassic) to Barremian (Lower Cretaceous). Tintinnina in these deposits are common and varied, *Calpionella* being mentioned most frequently. A doubtful upper Eocene occurrence is in Barbados and another is in the Calera limestone member of the Franciscan formation (Upper Jurassic) of central California. Recent reports indicate presence of fossil tintinnines in Mexico.

The occurrence of these protozoans in otherwise practically barren rocks, and the sharp time restrictions in their distribution give them some value for stratigraphic problems.

METHODS OF STUDY

Recent Tintinnina collected from suitable marine or fresh waters by means of fine silk nets are usually examined preserved in formalin-water mixture without further preparation.

Fossil Tintinnina must be studied by means of thin sections in which the tests are oriented at random. It is not possible to govern orientation because of the minute dimensions of the loricae, and only a few chance sections parallel to the median or sagittal axis occur; this orientation is necessary for reliable identification. Accordingly, it is easy to be led astray in interpretation of random sections cut at many different angles.

Precision of definition and description of Recent Tintinnina cannot be extended easily to fossils which mostly are preserved as calcitic replacements lacking details of wall structure or other parts.

CLASSIFICATION

The classification of Tintinnina is based essentially on characters of the lorica in manner corresponding to use of the shells of Foraminifera, Radiolaria, and many other invertebrates. The taxonomic arrangement of these protozoans by early authors has been stated succinctly by KOFOID & CAMPBELL (4, 5) who outline reasons for the greatly expanded classification proposed by them. The ciliates of this group now are placed in a suborder called Tintinnina, whereas previous students included the few known genera in a single family called Tintinnidae. The present system includes 13 families, 11 subfamilies, 73 genera, and 23 subgenera.

Specialists on Recent Tintinnina agree generally with the taxonomic arrangement introduced by KOFOID & CAMPBELL, but most paleontologists seem to have been unaware of this enlarged system, for they have continued to assign all genera represented by fossils to the family Tintinnidae. In this catchall assembly the ill-defined Calpionellae have been placed by several writers recently.

SYSTEMATIC DESCRIPTIONS

Suborder TINTINNINA Claparède & Lachmann, 1858

[=Tintinnoinea KOFOID & CAMPBELL, 1929; Tintinnoina CAMPBELL, 1942]

Body conical or trumpet-shaped, attached inside a test (lorica) that commonly incorporates coccoliths or other foreign bodies; lorica generally separable into flaring or cylindrical collar and conical, globose, or variously formed bowl; aboral region rounded, pointed, or bearing a horn, pedicel, knob, or lance; wall exhibiting structural evidences of annular or spiral formation; substance of wall with fine, uniform, primary alveolar structure, commonly with inner and outer laminae, between which a secondary, coarser, patterned prismatic structure may be developed, with local differentiation in parts of the lorica. Generally free-swimming in fresh water, brackish water, and the open sea. *Jur.-Rec.*

Family TINTINNIDIIDAE Kofoid & Campbell, 1929

[as Tintinnididae; emend. CAMPBELL herein]

Lorica tubular or diversely saccular, with or without suboral spiral structure, rarely with collar, aboral end open or closed; wall mainly gelatinous, freely agglomerating particles. *Rec.*

Tintinnidium KENT, 1882 [**Tintinnus fluviatilis* STEIN, 1863]. Aboral end closed.——FIG. 89,*17*. *T. mucicola* (CLAPARÈDE & LACHMANN), ×200 (8).

Leprotintinnus JÖRG., 1899 [**Tintinnus pellucidus* CLEVE, 1899]. Aboral end open.——FIG. 89,*16*. *L. neriticus* (CAMPBELL), ×200 (8).

Family CODONELLIDAE Kent, 1882

Lorica cup-shaped or tubular with or without collar which is neither spiral nor hyaline but mostly has constricted throat, aboral end closed and commonly pointed or with aboral horn; wall with minute primary and much coarser secondary or even tertiary regular or irregular structure and weakly developed laminae. *Jur.-Rec.*

Codonella HKL., 1873 [**C. galea*]. Collar sharply defined. *Rec.*——FIG. 89,*5*. **C. galea*, ×200 (8).

Codonaria K.-C., 1939 [**Codonella cistellula* FOL, 1884]. Like *Codonella* but also has suboral cone. *Rec.*——FIG. 89,*4*. **C. cistellula* (FOL), ×200 (8).

Codonopsis K.-C., 1939 [**Cyttarocylis ollula* BRANDT, 1906]. Like *Codonaria* but lacks constricted throat. *Rec.*——FIG. 89,*2*. **C. ollula* (BRANDT), ×200 (8).

Tintinnopsella COLOM, 1948 [**Calpionella carpathica* MURGEANU & FILIPESCU, 1933]. Like *Tintinnopsis* but has large oral opening and distinct laterally directed collar. *U.Jur.*(Tithon.)-*L.Cret.*(Neocom.), Eur.——FIG. 89,*3*. **T. carpathica* (MURGEANU & FILIPESCU), Tithon., Majorca, ×250 (7).

Tintinnopsis STEIN, 1867 [**T. beroidea*]. Wall structure irregular, throat only constricted in some; differs from *Tintinnopsella* in its generally less flared collar and narrower oral opening. *Rec.*——FIG. 89,*1*. *T. bütschlii* DADAY, ×200 (8).

