

An introduction to Echinodermata taxonomy

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Classification of the Phylum Echinodermata in the Animal Kingdom

How is animal classification achieved?

1. Body symmetry



Spherical

Any plane passing through the center divides a body in mirrored halves



Radial

More than two planes passing through the longitudinal axis can divide a body in mirrored halves

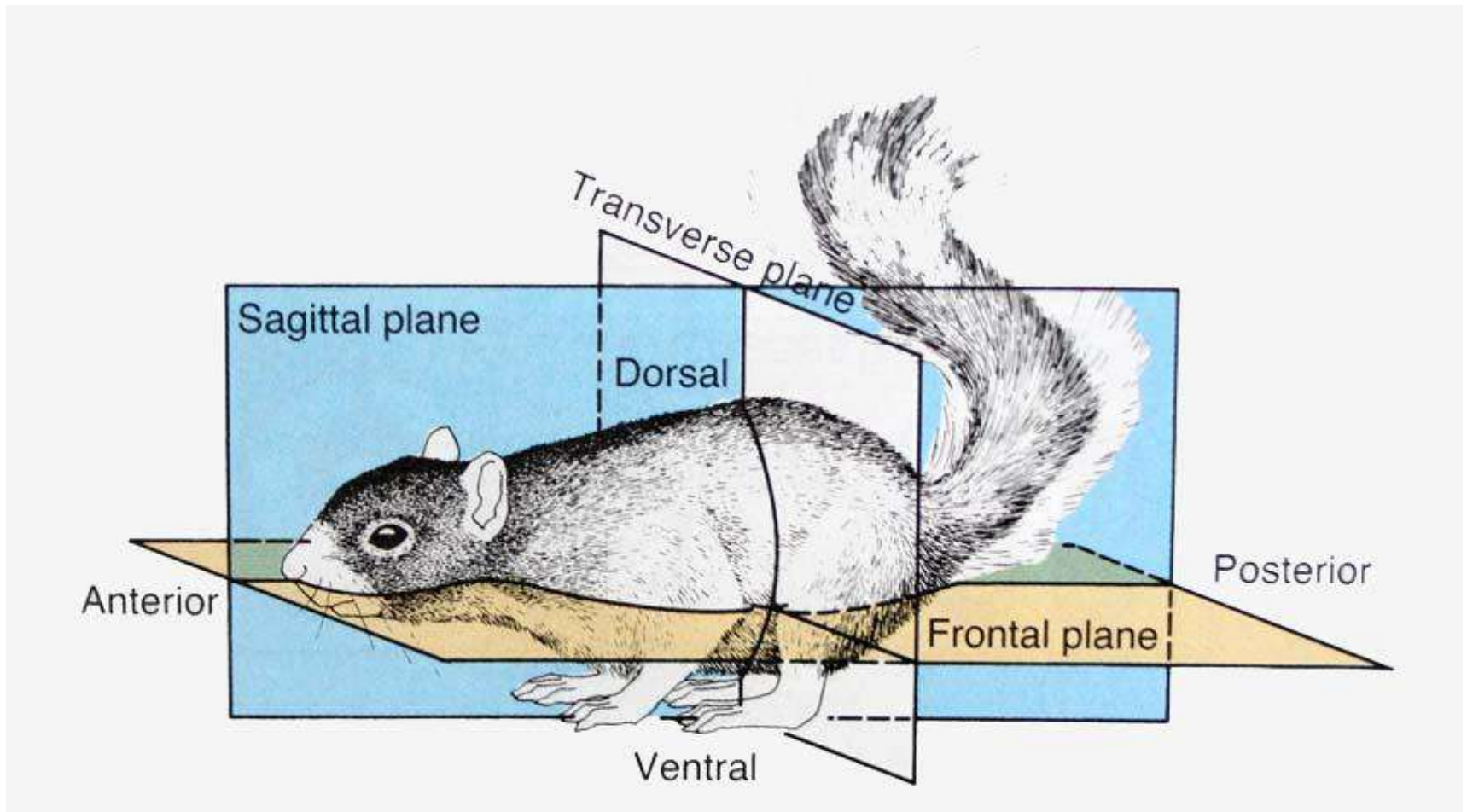


Bilateral

A sagittal plane divides into two mirrored halves (left and right)

Radiata and Bilateria

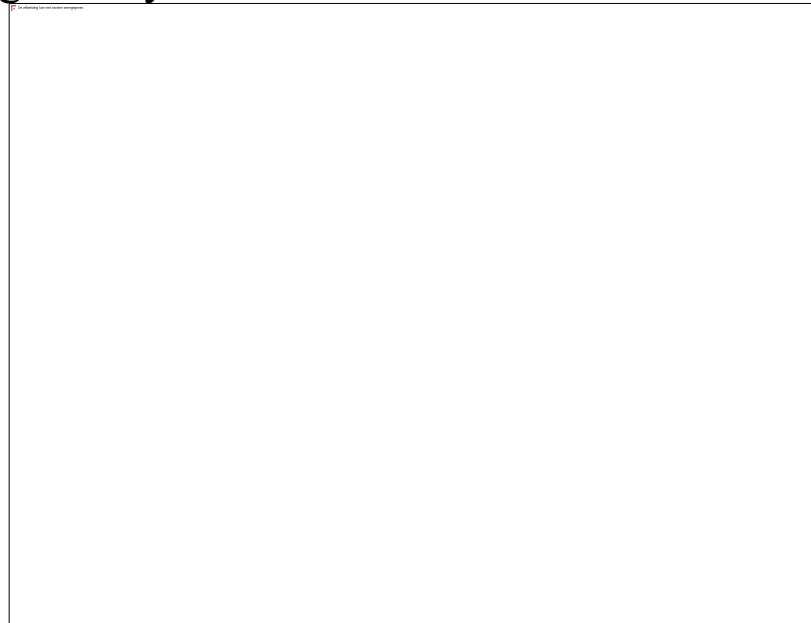
Terminology commonly utilized for bilaterally symmetrical animals



Classification of the Phylum Echinodermata in the Animal Kingdom

How is animal classification achieved?

1. Body symmetry (asymmetric, spherical, radial, bilateral)
2. Developmental pattern:
 - a. number of germ layers



Diploblastic and Triploblastic animals

Classification of the Phylum Echinodermata in the Animal Kingdom

How is animal classification achieved?

1. Body symmetry (asymmetric, spherical, radial, bilateral)
2. Developmental pattern:
 - a. number of germ layers
 - b. presence of coelomic cavity

Possibility 1:

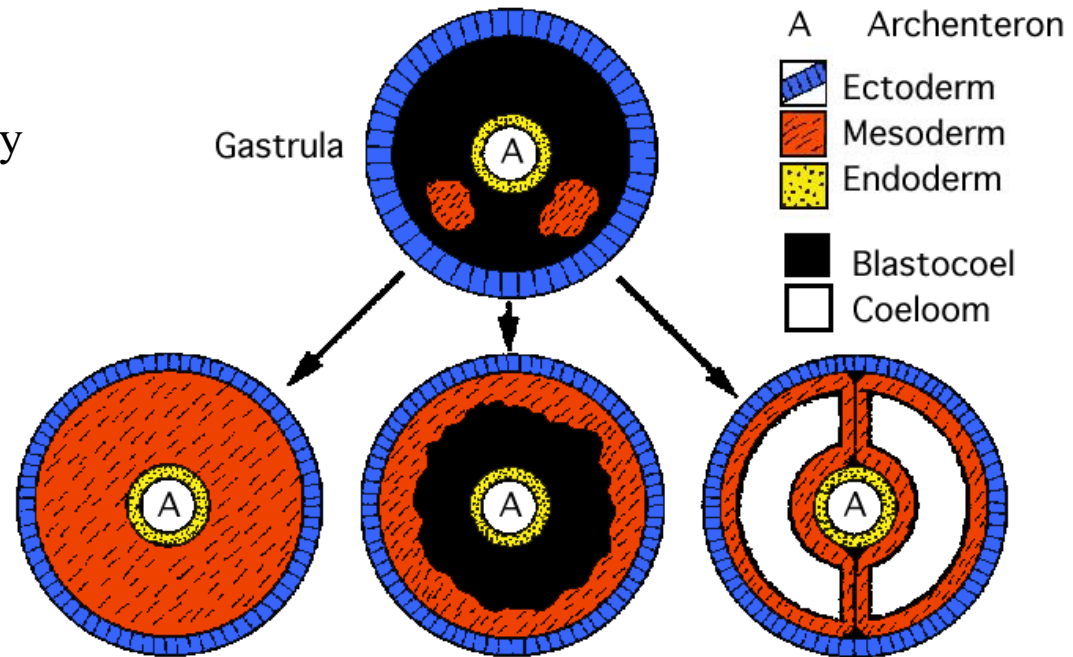
Mesoderm cells completely fill the blastocoel

Possibility 2:

Mesoderm cells only line the outer edge of the blastocoel

Possibility 3:

Space opens inside the mesoderm

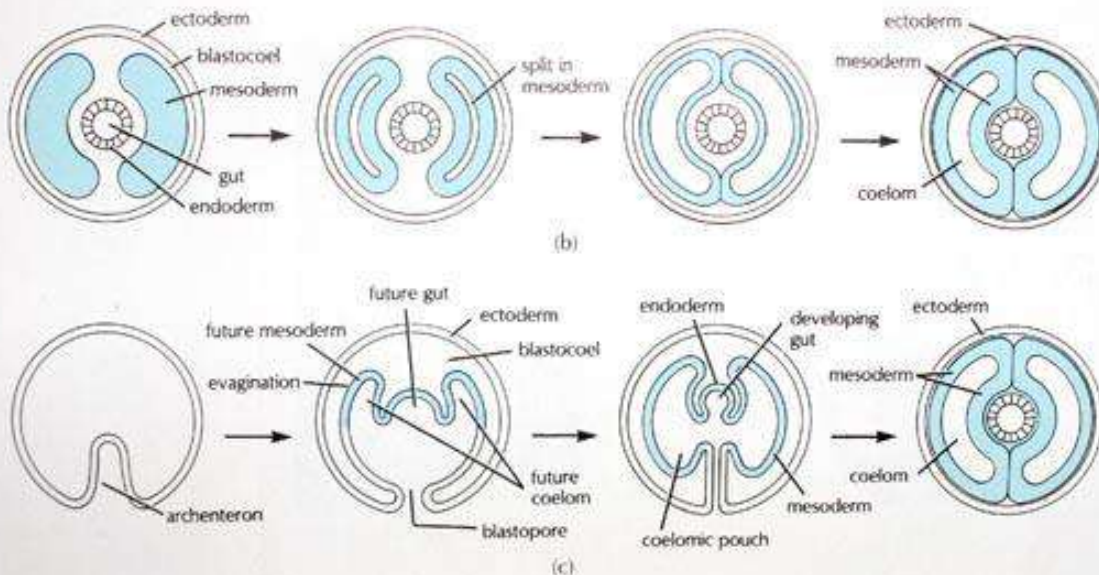


Acoelomates, pseudocoelomates and coelomates

Classification of the Phylum Echinodermata in the Animal Kingdom

How is animal classification achieved?

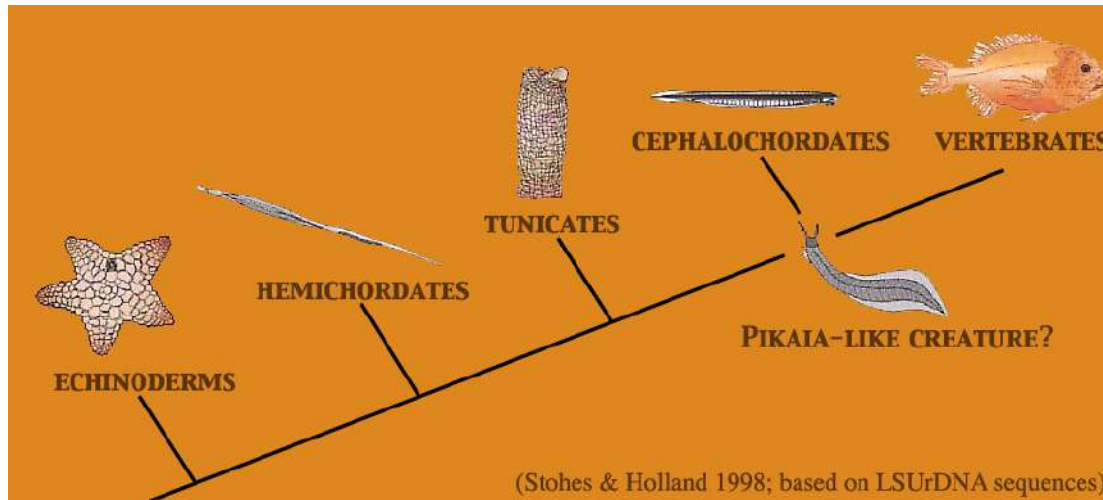
1. Body symmetry (asymmetric, spherical, radial, bilateral)
2. Developmental pattern:
 - a. number of germ layers
 - b. presence of coelomic cavity
 - c. mode of coelom formation



Possibility 1 - Schizocoely
Coelom formation by gradual enlargement of split in mesoderm

Possibility 2 - Enterocoely
Coelom formation through evagination of the archenteron

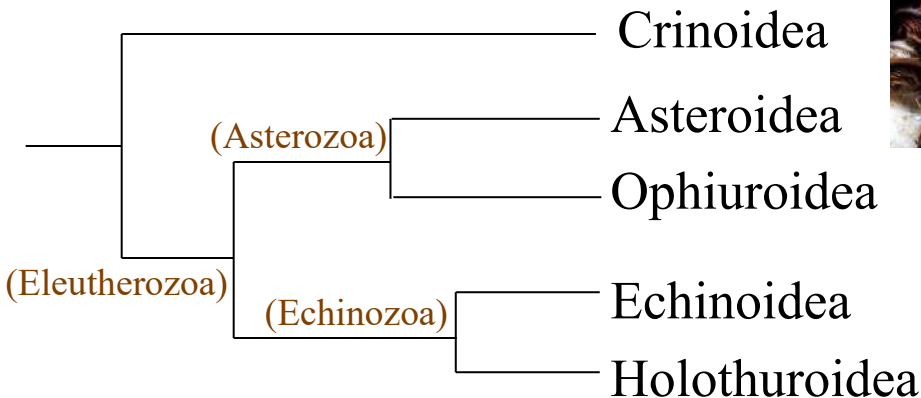
Where does that place Echinodermata in the Animal Kingdom?



Deuterostome lineage sister to hemichordates & chordates

- anus develops from blastoporus; mouth developing elsewhere
- enterocoelous coelomates
- radial, indeterminate cleavage
- endomesoderm, mesoderm derived from endoderm

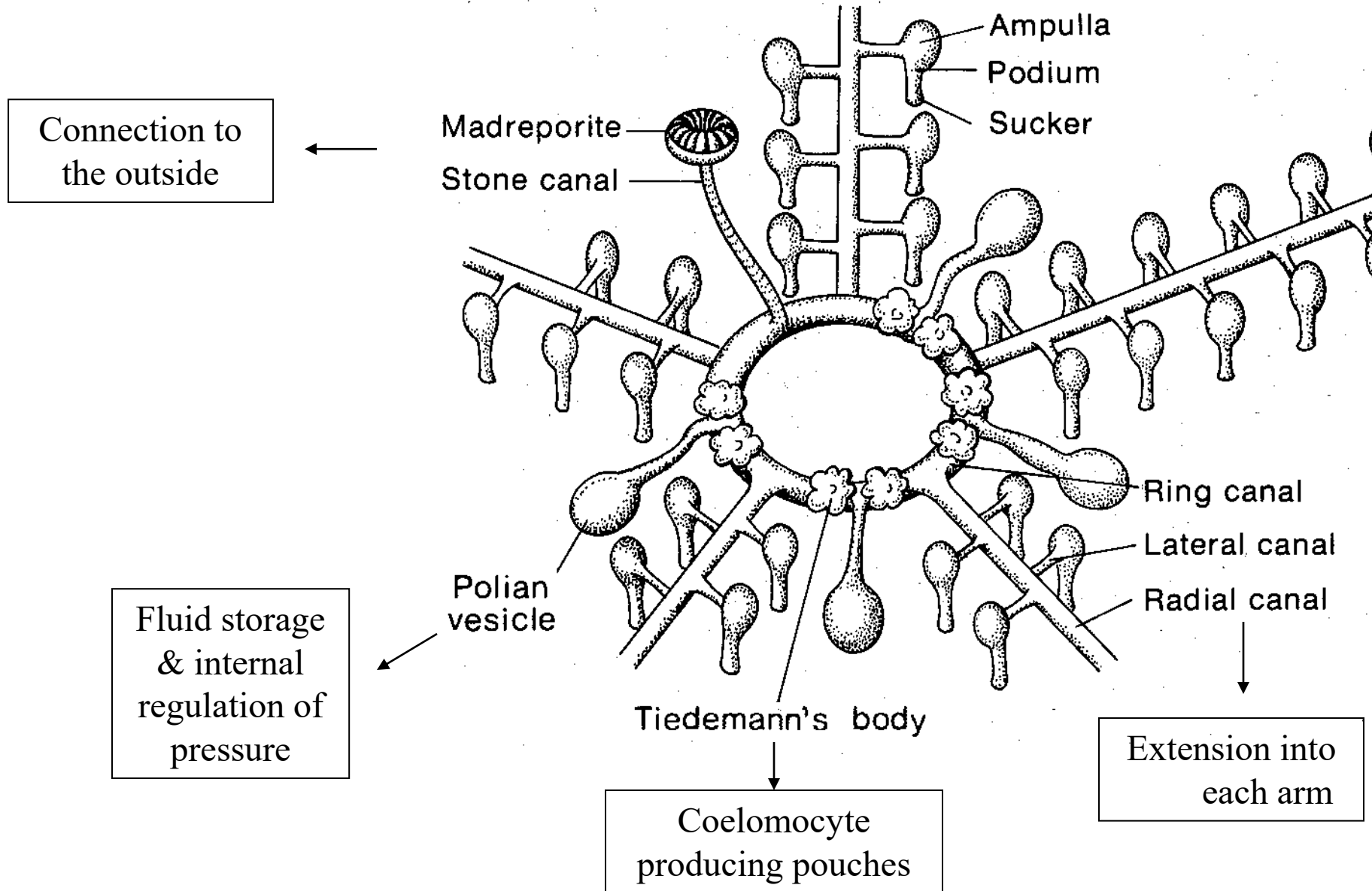
Five extant classes (after Janies 2001)



