Palaeontology

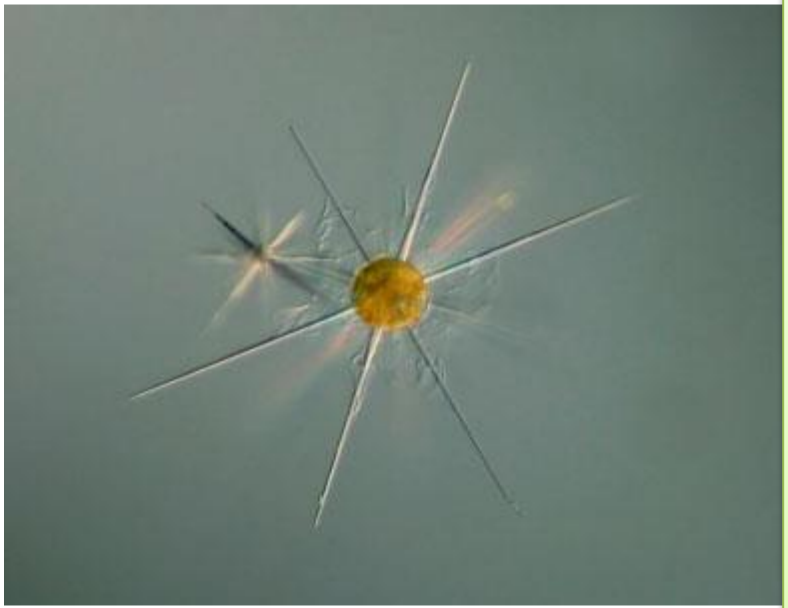
Lecture 7

Animal Kigdom: Porifera, Cnidaria

Radioralia

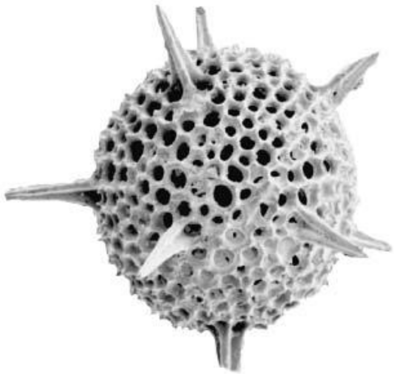
- They appeared in the Precambrian
  Useful in Biostratigraphy
  Small, medium to deep, warm and cold water
  Their name from their radial pseudopodia
  Dimensions 0.1 - 0.5 mm
  Manufacturers of silicate layers (radiolarites, 1cm / 1000 years)

The living cell



- The protoplasm is divided into two parts by a pseudo-chitin formation, the central capsule.
- The exterior the ectoplasm (secretes the skeleton or capsule)
- the internal the endoplasm (contains the nucleus and various organelles)
- The central capsule may consist of one, two or three layers
- The protoplasm forms outer radial pseudopodia of two types:
- Filipodia (simple protuberances of ectoplasm)
- Axopodia (protrusions that grow around an "axoplast" or spine)

Spumellaria



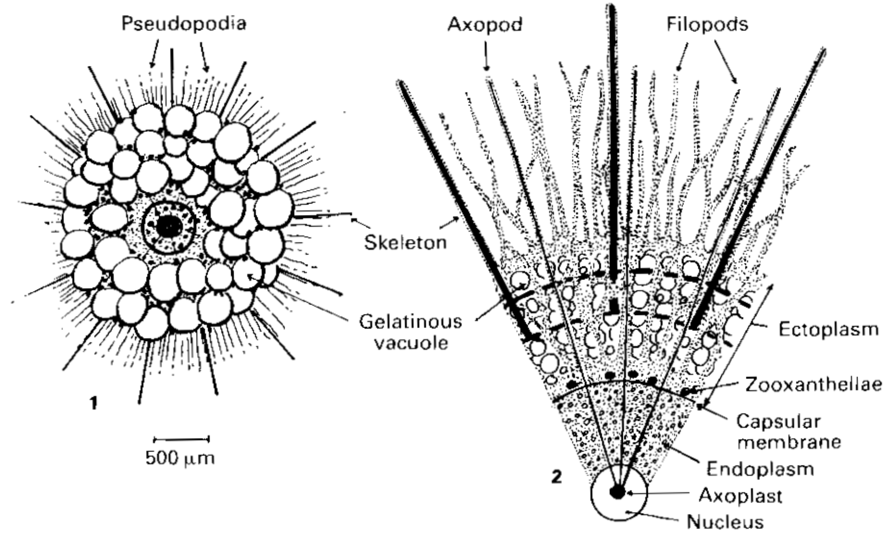
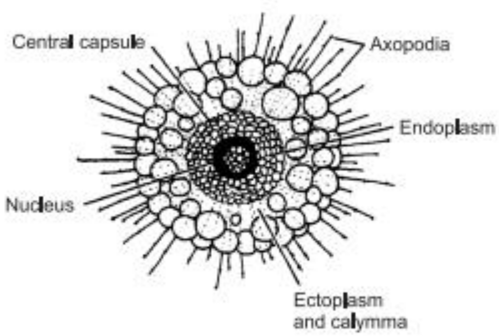
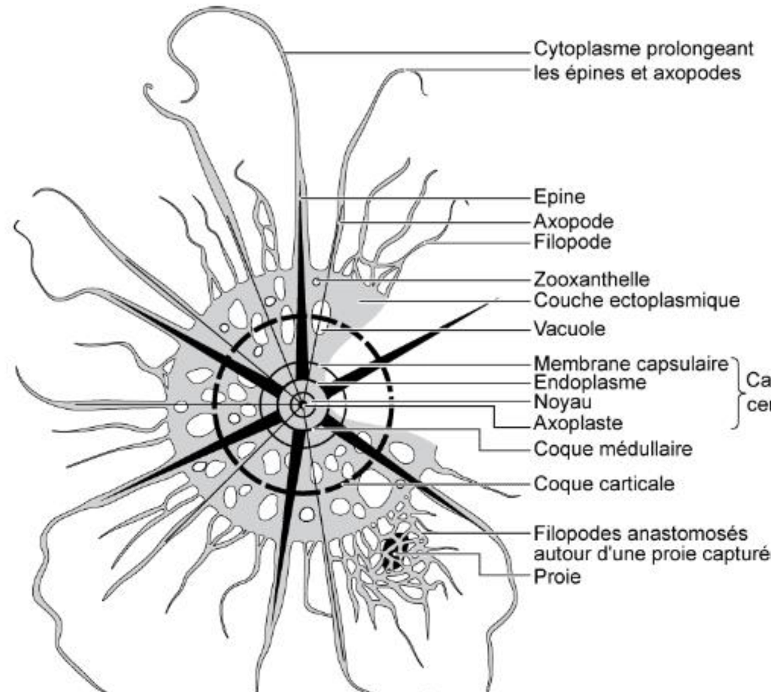
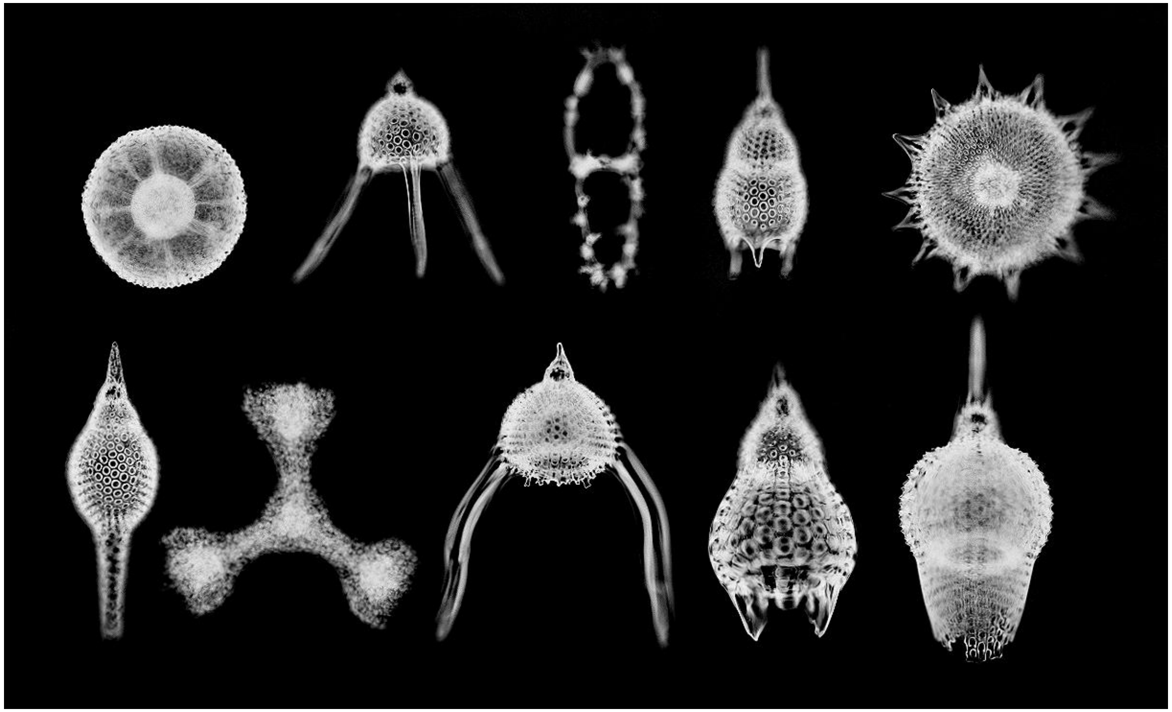


Fig. 8.1 External appearance and optical section of a living spumellarian polycystine radiolarian (×14)
Fig. 8.2 Diagram of part of a section of a spumellarian, the skeleton of which is formed from two concentric shells, trabeculae and radial spines

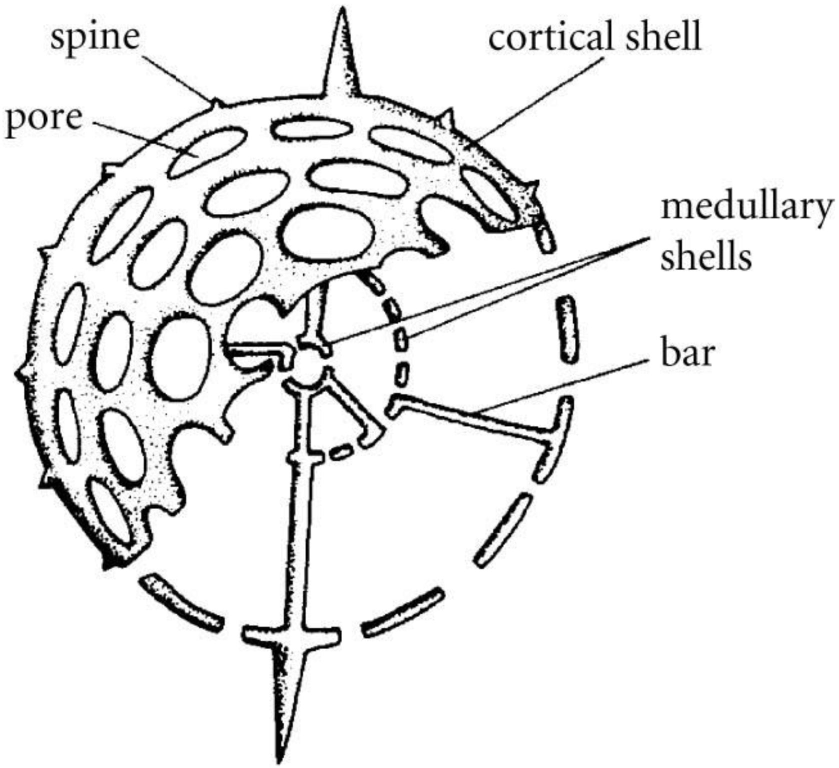




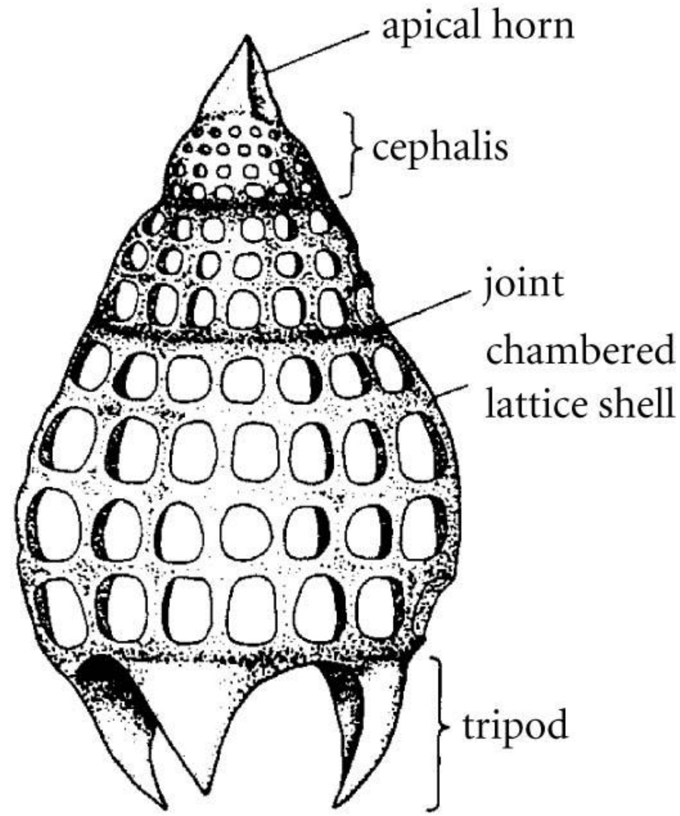
Radiolaria



Morphological features

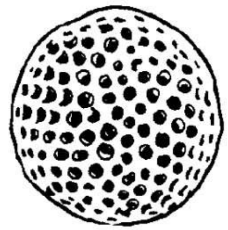


Spumellaria

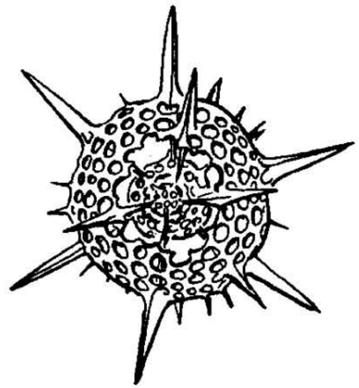


Nassellaria

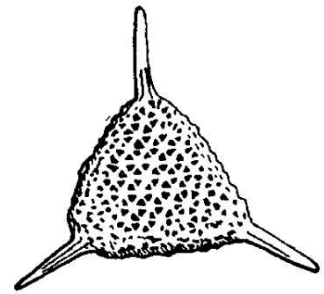
SPUMELLARIA



Lenosphaera

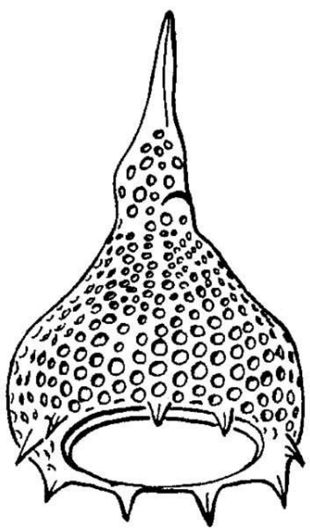


Actinomma

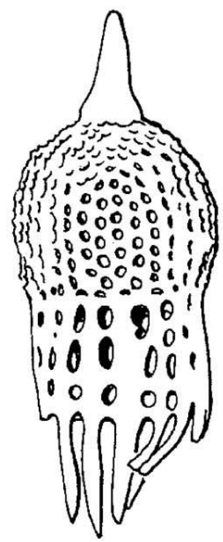


Alievium

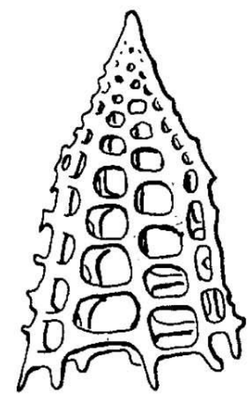
NASSELLARIA



Anthocyrtidium



Calocyclas



Peripyramis

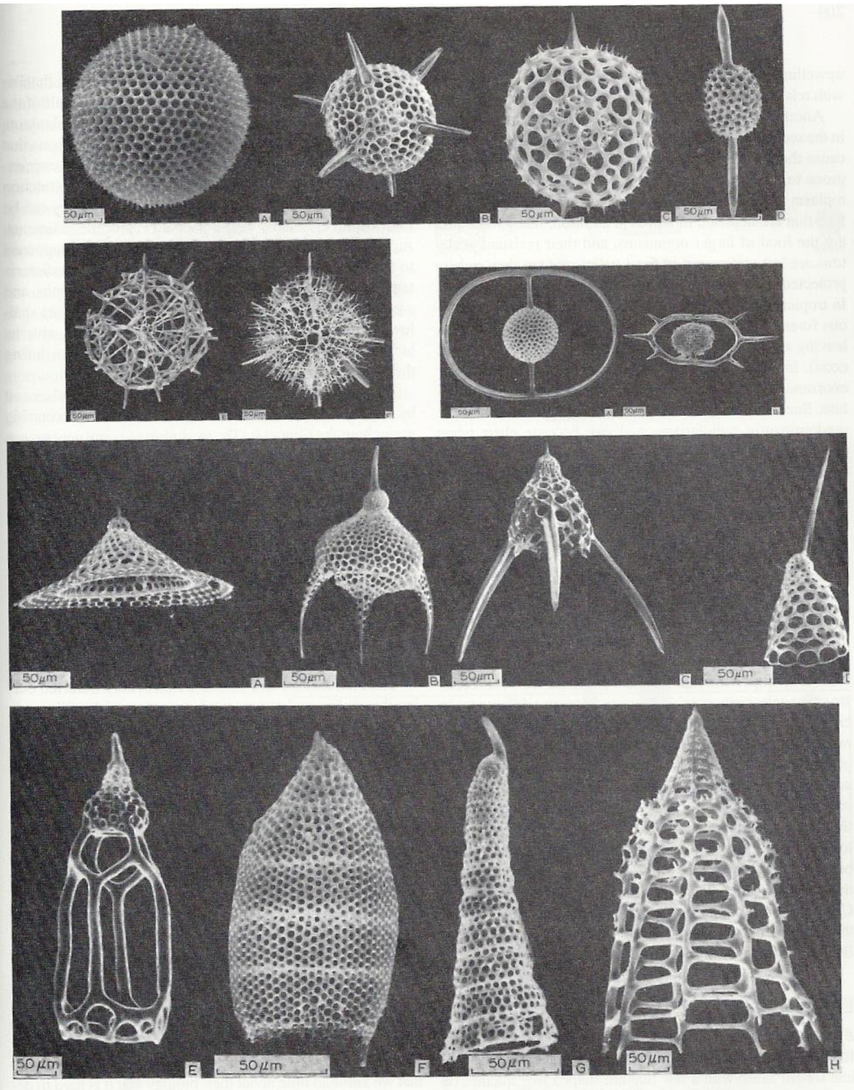


figure 11.12 Radiolarians exhibit a great variety of test shapes. The top two rows are all spumellarians, which tend to be radially symmetrical around a central point. The bottom two rows are nassellarians, which are symmetrical around an axis, so they tend to be shaped like cones, cylinders, bells, or helmets. The top row consists of actinommid spumellarians, as are the two on the left of the second row. The two on the right of the second row are the appropriately named saturnalins. All in the two bottom rows are

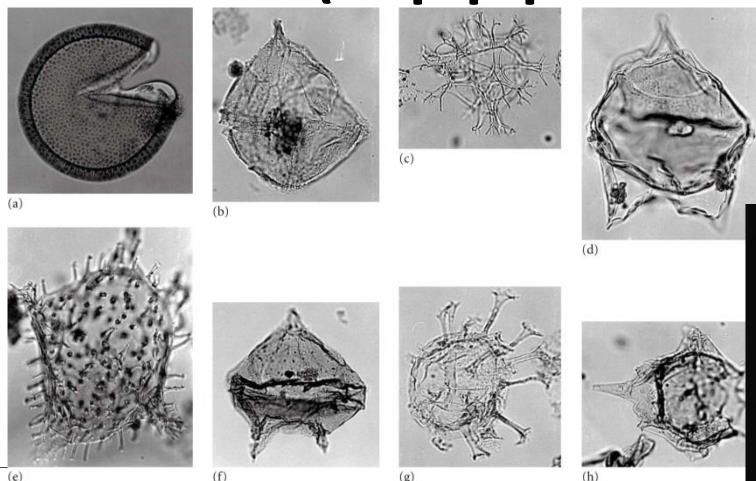
Ecology

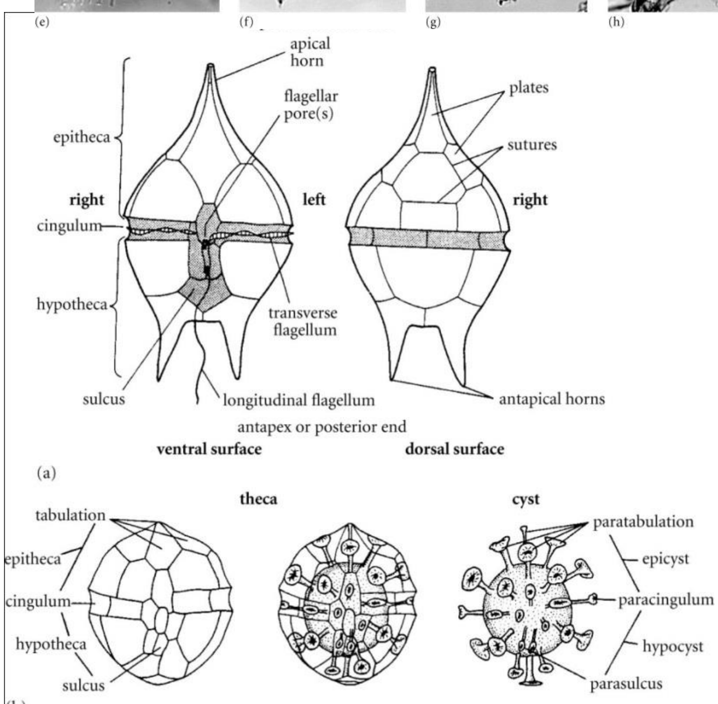
- They live for about a month
  They feed on small game like diatoms and coppers
  Reproduction by splitting, one descendant holds the original skeleton and the second one produces a new one with gyrocentric growth
  Intra-specific dimorphism has been observed, with different stages in their development cycle