Family CODONELLOPSIDAE Kofoid & Campbell, 1929

Lorica top-shaped, hyaline collar commonly with spiral or annular turns; dense bowl rotund; aboral end rounded or pointed and in some with aboral horn; wall of collar with primary structure, that of bowl coarse secondary and commonly superposed tertiary. *Jur.-Rec.*

Subfamily CODONELLOPSINAE Kofoid & Campell, 1929

[as Codonellopsidae *(partim)*]

Tall collar with prominent spiral or annular turns. *Rec.*

Codonellopsis Jörg., 1924 [**Codonella orthoceras* Brandt, 1906; SD K.-C., 1929]. Aboral end closed.

C. (Codonellopsis). Large lorica with wide collar and numerous spiral turns.

C. (Codonelloides) K.-C., 1939 [**C. contracta* K.-C., 1929]. Small lorica with narrow collar and few spiral turns.——Fig. 89,9. *C. (C.) globosa* K.-C., ×200 (8).

Laackmanniella K.C., 1929 [**Codonella naviculaefera* Laackmann, 1907]. Aboral end wide open.

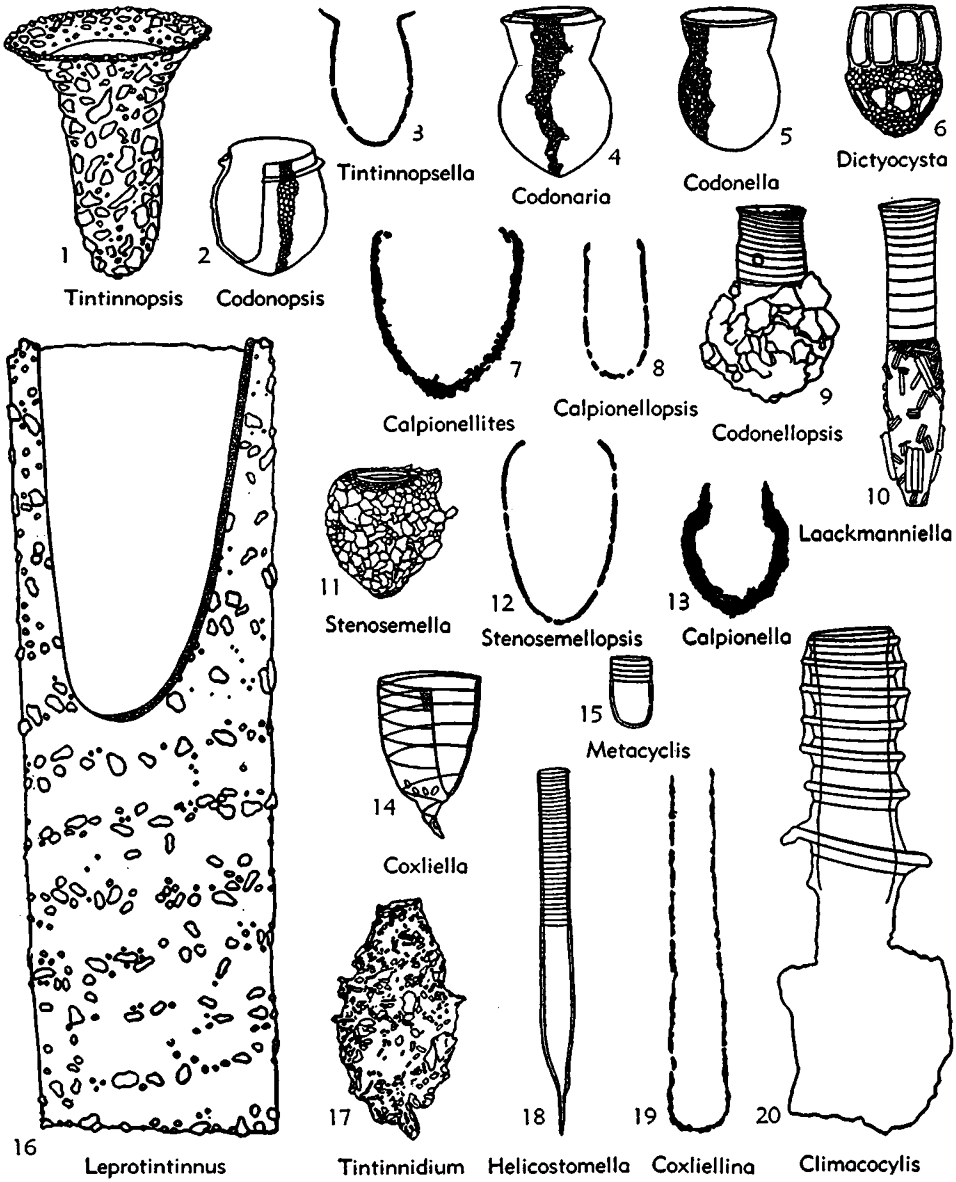

Fig. 89. Tintinnidiidae, Codonellidae, Codonellopsidae, Dictyocystidae, Coxliellidae (p. D172-D174).

——FIG. 89,*10*. **L. naviculaefera* (LAACKMANN), ×200 (8).

Subfamily STENOSEMELLINAE Campbell, nov.

Short collar without prominent turns. *Jur.-Rec.*

Stenosemella JÖRG., 1924 [**Tintinnopsis ventricosus* CLAPARÈDE & LACHMANN, 1858; SD K.-C., 1929]. Collar very short, without turns. *Rec.*——FIG. 89, *11*, **S. ventricosa* CLAPARÈDE & LACHMANN), ×200 (8).