Characteristics of Phylum Echinodermata

- Latin *echinatus*, prickly & Greek *derma*, skin + *ata*, characterized by
- Highly diverse (some 6,500 extant species belonging to 5 classes: some 13,000 extinct species belonging to, at least, another 16 classes), successful (invaded all of the marine realm) & ancient phylum (at least since the Cambrian, 560 mya)
- Three defining unique characteristics:
 - a complex system of fluid-filled channels, *the water-vascular system*, derived from a coelomic compartment
 - secondary derived *(bilateral larvae) pentamerous radial symmetry* in adults
 - *calcareous endoskeleton* derived from mesodermal tissue
 - *mutable connective tissue or catch tissue* allowing for rapid and drastic alteration of its stiffness

The water-vascular system (here: Asteroidea)

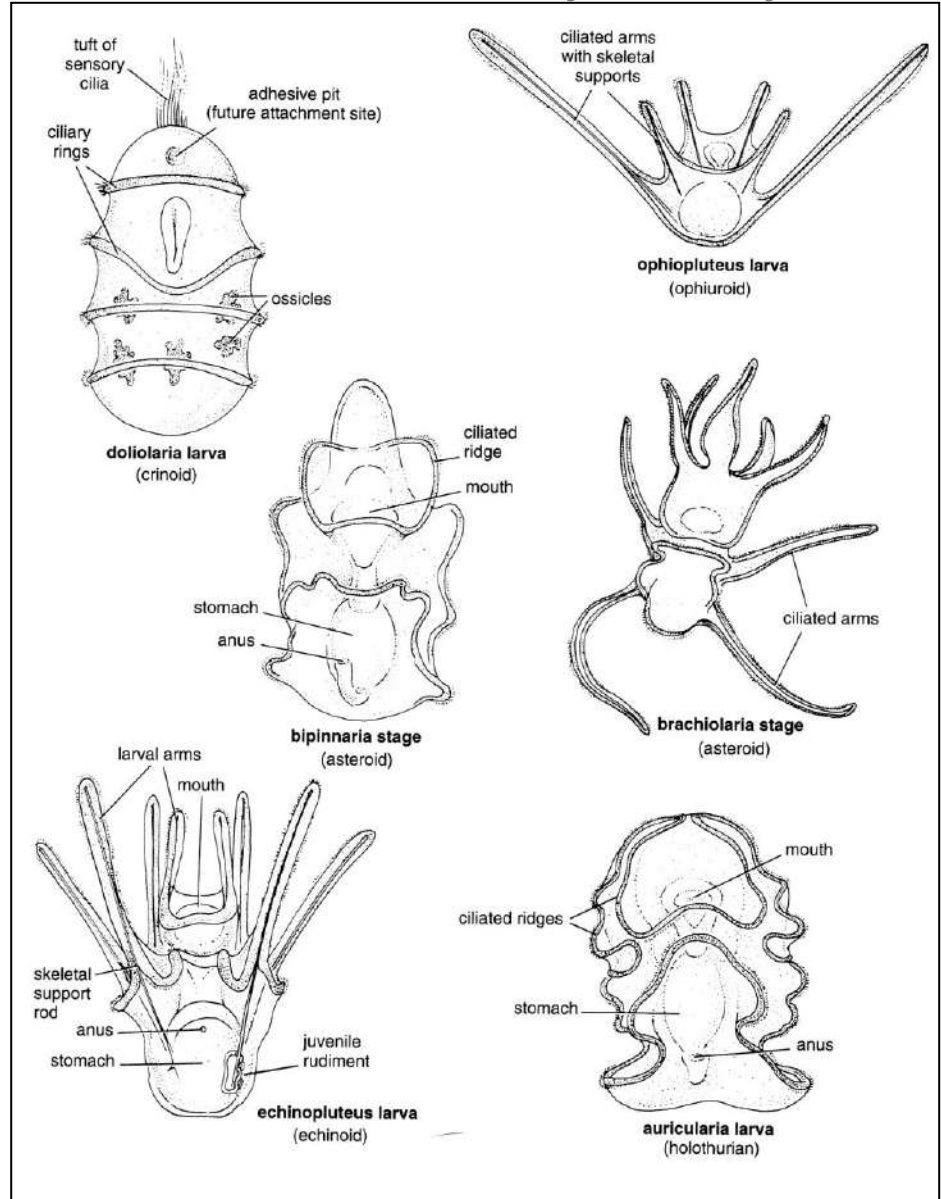
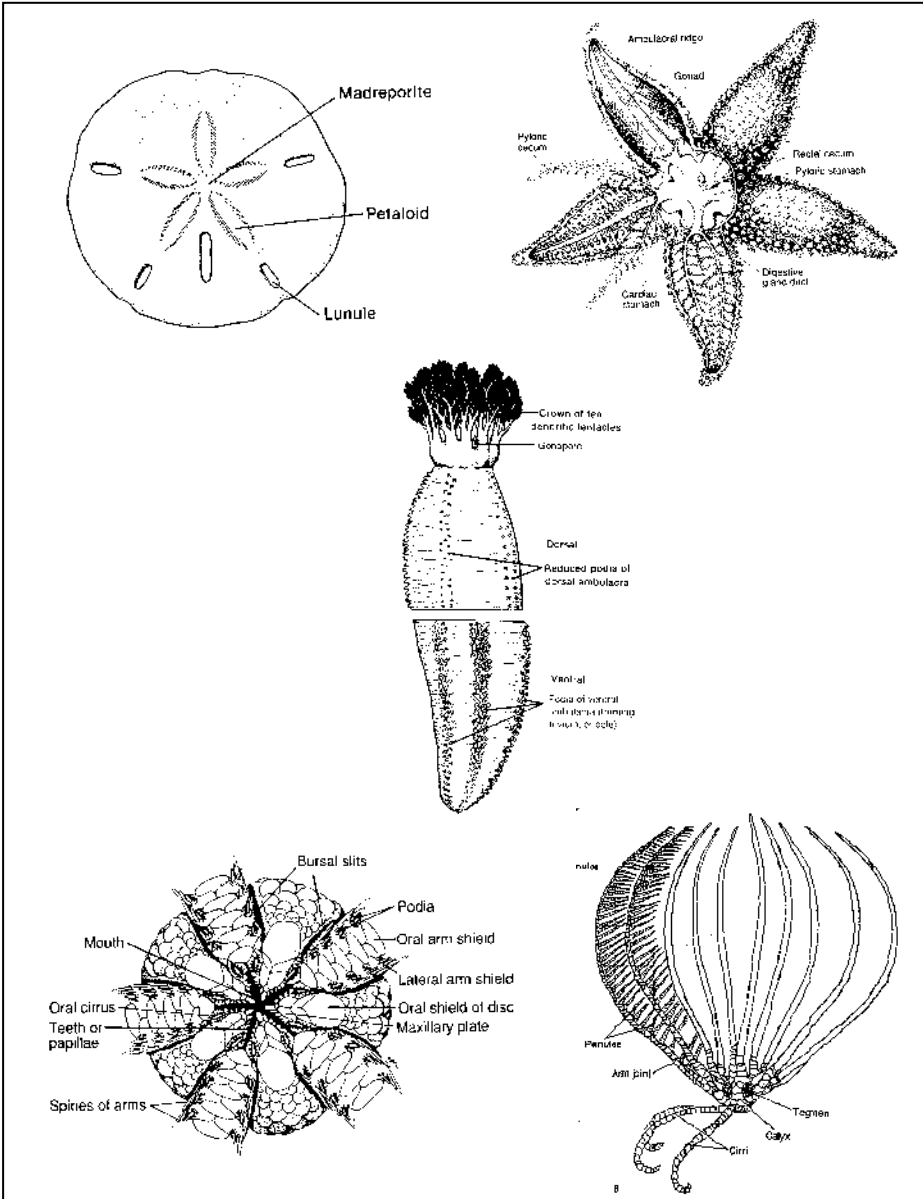


Bilateral and pentamerous symmetry

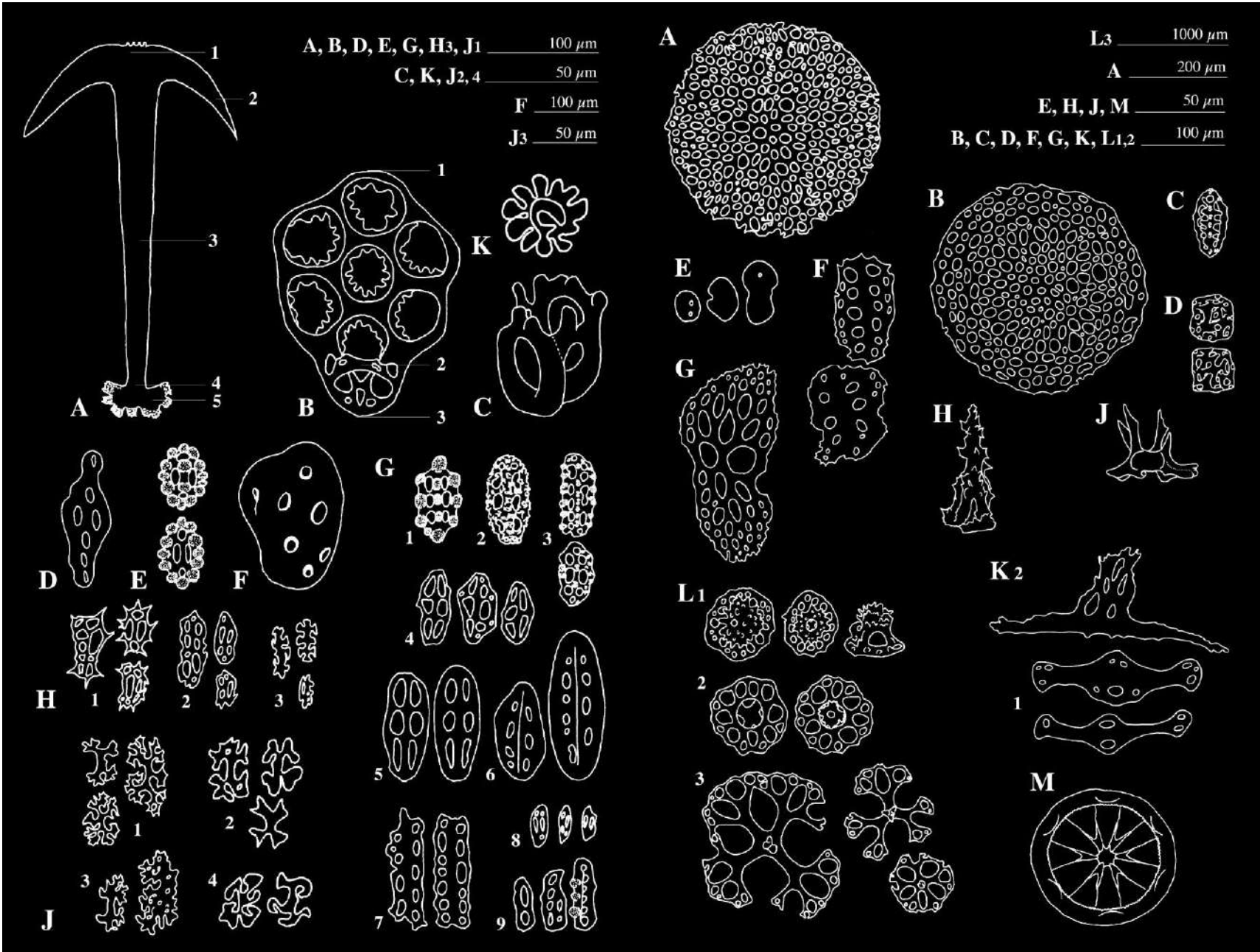


Adults: pentamerous radial symmetry

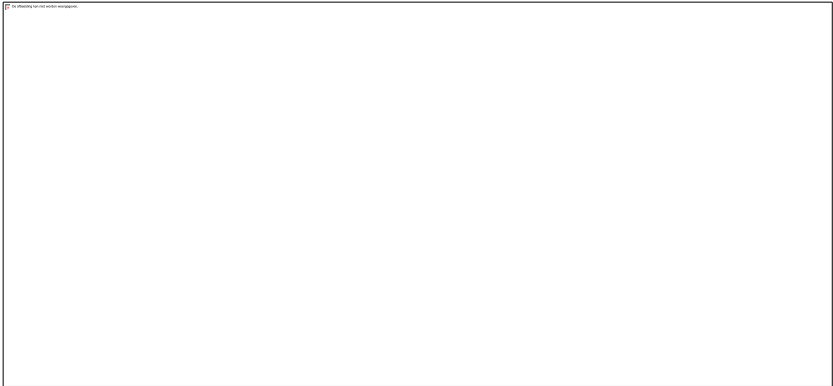
Larvae: bilateral symmetry



Endoskeleton (here Holothuroidea)