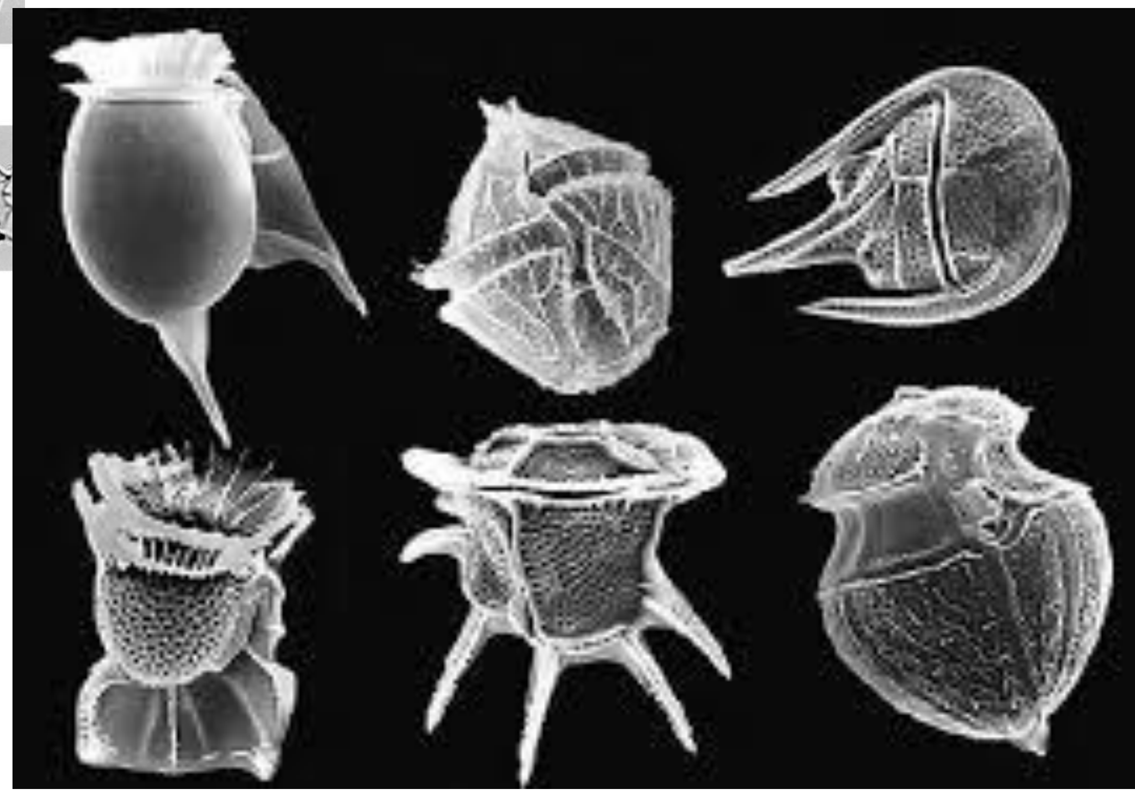
Ecology

- Stenohaline (salinity> 30 ‰)
  Pelagic faunas present a maximum growth at 100m.
  Abyssal faunas in deep bottoms
  Zonal faunas at different depths
  The temperature affects the shape and size, in the cold waters they have larger tests
  The tests of those living in surface waters smaller and thinner than in the deep
  Sensitive to climate change, they prefer calm waters
  When environmental conditions change, they migrate

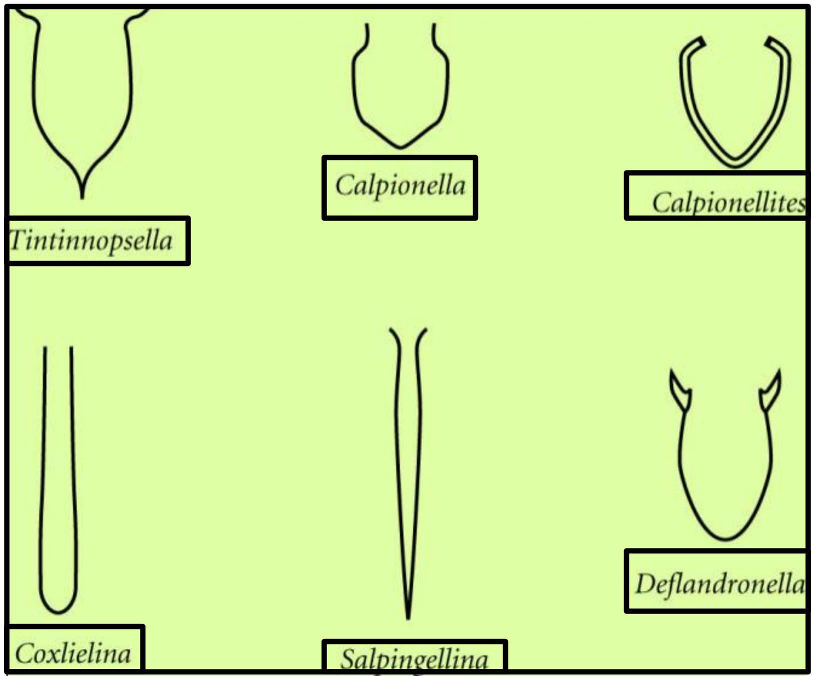
Phylum Dinoflagellates
(Uppper Proterozoic – today)







Phylum Ciliophora (Mesozoic-today)



Calpionelids

- Pelagic organisms that swim moving their cilia
- Calpionelids are a typical extinct family of the group (Late Jurassic-Early Cretaceous)

Kingdom Chromista

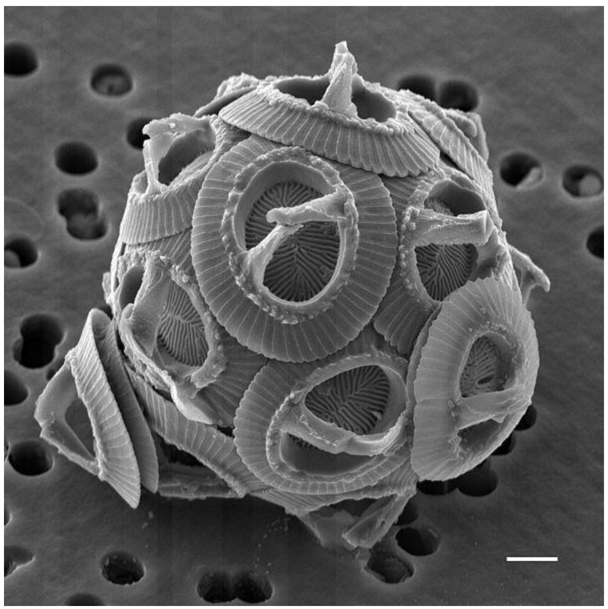
- Phylum Haptophyta
  - Class Prymnesiophyceae
  - Order Coccosphaerales (Coccolithophores)

(A) Heterococcolithophorales (heterococcoliths)

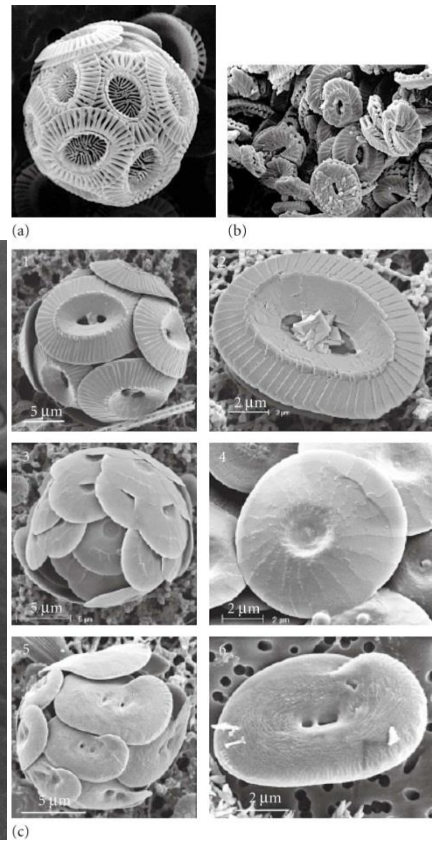
(B) Holococcolithophorales (holococcoliths)

- Φύλο Ochrophyta
  - Class Bacillariophyceae (Diatoms)
  - Order Centrales
  - Order Pennales

Order Coccosphaerales (Coccolithophores)



Coccosphere of Coccolithophore *Gephyrocapsa oceanica*. SEM photo.



- Calcareous nanophytoplankton

Photosynthetic unicellular eukaryotic organisms

First appeared in the Late Triassic

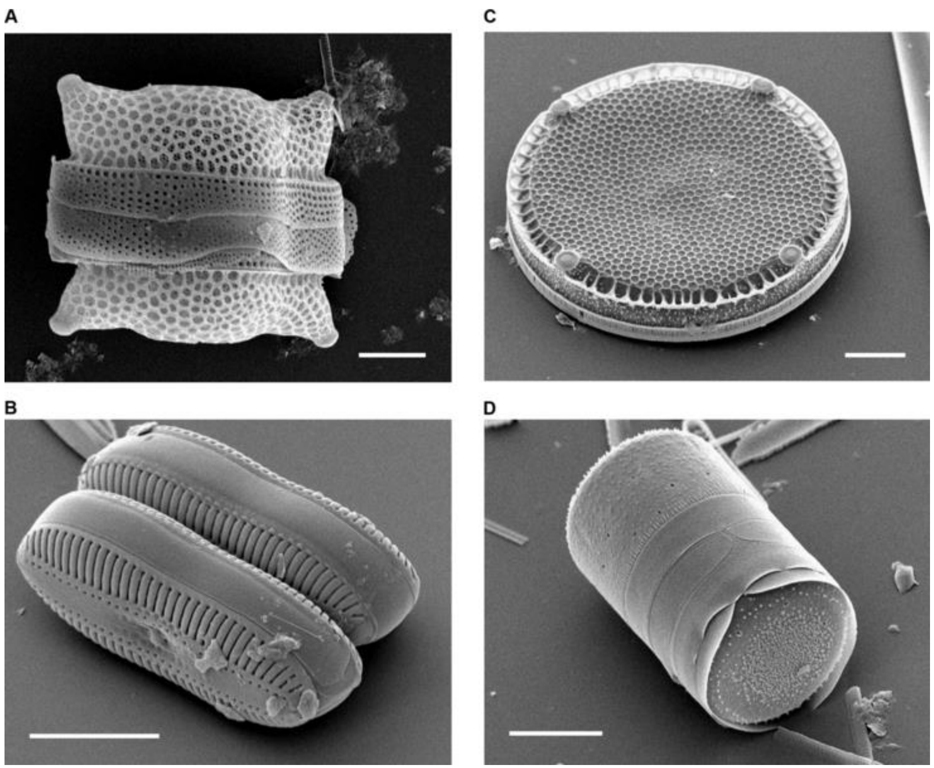
The shell consists of typical calcitic plates the coccoliths or the nannoliths

Coccoliths and nannoliths are formed by calcitic elements with composite morphology and structure

In living organisms coccoliths are attached to the cell membrane forming one or more layers that surround the cell, making the Coccosphere.

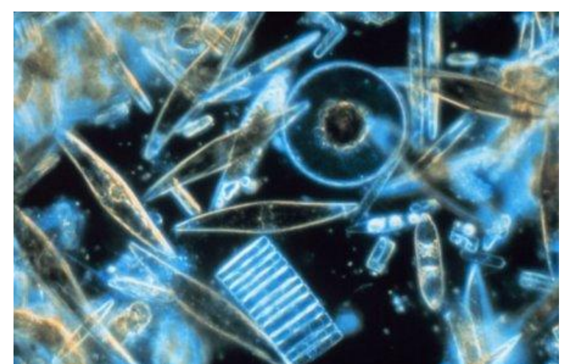
- They reproduce asexually (schizogony) or sexually (sexual coupling)

Subphylum Diatoms

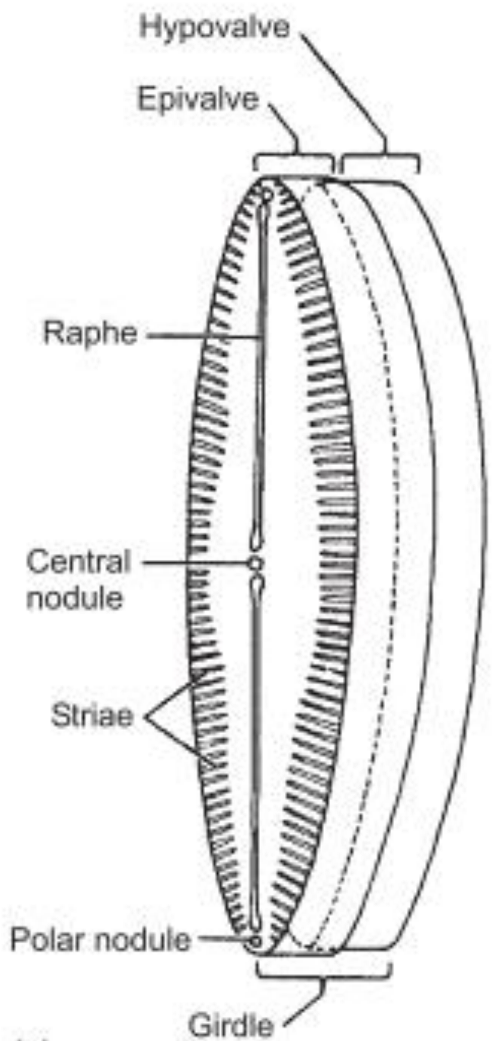


- Phytoplankton with silicate shell
- Euryhaline and Eurythermal
- Benthic and Planktonic
- The group Centrales (radiates) are mainly marine and Pennales (elongated and ellipsoid) mainly lacustrine.
- Appeared in Late Jurassic.

Diatoms. SEM pictures
A,B: Pennales- C,D:Centrales



Morphology of diatom frustule



Basic features of a diatom frustule

Reproduction

10 to 20 minutes to form a new hypovalve

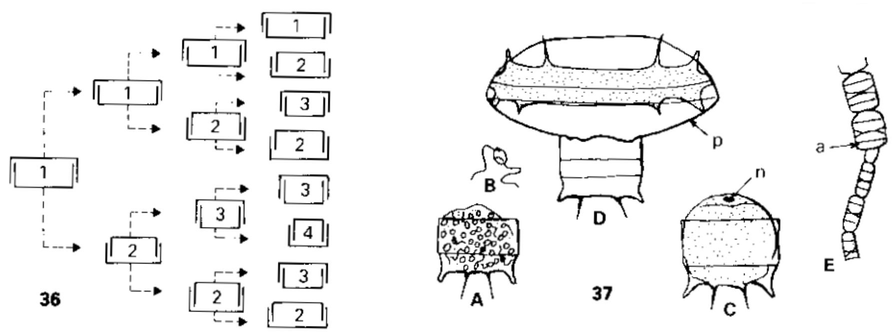


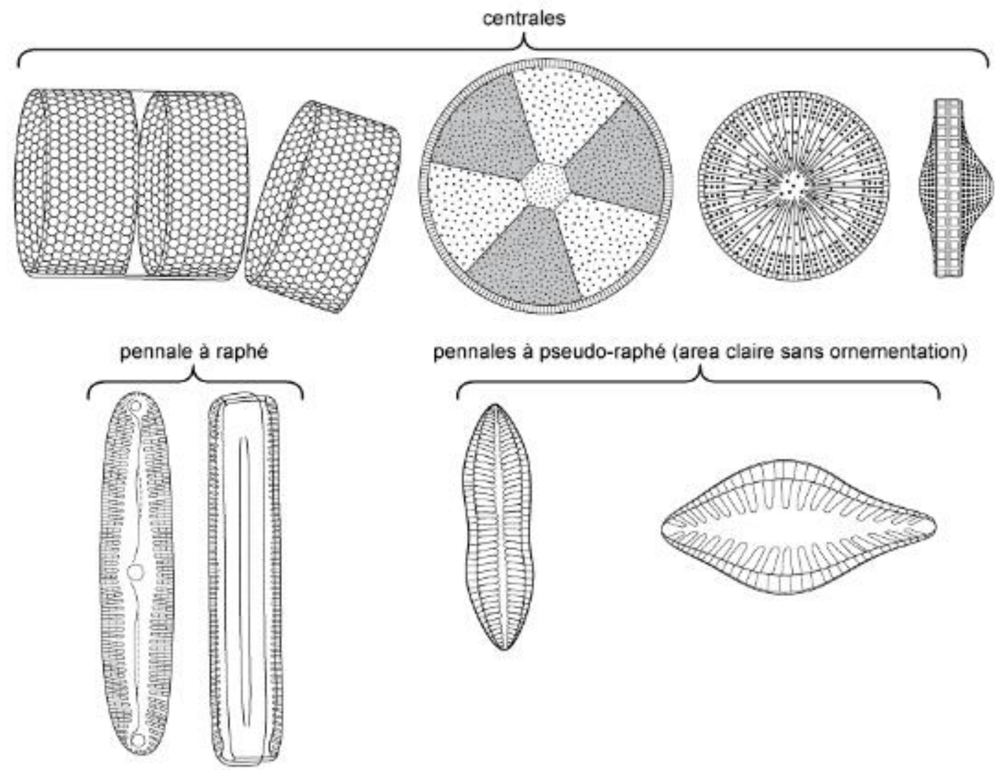
Fig 8.36 Asexual reproduction in diatoms. In *Coscinodiscus*, the initial cells, measuring 200 μm, produce cells the size of which diminishes by between 1 and 2 μm with each division. The regenerated valve is always the hypotheca. Mitosis ceases when the cells reach 55 to 60 μm

Fig. 8.37 Sexual reproduction in the diatom *Biddulphia*: **A**, production of antherozoids in a valve of the parent frustule (×200); **B**, biflagellate antherozoid (×540); **C**, oosphere in a valve of the parent frustule (n = nucleus) (×200); **D**, construction of the frustule of the auxospore within the perizonium (p), a membrane limiting the maximum extension of the oosphere after its departure from the parent frustule and fertilization (×200); **E**, row of cells showing abrupt increase in size after the appearance of the auxospore (a) (×80).

After Bergon (1974, figs 133 and 138)

Ecology and distribution

- Solitary or colonial
- 200 genera and 20000 living and fossil taxa
- 15% of modern species exist from the Eocene and 6% from Cretaceous



Ecology and distribution

- Several euryhaline and eurythermal
- Most of them stenotopic with specific ecological adjustments
- Marine as well as lacustrine

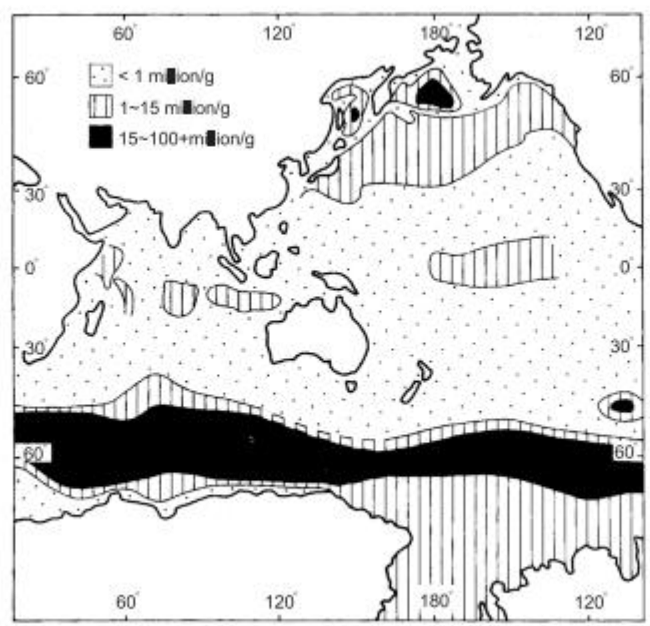
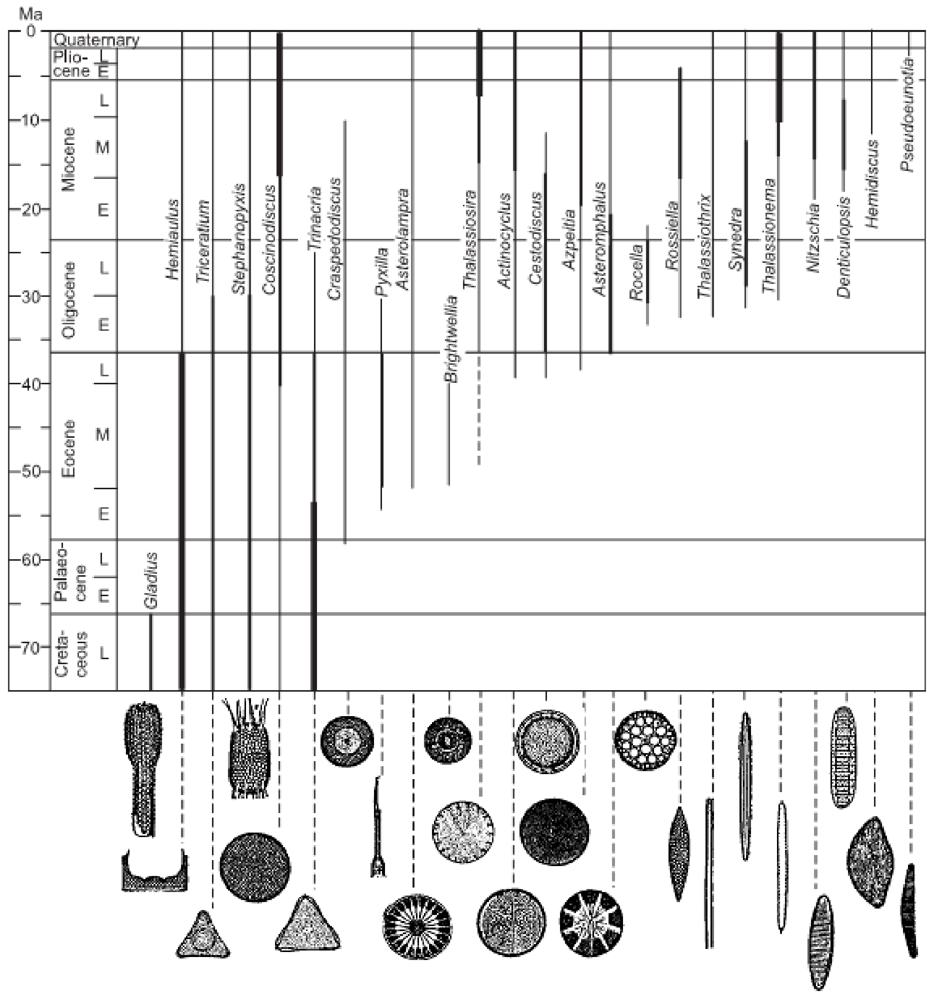


Fig. 17.3 The distribution of diatom frustules in surface sediments of the Indian and Pacific oceans, in millions per gram of sediment. (Based on Lisitzin, in Funnell & Riedel 1971, figure 10.11.)