Calpionella LORENZ, 1901 [**C. alpina*]. Collar erect, may be wanting. *U.Jur.*(Tithon.)-*L.Cret.*(Barrem.), Eur.-Asia-N.Am.——FIG. 89,*13*. **C. alpina,* Tithon., Majorca, ×500 (7).

Calpionellites COLOM, 1948 [**C. darderi*]. Collar with double inner wall. *L.Cret.*(Neocom.), Eur.——FIG. 89,*7*. **C. darderi,* Neocom., Balearic Isl., ×500 (7).

Calpionellopsis COLOM, 1948 [**C. thalmanni*]. Collar not flared. *L.Cret.*(Neocom.), Majorca.——FIG. 89,*8*. *C. simplex* COLOM, ×250 (7).

Stenosemellopsis COLOM, 1948 [**Calpionella hispanica* COLOM, 1939]. Like *Stenosemella* but lacks collar. *L.Cret.*(Neocom.), Eur.——FIG. 89,*12*. **S. hispanica* (COLOM), Majorca, ×250 (7).

Family DICTYOCYSTIDAE Kofoid & Campbell, 1929

Lorica with dense bowl and collar formed of arched frames; collar with 1 or 2 rows of regular, semicircular, squarish or rectangular windows either with or without closing panes; aboral end without horn; wall of bowl wholly reticulated with zoned fenestrae in some. *?Eoc., Rec.*

Dictyocysta EHR., 1854 [**D. elegans;* SD K.-C., 1929]. Windows prominent in tall collar. *?Eoc.,* Barbados, *Rec.*——FIG. 89,*6*. *D. grandis* BRANDT, Rec., ×200 (8).

Luminella K.-C., 1929 [**Tintinnopsis punctata* WAILES, 1925]. Low semicircular closed windows in short collar. *Rec.*

Wangiella DIE, 1934 [**W. dicollaria*]. Like *Luminella* but with single row of arched open windows in short collar. *Rec.*

Family COXLIELLIDAE Kofoid & Campbell, 1929

Aborally open or closed tubular or goblet-shaped lorica; if closed usually irregular; coiled lamina forming all or part of lorica; wall smooth; lorica usually delicate. *Cret.-Rec.*

Subfamily COXLIELLINAE Kofoid & Campell, 1929
[as Coxliellidae *(partim)*]

Spiral lamina forming whole lorica. *Cret.-Rec.*

Coxliella BRANDT, 1906 [**Cyttarocylis laciniosa* BRANDT, 1906; SD K.-C., 1929]. Lorica goblet-shaped; wall firm and opaque. *Rec.*

C. (Coxliella). Inner and outer laminae well-developed; secondary structure prominent.——FIG. 89,*14*. **C. (C.) laciniosa* (BRANDT) ×200 (8).

C. (Protocochliella) JÖRG., 1924 [**Amphorella ampla* JÖRG., 1899]. Laminae imperfectly separated; indistinct primary alveoli.

Climacocylis JÖRG., 1924 [**Cyttarocylis scalarius* BRANDT, 1906]. Lorica tubular; wall flaccid, nearly transparent. *Rec.*

C. (Climacocylis). Cylindrical lorica with spiral lamina mostly extended its whole length.——FIG. 89,*20*. **C. (C.) scalaria* (BRANDT), ×200 (8).

C. (Proclimacocylis) K.-C., 1939 [**Cyttarocylis sipho* BRANDT, 1906]. Tapering lorica with spiral extended not more than 0.65 of its length.

Coxliellina COLOM, 1948 [**C. berriasiensis*]. Like *Coxliella* but double wall fades aborally. *L.Cret.*(Berrias.), Majorca.——FIG. 89,*19*. **C. berriasiensis,* ×250 (7).

Stylicauda BALECH, 1951 [**Tintinnopsis platensis* Da Cunha & Fonsca, 1917]. Like *Coxliella* but has long aboral horn. *Rec.*

Subfamily METACYCLIDINAE Kofoid & Campell, 1929
[as Metacyclinae; emend. CAMPBELL, herein]

Spiral lamina confined to suboral region. *Rec.*

Metacyclis JÖRG., 1924 [**Tintinnus mediterraneus* MERESCHOWSKY, 1880]. Stout capsule-like lorica with few suboral rings.——FIG. 89,*15*. *M. lucasensis* K.-C., ×200 (8).

Helicostomella JÖRG., 1924 [**Tintinnus sublatus* EHR., 1833]. Narrow, elongate lorica with long aboral horn and commonly many suboral rings.——FIG. 89,*18*. *H. kiliensis* (LAACKMANN), ×200 (8).

Family CYTTAROCYLIDIDAE Kofoid & Campbell, 1929
[as Cyttarocylidae; emend. CAMPBELL, herein]

Bell- or kettle-shaped lorica, but subconical to elongate-conical in some; collar flared and set off by constriction from bowl; without spiral lamina; wall with coarse secondary structure. *Rec.*

Cyttarocylis FOL, 1881 [**Dictyocysta cassis* HKL., 1873].——FIG. 90,*11*. *C. conica* BRANDT, ×200 (8).

Family PTYCHOCYLIDIDAE Kofoid & Campbell, 1929

[as Ptychocylidae; emend. CAMPBELL, herein]

Bell- or kettle-shaped lorica; oral rim denticulate or with lip and furrow, otherwise simple; suboral region not annulated, with spiral lamina in some; bowl commonly elongated, with aboral horn; wall trilaminate. *Cret.-Rec.*

Ptychocylis BRANDT, 1896 [**Tintinnus urnula* CLAPARÈDE & LACHMANN, 1858]. Oral margin denticulate; bowl stout; wall roughened. *Rec.*

Cymatocyclis LAACKMANN, 1909 [**Cyttarocylis drygalskii* LAACKMANN, 1907; SD K.-C., 1929]. Bowl of elongate lorica strongly plicated; oral margin simple. *Rec.*——FIG. 90,*1*. *C. vanhoffeni* (LAACKMANN), ×200 (8).