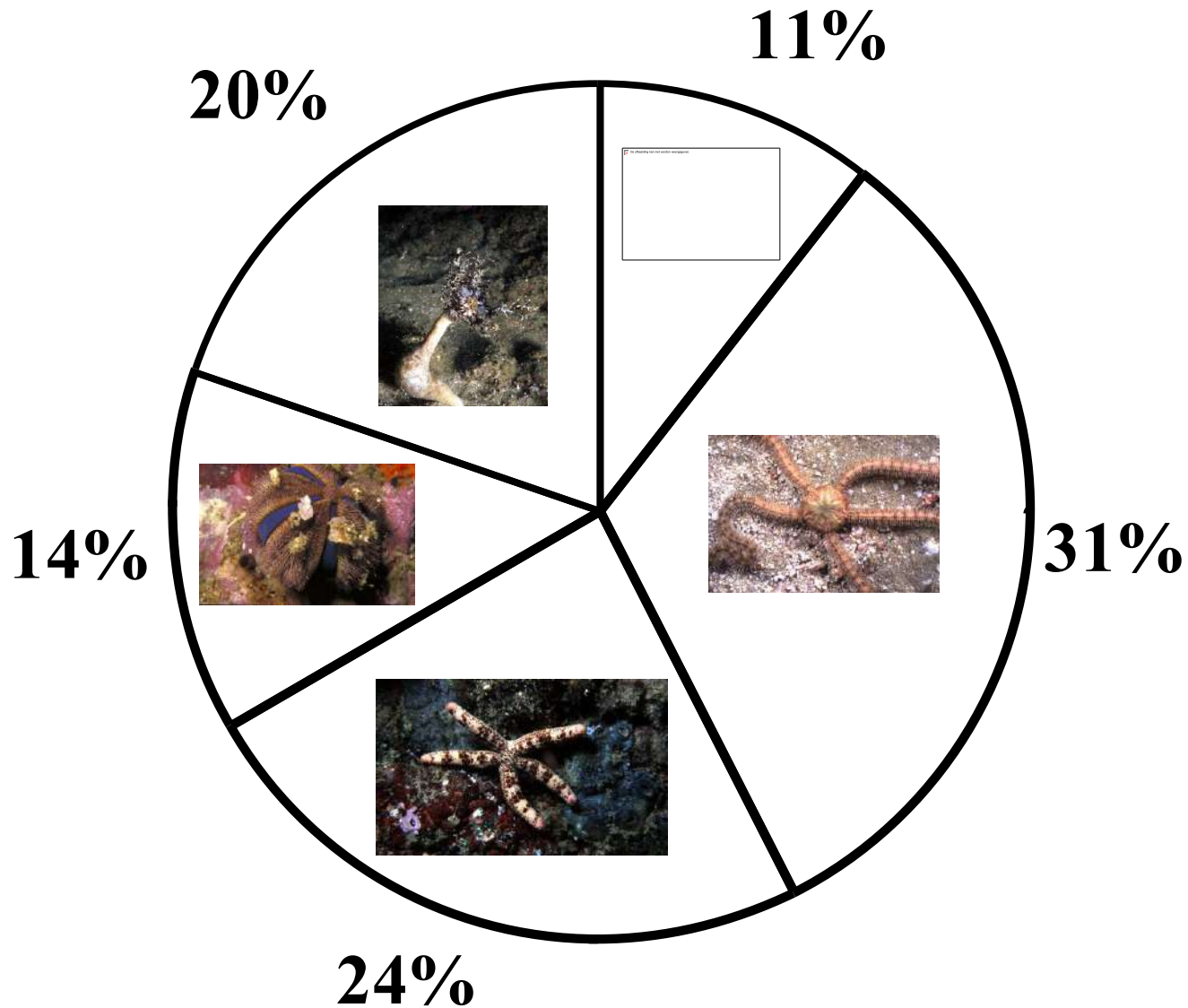
Mutable connective tissue



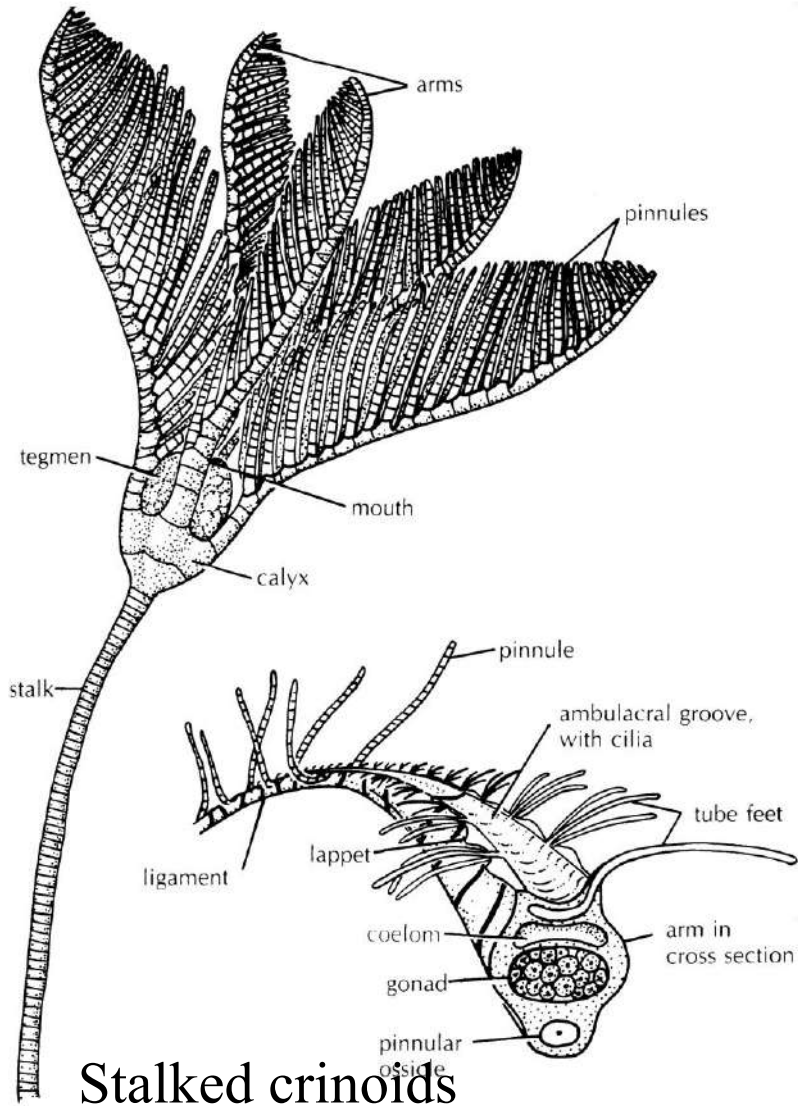
Other, non-unique characteristics of Phylum Echinodermata

- Body unsegmented with five (or more) radiating area, *ambulacra*, alternating with *interambulacra*;
- *No cephalization*; poorly developed nervous system; sensory system of tactile and chemoreceptors, podia, tentacles, photoreceptors and statocysts;
- Complete digestive system; anus absent in ophiuroids;
- Blood-vascular system (*hemal system*) much reduced, functionality remains poorly known (transport of nutrients from coelome to gonad?);
- Respiration by dermal branchiae, tube feet, respiratory trees (holothuroids) and bursae (ophiuroids);
- *Excretory organs absent*; although a cilia-driven nephridial system occurs in the larvae
- Mostly *dioceus* (few hermaphroditic); gonad multiple in most (single in holothuroids); *external fertilization*; development through free-swimming bilateral larval stages (some with direct development); subsequent metamorphosis
- Large *regeneration capacity*

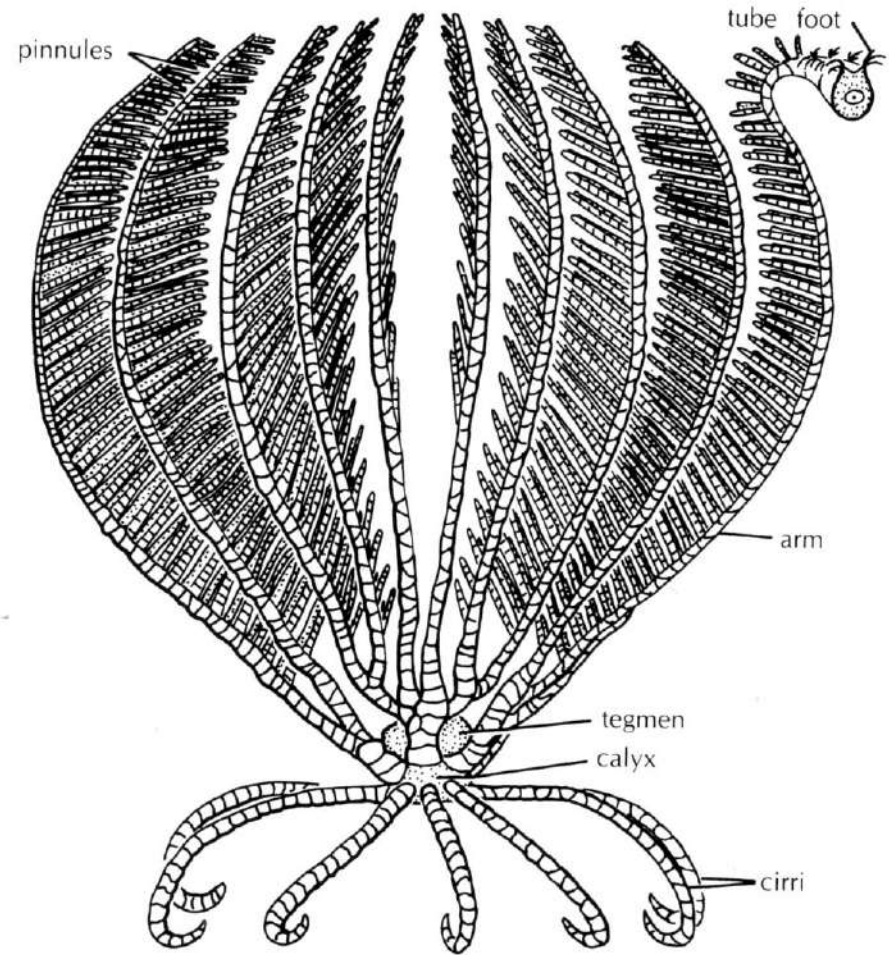
The five classes of extant echinoderms



Class Crinoidea - sea lilies & feather stars



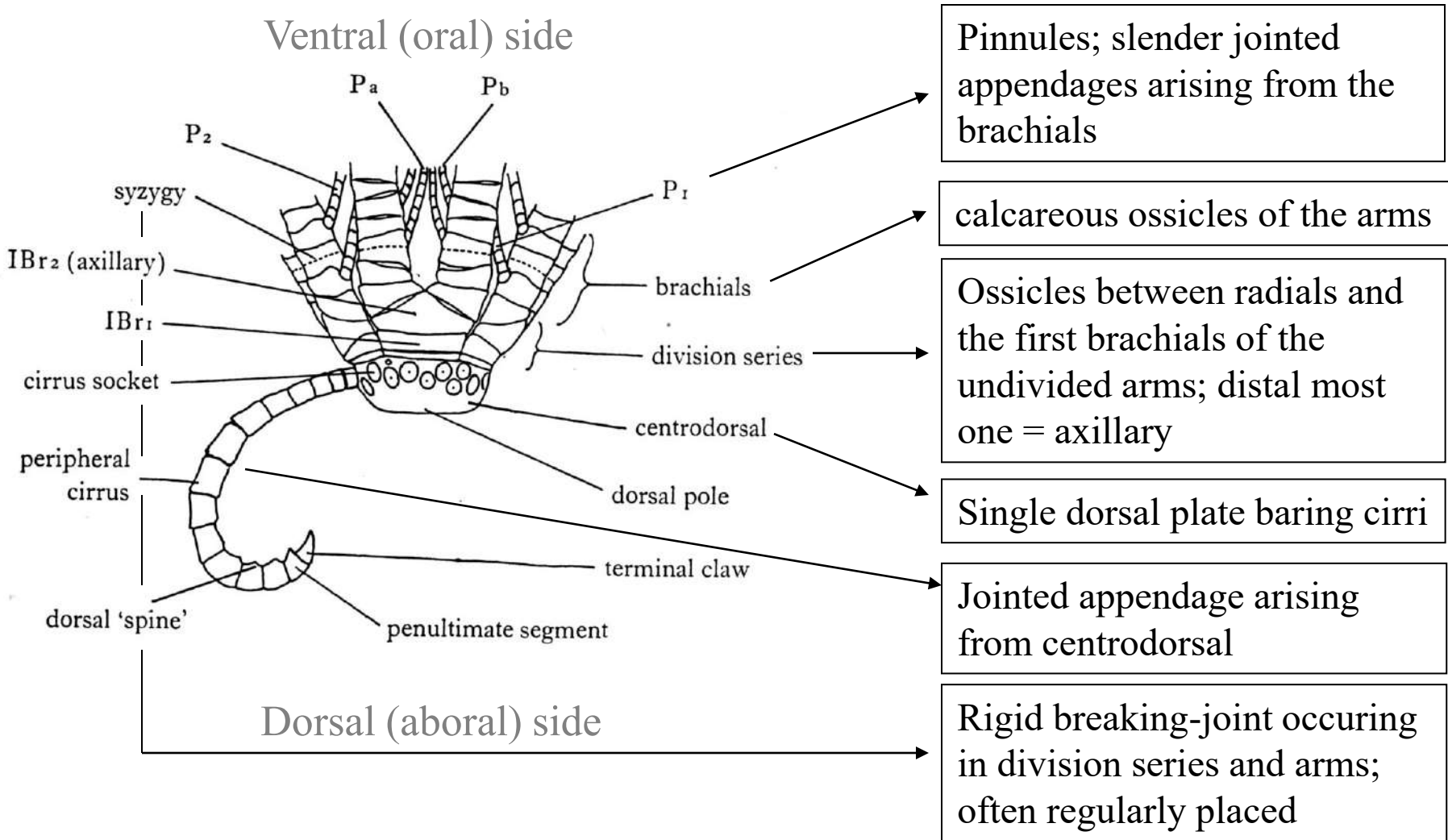
Stalked crinoids
(~100 species)



Non-stalked, motile comatulids
(~600 species)