Distribution of main Diatom taxa



Metazoa

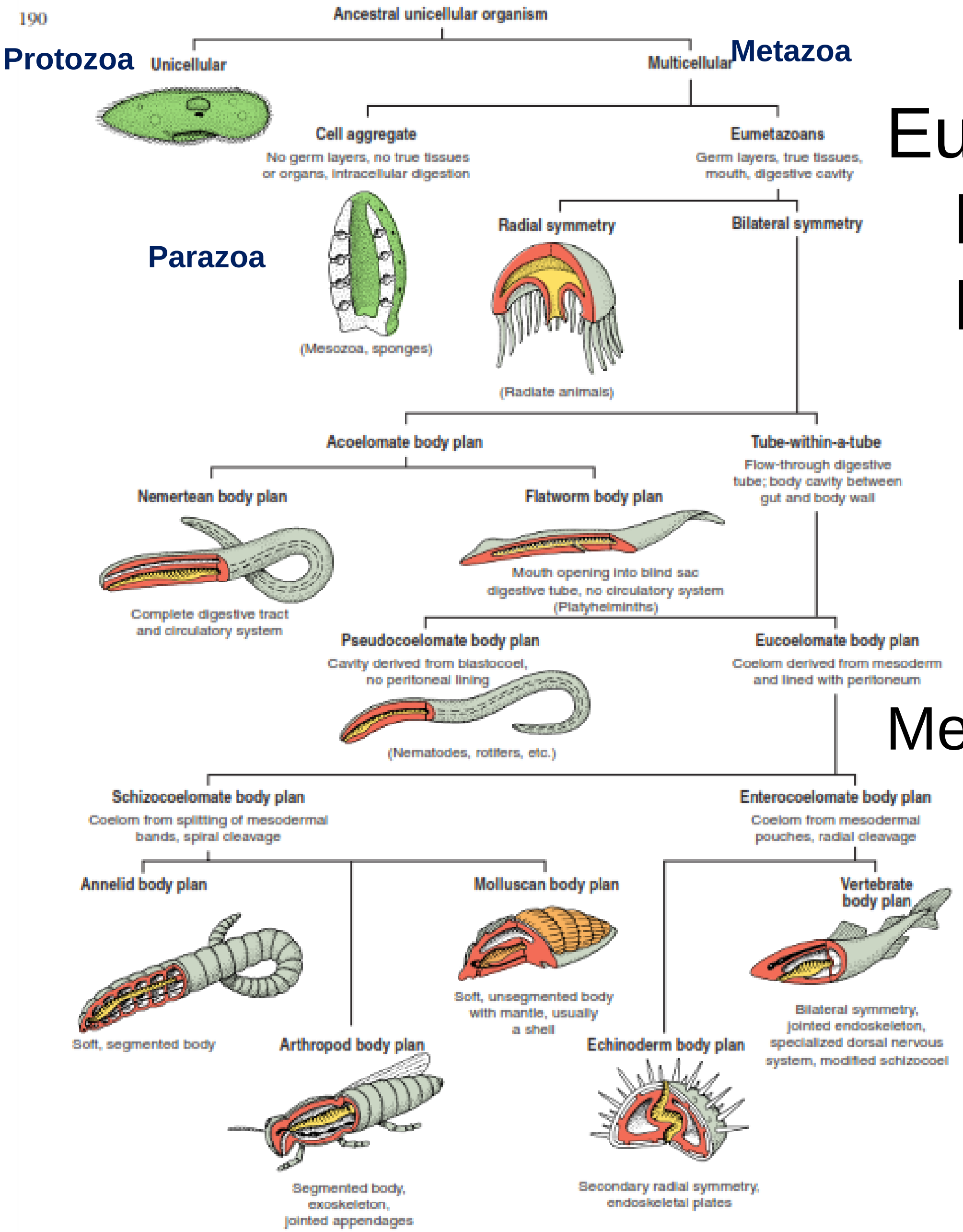


Figure 9-9

Architectural patterns of animals. These basic body plans have been variously modified during evolutionary descent to fit animals to a great variety of habitats. Ectoderm is shown in gray, mesoderm in red, and endoderm in yellow.

Eukaryotic «Animals»

Protozoa

Metazoa

Metazoa

Mesozoa Parazoa Eumetazoa

Parazoa

- Multi-cellular eukaryotic organisms
- Degree of organization between Protozoa and Metazoa
- Few types of cells not organized into tissues
- Absence of a nervous system
- Phylum Porofora and Phylum Plakozoa

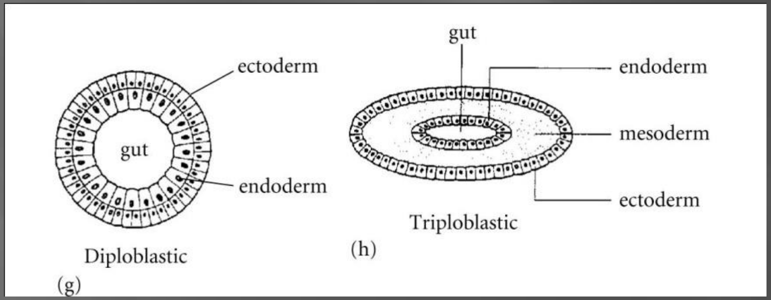
Eumetazoa

Radiata

- Diploblastic (two germ layers: ectoderm, endoderm)

Bilateria

- Triploblastic(three germ layers : ectoderm, mesoderm, endoderm)



- Cell to tissue grade of organisation

- Tissue to organ grade of organisation

Bilateria

ACOELOMATE

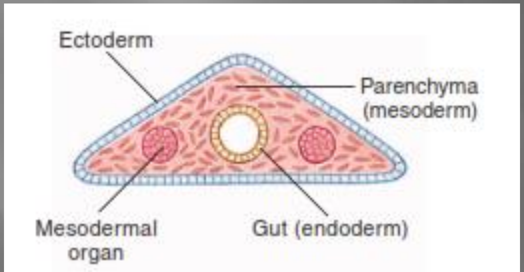
Without a true coelom

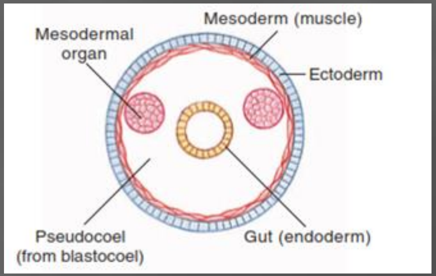
PSEUDOCOELOMATE

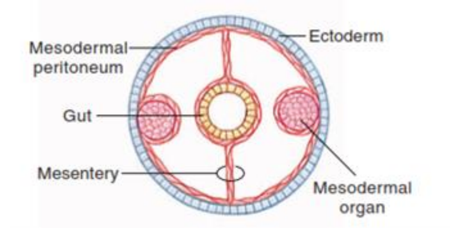
With a cavity surrounding the gut which is not lined with mesoderm

EUCOELOMATE

With a true coelom not lined with mesoderm







EUCOELOMATE

PROTOSTOMIA

- Blastopore (Mouth)
- Spiral cleavage
- Schizocoelous
- Ectodermal skeleton

DEUTEROSTOMIA

- Blastopore (Anus)
- Radial cleavage
- Enterocoelous
- Mesodermal skeleton

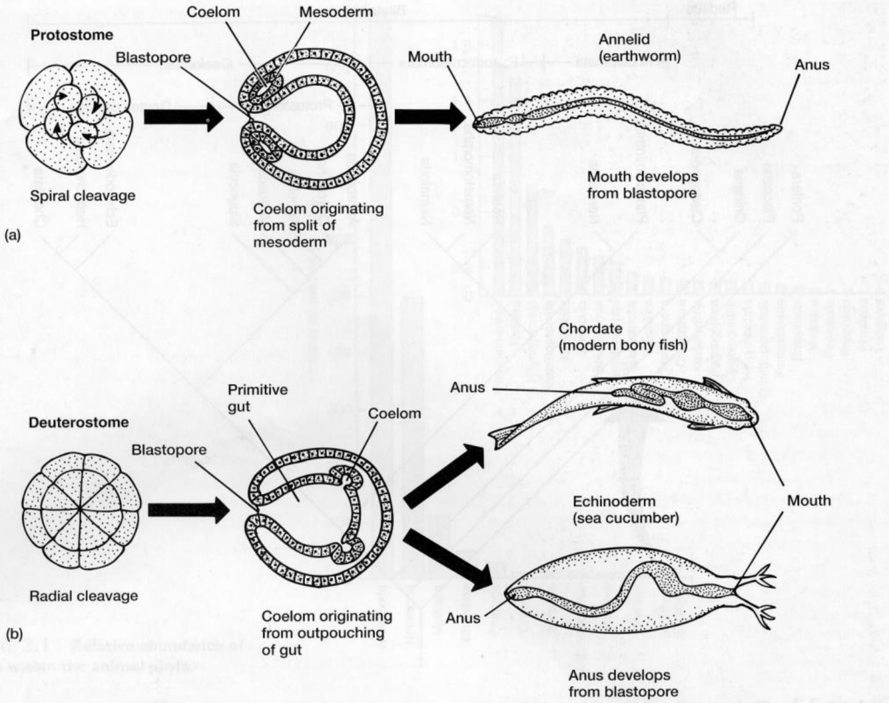


FIGURE 2.3 **Protostomes and deuterostomes.** Coelomates are divided into two major groups on the basis of embryonic characteristics. (a) Protostomes show spiral cleavage, coelom formation by splitting of the mesoderm, and derivation of the mouth from the blastopore. (b) Deuterostomes exhibit radial cleavage, coelom formation by outpocketing of the gut, and derivation of the anus from or in the vicinity of the blastopore.

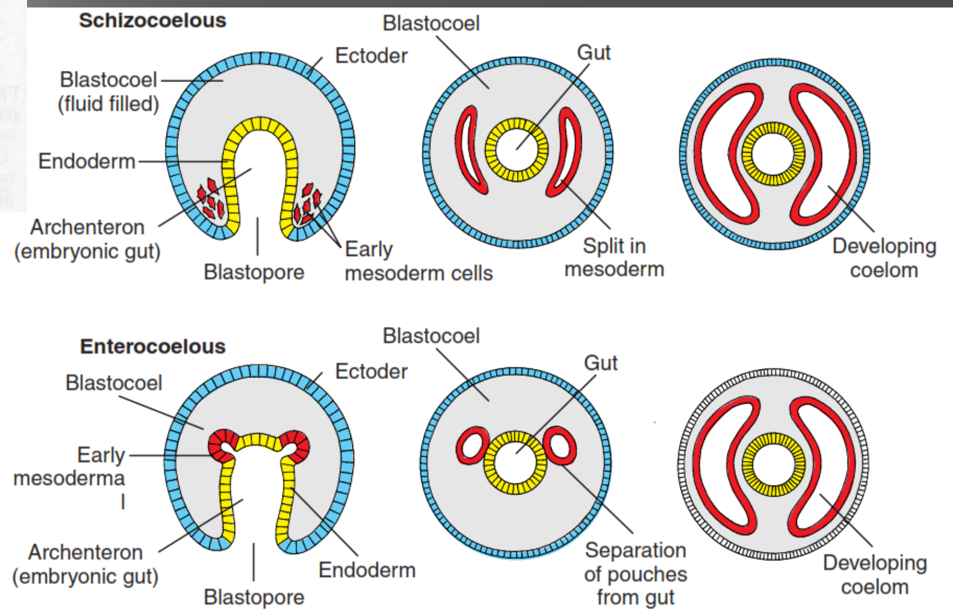
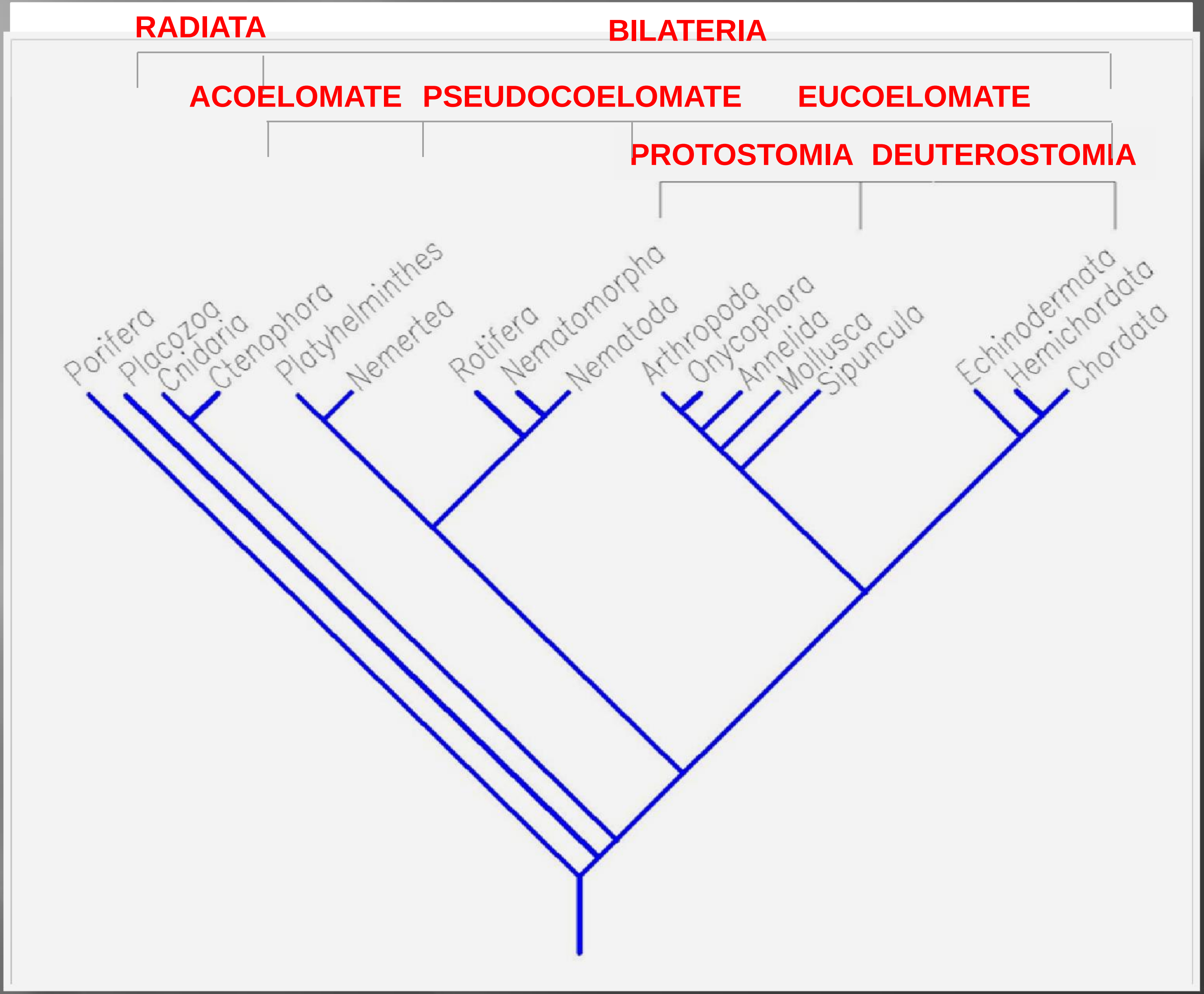
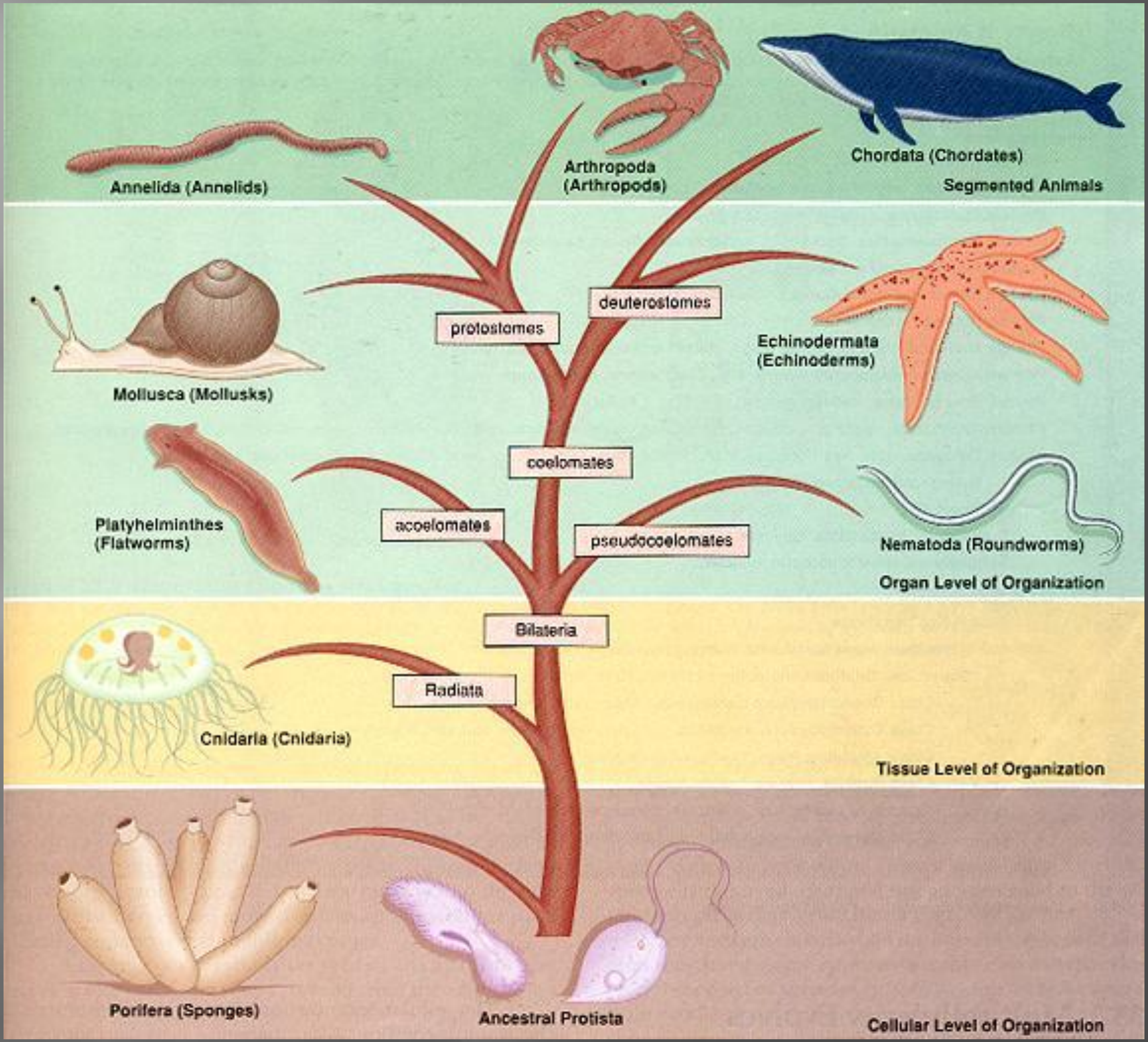


Figure 9-13

Types of mesoderm and coelom formation. In schizocoelous formation, the mesoderm originates from the wall of the archenteron near the blastopore and proliferates into a band of tissue that splits to form the coelom. In enterocoelous formation, most mesoderm originates as a series of pouches from the archenteron; these pinch off and enlarge to form the coelom. In both formations, the coeloms expand to obliterate the blastocoel.



Phylogenetic relations between the main animal taxonomic groups.