Favella JÖRG., 1924 [**Tintinnus ehrenbergii* CLAPARÈDE & LACHMANN, 1858; SD K.-C., 1929]. Like *Cymatocylis* but usually shorter, and lacks strong pleats on surface. *Rec.*——FIG. 90,*2*. *F. panamensis* K.-C., ×200 (8).

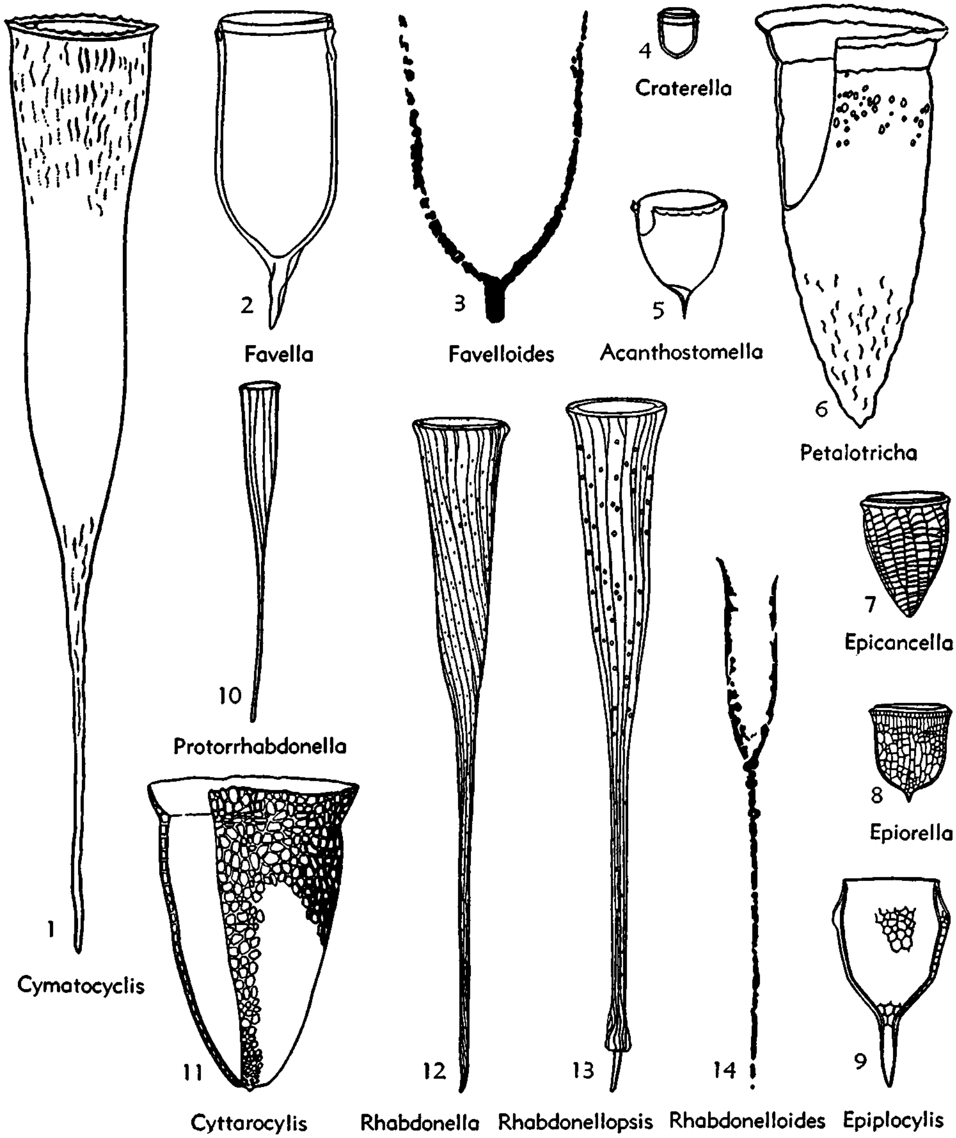

FIG. 90. Cyttarocylididae, Ptychocylididae, Epiplocylididae, Petalotrichidae, Rhabdonellidae (p. D174-D176).

Favelloides COLOM, 1939 [**F. balearica*]. Collar not flared. *L.Cret.*(Neocom.), Marjorca.——FIG. 90,*3*. **F. balearica*, ×500 (7).

Porecus CLEVE, 1902 [**Porella apiculata* CLEVE, 1900]. Like *Favella* but outer surface covered by coccoliths. *Rec.*

Protocymatocylis K.C., 1929 [**Cymatocylis vanhoffeni subrotundata* LAACKMANN, 1909]. Oral rim with channel. *Rec.*

Family EPIPLOCYLIDIDAE Kofoid & Campbell, 1929

[as Epiplocylidae; emend. CAMPBELL, herein]

Lorica short, stout, acorn-shaped; oral rim entire; suboral region simple or with shelf; aboral end blunt, pointed, or acuminate, commonly with horn; wall covered by deep polygonal reticulations forming suboral elevated vertical ridges, or whole surface cancellate. *Rec.*

Epiplocylis JÖRG., 1924 [**Cyttarocylis acuminata* DADAY, 1887; SD K.-C., 1929]. Oral margin simple; no collar; aboral horn well-developed.——FIG. 90,*9*. **E. acuminata* (DADAY), ×200 (8).