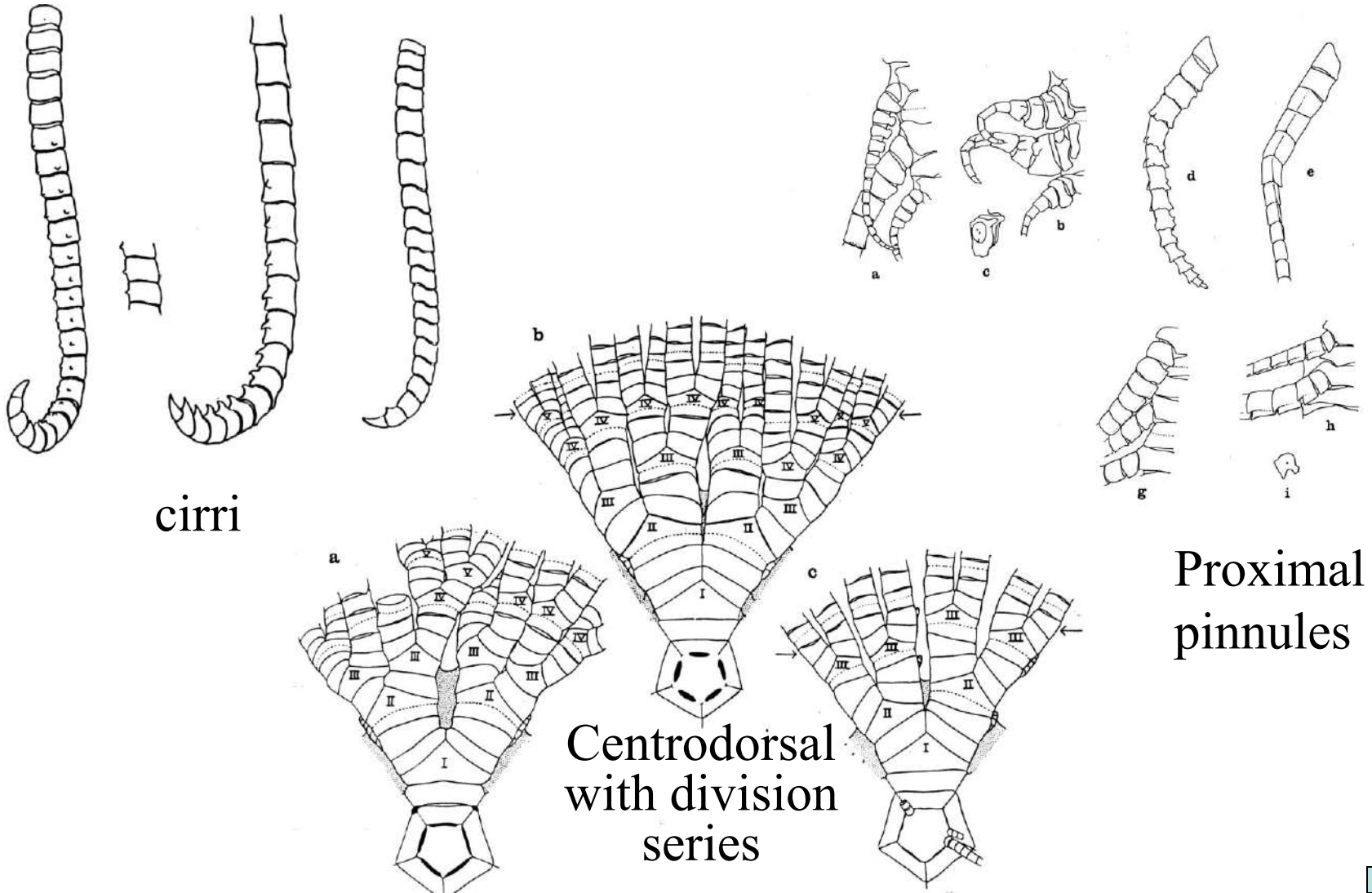
Basics to the taxonomy of the Crinoidea

Largely based upon skeletal elements

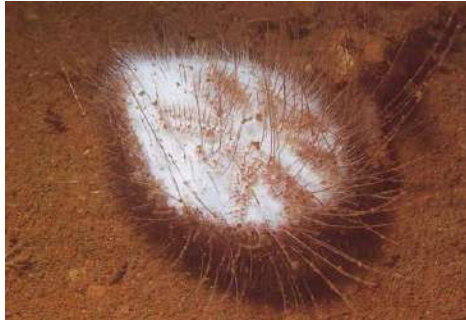


Basics to the taxonomy of the Crinoidea

Largely based upon skeletal elements, with their detail



Class Echinoidea - sea & heart urchins, sand dollars



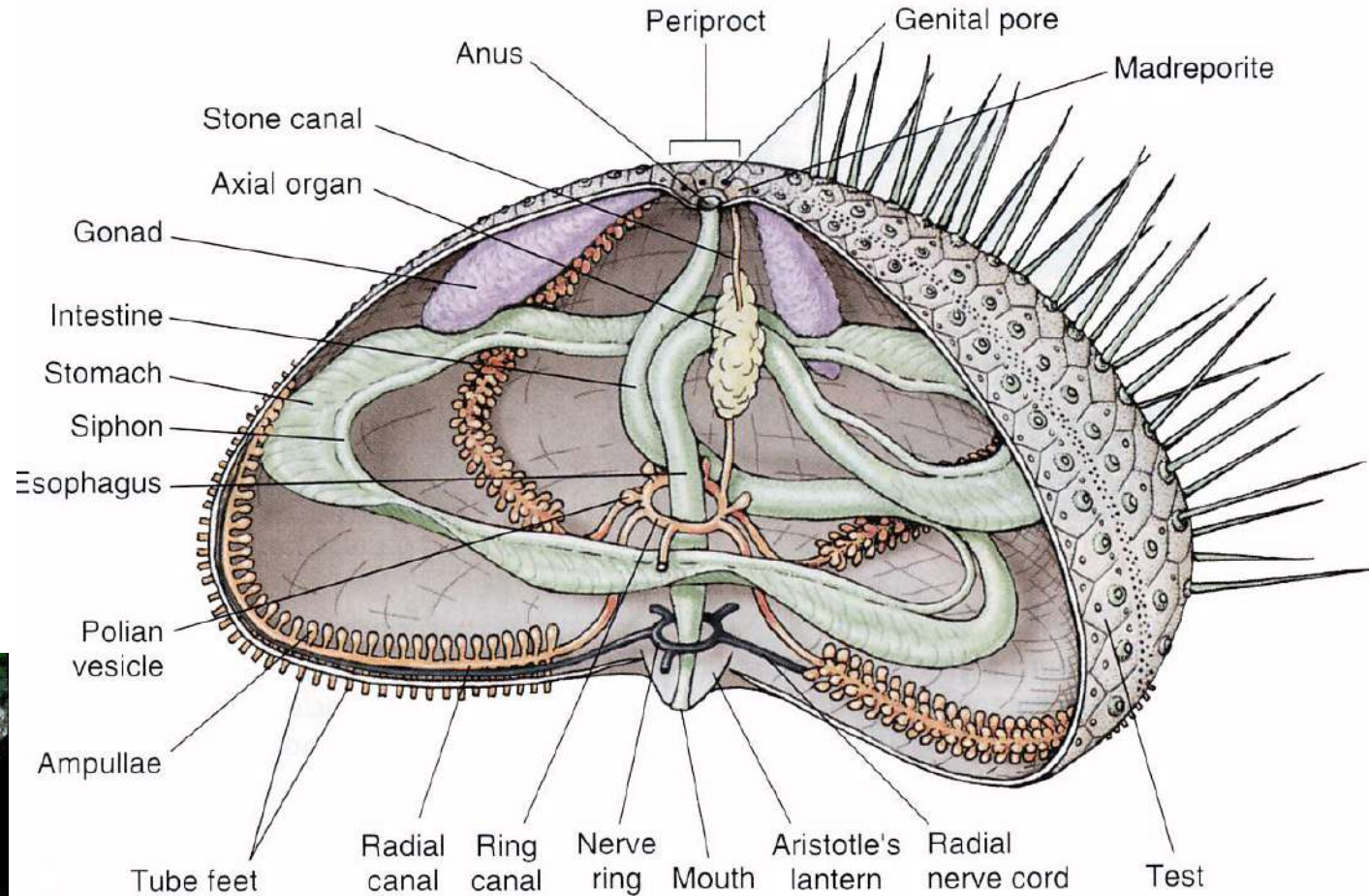
Heart urchins



Sand dollars

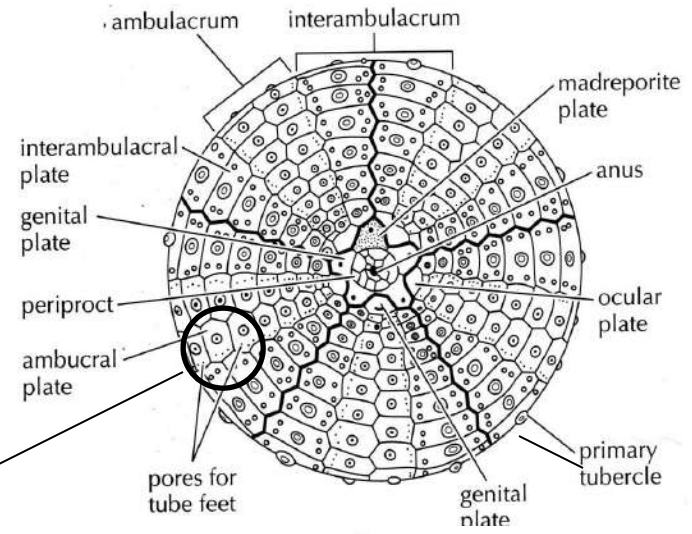
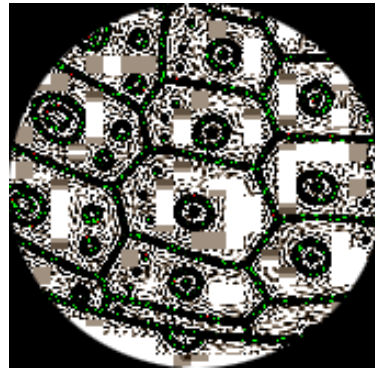


Sea urchins

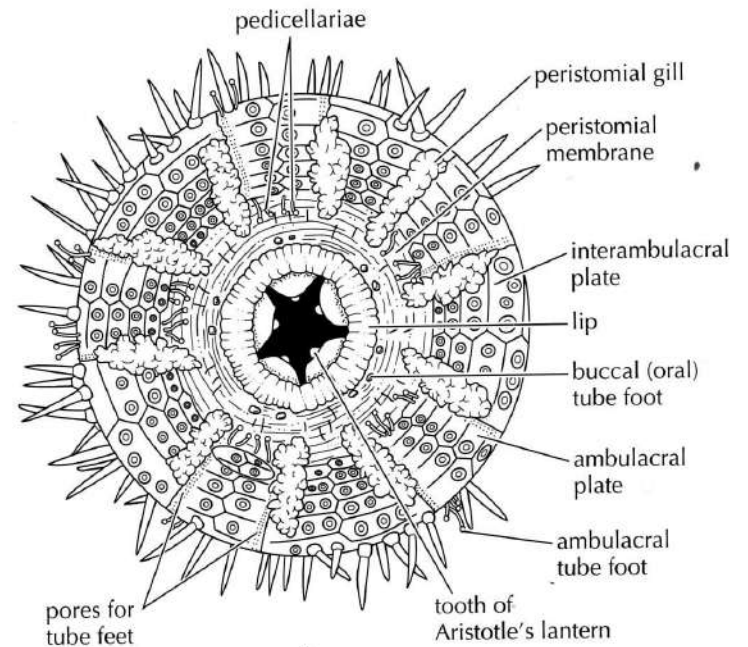
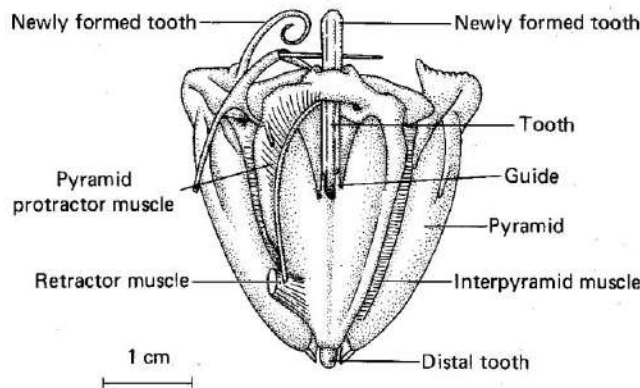


Defining characteristics of the Echinoidea

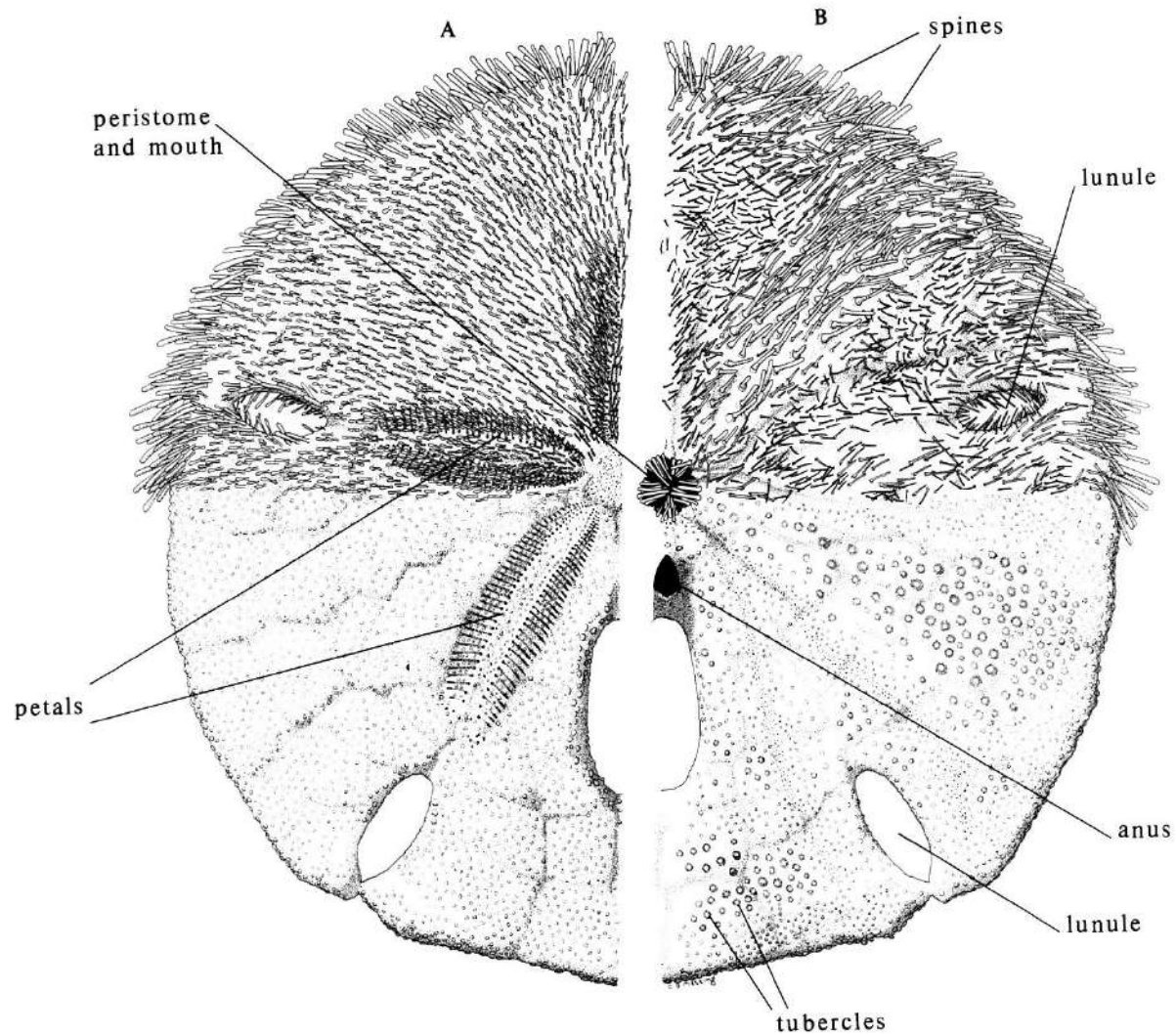
Ossicles joined to form a rigid test, with podia passing through pores in ambulacral plates



Aristotle's lantern for grazing



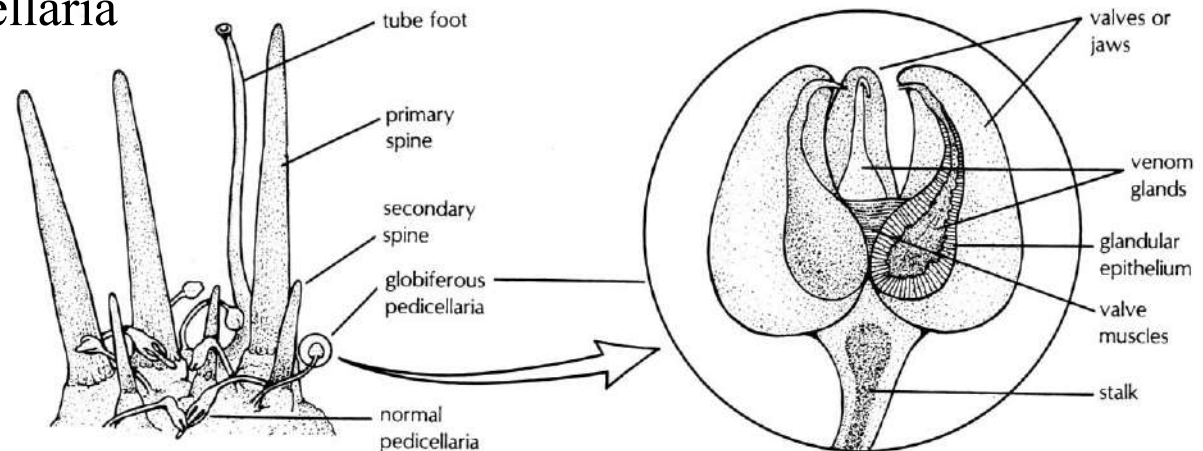
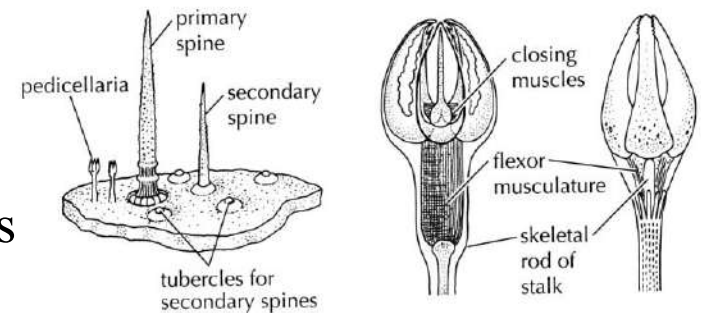
Defining characteristics of the Echinoidea



Basics to the taxonomy of the Echinoidea

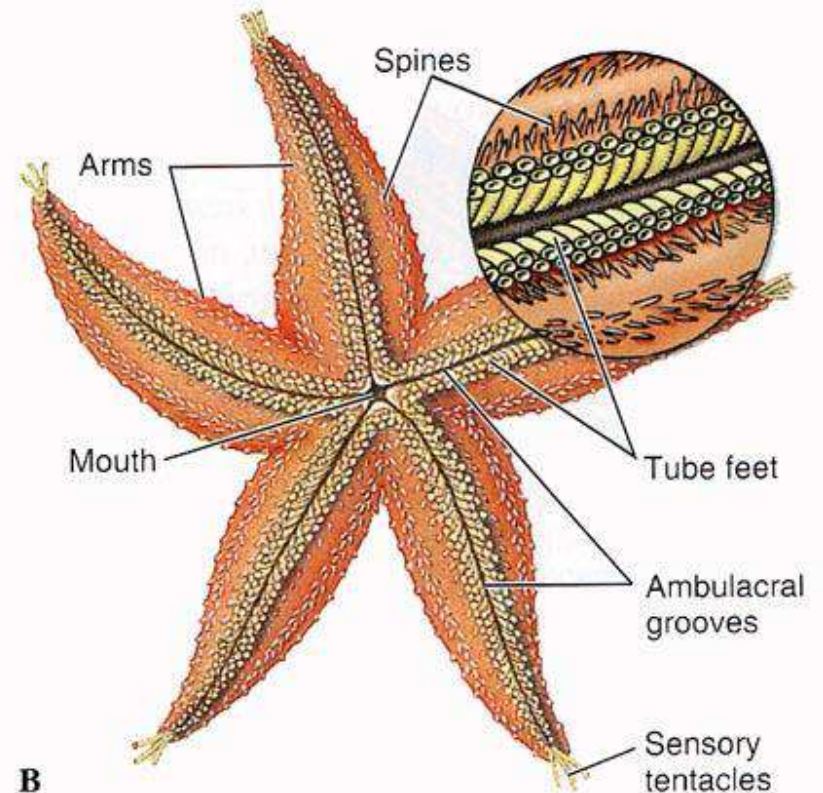
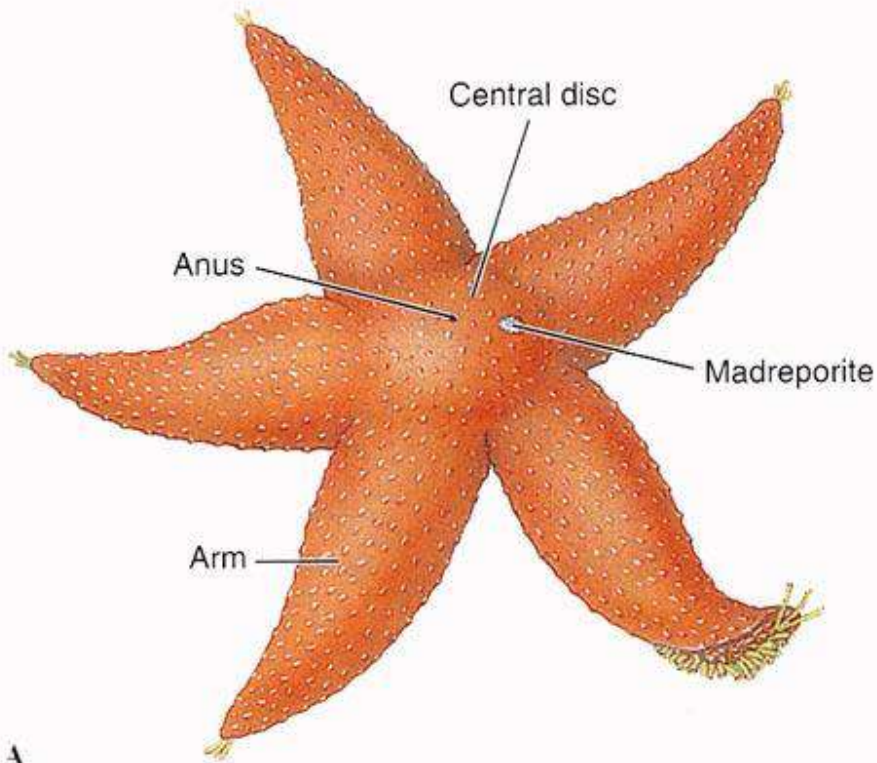
Largely based upon skeletal elements

- Form of test
- Position of anus (aboral for regularia, oral for irregularia)
- Structure of apical system
- Arrangement of ambulacral plates, pore pairs
- Structure of spines, tubercles
- Structure of pedicellaria
- ...