Arthropoda
(Arthropods)
Chordata (Chordates)
Annelida (Annelids)
Segmented Animals
deuterostomes
protostomes
Echinodermata
(Echinoderms)
Mollusca (Mollusks)
coelomates
Platyhelminthes
(Flatworms)
acoelomates
pseudocoelomates
Nematoda (Roundworms)
Organ Level of Organization
Bilateria
Radiata
Cnidaria (Cnidaria)
Tissue Level of Organization
Porifera (Sponges)
Ancestral Protista
Cellular Level of Organization

Invertebrates

- All Metazoa lacking vertebral column
- All other Phyla except the Subphylum Vertebrata which belongs to the Phylum Chordata
- They live in different environments
- They have a great variety in how they move and feed
- Plentiful as fossils, useful for biostratigraphic correlations
- They came from Protozoa

Porifera (sponges)

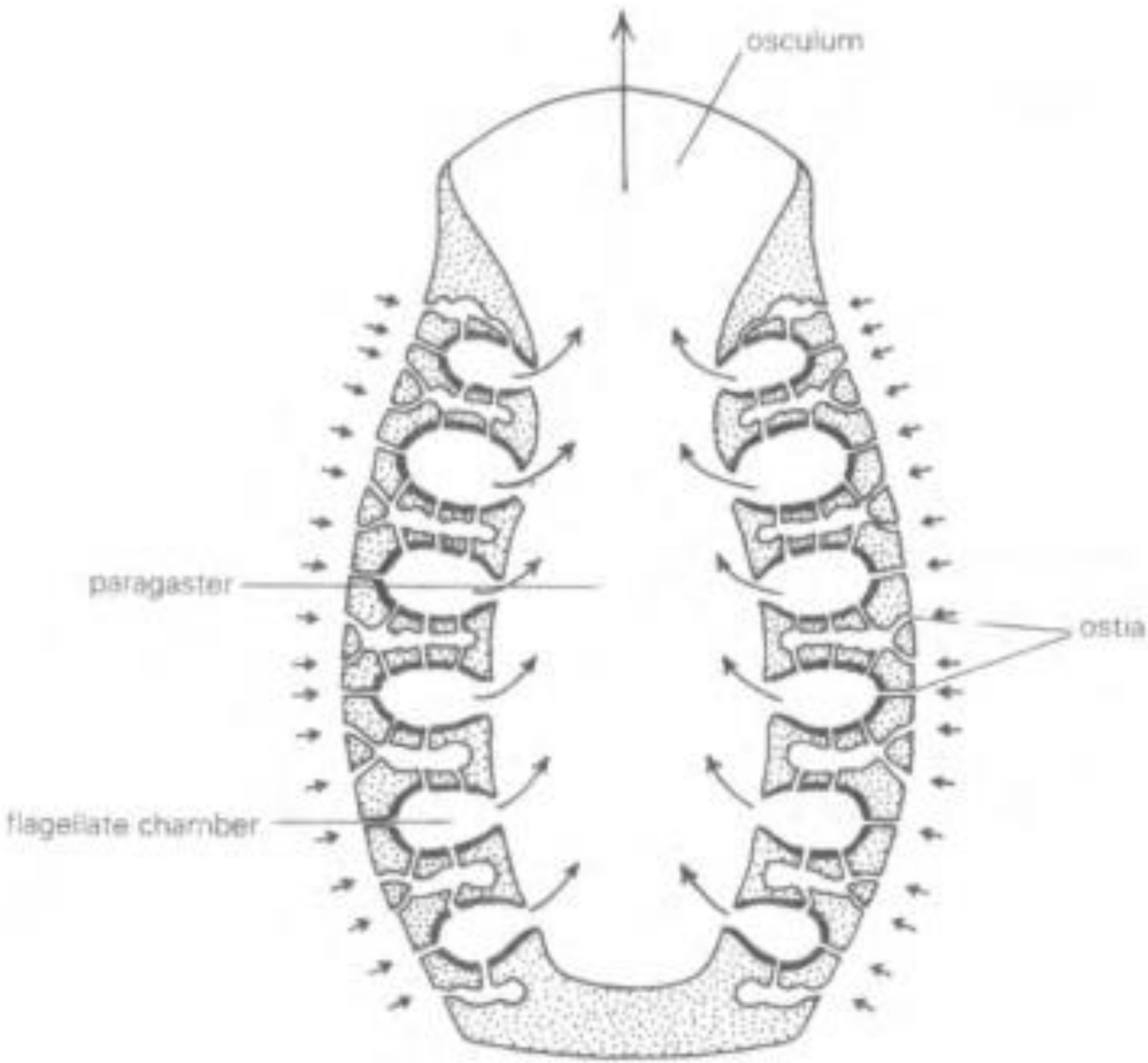
- They belong to Parazoa
- They came from a protozoan
  The only multicellular organisms that have choanocytes (such as flagellates)
  The osculum is not the largest cavity in the body
- A dead-end evolutionary line, as they are not ancestors of eumetazoa
- Possibility to regenerate body parts
- Size 1mm - 2m

Morphology

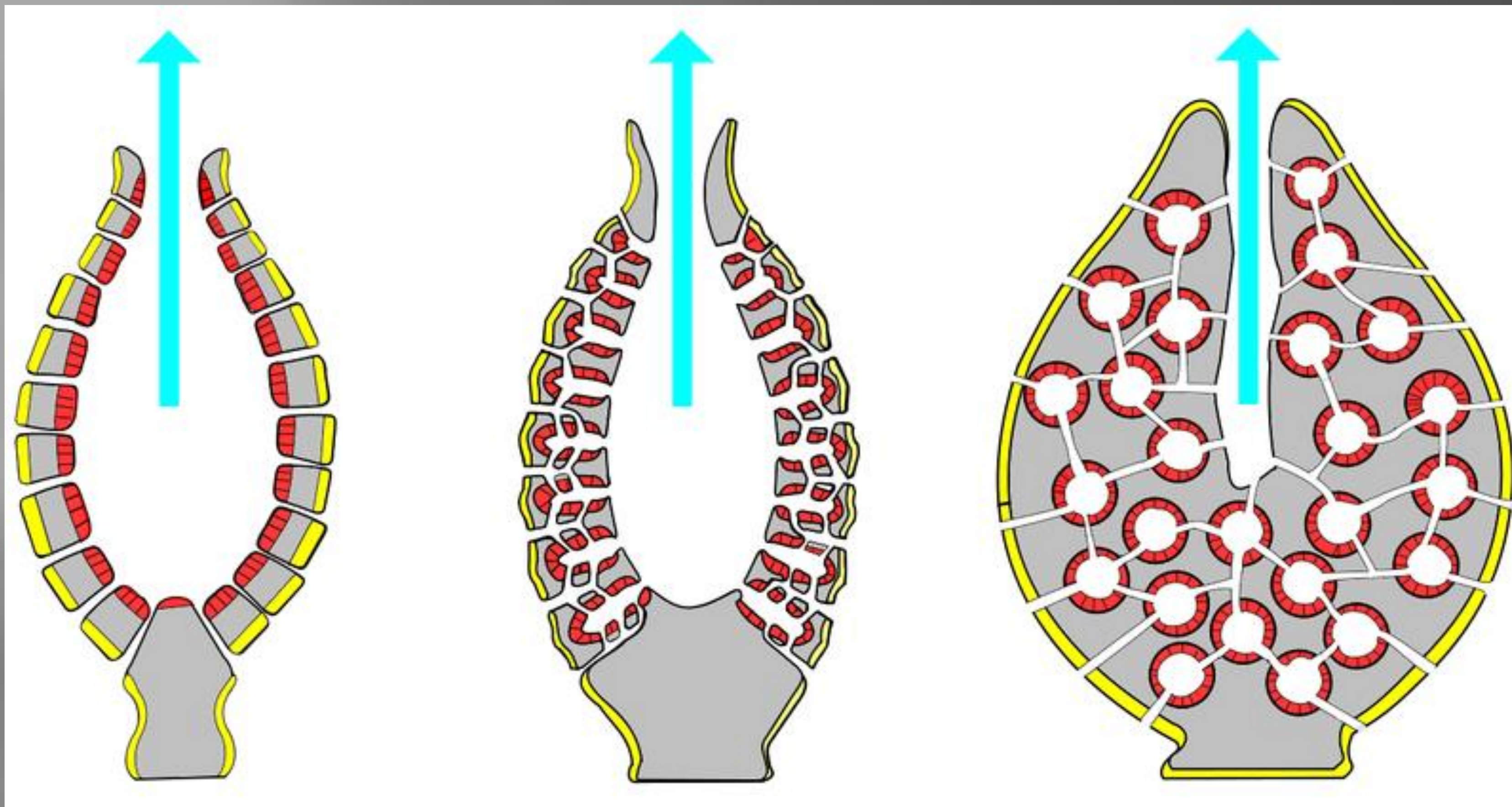
- It consists of a sack-shaped body with a central cavity the paragaster, open at the top at the osculum
- The outer surface is porous covered with pinacocytes
- The ostia communicate with incurrent canals with chambers within the sponge body which communicate with the paragaster and circulate the water
- The chambers and the paragaster are covered with chanocytes

Morphology

- Between outer surface and choanocytes mesenchymal substance with amobocytes the mesoglea or mesenchymal layer
- From amoeocyte differentiation we have food cells, sclerocytes (they secrete skeletal elements the spicules), spongocytes (produce spongin), archaeocytes (digest food particles and produce gemmules for reproduction)


osculum
paragaster
ostia
flagellate chamber

Body types



Askon **Sykon** **Leukon**

Body types

- Ascon: simplest type with a large paragaster lined with choanocytes (up to 10 cm)
  Sycon: advanced ascon with several chambers
  Leukon: the most sophisticated form that most sponges belong to. Individual sycon cavities communicate with the paragaster

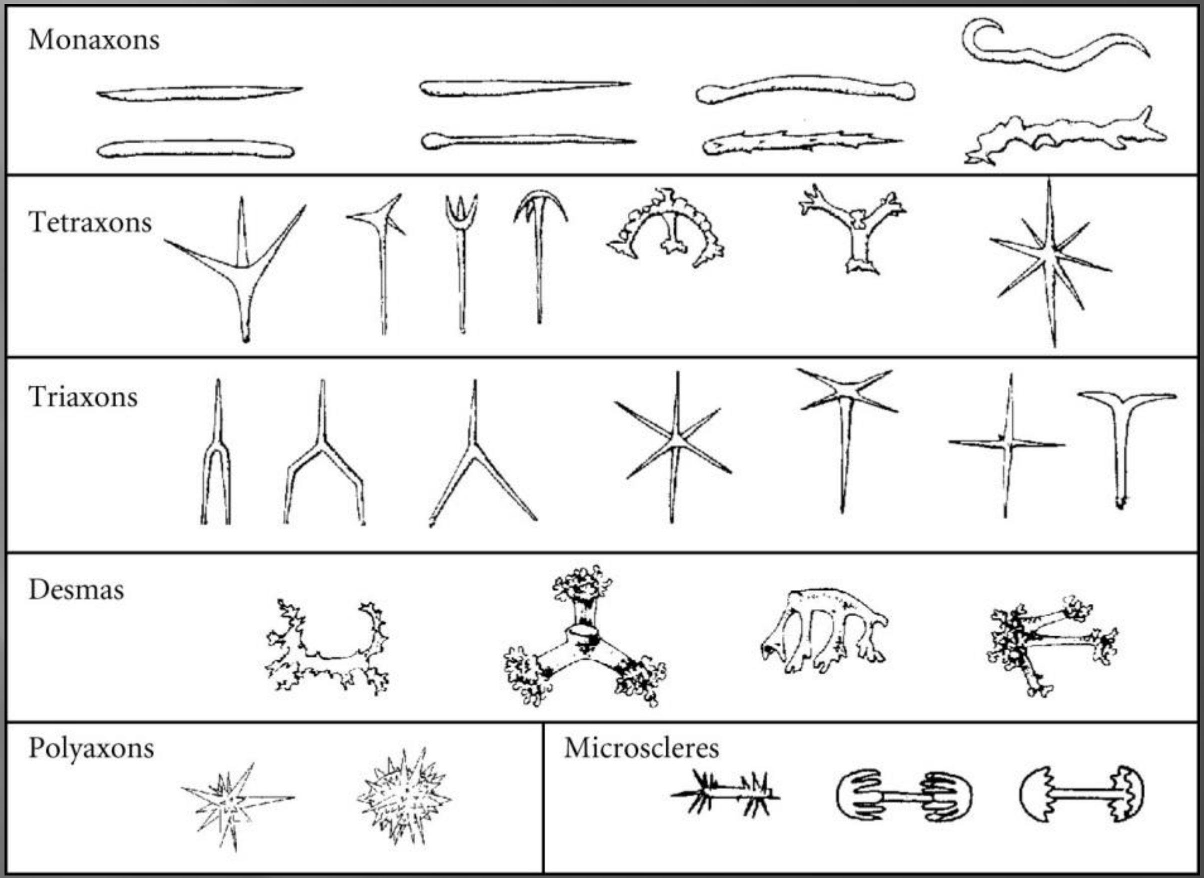
Skeleton

- Consists of:
  Spongin
  Calcareous spicules (calcite)
  Silicate spicules (amorphous silicon)
  Calcareous and Silicate spicules
  Silicate spicules and spongin
  Spicules and solid calcareous frame

Spicules

- Form
  - Single (monaxon)
  - Asteroid
  - Radial
  - Symmetrical
  - Irregular
  - Desmas
- Size
  - Megascleres (forming frames)
  - Microscleres (solitary)
  - 2mm – 2 cm
  - 20 – 50 cm in Hexactinellida

Spicules



Monaxons
Tetraxons
Triaxons
Desmas
Polyaxons
Microscleres

Classification

- Class Calcarea (Cambrian - Today)

  Monaxons, di-, tri-, or tetraxon calcareous spicules. Marine sponges of all three types.

- Hexactinellida (Early Cambrian - Today)

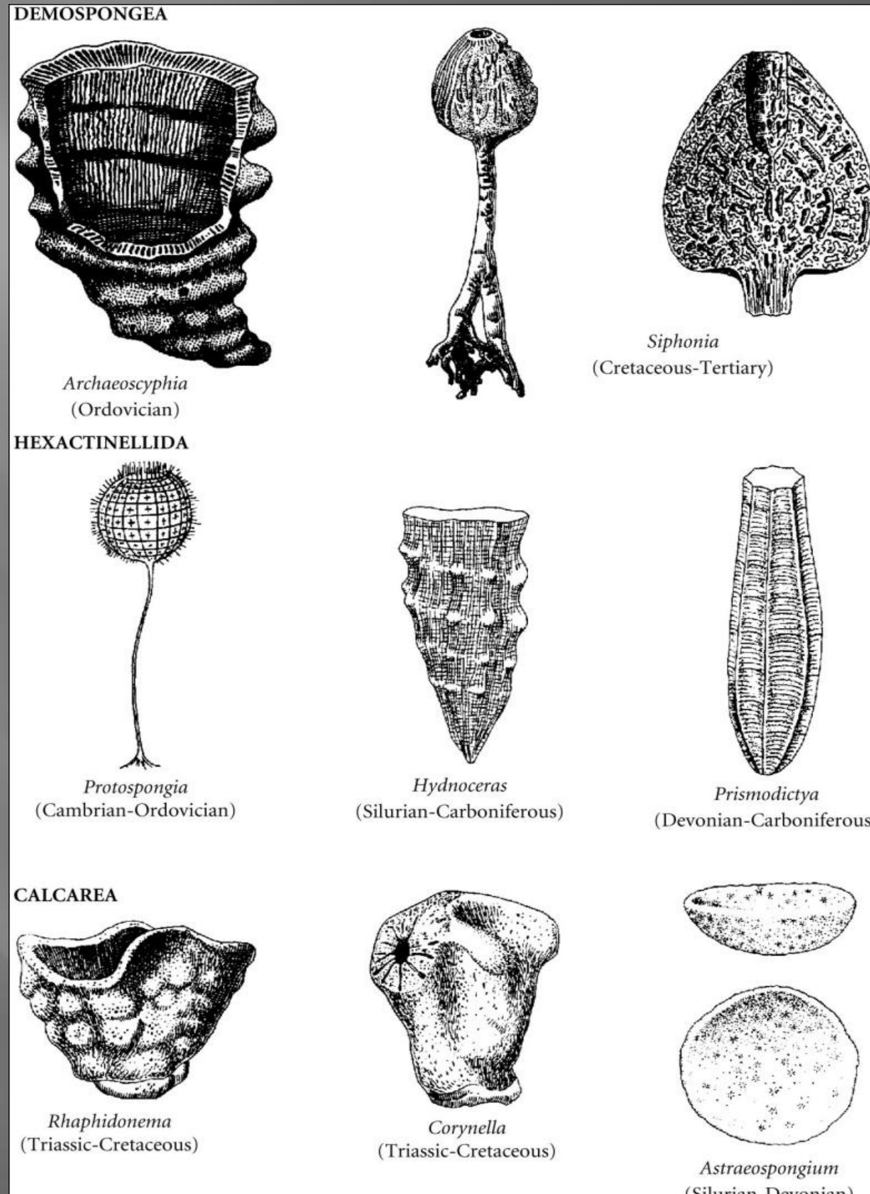
  Hexaxon silicate spicules interconnected forming frames. Body cylindrical or like a funnel. Deep water syconoid or leukonoid.

- Demospongiae (Cambrian - Today)

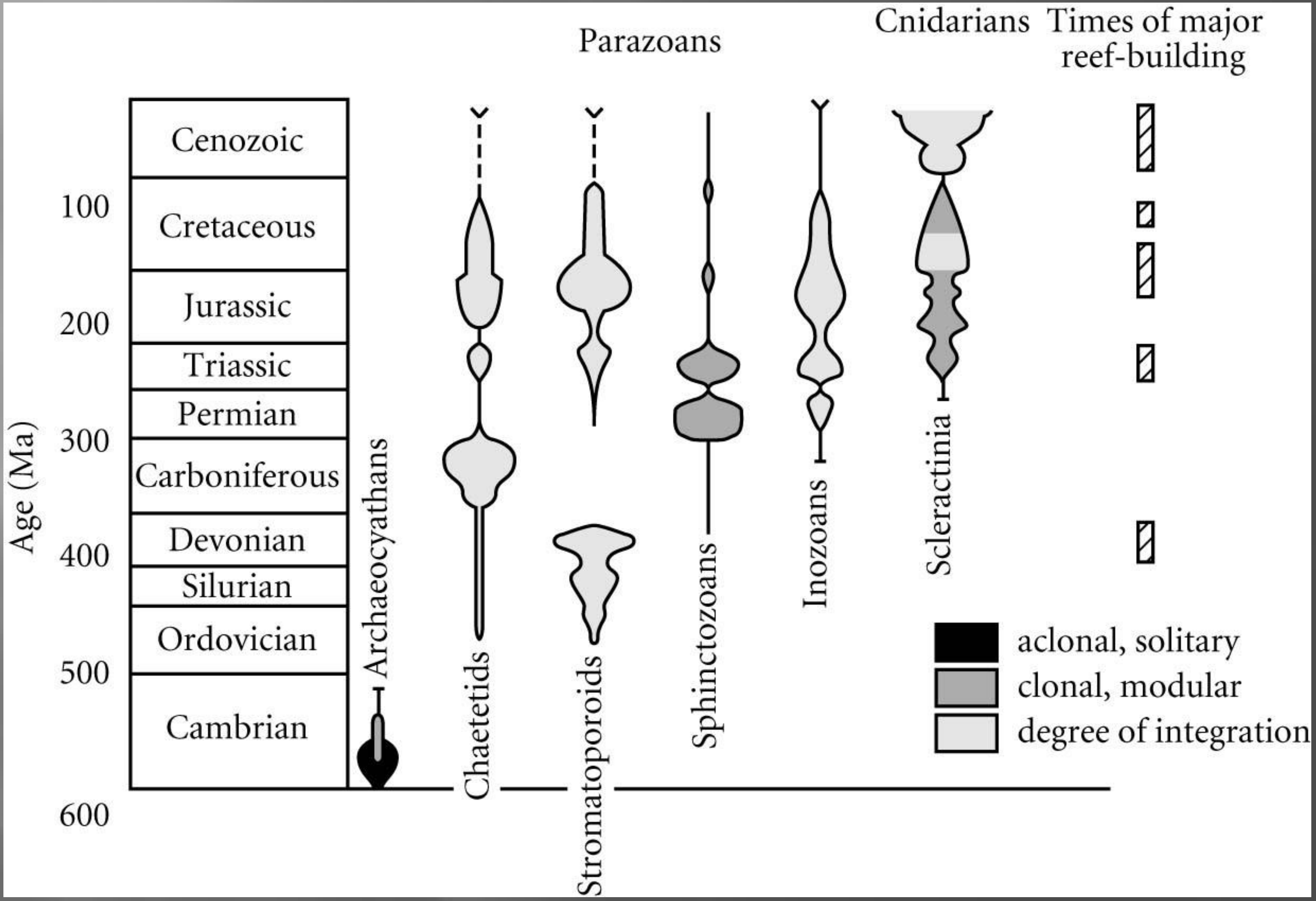
  Silicate spicules or spongin or both. Leukonoid. Marine sponges except the freshwater family Spongillidae

Demospongiae

1. Spicular (known only from spicules)
2. Sclerospongiae (aragonitic skeleton with silicate spicules and spongin)
3. Chaetetids (Recently included in sponges)
4. Stromatoporoids (calcareous skeleton with silicate spicules, recently included in sponges)
5. Sphinctozoans (irregular chambers around the paragaster)


DEMOSPONGEA
Archaeoscyphia
(Ordovician)
Siphonia
(Cretaceous-Tertiary)
HEXACTINELLIDA
Protospongia
(Cambrian-Ordovician)
Hydnoceras
(Silurian-Carboniferous)
Prismodictya
(Devonian-Carboniferous)
CALCAREA
Rhaphidonema
(Triassic-Cretaceous)
Corynella
(Triassic-Cretaceous)
Astraeospongium
(Silurian-Devonian)

Sclerospongiae



Parazoans
Cnidarians
Times of major reef-building
Age (Ma)
100
200
300
400
500
600
Cenozoic
Cretaceous
Jurassic
Triassic
Permian
Carboniferous
Devonian
Silurian
Ordovician
Cambrian
Archaeocyathans
Chaetetids
Stromatoporoids
Sphinctozoans
Inozoans
Scleractinia
aclonal, solitary
clonal, modular
degree of integration

Ecology

- Mostly marine organisms
  Sessile benthic
  They filter the food from the water
  Usually solitary in coastal or deep depth zones
  In the past they lived in colonies
  The Demospongiae in all the depths
  The Calcarea from the coastal to the deep (2200 m)
  Hexactinellida from the continental shelf to the abyssal zone, at depths of> 90 m and mainly > 200 m
  Several of them creators of reefs
  Today 1400 genera and 10000 species of sponges

Phylum Cnidaria

Cnidarians

- Cnidarians are the simplest of all true metazoans
- They are of an evolutionary grade higher than sponges since their cells are properly organized in tissues which are normally constructed on a radial plan (radial or biradial symmetry).
- The cell wall is diploblastic (cells organized in two layers); the outer ectoderm and inner endoderm, which have no body cavity between them but only a jelly-like structureless layer.
- In this mesogloea runs a simple nerve net, and no separate excretory or circulatory systems

Cnidarians

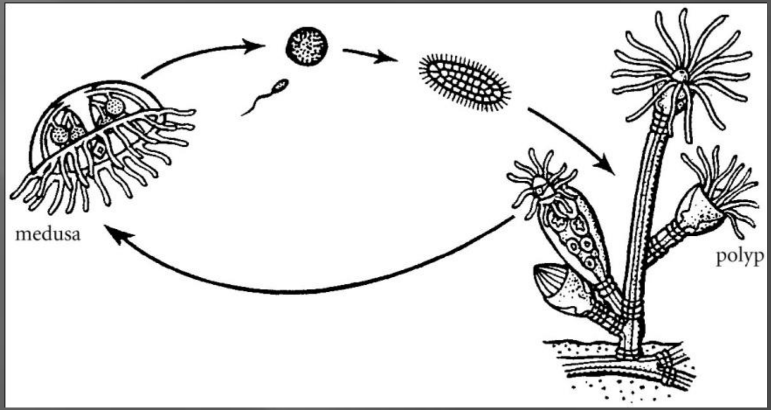
- The single body cavity (enteron) has only one opening, the mouth
- This also serves as an anus and is normally surrounded by a ring of tentacles.
- It is lined by endoderm which is sometimes infolded to form radial partitions or mesenteries, increasing the area over which digestion may take place, for the primary function of the endoderm is digestive.