Epicancella K.-C., 1929 [**Cyttarocylis nervosa* CLEVE, 1900]. Suboral collar well-developed; surface cancellate.——FIG. 90,*7*. **E. nervosa* (CLEVE), ×200 (8).

Epiorella K.-C., 1939 [**Cyttarocylis reticulata* OSTENFELD & SCHMIDT, 1901]. Like *Epiplocylis* but with crestlike collar and distinct suboral shelf. ——FIG. 90,*8*. **E. reticulata* (OSTENFELD & SCHMIDT), ×200 (8).

Family PETALOTRICHIDAE Kofoid & Campbell, 1929

Lorica cup-shaped with smooth or denticulate oral rim; mouth wide open, with one or more collars; wall hyaline or with faint primary structure. *Rec.*

Subfamily PETALOTRICHINAE Kofoid & Campell, 1929

Oral rim with single collar. *Rec.*

Petalotricha KENT, 1882 [**Tintinnus ampulla* FOL, 1881]. Bowl without prominent fenestrae.——FIG. 90,*6*. *P. foli* K.-C., ×200 (8).

Wailesia K.-C., 1939 [**Dictyocysta apiculata* WAILES, 1925]. Large postnuchal fenestrae.

Subfamily CRATERELLINAE Kofoid & Campell, 1929

Oral rim with 2 collars. *Rec.*

Craterella K.-C., 1929 [**Tintinnus urceolatus* OSTENFELD, 1889]. Collars without denticles.——FIG. 90,*4*. *C. armilla* K.-C., ×200 (8).

Acanthostomella JÖRG., 1927 [**Amphorella norvegica* DADAY, 1887]. Outer collar with denticles.——FIG. 90,*5*. *A. lata* K.-C., ×200 (8).

Family RHABDONELLIDAE Kofoid & Campbell, 1929

Lorica chalice-shaped to conical, mouth commonly with low gutter but without teeth; aboral end may bear a long pedicellate horn; wall with numerous vertical, raised ribs. *Cret.-Rec.*

Rhabdonella BRANDT, 1906 [**Tintinnus spiralis* FOL, 1881; SD K.-C., 1929]. Like *Rhabdonellopsis* but aboral horn lacks distinct knob. *Rec.*——FIG. 90,*12*. *R. conica* K.-C., Rec., ×200 (8).

Epirrhabdonella K.-C., 1939 [**E. coronata*]. Oral rim crested; without aboral horn. *Rec.*

Protorrhabdonella JÖRG., 1924 [**Cyttarocylis simplex* CLEVE, 1900; SD K.-C., 1929]. Oral rim without gutter. *Rec.*

P. (Protorrhabdonella). Short convex lorica.

P. (Eurrhabdonella) K.-C., 1939 [**P. mira* K.-C., 1929]. Elongate lorica.——FIG. 90,*10*. *P. (E.) mira*, ×200 (8).

Rhabdonelloides COLOM, 1939 [**R. inesperatta*]. Like *Rhabdonella* but with very greatly elongated simple horn. *L.Cret.*(Neocom.), Balearic Isl.——FIG. 90,*14*. **R. inesperatta*, Valang., Majorca, ×250 (7).

Rhabdonellopsis K.-C., 1929 [**Cyttarocylis hebe apophysata* CLEVE, 1900]. Elongate chalice-shaped bowl; aboral horn with strong knob at junction of pedicel and lance. *Rec.*——FIG. 90,*13*. *R. longicaulis* K.-C., ×200 (8).

Family XYSTONELLIDAE Kofoid & Campbell, 1929

Lorica elongate, more or less chalice-shaped, with long narrow pedicel; wall generally with primary and secondary structure, without vertical ribs. *Jur.-Rec.*

Xystonella BRANDT, 1906 [**Cyttarocylis treforti* DADAY, 1887; SD K.-C., 1929]. Oral rim channeled. *Rec.*

X. (Xystonella). Differentiated pedicel and lance.

X. (Proxystonella) K.-C., 1939 [**X. lanceolata* BRANDT, 1906]. Aboral horn simple.

X. (Spiroxystonella) K.-C., 1939 [**X. scandans* BRANDT, 1906]. Bowl with wide spiral shelf.——FIG. 91,*1*. **X. (S.) scandans* (BRANDT), Rec., ×200 (8).

Parafavella K.-C., 1929 [*pro Tintinnus* RÜST, 1885 (*non* SCHRANK, 1803)][**Tintinnus denticulatus* EHR., 1840]. Oral rim generally denticulate; aboral horn may be lacking. *Jur.-Rec.*, Eur.——FIG. 91,*15*. *Parafavella* sp., from coprolite, Jur., Alps, ×160 (9).

Parundella JÖRG., 1924 [**Undella lachmanni* DADAY, 1887; SD K.-C., 1929]. Thin, erect oral rim without channel. *Rec.*——Fig. 91,*14*. *P. invaginata* K.-C., ×200 (8).

Xystonellopsis Jörg., 1924 [**Undella paradoxa* Cleve, 1900; SD K.-C., 1929]. Thin oral rim abruptly flared. *Rec.*

X. (Xystonellopsis). Suboral region simple; aboral region highly differentiated.

X. (Euxystonellopsis) K.-C., 1939 [**Xystonella ornata* Brandt, 1906]. With massive suboral necklace.——Fig. 91,2. **X. (E.) ornata* (Brandt), ×200 (8).