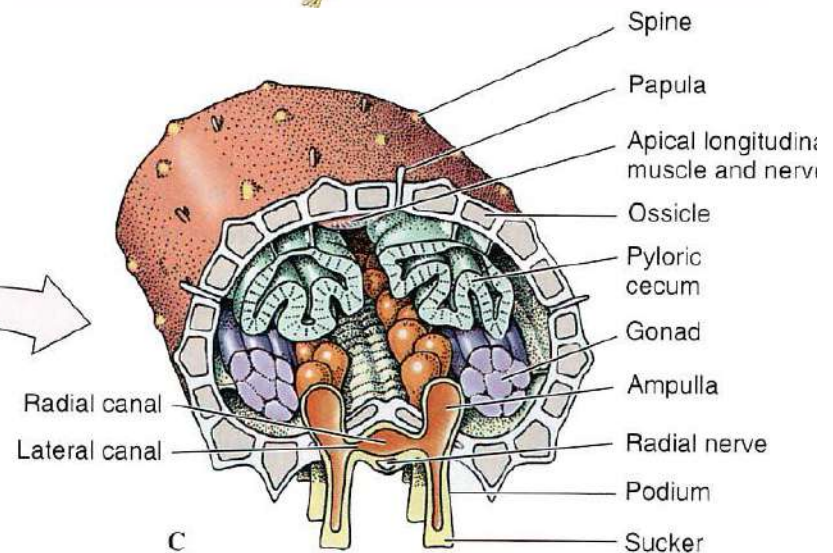
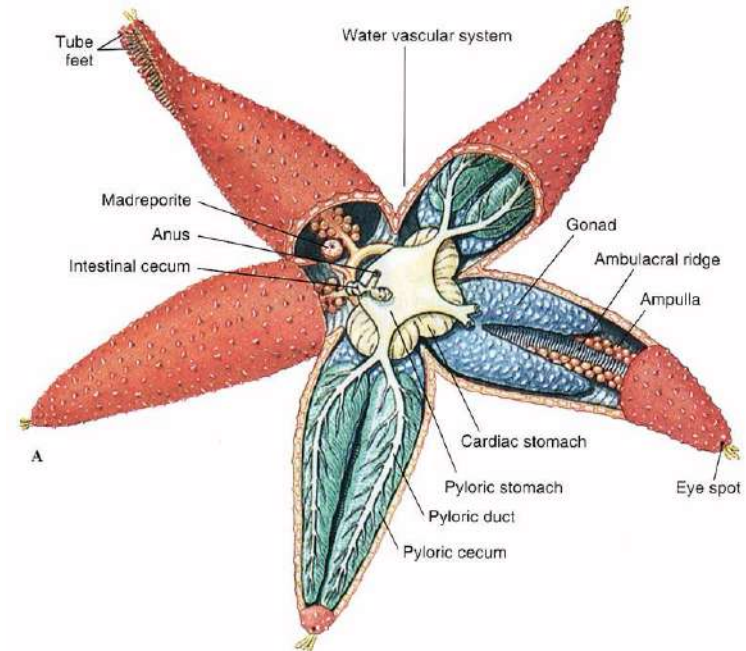
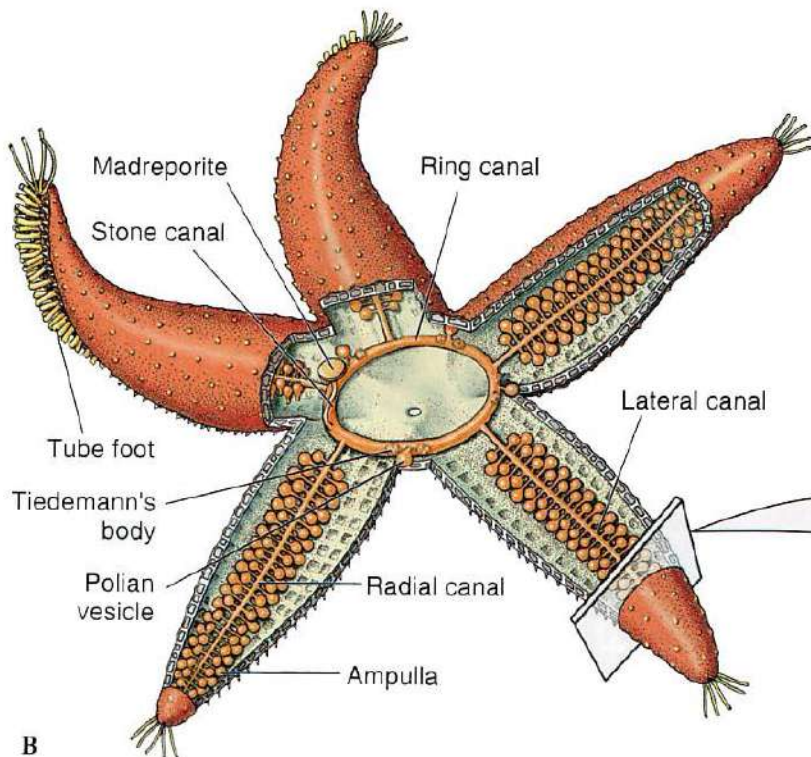
Class Asteroidea - sea stars or starfish

External anatomy



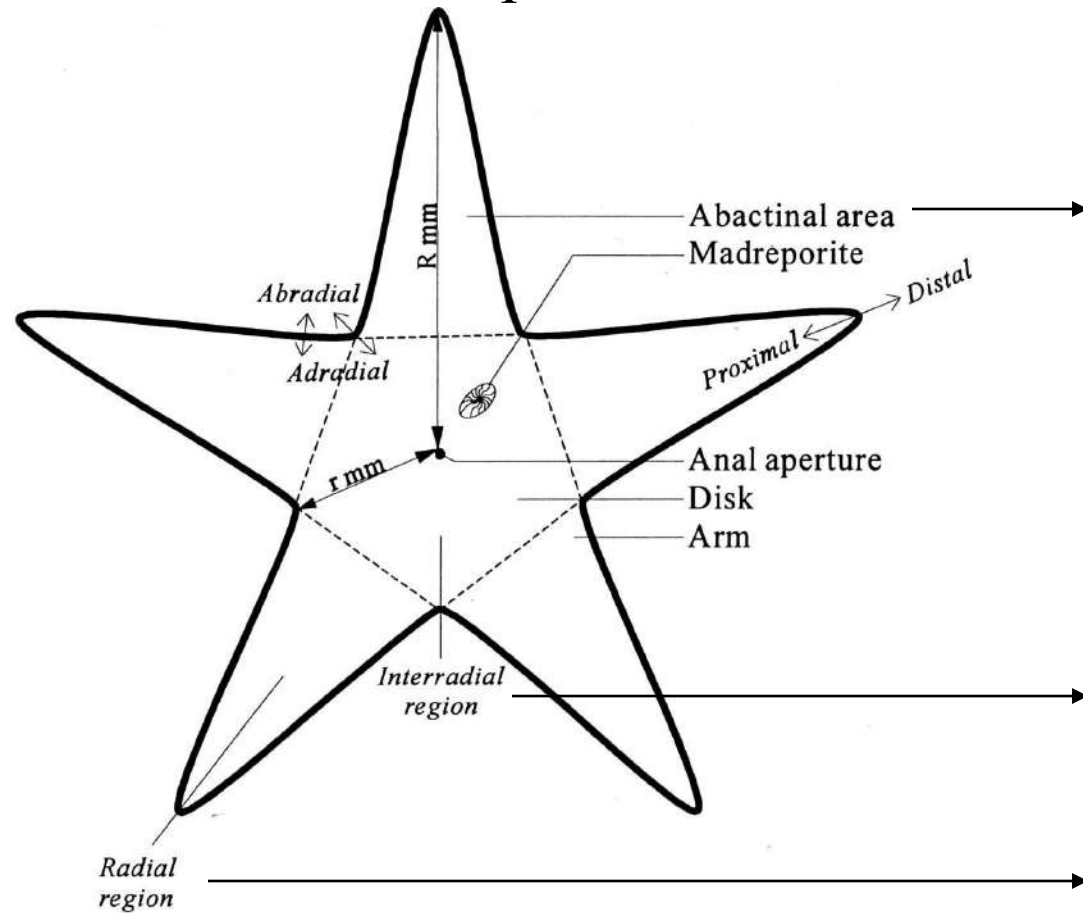
Class Asteroidea - sea stars or starfish

Internal anatomy



Basics to the taxonomy of the Asteroidea

Again mainly based on skeletal characteristics, mainly the architecture of plates and various secondary appendages



The area of the upper side, extending up to the ventral lateral faces of the arms

Ab = away from
Ad = to, with

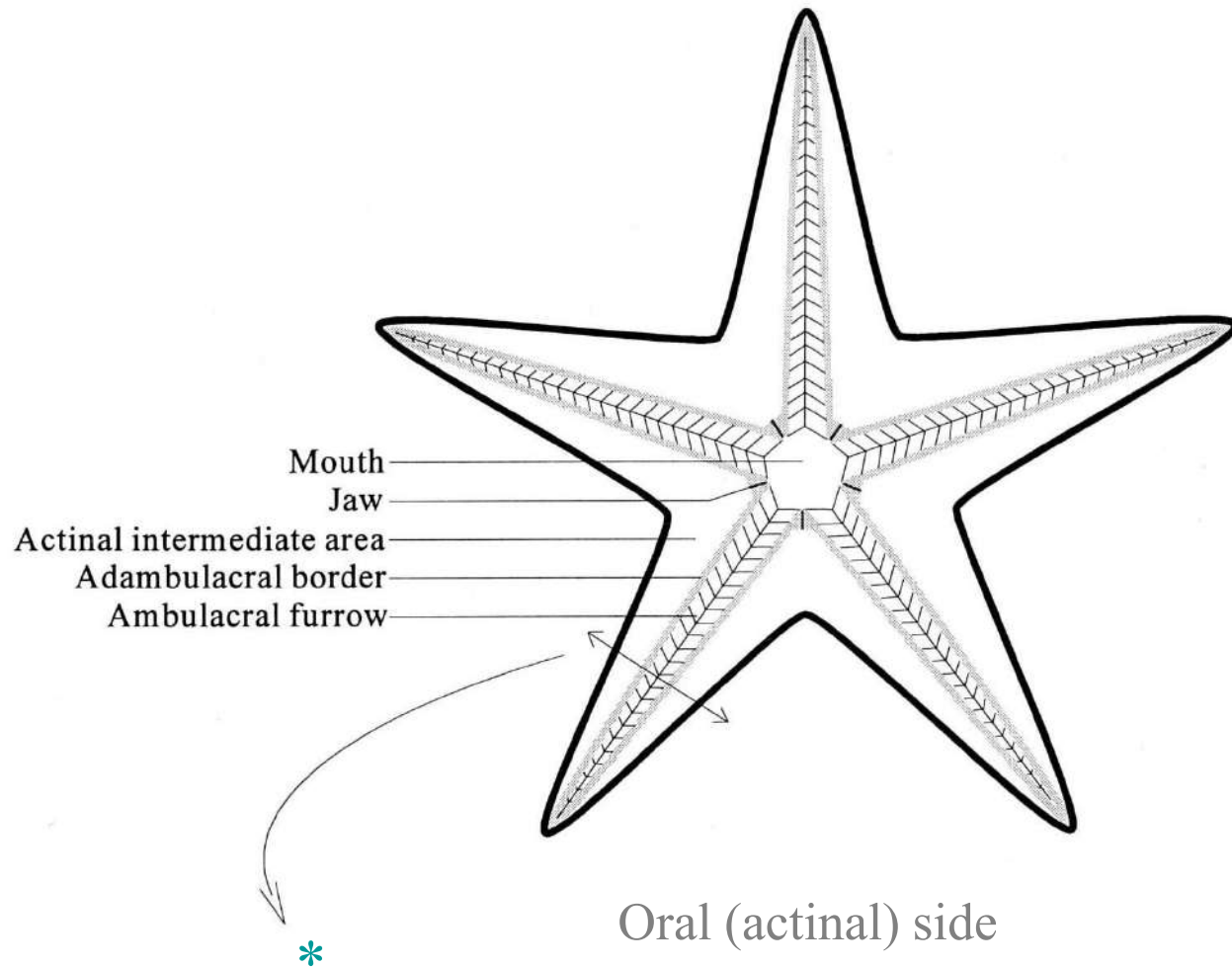
Restricted to the disc, variously developed according to taxon