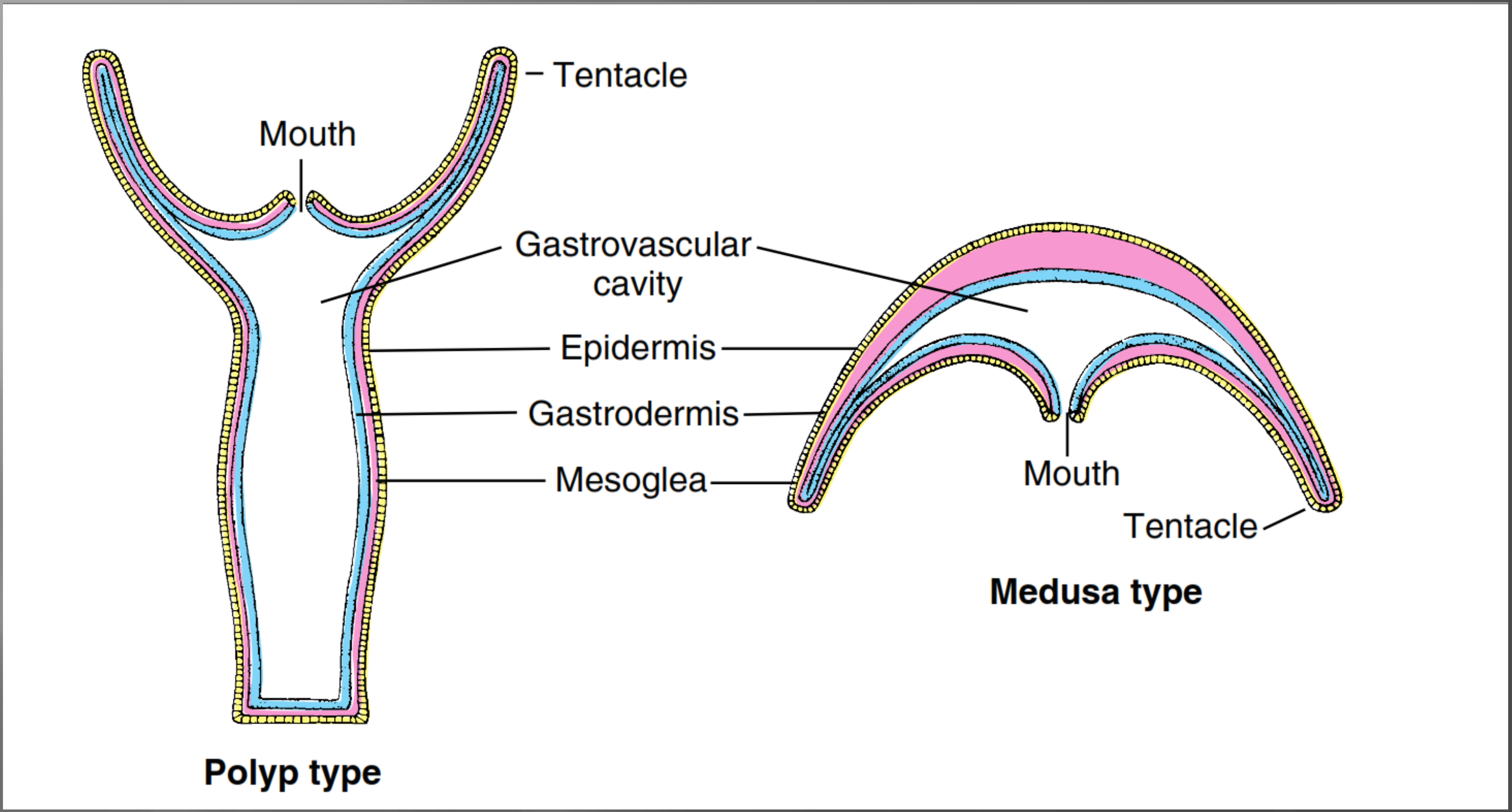
Cnidarians

- The cells of the ectoderm are more highly differentiated.
- the principal types are the musculoepithelial cells and there are also sense cells leading to the nerve net below.
- In addition there are ectodermal stinging cells, the nematocysts (large cells that contain poison). A small sensory hair on the outside of the nematocyst, the **cnidocil**, is sensitive to vibrations in the water, and when a small organism passes close to the cnidarian it triggers the nematocyst to discharge.
- the thread is shot out with great force, penetrating the prey so that it is injected and paralysed by the poison. Batteries of nematocysts are found on the tentacles, which all discharge together.
- The captured prey, held fast by the threads, is conveyed to the mouth as the tentacle then bends into it. Further transport of food is by mucus strings.

Ontogeny: polymorphism

- Cnidaria are characterized by a life-cycle in which successive generations are of different kinds.
- This alternation of generations or temporal polymorphism is typical of the less specialized Cnidaria but may be suppressed entirely in the more 'advanced' kinds.
- Two types of individual, the normally fixed polyp and the free swimming medusa, alternate successively so that the polyp gives rise asexually to medusae, which reproduce sexually so that their zygotes produce polyps, and so on




Tentacle
Mouth
Gastrovascular cavity
Epidermis
Gastrodermis
Mesoglea
Polyp type
Mouth
Tentacle
Medusa type

Major characteristics

- Today, corals, sea anemones, jellyfish and the small colonial hydroids are all representatives of Phylum Cnidaria.
- The first Cnidaria appeared in the Precambrian
- They may be solitary or colonial
- Common in warm shallow seas, although some can live as deep as 6000 m and as cold as 1^{o}C
- they are often polymorphic with alternate polyps and medusae.
- They might have either calcareous or organic skeletons (first lime-secreting corals in Ordovician)

Classification

- There are three classes:

  Class 1. Hydrozoa (Precam. - Rec.): Hydroids

  Class 2. Scyphozoa (Precam.-Rec.): Most large jellyfish.

  Class 3. Anthozoa (Precam.-Rec.): Corals, sea-anemones, gorgonians, sea-pens.

  Class 4. Cubozoa (Carboniferous-Rec.): Box jellyfish.

- In Class Scyphozoa the medusoid phase is dominant and the polypoid phase very reduced
- In Class Anthozoa the medusoid has been eliminated entirely and the polypoid phase has become the sexual generation

Class Anthozoa

- Anthozoa are polyps with no trace of a medusoid stage.
- Anthozoans are solitary or colonial, entirely marine cnidarians.
- Include corals, sea-anemones, gorgonians and sea-pens
- They always have a **tubular gullet** or **stomodaeum** leading down into the enteron, which hydrozoan polyps do not have.
- The interior itself is divided by radial partitions (**mesenteries**) whose number and morphology is important in the subdivision of the class.
- Those that secrete hard parts (especially the corals) are of great geological importance, often forming thick beds in the Palaeozoic
- From Tertiary time onwards true coral reefs of vast thicknesses have formed, and corals living as reef formers are probably more important now than at any other time.

Class Anthozoa

- Anthozoans are grouped in three subclasses:

1. Ceriantipatharia
2. Octocorallia
3. Zoantharia

- SUBCLASS CERIANTIPATHARIA

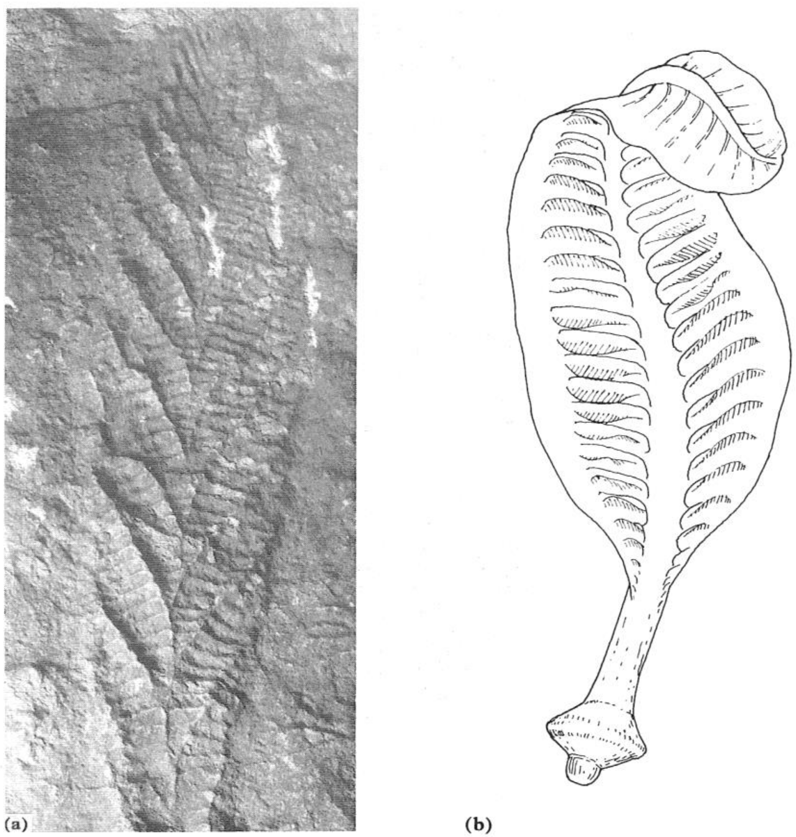
  They are solitary or colonial polyps which for morphological reasons are placed apart from other groups. They are virtually unknown as fossils.
- SUBCLASS OCTOCORALLIA

  Octocorallia (?Precam., Ord. - Rec.), poorly known as fossils

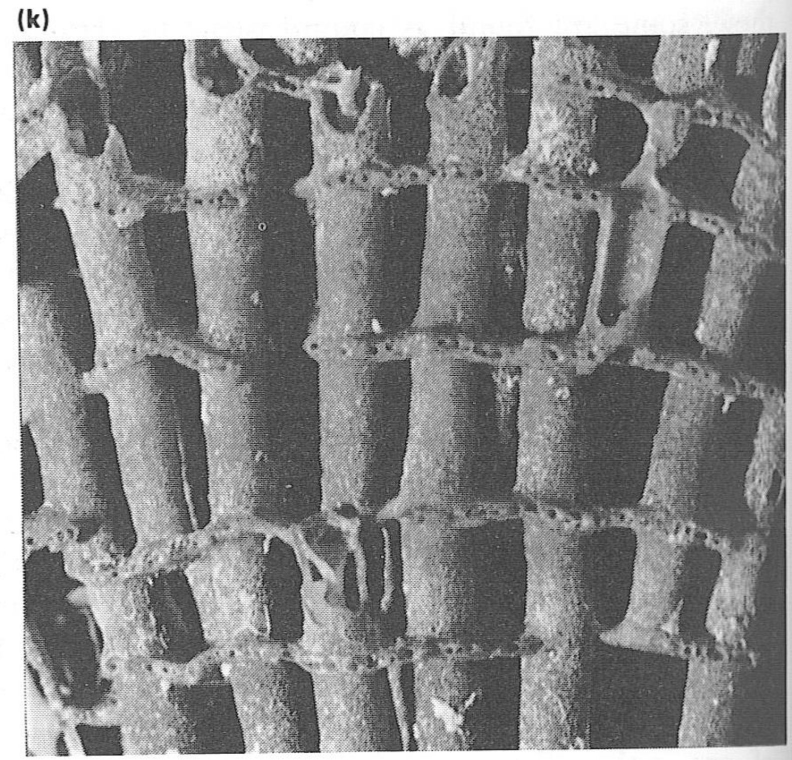
  the gorgonians (Order Gorgonacea) common in many modern coral reefswhere the colony forms a flat fan of anastomosing branches of tubes

  The sea-pens (Order Pennatulacea) are another kind of octocoral. Here the colony has the form of a feather, the base of which is set in mud while the feathery upper branches are lined with autozooids.

  The Ediacaran *Charniodiscus* has usually been interpreted as a sea-pen and if so indicates early success for this group



77 **Possible sea-pen fossils.**
a, *Charnia*, Precambrian (Charnian), Charnwood Forest, Leicestershire (× 0.7).
b, *Charniodiscus*, a reconstruction by M.F. Glaessner.



Recent *Gorgonia*

Subclass Zoantharia: Corals

- Six orders are now defined

1. Rugosa (M. Ord.-U. Perm.)
2. Tabulata (L. Ord.-U.Perm.)
3. Scleractinia (Trias.-Rec.)
4. Heterocorallia (U. Dev.-L. Carb.)
5. Cothomida (M. Cam.)
6. Kilbuchophyllida (U. Ord.)

Rugosa

- The Rugosa are an **exclusively Palaeozoic group** (Mid-Ordovician-Permian)
- Nearly went extinct in Late Devonian
- solitary and colonial (compound) corals
- Mostly attached to soft substrates, half sunk in mud
- Primitively they show bilateral symmetry, arising because the numerous meta-septa are inserted in four loci alone

morphology

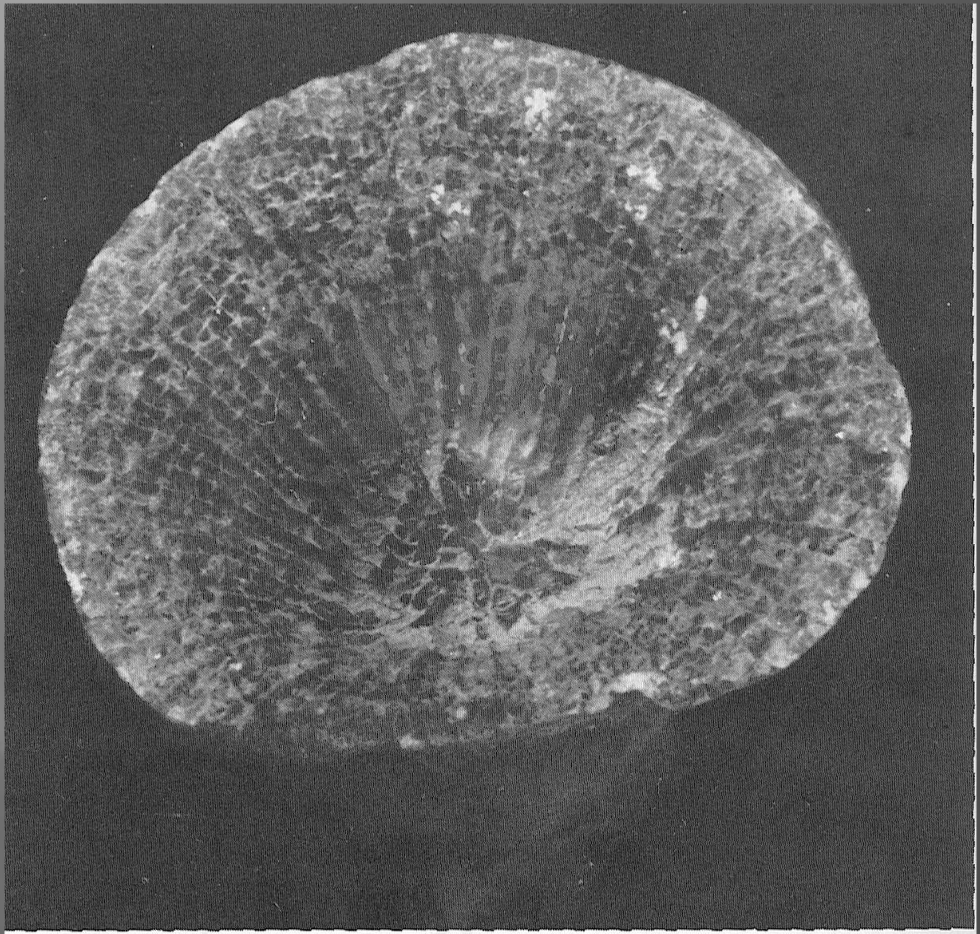
- The enteron is divided biradially by numerous mesenteries.
- The soft basal tissues secrete an aragonitic cup or **corallum** which is short and horn-shaped.
- It has an outer, thin calcareous wall (**epitheca**) which extends from the tip to the upper (distal) surface or **calice**
- In the epitheca numerous radially arranged septa lie between the paired mesenteries.
- Except from vertical, radial septa there are horizontal elements, the **tabulae** and the **dissepiments**, which are important in some Rugosa

Zaphrentites

Εικόνα 10:Zaphrentites phrygia, M. Devonian, Ohaio, Calice

Εικόνα 11:Zaphrentites phrygia, M. Devonian, Ohaio,

Calice



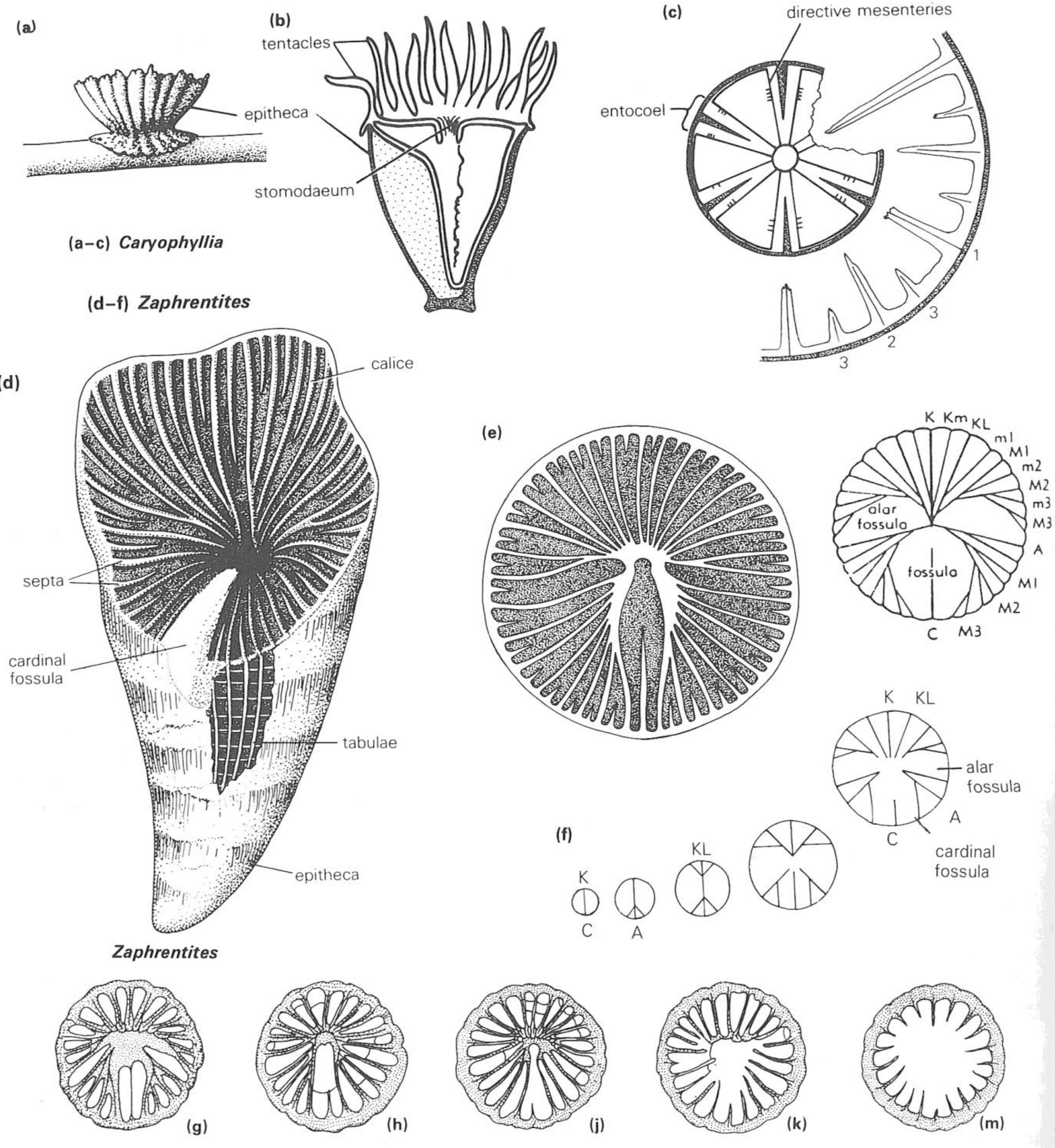
64 Calice of a solitary rugose coral.

The septa

- The septa are thin vertical plates arranged in a characteristic biradial pattern, which develops to maturity throughout the ontogeny of the coral.
- The first-formed **protosepta** are larger and more pronounced than the **metasepta** intercalated between them
- Their manner of insertion can be studied by investigating the ontogeny of the coral from the early stages; this is usually done by making serial sections normal to the axis, from the tip to the calice, and arranging them in a successional series.
- When young a single proseptum divides the corallum into **cardinal** (C) and **counter** (K) prosepta
- Two other pairs of prosepta follow: the **alar** (A) adjacent to the cardinal septum, and the **counter-lateral** (KL).