X. (Macroxystonellopsis) K.-C., 1939 [**X. clevei* K.-C., 1929]. Elongated pedicel, greatly expanded knob and slender lance.

X. (Paraxystonellopsis) K.-C., 1939 [**X. acuminata* K.-C., 1929]. Stout bowl and simple lance without knob.

X. (Parundellopsis) K.-C., 1939 [**X. epigrus* K.-C., 1929]. Short, stout lorica with lance and knob.

X. (Proxystonellopsis) K.-C., 1939 [**X. cyclas* K.-C., 1929]. Bowl suborally thickened.

X. (Xystonelloides) K.-C., 1939 [**Cyttarocylis pulchra* Kofoid, 1905]. Highly differentiated suboral thickened rings; pronouncedly developed knob and lance.

Family UNDELLIDAE Kofoid & Campbell, 1929

Goblet-shaped lorica; suboral region diverse; aboral end closed; wall generally trilaminate, intermediate region without secondary structure. *Rec.*

Subfamily UNDELLINAE Kofoid & Campbell, 1929

[as Undellidae *(partim)*]

Without suboral ledge or inner collar. *Rec.*

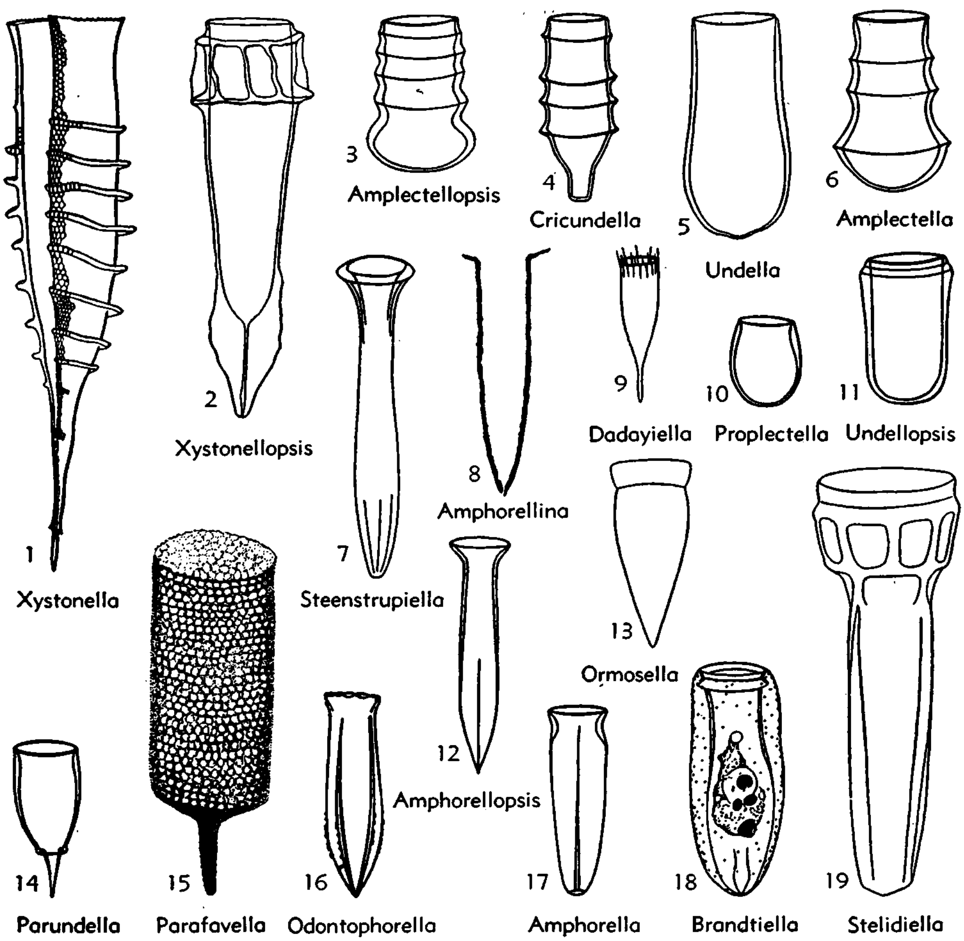

Fig. 91. Xystonellidae, Undellidae, Tintinnidae (p. D176-D178).

Undella DADAY, 1887 [*U. *hyalina;* SD K.-C., 1929]. Lacking suboral rings; bowl pointed, angled, or rounded.——FIG. 91,*5*. *U. dilatata* K.-C., X200 (8).

Amplectella K.-C., 1929 [**Undella collaria* BRANDT, 1906]. Suboral rings; expanded, rounded bowl. ——FIG. 91,*6*. **A. collaria* (BRANDT), ×200 (8).

Amplectellopsis K.-C., 1929 [**A. biedermanni*]. Like *Amplectella* but lacks suboral rings.——FIG. 91,*3*. **A. biedermanni,* ×200 (8).

Cricundella K.-C., 1929 [**Undella tridivisa* BRANDT, 1906]. Aboral end rounded or subconical; prominent suboral rings.——FIG. 91,*4*. *C. quadridivisa* K.-C., ×200 (8).

Subfamily UNDELLOPSINAE Campbell, 1942

Suboral ledge prominent; no inner collar. *Rec.*

Undellopsis K.-C., 1929 [**Undella marsupialis* BRANDT, 1906].