Arm, with corresponding part of disc

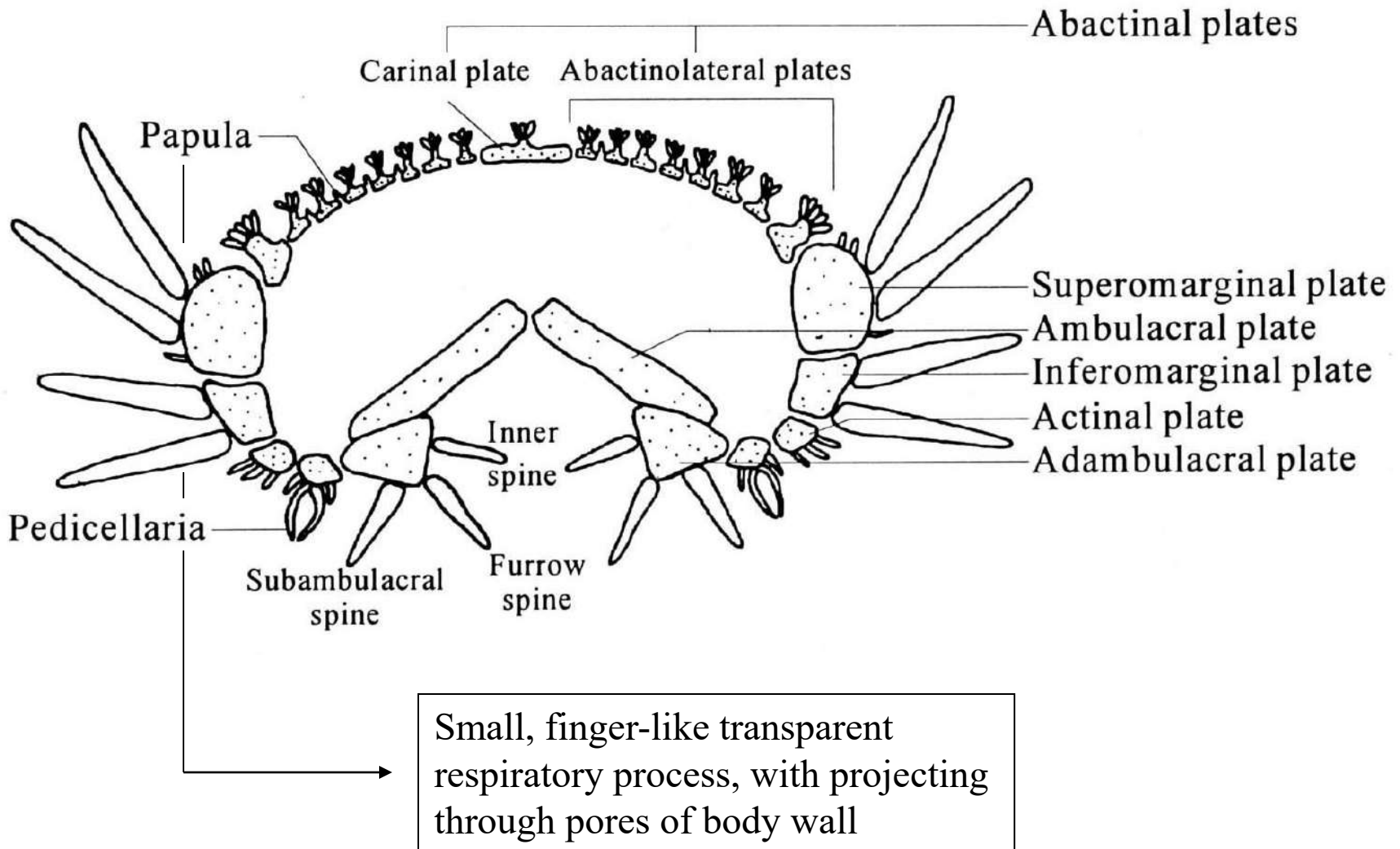
Aboral, dorsal (abactinal) side

Basics to the taxonomy of the Asteroidea

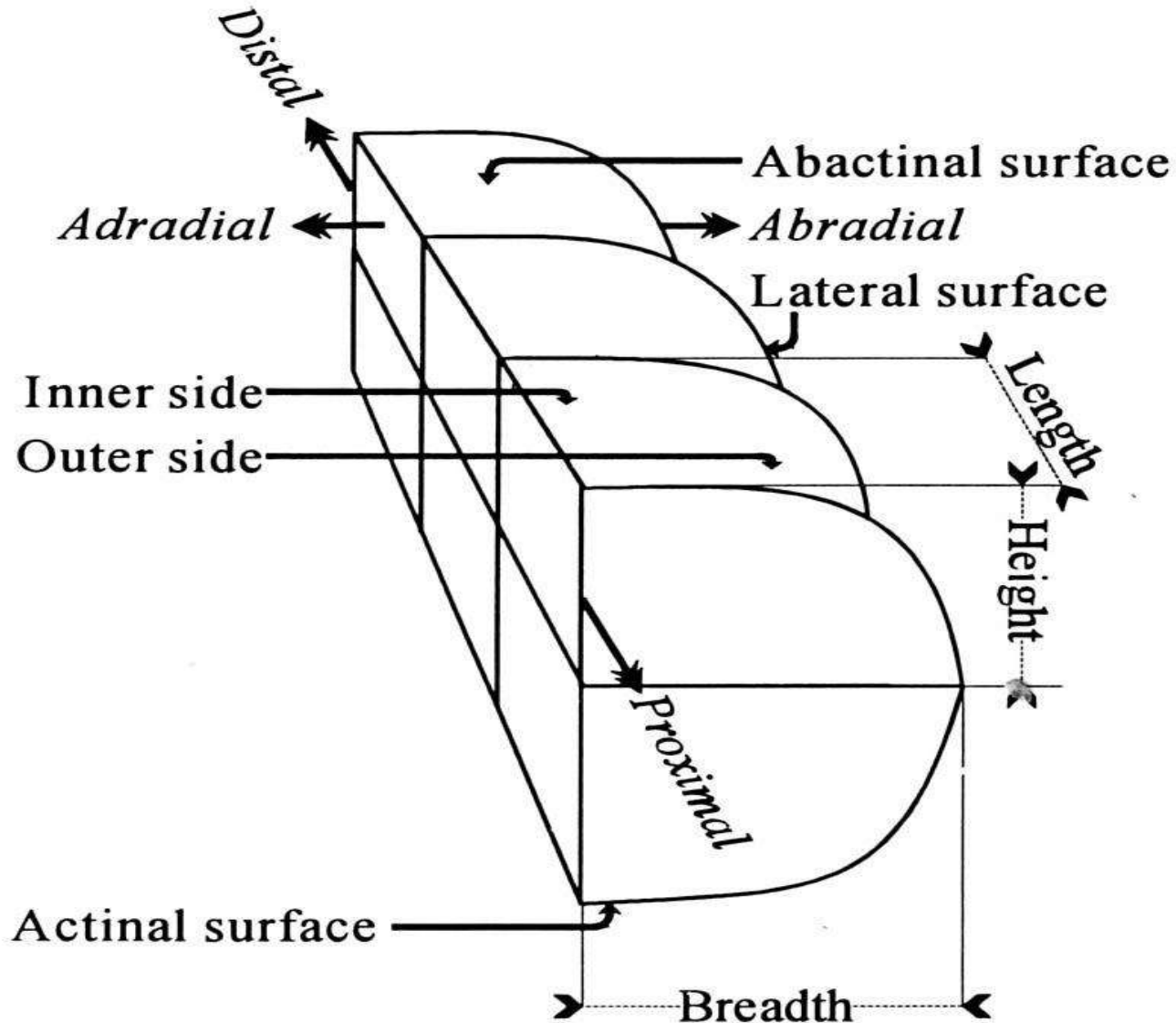
Again mainly based on skeletal characteristics, mainly the architecture of plates and various secondary appendages



Basics to the taxonomy of the Asterozoa



Basics to the taxonomy of the Asterozoidea



Class Ophiuroidea - Brittle & feather stars

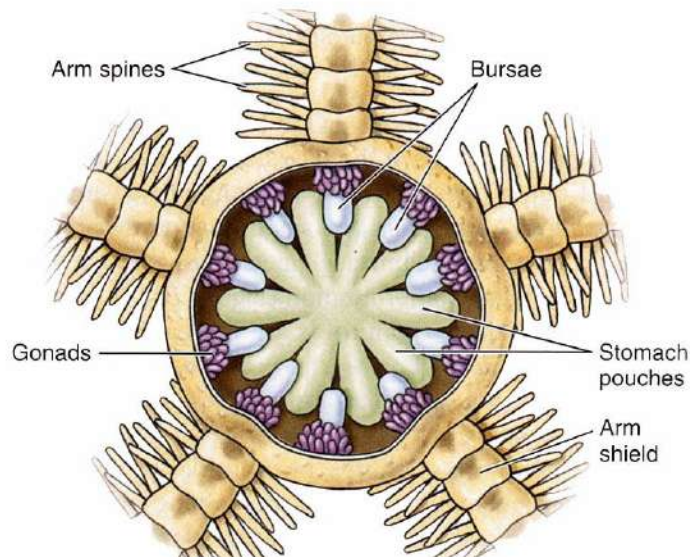
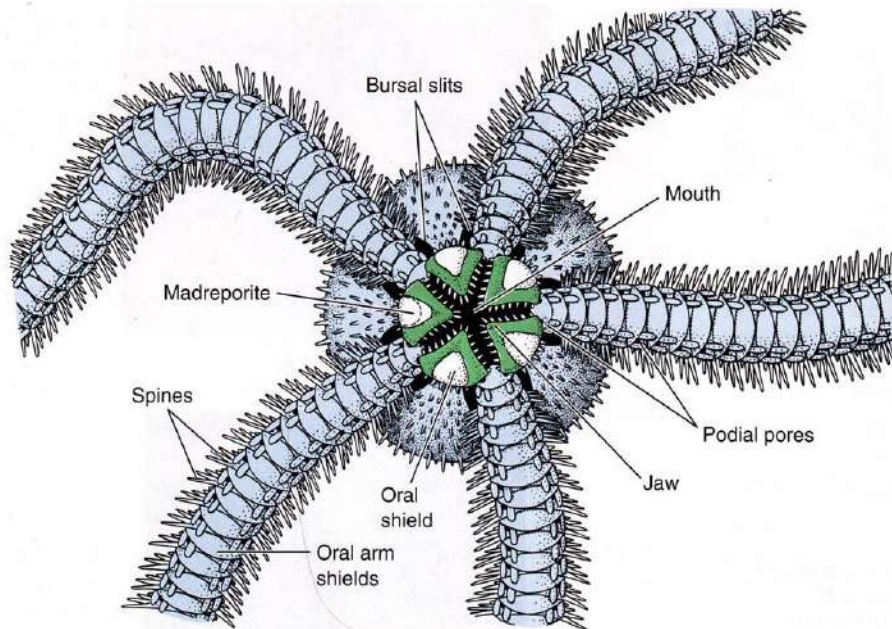


Euryalae - disc and arms covered with thick skin; arm spines scarce reduced, inserted ventrally



Ophiurae - disc and arms covered with thick scales (sometimes concealed by a skin and granules); arm spines inserted laterally

Class Ophiuroidea - some general characteristics



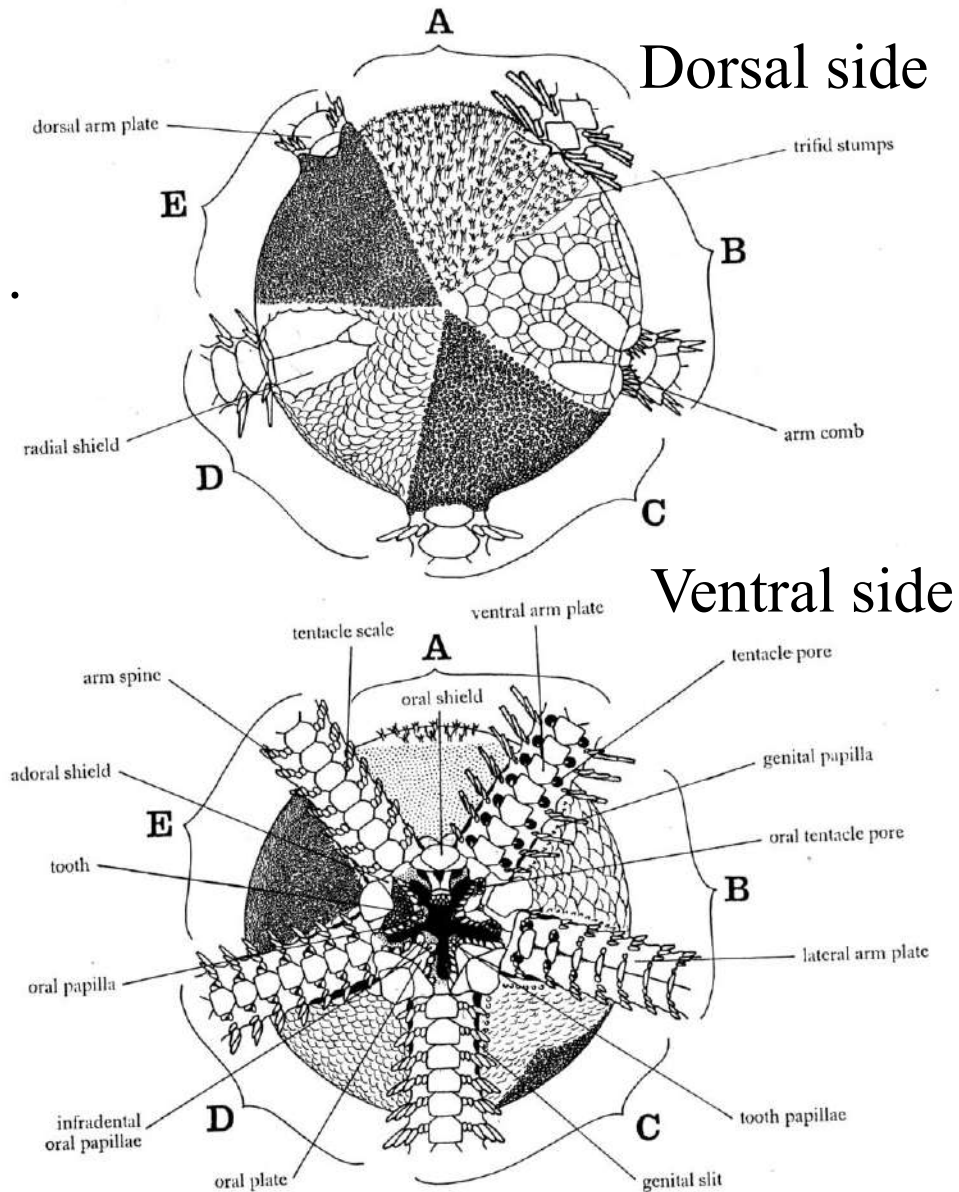
Some notable differences with Asteroidea

- No pedicellariae or papulae
- Ambulacral grooves closed
- Tube foot without suckers
- Madreporite on oral surface (on one of the oral shields)
- No ampullae
- No anus
- Visceral organs confined to the disc
- Respiration through bursae

Basics to the taxonomy of the Ophiuroidea

Largely based on skeletal elements: articulated ossicles (vertebrae), plates, spines, jaws,...

- A: Ophiotrichidae
- B: Ophiuridae
- C: Ophiocomidae
- D: Amphiuridae
- E: Ophiodermatidae



Basics to the taxonomy of the Ophiuroidea

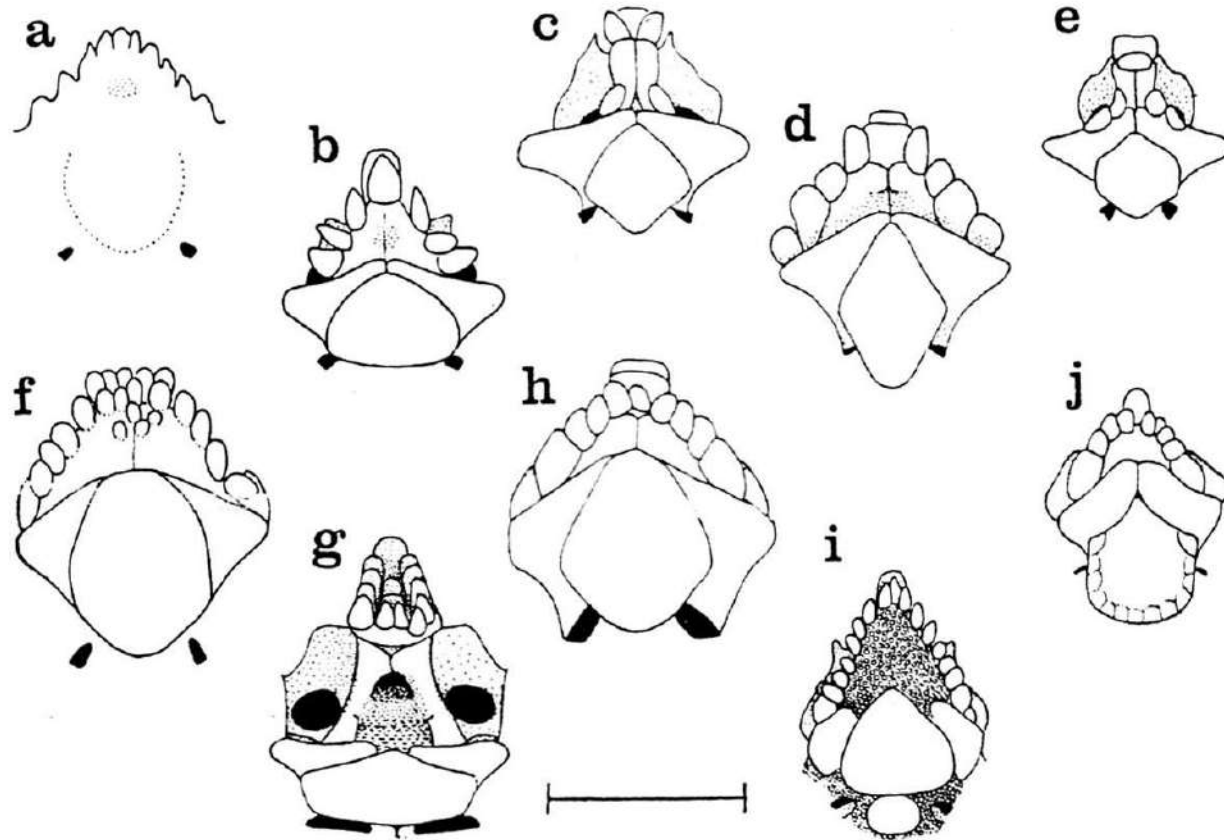
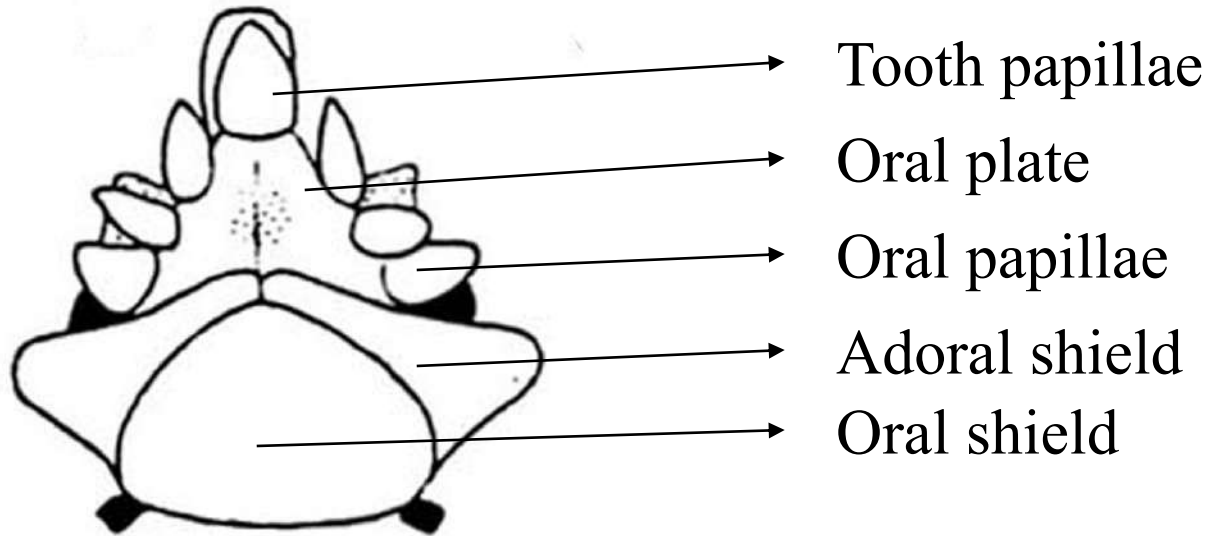


FIG. 22. Single jaws of: a. *Ophiomyxa australis*, b. *Ophiacantha discoidea*, c. *Amphiura septemspinosa*, d. *Amphioplus* (*Lymanella*) *hastatus*, e. *Ophiactis savignyi*, f. *Ophiocoma pica*, g. *Ophiothrix savignyi*, h. *Ophionereis lineata*, holotype, i. *Ophiarachnella infernalis* and j. *Ophiolepis cincta*. In a, f, i and j the scale equals 2 mm., in b, e and g it equals 1 mm. and in c and d 0.7 mm.