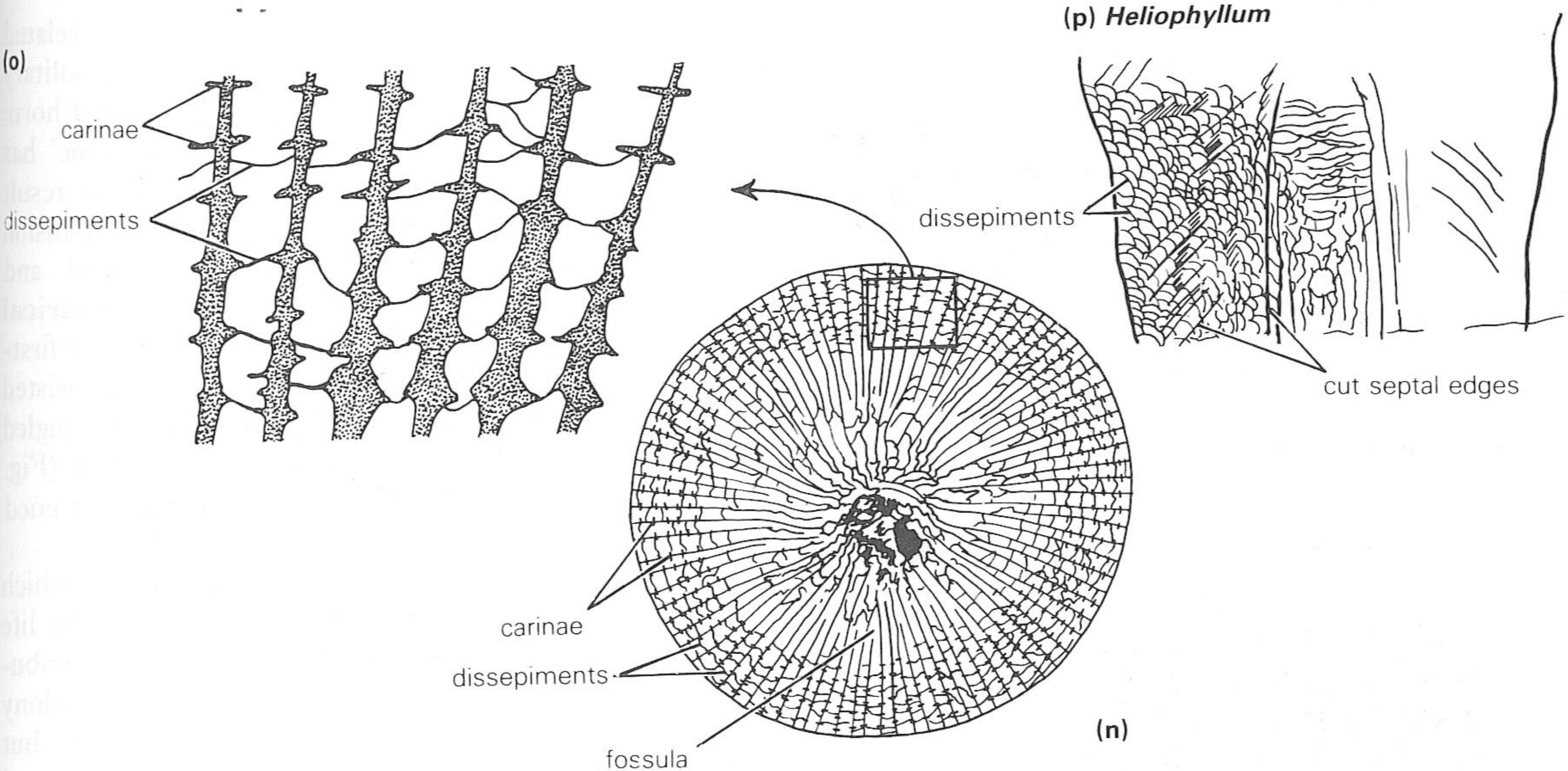
The septa

- The metasepta are inserted serially in four quadrants only, on the 'cardinal' side of the alar and counter-lateral septa.
- Through differential growth the counter-lateral and alar septa move towards the counter-septum to make room for new metasepta.
- Short minor septa (second-order metasepta) are laid down between the first-order metasepta.
- Around the cardinal septum there is a **cardinal fossula** where metasepta are not inserted, and especially during the intermediate growth stages there are lateral (alar) fossulae as well.


(a)
(b)
(c)
directive mesenteries
tentacles
epitheca
entocoel
stomodaeum
1
3
2
3
(a–c) Caryophyllia
(d–f) Zaphrentites
(d)
calice
septa
cardinal fossula
tabulae
epitheca
(e)
K Km KL
m1
M1
m2
M2
m3
M3
A
M1
M2
M3
C
alar fossula
fossula
K KL
alar fossula
A
C
cardinal fossula
(f)
K
C
A
KL
Zaphrentites
(g)
(h)
(j)
(k)
(m)

Tabulae and dissepiments

- Tabulae are flat horizontal plates forming a floor to the cavity in which the polyp resided.
- The major septa join together in a central boss formed of updomed tabulae.
- the dissepiments are concentrated in a broad marginal zone or dissepimentarium
- These are small curving plates located between the septa and set normal to them, inclined downwards at about 45° to the epitheca.
- Another characteristic feature is the presence of carinae: short bars projecting laterally from the septa.


(o)
carinae
dissepiments
(p) Heliophyllum
dissepiments
cut septal edges
carinae
dissepiments
fossula
(n)

Form of corallum

- In solitary Rugosa the usual shape is a curved horn
- If the 'cone' has expanded very fast, a flat **discoidal** shape may result
- with progressively less abrupt expansion **patellate**, **turbinate**, **trochoid** and **ceratoid** forms will be the product
- **Cylindrical** corals are virtually straight-sided, except for the first-formed part
- **scolecoid** forms are irregularly twisted cylinders
- **pyramidal** types have sharply angled sides
- In **calceoloid** genera, possess a curved corallum with one flattened side and a lid or **operculum**.

Type of corallum

- Colonial Rugosa are those in which a single skeleton (corallum) is produced by the life activities of numerous adjacent polyps each contributing a **corallite** to the whole.
- The habit of the colony may be variably influenced by the environment, but colony type, which includes the morphology and relations of the corallites, is more rigidly defined genetically.
- In the **fasciculate** type the corallites are cylindrical but not in contact.
- There are two kinds of fasciculate morphologies: **dendroid**, with irregular branches

  phaceloid, in which the corallites are more or less parallel and sometimes joined by connecting processes.

- **Massive** corals are those in which the corallites are so closely packed as to be polygonal in section. Several kinds of massive corals are distinguished:

1. **cerioid**, in which each corallite retains its wall
2. **amural**, in which the corallite walls are wholly or partially lost but the septa stay unreduced
3. **thamnasterioid** , in which the septa of adjacent corallites are confluent and often sinuous or twisted
4. **aphroid**, where the septa are reduced at their outer ends so that neighbouring corallites are united by a zone of dissepiments alone
5. **indivisoid**, in which septa are absent and dissepimental material is dominant (very uncommon)

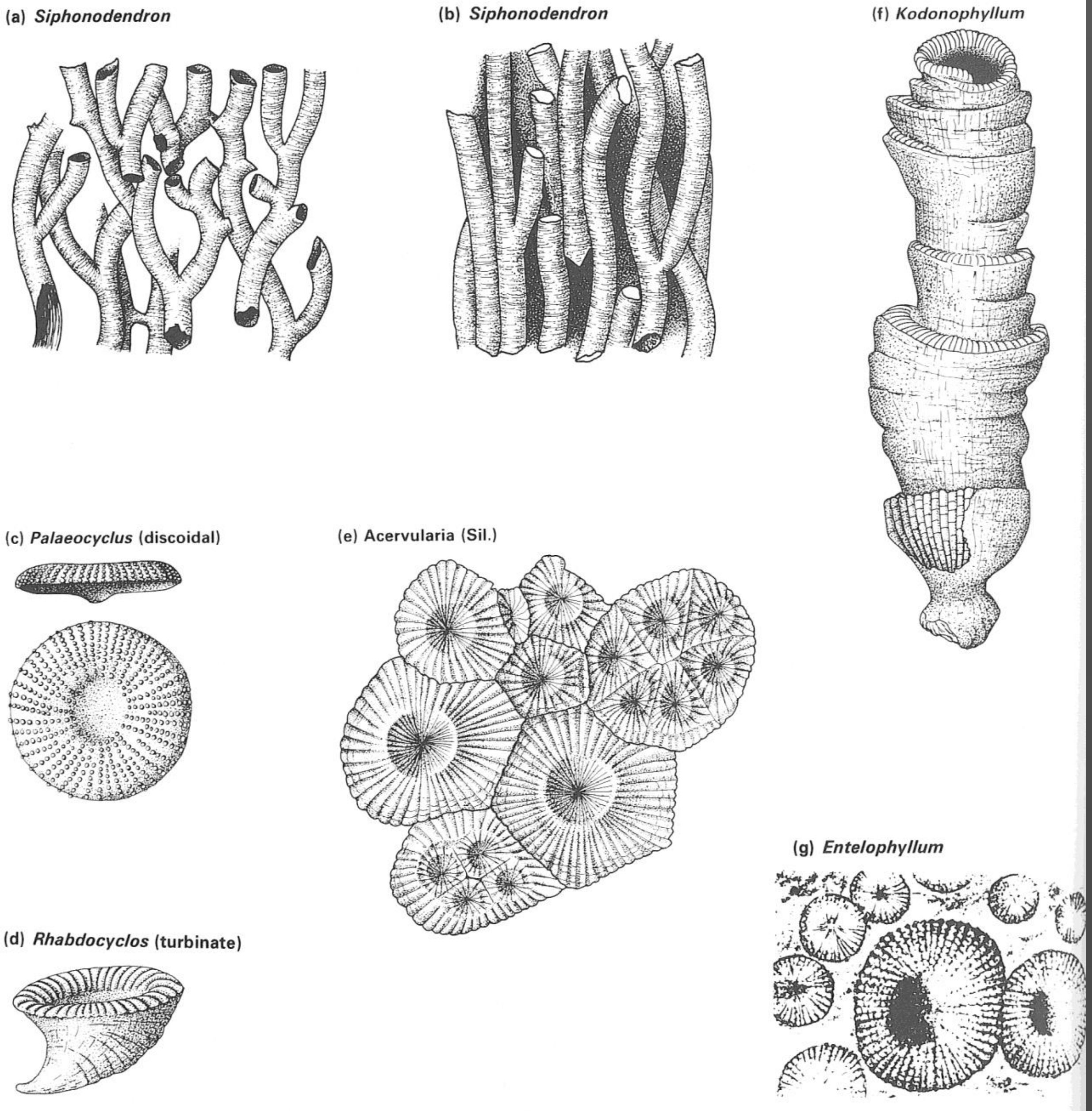


Figure 5.7 Form of corallum in Rugosa: (a) *Siphonodendron*, fasciculate dendroid; (b) *Siphonodendron*, phaceloid; (c) *Palaeocyclus* (Sil.), discoidal; (d) *Rhabdocyclus*, turbinate form; (e) axial increase in ceriod Silurian *Acervularia*; (f) rejuvenescence in Silurian *Kodonophyllum*; (g) offsets in Silurian *Entelophyllum*. (Mainly redrawn from Milne-Edwards and Haime 1850)

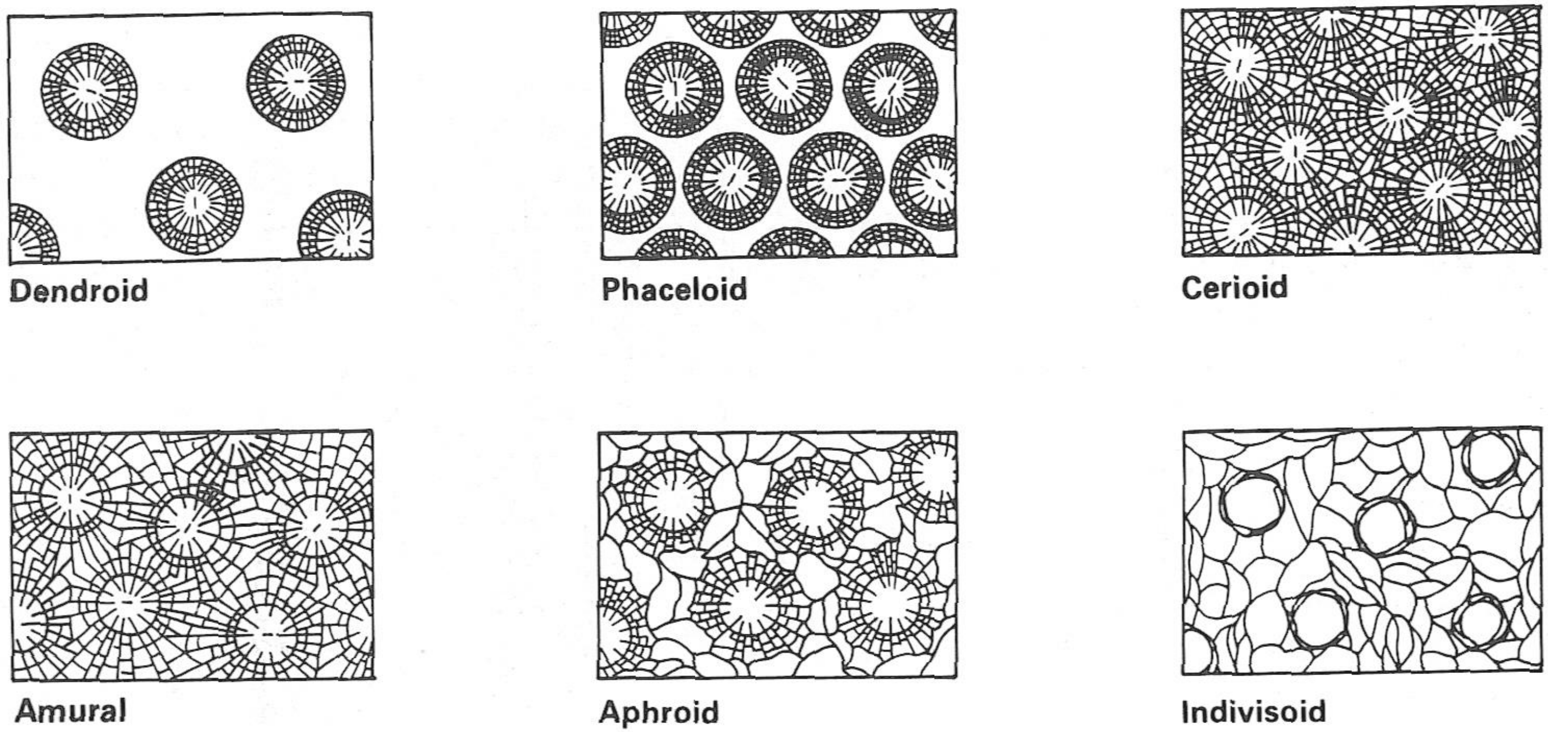
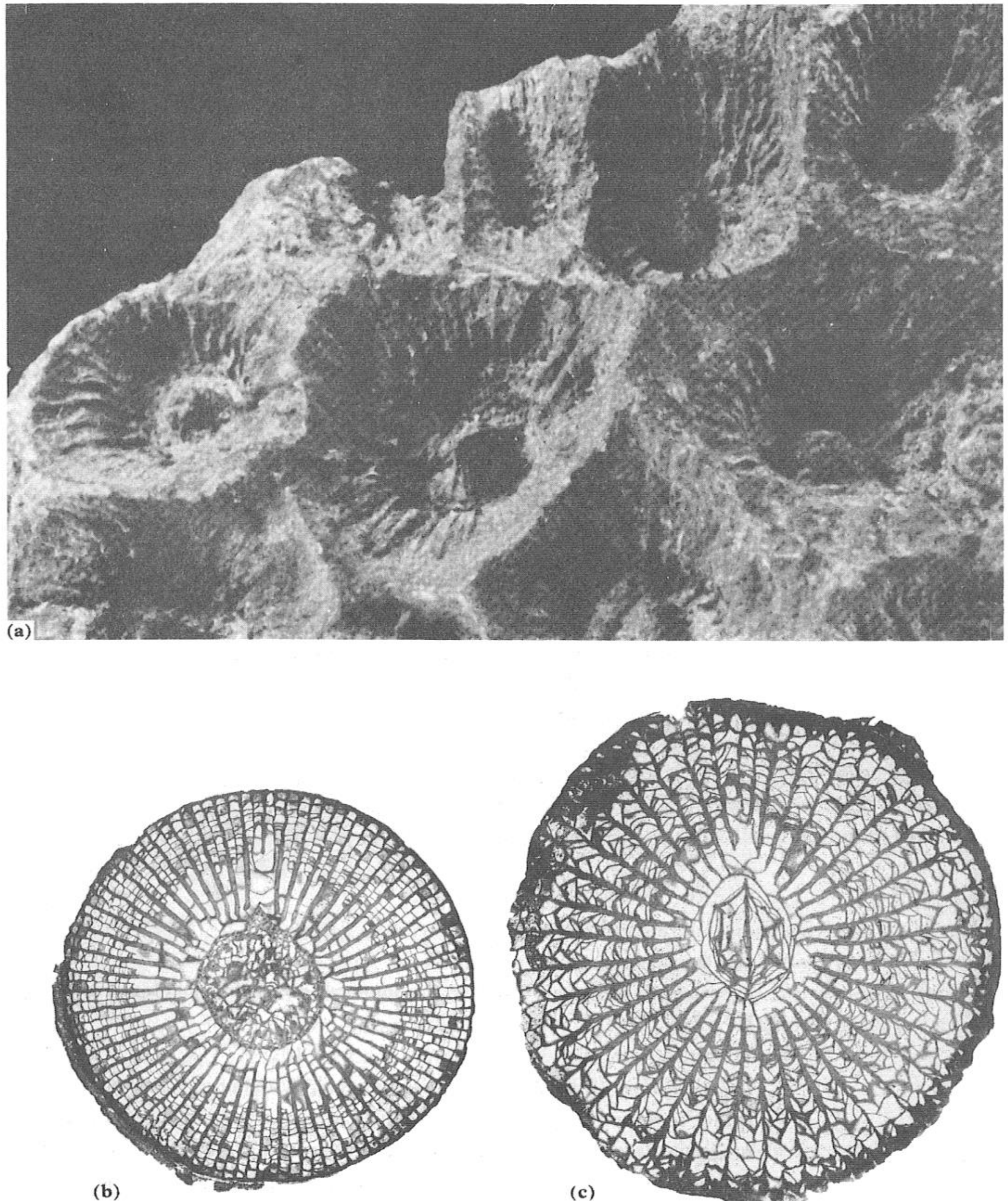
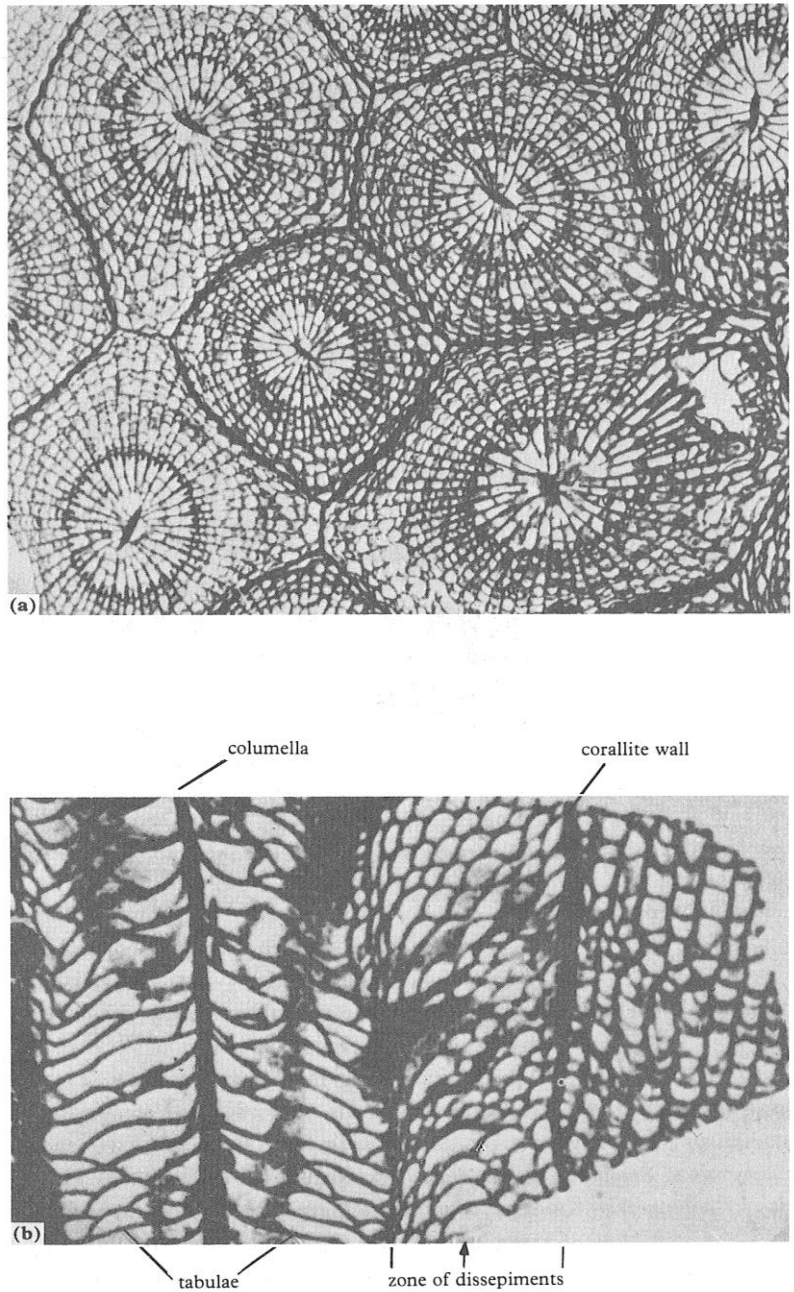


Figure 5.5 Transverse sections through compound Rugose coral colonies, with terminology of different types



69 Corals.

a, *Actinocyathus*, upper surface (× 4). b, *Aulophyllum*, transverse section (× 3). c, *Dibunophyllum*, transverse section (× 3). All from L Carboniferous. (Specimens in Sedgwick Museum.)