U. (Undellopsis). No rings below suboral ledge.——FIG. 91,*11*. *U. (U.) pacifica* K.-C., ×200 (8).

U. (Undellicricos) K.-C., 1929 [**Undella bicollaria* BRANDT, 1906]. One or more suboral rings.

Subfamily PROPLECTELLINAE Campbell, 1942

Distinct inner collar present. *Rec.*

Proplectella K.-C., 1929 [**Tintinnus claparèdei* ENTZ, 1885].——FIG. 91,*10*. **P. claparèdei* (ENTZ), ×200 (8).

Family TINTINNIDAE Claparède & Lachmann, 1858

Lorica of various forms; oral region almost invariably flared; aboral end open or closed; wall hyaline, rarely with secondary structure. *Cret.-Rec.*

Subfamily TINTINNINAE Claparède & Lachmann, 1858

[as Tintinnidae *(partim)*]

Collar simple; aboral end closed. *Cret.-Rec.*

Tintinnus SCHRANK, 1803 [**Trichoda inquilinus* MÜLLER, 1776; SD APSTEIN, 1915]. Collar slightly flared; oral margin entire; aboral end rounded; wall thin. *Rec.*

Albatrossiella K.-C., 1929 [**Undella filigera* LAACKMANN, 1909]. Like *Amphorella* but with long aboral horn. *Rec.*

Amphorella DADAY, 1887 [**Tintinnus quadrilineatus* CLAPARÈDE & LACHMANN, 1858]. Vaselike; without aboral horn or suboral facets; fins simple. *Rec.*——FIG. 91,*17*. **A. quadrilineata* (CLAPARÈDE & LACHMANN), ×200 (8).

Amphorellina COLOM, 1948 [**A. subacuta*]. Like *Amphorellopsis* but slightly ovoid in outline. *L.Cret.*(L.Neocom.), Majorca.——FIG. 91,*8*. **A. subacuta,* ×250 (7).

Amphorellopsis K.-C., 1929 [**Amphorella acuta* SCHMIDT, 1901]. Aboral end pointed, otherwise resembles *Amphorella. Rec.*——FIG. 91,*12*. **A. acuta* (SCHMIDT), ×200 (8).

Bursaopsis K.-C., 1929 [**Amphorella striata* DADAY, 1887]. Collar not flared. *Rec.*

Canthariella K.-C., 1929 [**C. brevis*]. No aboral horn or fins; bowl very short; aboral end angulated. *Rec.*

Dadayiella K.-C., 1929 [**Tintinnus ganymedes* ENTZ, 1884]. Like *Albatrossiella* but has stouter aboral horn and facetted suboral oral region. *Rec.* ——FIG. 91,*9*. **D. ganymedes* (ENTZ), ×200 (8).

Odontophorella K.-C., 1929 [**O. serrulata*]. Like *Amphorella* but fins provided with sharp teeth. *Rec.*——FIG. 91,*16*. **O. serrulata,* ×200 (8).

Steenstrupiella K.-C., 1929 [**Tintinnus steenstrupii* CLAPARÈDE & LACHMANN, 1858]. Like *Canthariella* but larger, without aboral horn, with rounded aboral end and restricted low fins. *Rec.*——FIG. 91,*7*. *S. entzi* K.-C., ×200 (8).

Subfamily STELIDIELLINAE Kofoid & Campell, 1929

Collar made up of suboral band set off by groove or ledge usually forming a necklace; aboral end closed. *Rec.*

Stelidiella K.-C., 1929 [**Tintinnus stelidium* BIEDERMANN, 1893]. Scabbard-shaped; suboral necklace with closed fenestrae and raised frames; aboral end blunt.——FIG. 91,*19*. *S. fenestrata* K.-C., ×200 (8).

Brandtiella K.-C., 1929 [**Tintinnus palliatus* BRANDT, 1906]. Resembles *Ormosella* but has spool-like suboral ring, purselike aboral end without horn, and unique outer gelatinous envelope. ——FIG. 91,*18*. **B. palliata* (BRANDT), ×200 (8).

Ormosella K.-C., 1929 [**O. cornucopia*]. Without necklace or outer sheath; aboral end pointed, some with aboral horn; bowl may be facetted. *Rec.*——FIG. 91,*13*. **O. cornucopia,* ×200 (8).

Prostellidiella K.-C., 1939 [**Stelidiella phialia* K.-C., 1929]. Like *Stelidiella* but necklace lacks fenestrae and frames.

Subfamily SALPINGELLINAE Kofoid & Campbell, 1939

Aboral end open. *Cret.-Rec.*

Tribe SALPINGELLIDES Campbell, nov.

Lorica nail-shaped. *Cret.-Rec.*

Salpingella JÖRG., 1924 [**Tintinnus acuminatus* CLAPARÈDE & LACHMANN; SD K.-C., 1929]. Fins limited to aboral region. *Rec.*——FIG. 92,*4*. *S. jugosa* K.-C., ×200 (8).

Epicranella K.-C., 1929 [**E. prismatica*]. Lorica with suboral arched ridges. *Rec.*——FIG. 92,*5*. **E. prismatica,* ×200 (8).

Rhabdosella K.-C., 1929 [**Salpingella cuneolata*] [=*Epirrhabdosella* CAMPBELL, 1942 (obj.)].

Facetted lorica without fins or suboral arched ridges. *Rec.*——Fig. 92,*2*. *R. octogenata* K.-C., ×200 (8).