Basics to the taxonomy of the Ophiuroidea



Basics to the taxonomy of the Ophiuroidea

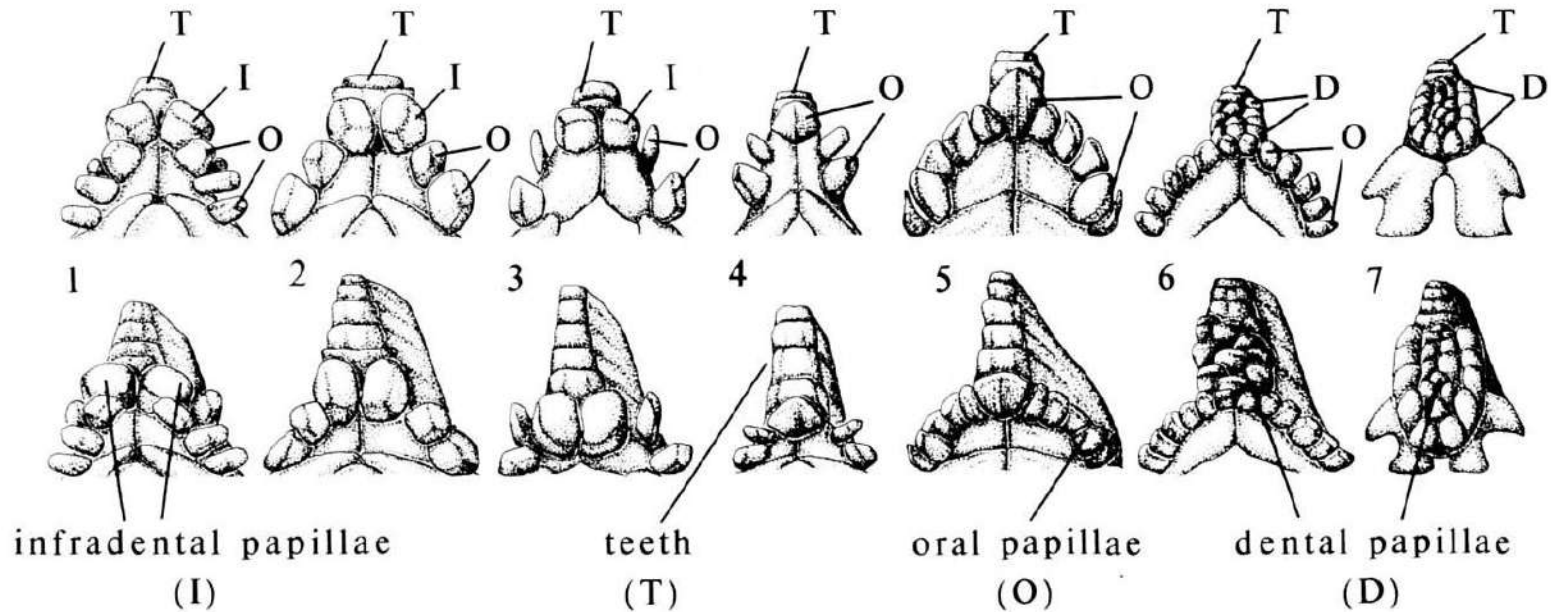
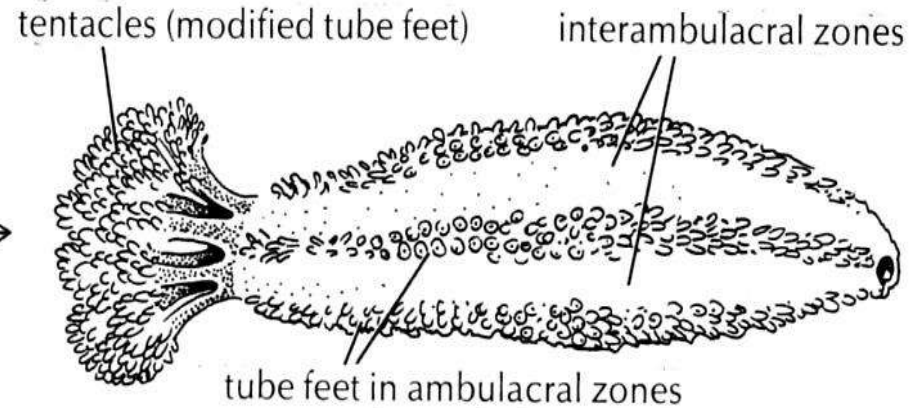
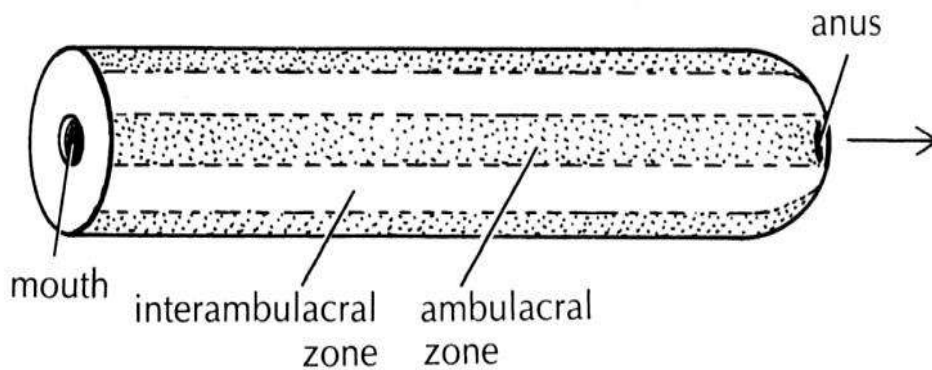
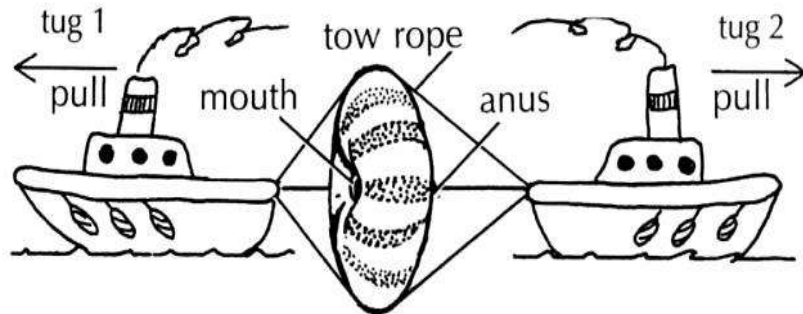
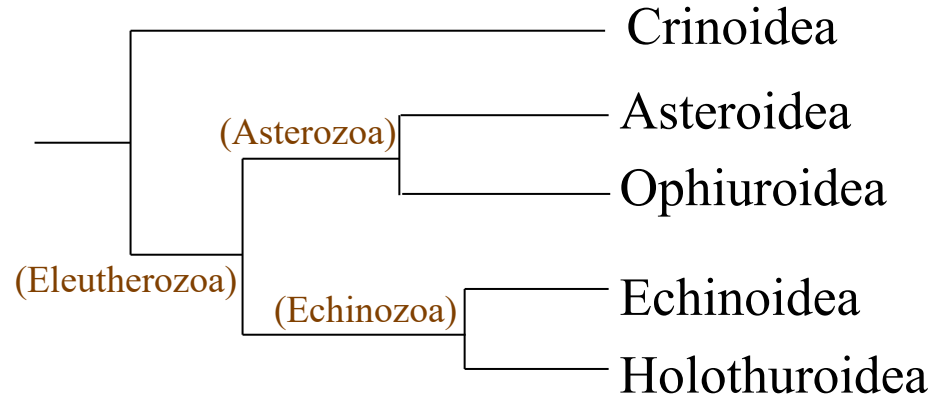


FIGURE 32. Brittle star jaw structures showing configurations of the dental papillae (D), infradental papillae (I), oral papillae (O), and teeth (T) that are characteristic of different families and genera. Upper row: ventral view of the jaw; lower row: the proximal edge of the jaw, showing the tooth row that projects into the mouth. (1) *Amphioplus thrombodes*, (2) *Ophiophragmus pulcher*, and (3) *Amphiura kinbergi* with paired infradental papillae at the apex of the jaw; (4) *Ophiactis savignyi* with two oral papillae on each side of the jaw, and (5) *Ophiolepis elegans* with several pairs of oral papillae; (6) *Ophiocoma echinata* with a cluster of dental papillae and a series of oral papillae, (7) *Ophiothrix suensonii* with a large cluster of dental papillae, oral papillae lacking. Illustration by R. Mooi.

Sister group of the Echinoidea



Holothuroidea - defining characteristics

- Worm-shaped body, greatly elongated along oral/aboral axis
- Presence of calcareous ring (attachment point for muscles operating the oral tentacles and for the anterior ends of other muscles that contract the body longitudinally)
- Circlet of oral tentacles of various form (digitate, pinnate, peltate)
- Body ossicles reduced to microscopic size (sometimes completely absent) and embedded individual in different tissues
- Radial canals give rise to five primary tentacles => longitudinal canals
- Presence of respiratory trees: highly branched, muscular respiratory structures, extended from the cloaca into the coelomic cavity (cloacal breathing) (not in Apoda, some Elasipoda)
- Presence of Cuvierian tubules (Holothuriidae only)

Apodida (269 species, 32 genera, 3 families)

Tentacles digitate, pinnate or, in some small species, simple. Respiratory trees absent. Tube feet completely absent. Calcareous ring without posterior projections. Body wall is very thin and often transparent. Found in both shallow and deep water.

Elasipodida (141 species, 24 genera, families)

Tentacles shield-shaped and used in shovelling sediment. Respiratory trees present. Calcareous ring without posterior projections. With the exception of Deimatidae, body wall soft to gelatinous. All forms live in deep water.

Aspidochirotida (340 species, 35 genera, 3 families)

Tentacles shield-shaped. Respiratory trees present. Calcareous ring without posterior projections. Body wall generally soft and pliant. Most forms live in shallow water, though one family is restricted to the deep sea.

Molpadiida (95 species, 11 genera, 4 families)

Tentacles simple. Respiratory trees present. Calcareous ring without posterior projections. Body wall generally soft and pliant. Most forms live in shallow water, though one family is restricted to the deep sea.

Dendrochirotida (550 species, 90 genera, 7 families)

Tentacles highly branched and extended to filter material from the water column. Respiratory trees present. Some members with a calcareous ring composed of numerous small pieces or having long posterior extensions. Possess muscles for retracting oral introvert. Body wall may be hardened from enlarged plate-like ossicles. Live either attached to hard bottoms or burrow in soft sediment. Most species live in shallow water.

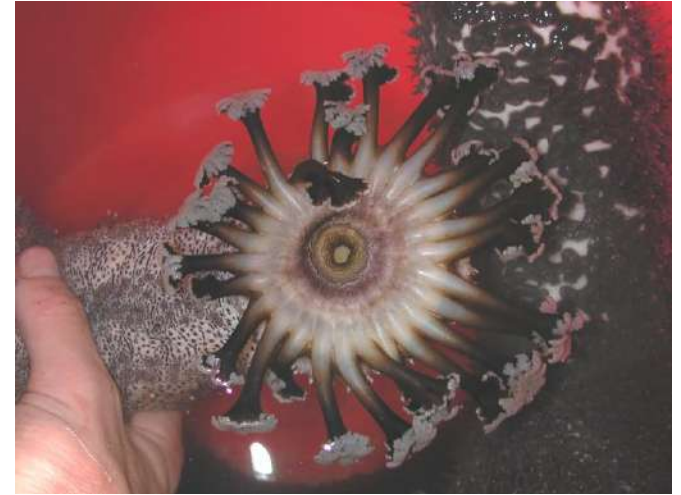
Dactylochirotida (about 35 species, 7 genera, 3 families)

Tentacles simple or with a few small digits. Respiratory trees present. Calcareous ring without posterior projections. Possess muscles for retracting oral introvert. All members have a rigid body encased in enlarged flattened ossicles. Body usually "U" shaped. All members live burrowed in soft sediment. Most live in deep water.

Dominant shallow-water groups



Dendrochirotida



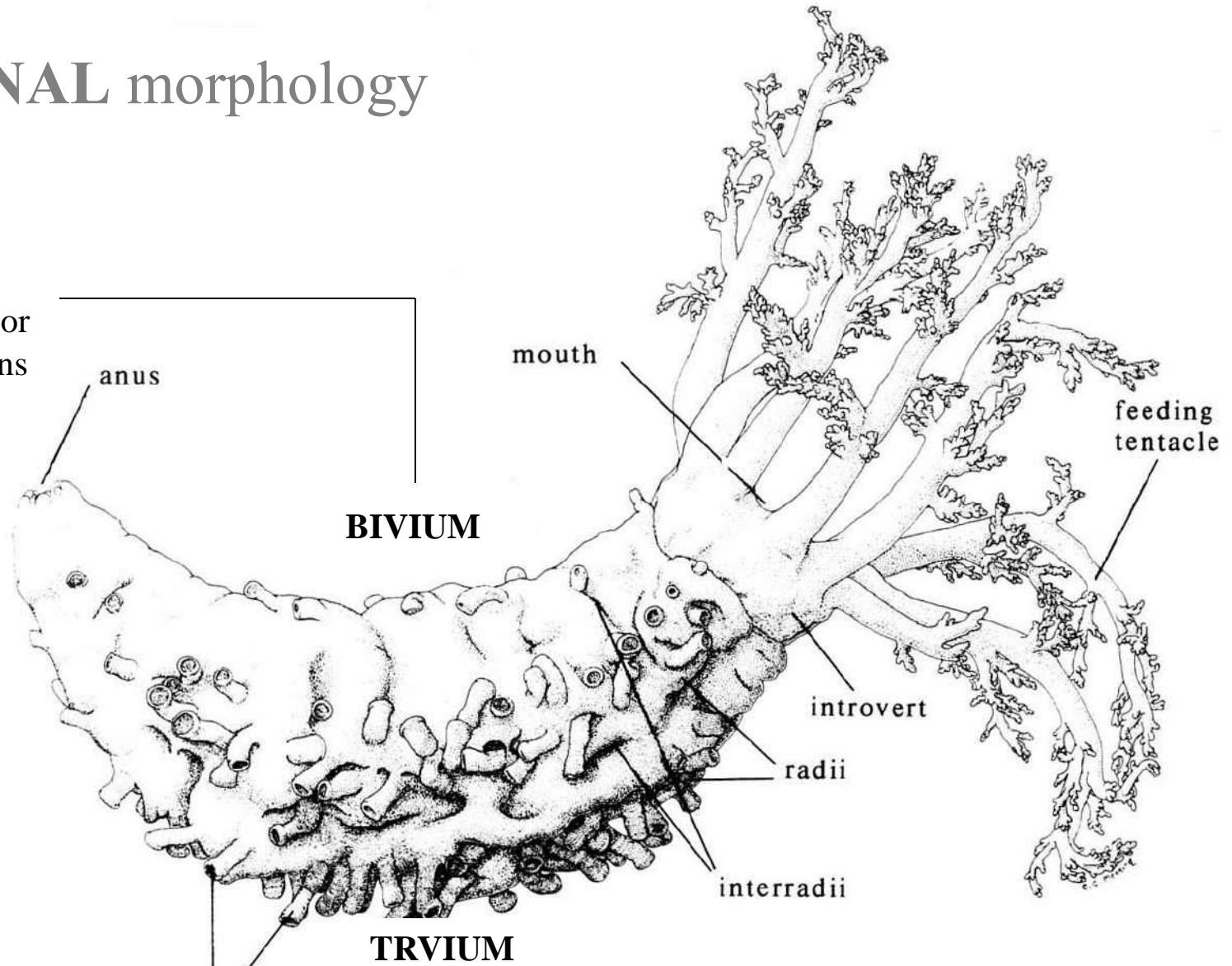
Apodida



Aspidochirotida

EXTERNAL morphology

2 ambulacral (or radial) and 3 interambulacral (or interradial) regions



feeding tentacle

mouth

anus

BIVIUM

introvert

radii

interradii

TRIVIUM

tube feet

3 ambulacral and 2 interambulacral regions

INTERNAL morphology

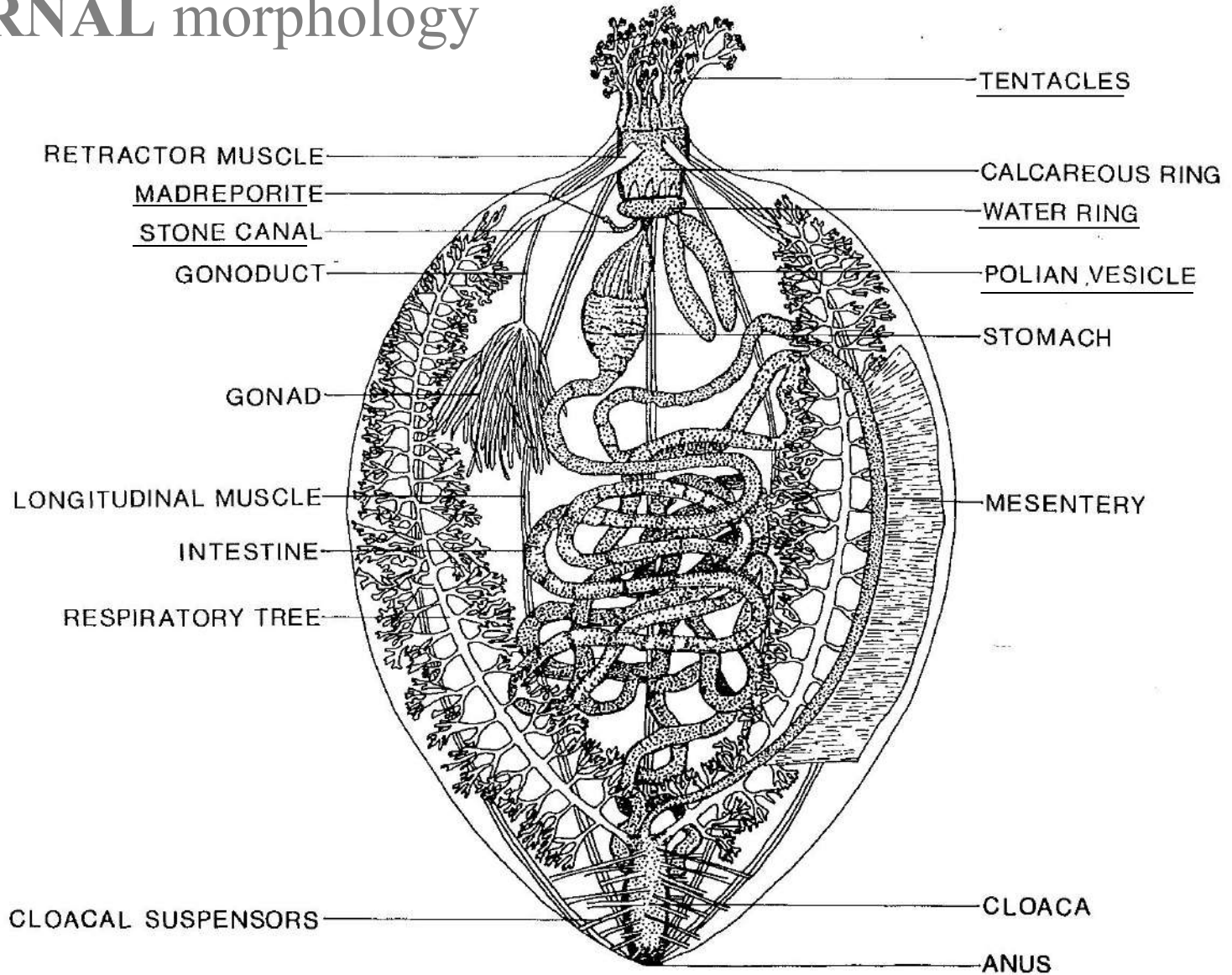
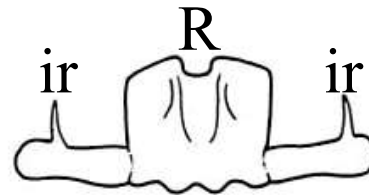
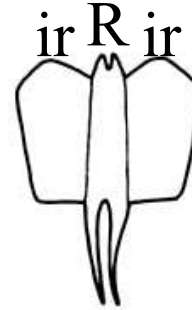


Figure 3. Anatomy of the holothurian, *Sclerodactyla briareus*, order Dendrochirotida (after Coe, 1912).