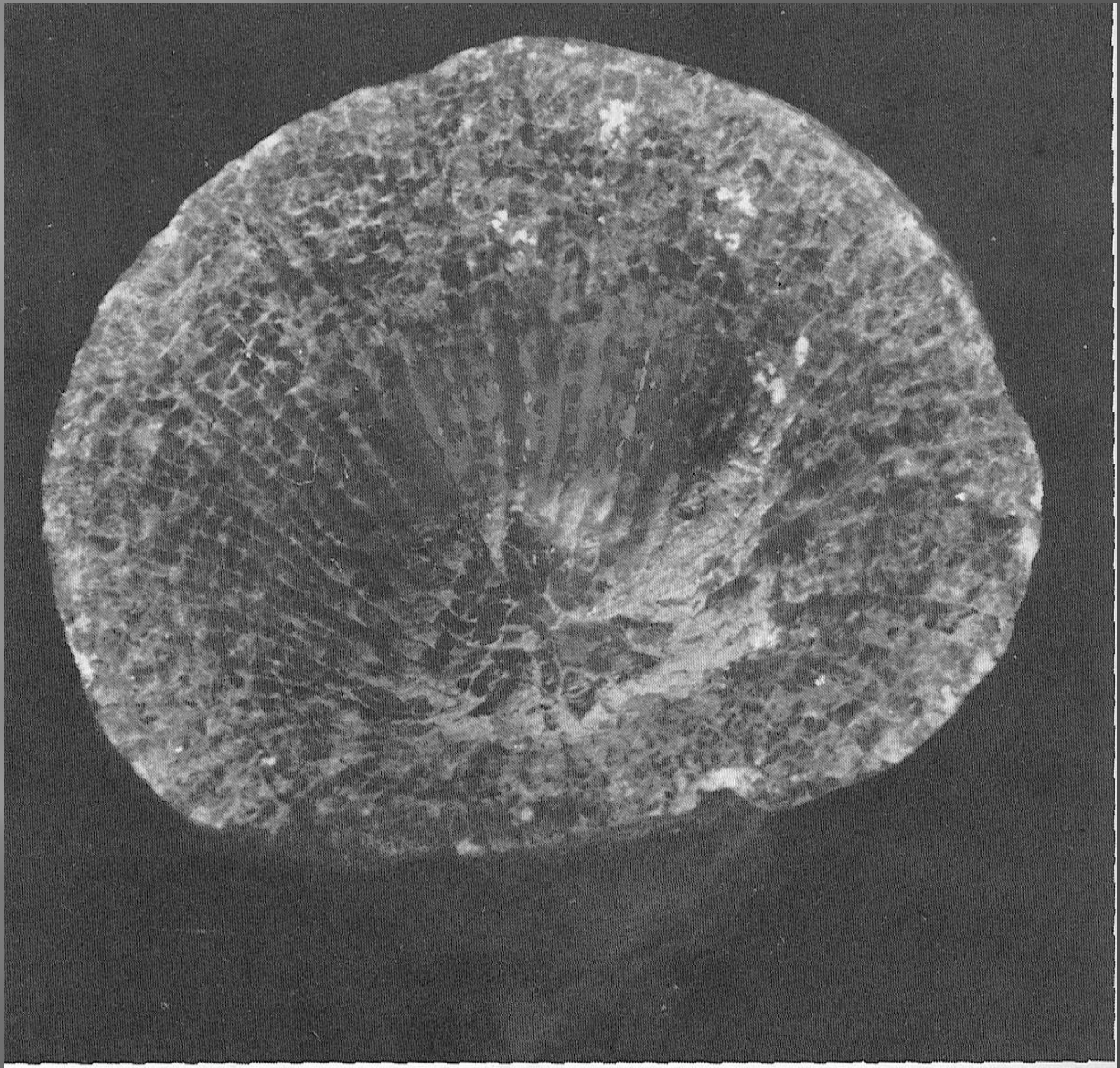


67 ***Lithostrotion*, L Carboniferous, cerioid form.**

a, a transverse section (× 3.5). b, a longitudinal section (× 5.5).

calice

- The **calice** is that part of the coral which, in life, was in contact with the basal ectoderm of the polyp.
- It is in effect a mould of the secretory surface.
- It is not commonly seen in specimens preserved in limestones unless these have been weathered, but in individuals collected from shales calicular surfaces can often be clearly seen.
- Usually there is an annular calicular platform surrounding a deep central depression (calicular pit).
- Some genera with an axial complex have a marked calicular boss where it emerges to the surface, but this is not always present. The form of the calice is quite variable even within families



64 Calice of a solitary rugose coral.

Budding and increase

- When a compound coral grows the first-formed protocorallite gives rise asexually to offsets, which may form in a number of ways.
- budding is used for the soft parts,
- increase for the skeleton.
- three main methods of increase and budding:

1. Axial increase
2. Peripheral increase
3. Lateral increase

Tabulata

- The tabulate corals are also entirely **Palaeozoic**,
- though they appear a little earlier (Cambrian or Lower Ordovician) than the Rugosa they have an otherwise similar time range.
- Nearly went extinct in Late Ordovician and Late Devonian
- They are always colonial, never solitary, and usually their corallites are small
- Invariably they have prominent tabulae, but other skeletal elements, in particular the septa, are reduced or absent.
- Having relatively few structural elements, the Tabulata are of comparatively simple construction.

form of corallum

- The corallum (colonial skeleton) is built up by individual polyps which may or may not be directly connected to each other.
- **Cerioid** forms have polygonal corallites all in contact.
- **Cateniform** colonies have elongated corallites joined end to end in wandering palisades.
- **Fasciculate** tabulates have cylindrical corallites which may be dendroid or phaceloid and may be provided with connecting tubules.
- **Auloporoid** genera have a branching tubular structure and often an encrusting creeping habit. They usually encrust hard substrates but are sometimes free living.
- **Coenenchymal** types, characteristic of the more advanced tabulates have no dividing walls between the corallites but instead a common mass of complex tissue, the coenenchyme, deposited by a common colonial tissue (coenosarc) in between the polyps and forming a dense calcareous mass in which the corallites are embedded.
- Other tabulates may be massive, foliaceous (in which habit the coral forms thin overlapping laminar sheets) or creeping.

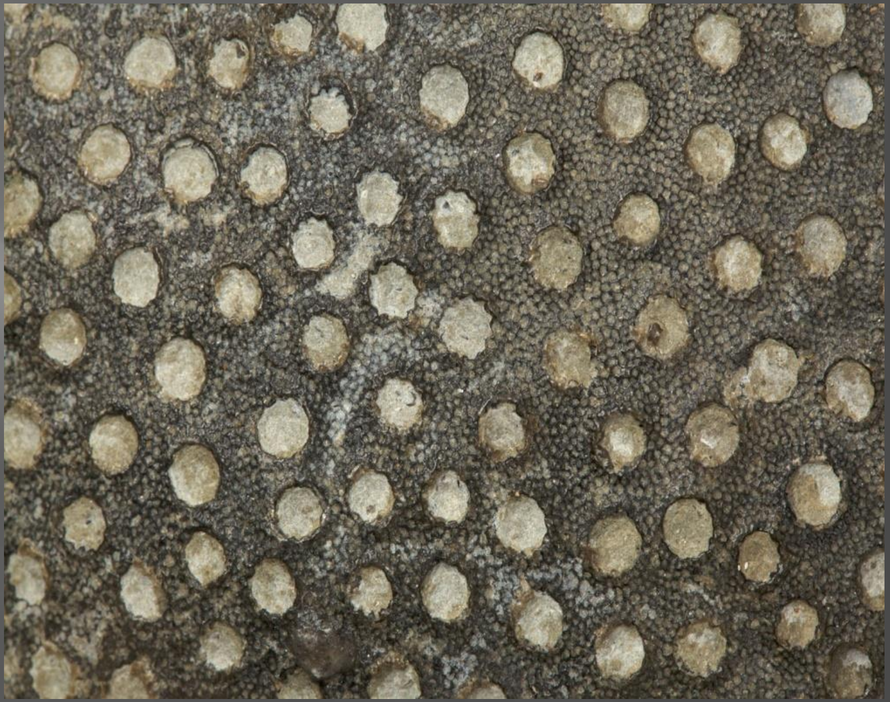
skeletal elements

- **Tabulae**, are the most important skeletal elements, are always present and commonly traverse the corallite horizontally.
- Sometimes they are replaced by smaller **tabellae**.
- Septa in tabulates are rarely more than short spines, often 12 in number, but in some cases they do reach the centre of the corallite.
- Septal insertion in a sequence similar to that of the Rugosa
- Where there is a marginal zone, it can be of two kinds: either a thickened zone of annular lamellae or growth of the marginarium is accompanied by the loss of the corallite walls, resulting in a coenenchyme
- The production of a coenenchyme is one of the more important evolutionary trends, the other the mural pores or connecting tubules for corallite interconnection

budding

- Can grow either peripherally or laterally

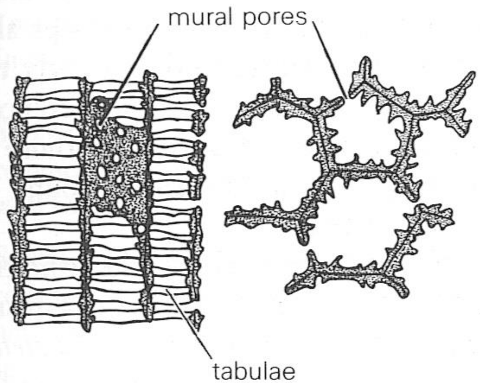
Halysites & Heliolites



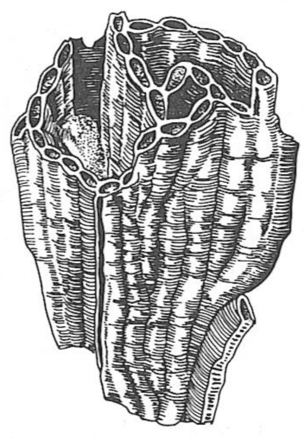
Halisites sp., Silurian

Heliolites, Silurian

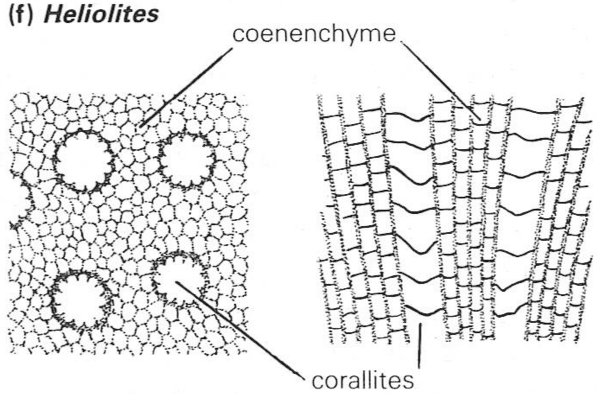
(a) ***Favosites***

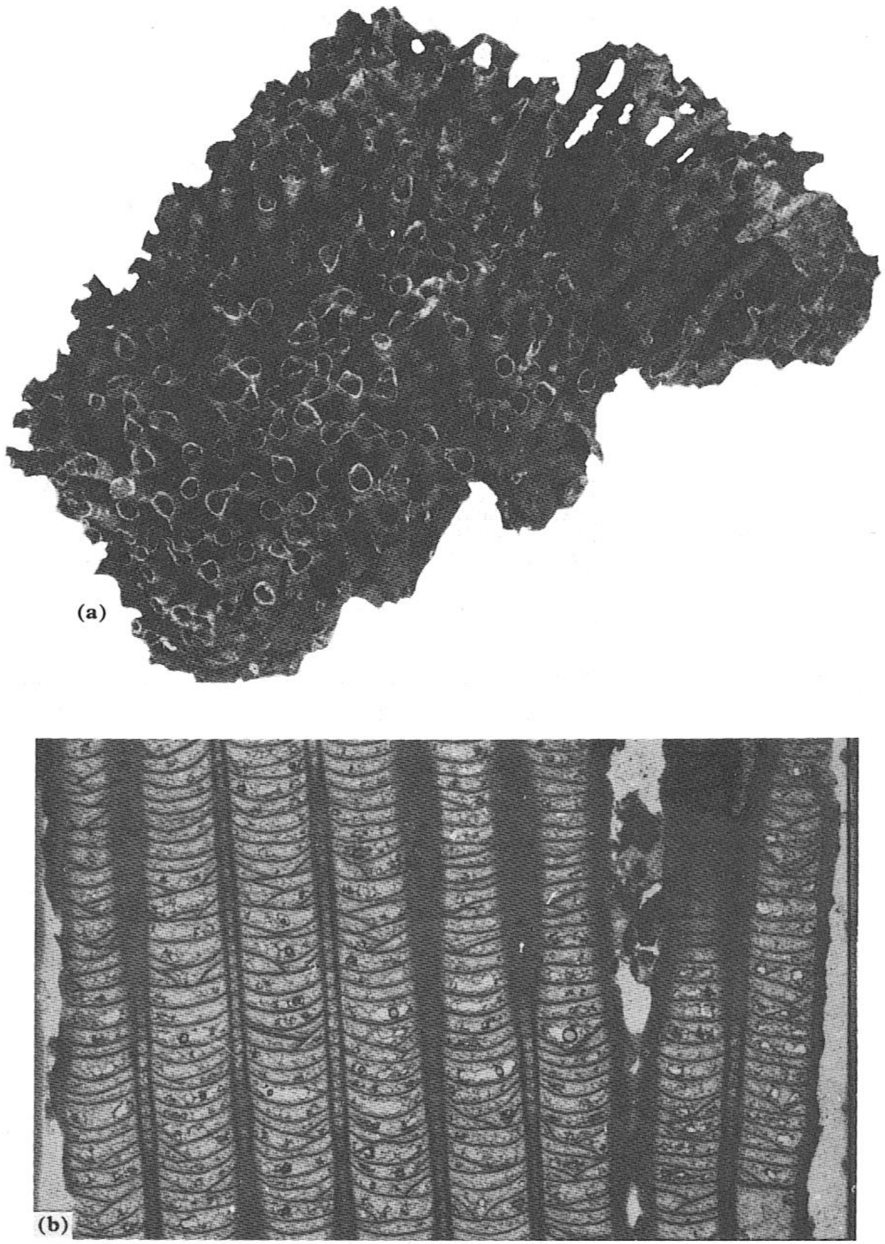


(d) ***Halysites***



(f) ***Heliolites***





71 Tabulate corals.

a, *Syringopora*, L Carboniferous (× 1.4), corallum is silicified. b, *Halysites*, Silurian (× 7); vertical section showing coenenchyme of single tubule between corallites. (From an exhibit in the Sedgwick Museum.)

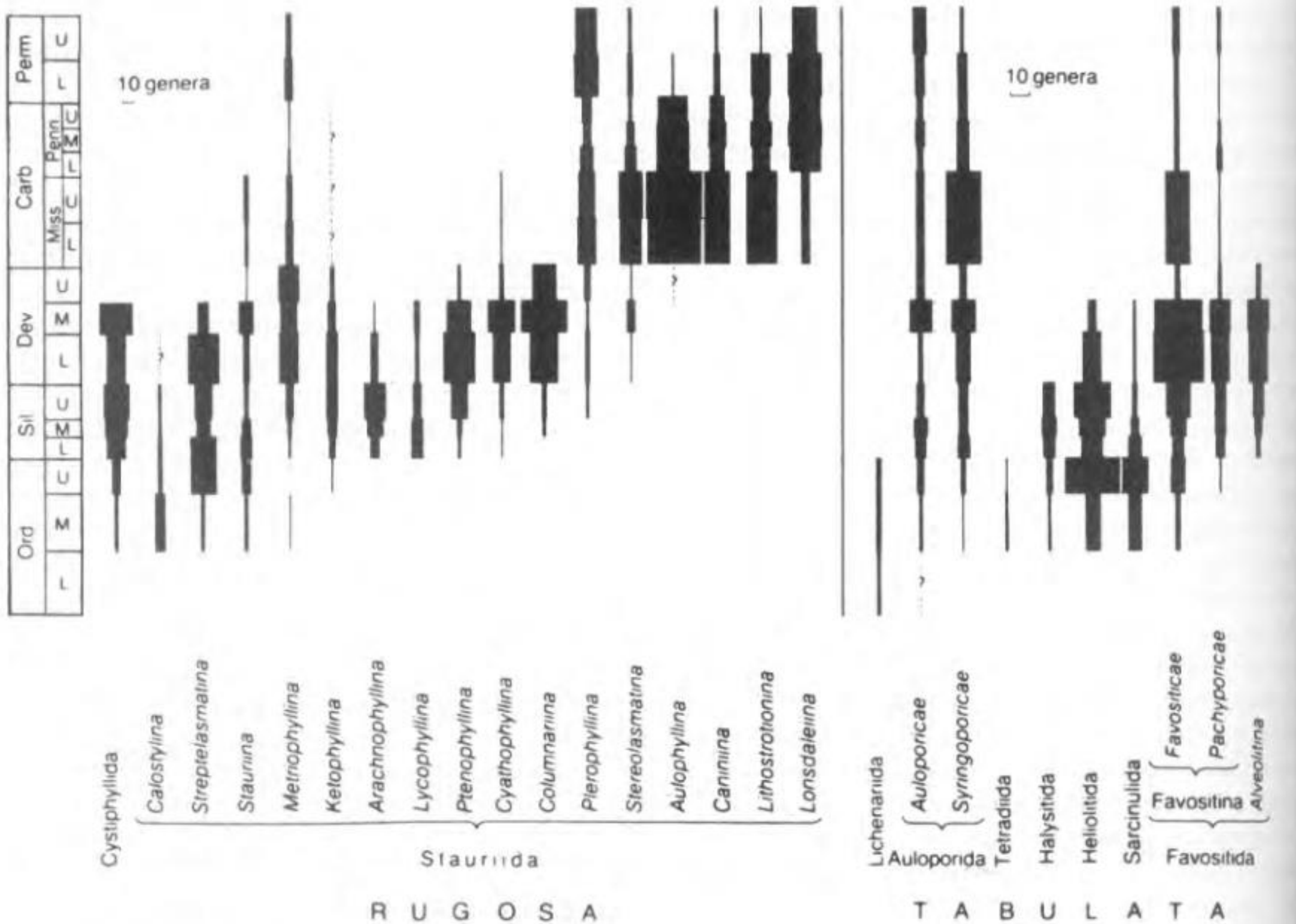


Figure 5.11 Time ranges of supersuborders (and some suborders and families) of Rugosa and Tabulata. (Redrawn from Scrutton, 1986)

Scleractinia

- All post-Lower Triassic corals are included in Subclass Zoantharia with its single Order Scleractinia.
- Most of them, secrete an aragonitic exoskeleton in which the septa are inserted between the mesenteries in multiples of six.
- After the first six protosepta grow, successive cycles of 6, 12 and 24 metasepta are inserted in all six quadrants.
- Through their pattern of septal insertion the Scleractinia are immediately distinguished from the Rugosa.
- Each of the earlier cycles is complete before the next cycle grows, though in some cases this system breaks down in the higher cycles.

- The skeleton originates as a thin basal plate from which the septa arise vertically.
- As this skeleton grows upwards the lower margin of the polyp hangs over it as an edge zone.
- Within the cup there may be dissepiments as well as septa.
- In general, the structure of both simple and compound scleractinians is light and porous, rather than solid as in the Rugosa.
- In several respects other than the primary septal plan the Scleractinia differ from Palaeozoic groups and independent evidence now shows that Scleractinia arose from a group of sea-anemones rather than from anv Palaeozoic coral.

Form and structure

- Scleractinians may be solitary or compound
- In solitary scleractinians the form of the corallum depends on the relative rates of vertical and peripheral growth once the basal plate has been secreted.
- peripheral growth, a discoidal form results
- commonest kinds are turbinate or conical coralla in which the axis is straight, though horn-shaped and cylindrical types are common.

- In colonial forms, the corallites are interconnected as a result of repeated asexual division by the polyps.
- As with the Rugosa there are dendroid, phaceloid, thamnasteroid and, rarely, aphroid types.
- In cerioid scleractinians the thecae of adjacent polygonal corallites are closely united and of dissepimental or septal origin, by contrast with the walls of cerioid rugosans, which are epithecal.
- Plocoid types of corallites have separated walls but united by dissepiments. Ramose types of creeping habit also exist.