Salpingacantha K.-C., 1929 [**Tintinnus acuminatus undatus* Jörg., 1899]. Oral margin with sharp teeth, otherwise resembles *Salpingella*. *Rec.*——Fig. 92,*3*. **S. undata* (Jörg.), ×200 (8).

Salpingellina Colom, 1948 [**S. levantina*]. Like *Salpingella* but narrowly conical. *L.Cret.*(Neocom.), Majorca.——Fig. 92,*6*. **S. levantina* ×250 (7).

Salpingelloides Campbell, 1942 [**Tintinnus costatus* Laackmann, 1909]. Fins extended whole length of lorica, unlike *Salpingella*. *Rec.*——Fig. 92,*1*. *S. altiplicata* (Merkle), ×200 (8).

Tribe EUTINTINNIDES Campbell, nov.

Lorica tubular. *Rec.*

Eutintinnus K.-C., 1939 [**Tintinnus birictus* K.-C., 1929]. Rigid lorica without fins.

E. (Eutintinnus). Oral rim entire; tube of similar diameter throughout. Fig. 92,*8*. **E. (E.) birictus* ×200 (8).

E. (Ceratotintinnus) K.-C., 1939 [**Tintinnus angustatus* Daday, 1887]. Oral rim entire; aboral end contracted.

E. (Odontotintinnus) K.-C., 1939 [**Tintinnus turris* K.-C., 1929]. Oral rim with sharp denticles; tube of similar diameter throughout.

Daturella K.-C., 1929 [**Tintinnus stramonium* Brandt, 1906]. Flaccid lorica; ribbon-like fins extending nearly whole length of tube.——Fig. 92,*7*. **D. stramonium* (Brandt), ×200 (8).

Clevea Balech, 1948 [**C. melchersi*]. Like *Eutintinnus* in form but aborally flaccid, as in *Daturella;* oral teeth present, fins lacking. *Rec.*

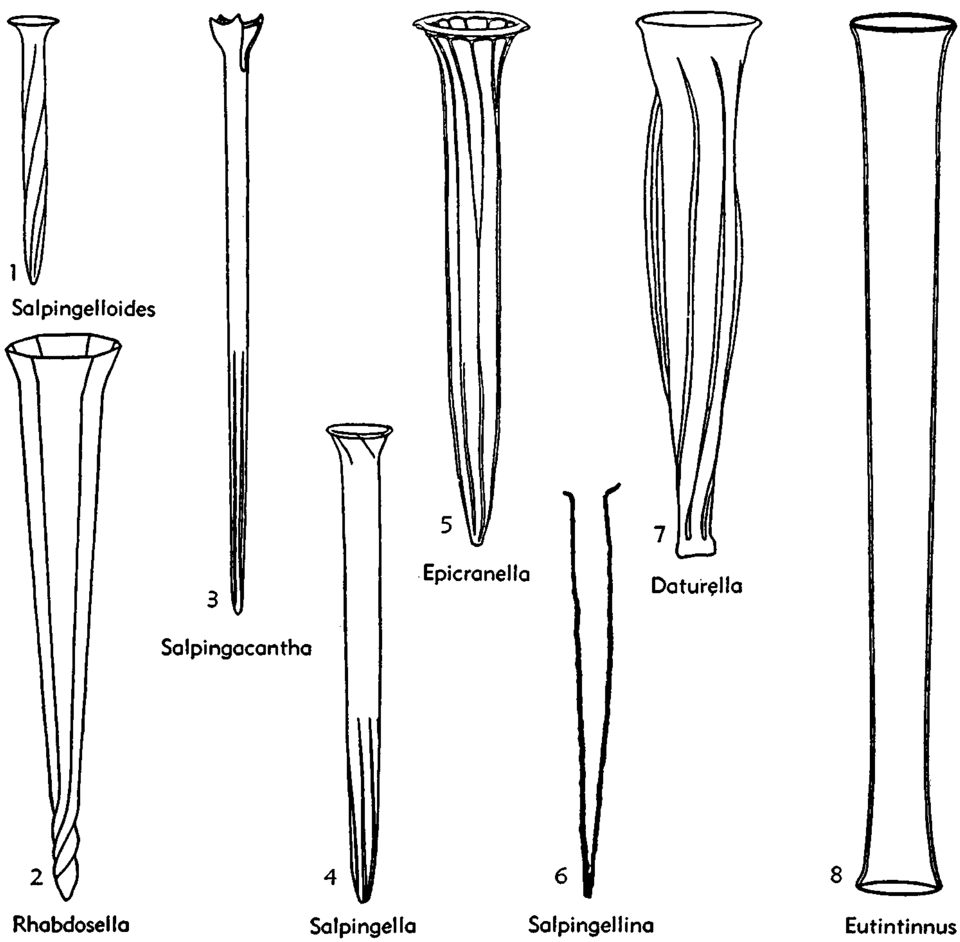

Fig. 92. Tintinnidae (p. D178, D179).

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SOURCES OF ILLUSTRATIONS

(6) **Campbell, A. S.** (original).
(7) **Colom, G.**
(8) **Kofoid, C. A., & Campbell, A. S.**
(9) **Rüst, D.**

INDEX

Names included in the following index are classified typographically as follows: (1) Roman capital letters are used for suprafamilial taxonomic units which are recognized as valid in classification; (2) italic capital letters are employed for suprafamilial categories which are considered to be junior synonyms of valid names; (3) generic and family names accepted as valid and morphological terms are printed in roman type; and (4) generic and family names classed as invalid, including junior homonyms and synonyms, are printed in italics.