- In addition there are two other types which do not correspond to any rugosan type:

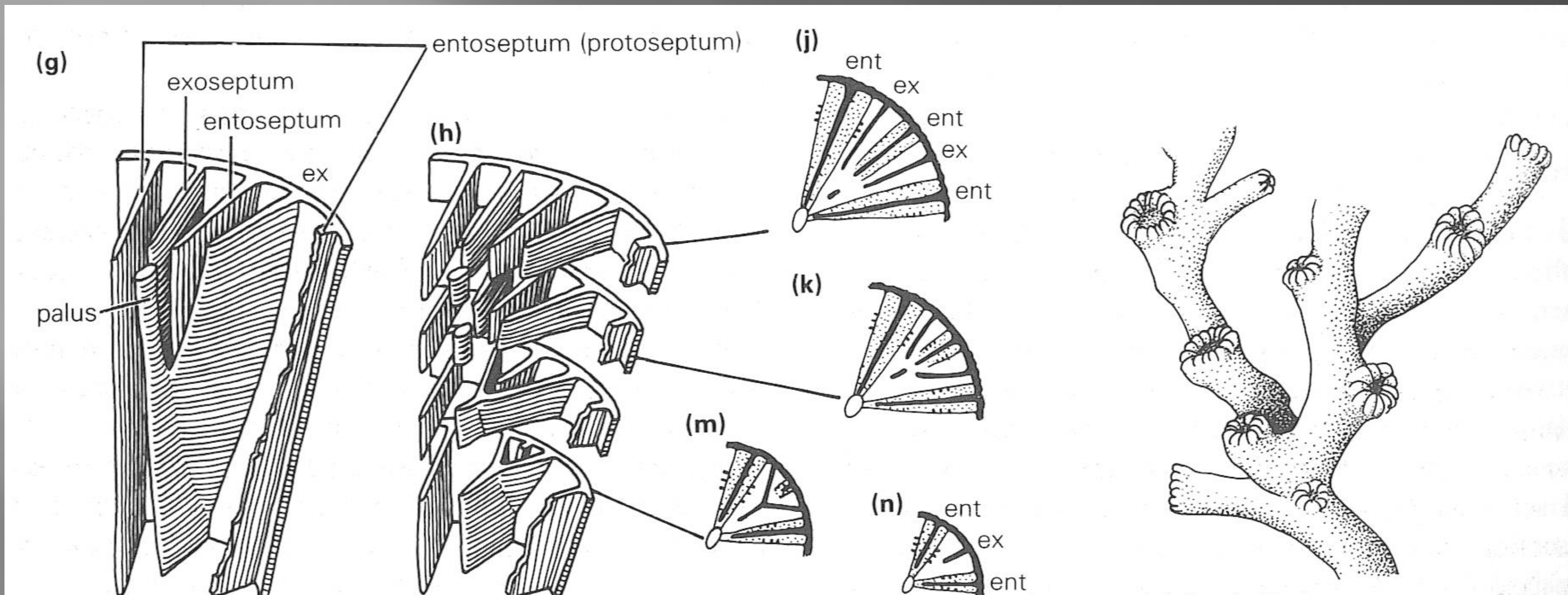
  (a) the meandroid type in which corallites are arranged in linear series with the cross-walls absent, and confined within the lateral walls which run irregularly over the surface like the convolutions of a human brain;

  (b) the hydnophoroid type in which the centres of the corallites are arranged around little hillocks or monticules.
- In habit scleractinian colonies may be branching (ramose), massive, encrusting and creeping (reptant) or foliaceous. Sometimes adjacent colonies of the same species fuse to form a single colony.

septa

- Septa are formed of aragonitic trabeculae (simple or compound) normally arranged in a fan-like system and often with a denticulate upper surface
- Usually the trabeculae are united, though sometimes the trabecular framework is loosely united and may be perforated(**fenestrate septa)**.
- The grouping of trabeculae and their structure are important stable characters for taxonomy. They form initially from aragonitic spherulites in an organic matrix.
- mesenteries have a double layer of endoderm separated by a thin sheet of mesoglea. Muscles are arranged on one side of the mesentery only, and the mesenteries are grouped in pairs with the pleated muscle blocks facing each other. The space within such a pair is the entocoel, while in between (the muscles facing away from each other) is the exocoel.

- Septa are thus entocoelic (entosepta) or exocoelic (exosepta) in origin; usually the first two cycles are of entosepta, the rest of exosepta.
- In some scleractinians there may be a peculiar growth system producing vertical pillars (**pali**) along the inner edges of some of the entosepta.
- If a **columella** forms it is always of septal origin and may begin as pali; it is usually a central rod or a dividing plate formed from a proseptum.
- The septa are often connected by cross-bars called **synapticulae** which grow towards each other from the walls of adjacent septa and eventually fuse, perforating the mesenteries in the process.



(g)
entoseptum (protoseptum)
exoseptum
entoseptum
ex
palus
(h)
(j)
ent
ex
ent
ex
ent
(k)
(m)
(n)
ent
ex
ent

(p) ***Lophelia***

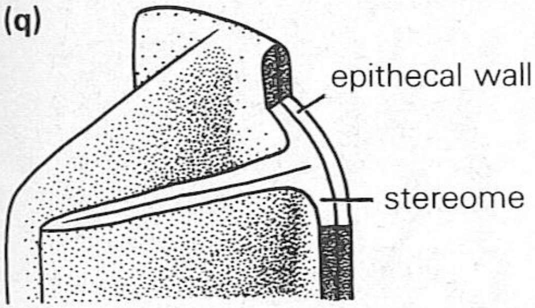
- The thin basal plate is semitransparent and firmly adherent to the substratum; it may later be thickened by secondary deposits.
- The epitheca is not developed in many scleractinians but if present may consist of chevron-like crystallites of aragonite.
- Dissepiments, like those of the Rugosa, are secreted by the base of the polyp.

- Endothecal dissepiments are confined within the corallite, but in some colonial scleratinians the corallites are united by a common spongy tissue, the **coenosteum**, which may be formed partially of exothecal dissepiments and partially by rods and pillars (costae)
- Tabular dissepiments are flattish plates extending across the whole width of the corallite or confined only to its axial part
- Vesicular dissepiments are small arched plates, convex upwards and overlapping, and usually inclined downwards and inwards from the edge of the corallite.

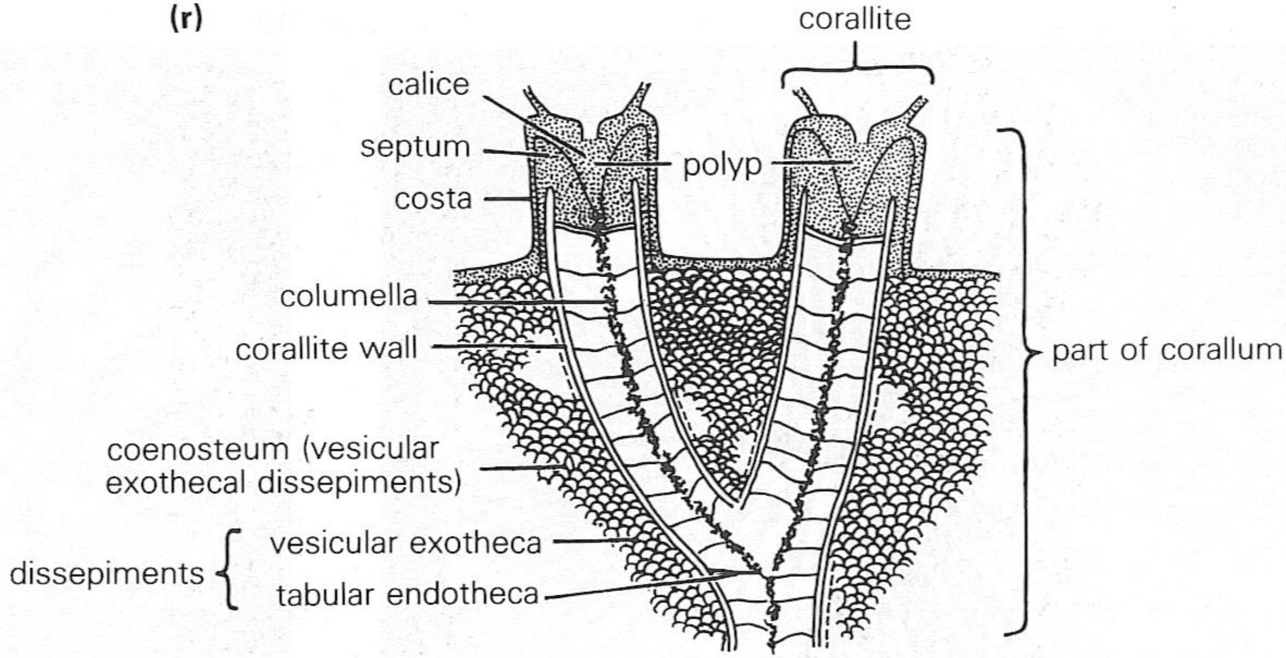
secondary structures

- **Stereome** is an adherent layer of secondary tissue which may cover the septal surface.
- It is composed of transverse bundles of aragonitic needles.
- In compound scleractinians individual corallites are usually separated by a complex perforated tissue: the **coenosteum**.
- This may consist entirely of exothecal dissepiments (tabular) or other material, but it provides a support for numerous canals linking the individual corallites and binding the living tissues together in a functionally cohesive mass.

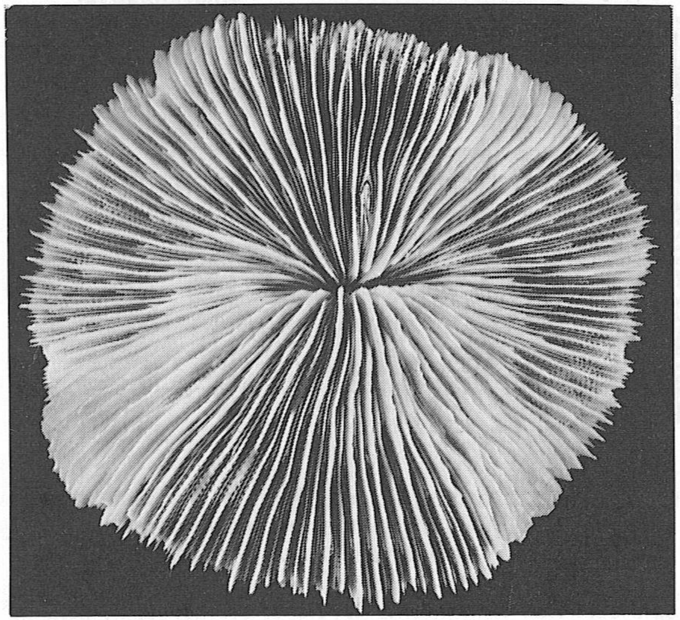
(q)


epithecal wall
stereome

(r)


corallite
calice
septum
costa
polyp
columella
corallite wall
part of corallum
coenosteum (vesicular
exothecal dissepiments)
dissepiments
vesicular exotheca
tabular endotheca

(a)



(b)

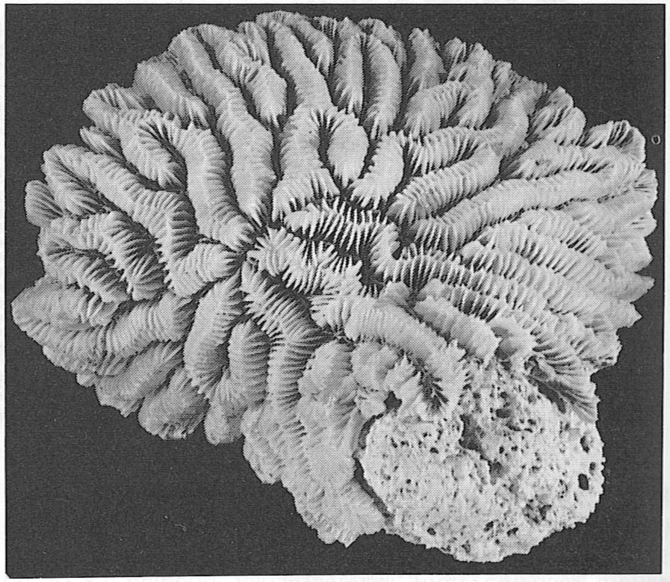
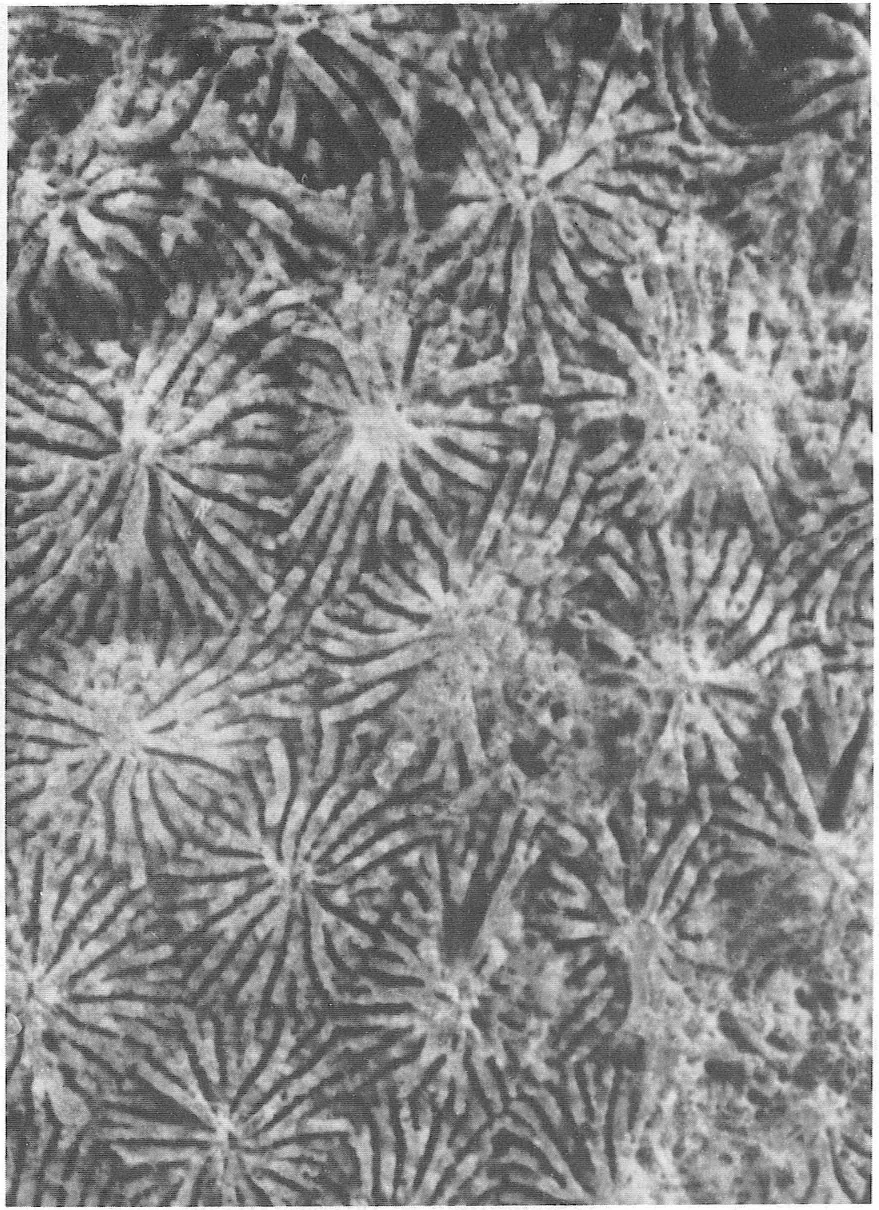


Figure 5.16 (a) *Fungia*, a large Recent solitary scleractinian, showing several orders of septa (×0.5); (b) *Meandrina*, a Recent colonial coral from Barbados with typically meandroid structure resulting from intratentacular budding (×0.5) (cf. Fig. 5.12b). (Photographs reproduced by courtesy of C. Chaplin)



75 **Jurassic reef-living coral, *Isastraea*, Corallian, Jurassic, Upware, Cambridgeshire (× 4).**

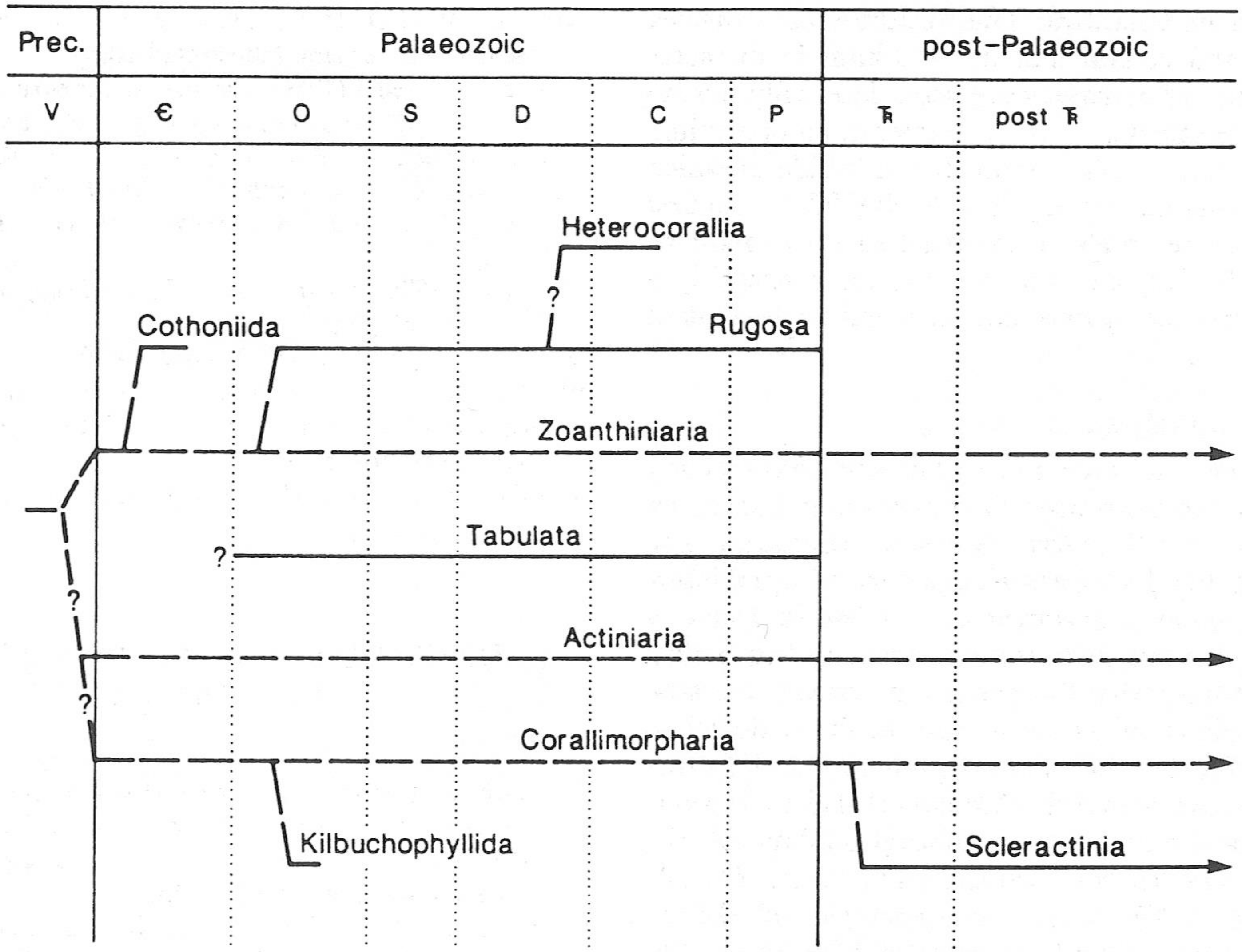


Figure 5.20 Relationships of the various groups of corals. The ranges of the uncalcified sea-anemones from which they were derived (Zoantharinaria, Actinaria, Corallimorpharia) are shown by dashed lines. (Redrawn from Scrutton and Clarkson 1990)

Ecology

- Attached organisms
- Rugose corals on a loose substrate and calm waters
- It is not known whether they lived symbiotically with algae
- They were abundant in depths of up to 10 meters and were scarce in larger ones
- They were fixed to the substrate either with root like “talons” or rarely with cement

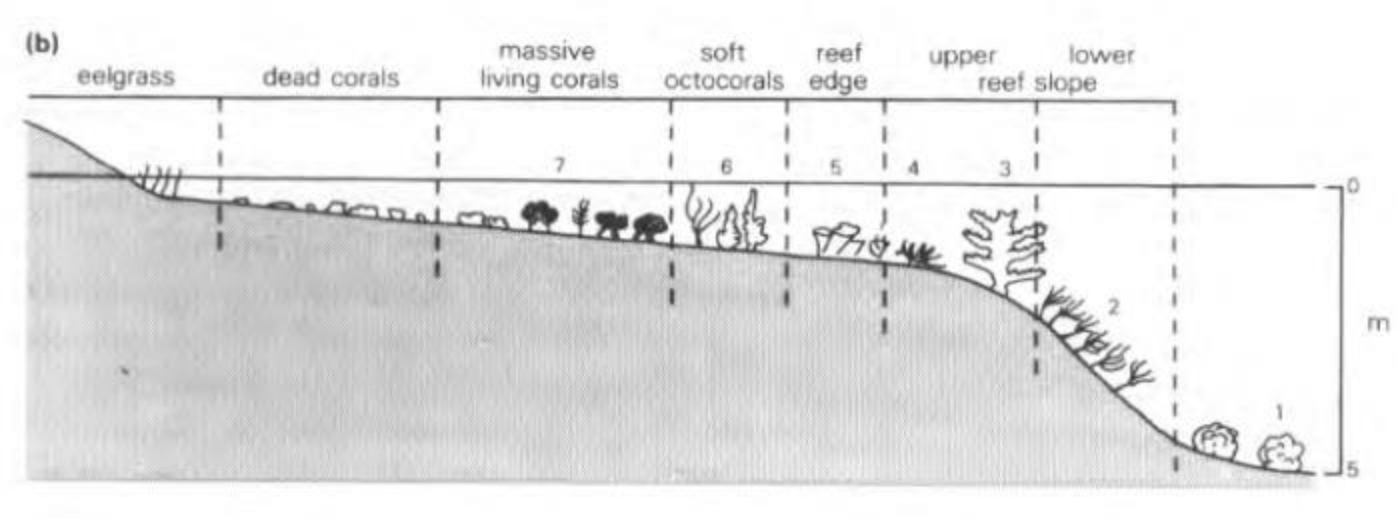
Ecology Scleractinia

- Scleractinia are divided into two categories:
  - Zooxanthellates living symbiotically with algae
  - Non-zooxanthellates not living symbiotically with algae
- Zooxanthellates in small depths <50m in well lit water
- Their food is produced by the algae and because of the produced O they grow very fast.
- Temperatures> 18^o C (maximum growth 25-29^o) (tropical - subtropical)
- Normal salinity and clean waters
- Waves do not affect them
- Reef builders

Ecology Scleractinia

- Most non-zooxanthellates do not build reefs as they are solitary
- They can live in deep depths up to 6000m but mostly abundant up to 500m
- Temperature 5-10º C but also can survive below zero degrees
- They can live in full darkness

Coral reefs



(b)
eelgrass
dead corals
massive living corals
soft octocorals
reef edge
upper
lower
reef slope
7
6
5
4
3
2
1
0
m
5