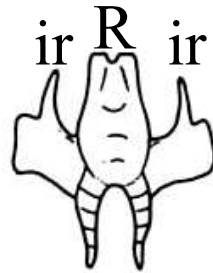
Taxonomic characters - structure calcareous ring



Holothuria



Thyone



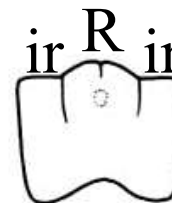
Phyllophorus



Cladolabes



Acaudina



Euapta

Taxonomic characters - Morphology, number and position of tentacles

Dendritic

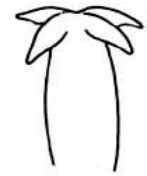
Peltate

Digitate

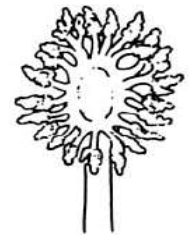
Pinnate



Dendrochirotida



Caudinidae



Aspidochirotida



Synapta

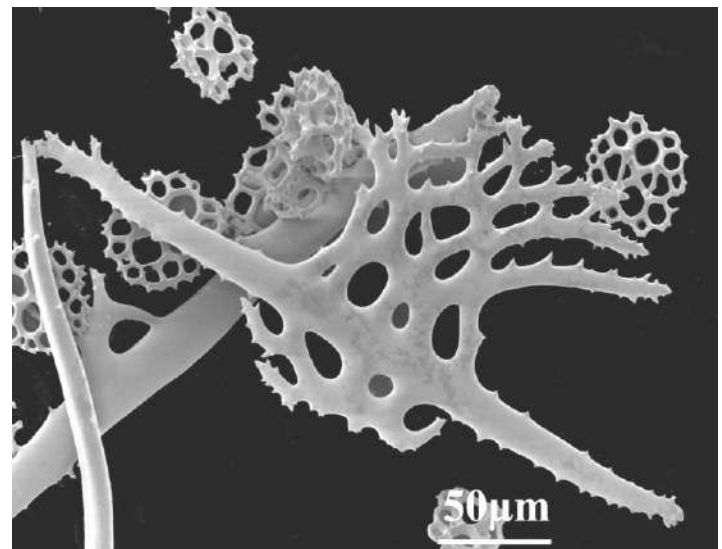
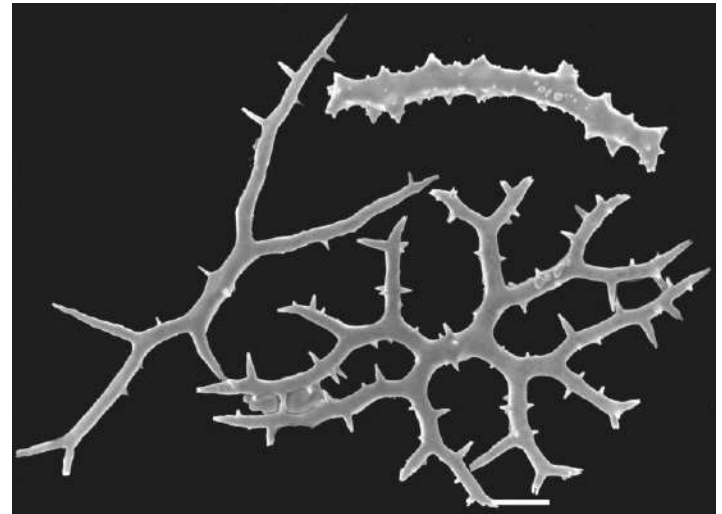
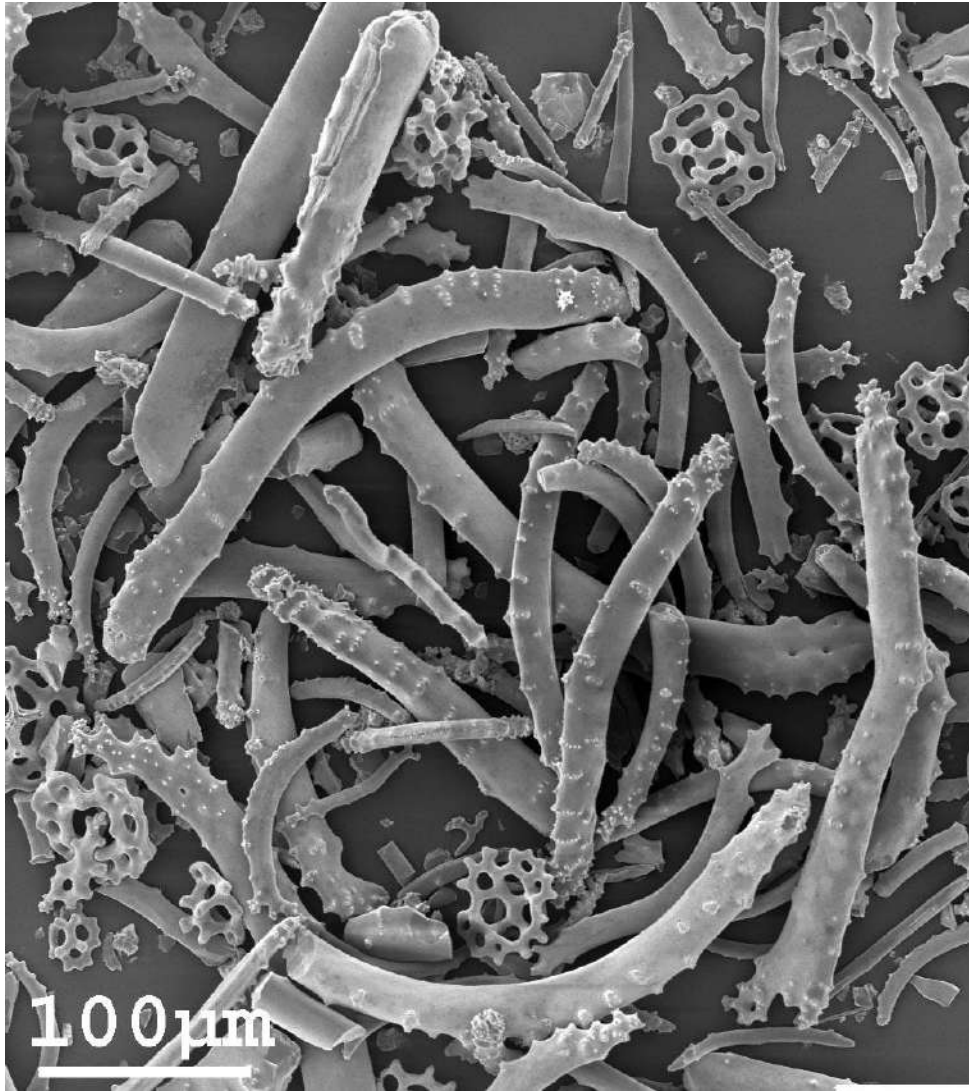


Chiridota/Polycheira

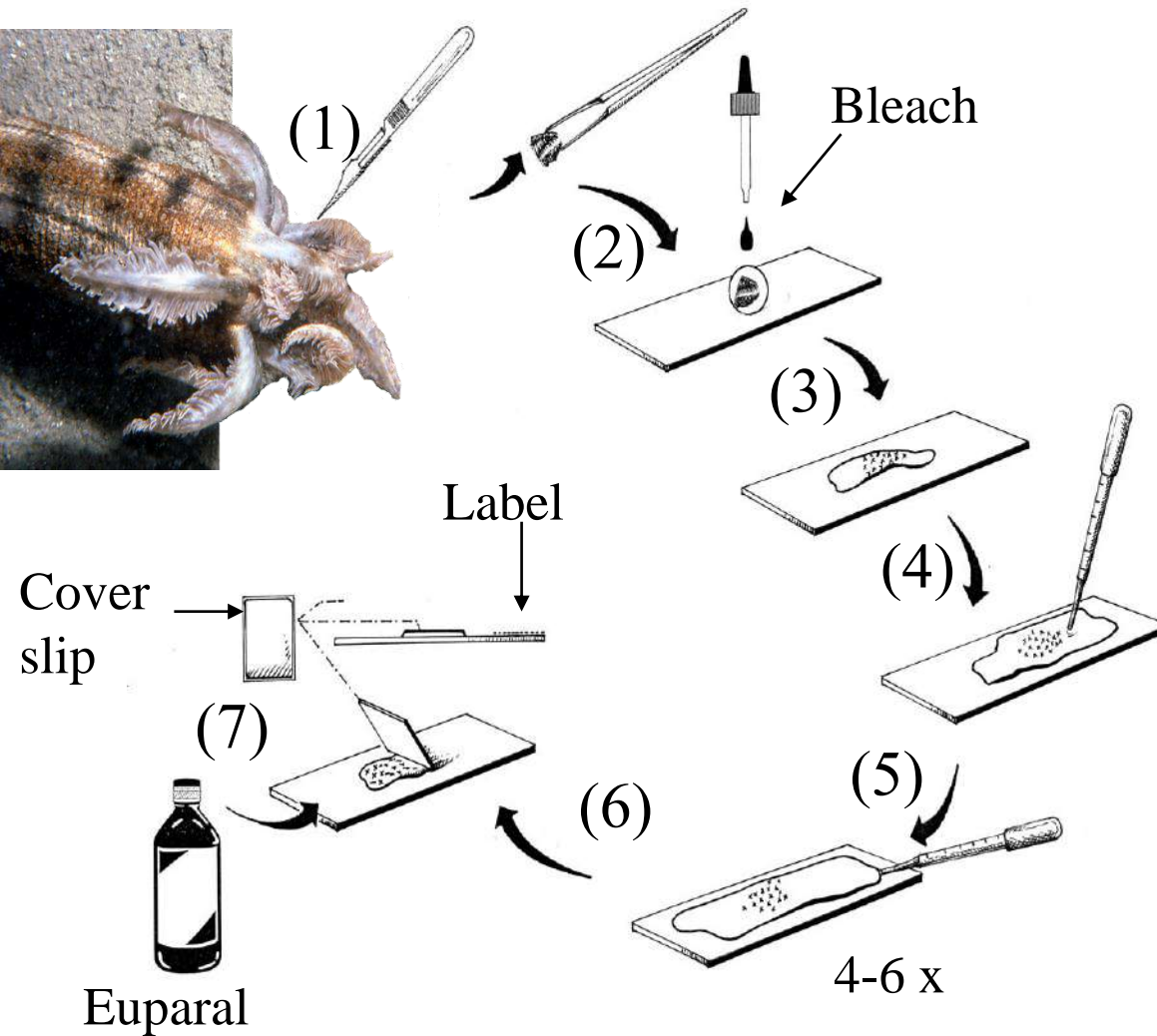


Synapta

Taxonomic characters - ossicles



Ossicle preparation

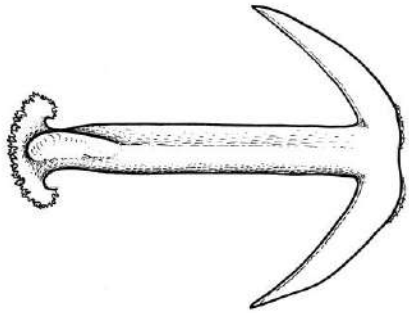


- (1) Remove one tissue type
- (2) Place tissue in small drop of bleach and
- (3) Let dissolve
- (4) Rinse with distilled water
- (5) Repeat 4 to 6 times
- (6) Let dry completely
- (7) Mount with neutral mounting agent (eg euparal) and immediately put a label

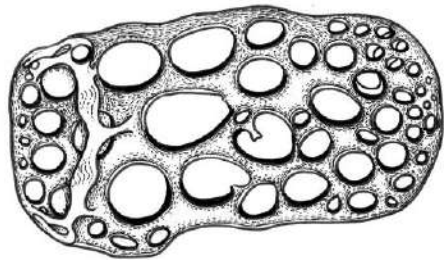
Well-labeled microscope slide



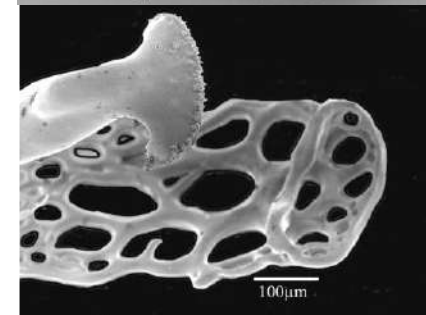
Common ossicle types



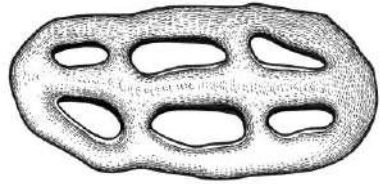
Anchor (German: *Anker*; French: *ancree*; Spanish: *ancla*). Ossicle shaped as an anchor. Anterior end of shaft terminates in 2 flukes which may be smooth or laterally finely dented; *vertex* sometimes with minute knob-like projections; flukes often slightly raised distally out of horizontal plane; *stock* finely rugose or branching; stock end of anchor (*keel*) articulated with corresponding anchor plate by connective tissue.



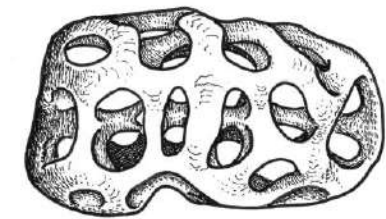
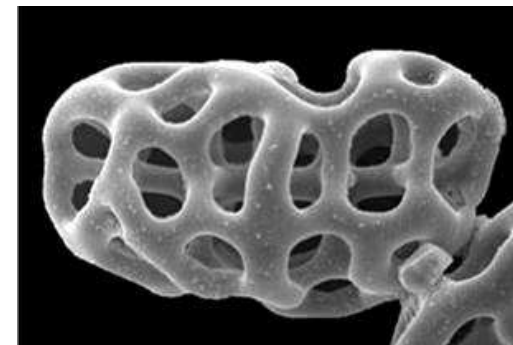
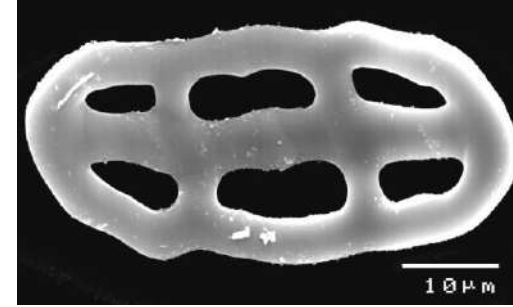
Anchor plate (German: *Ankerplatte*; French: *plaque anchorale*; Spanish: *placa ancla*). Ossicles shaped as rounded, oval, pyriform or rectangular plates with anterior side of plate usually wider than posterior side. Anterior side with large, smooth or variably denticulate holes; posterior side with smaller, generally smooth, holes. Arch-like smooth or toothed transverse bar (*bridge*) usually more or less well developed near the posterior end.



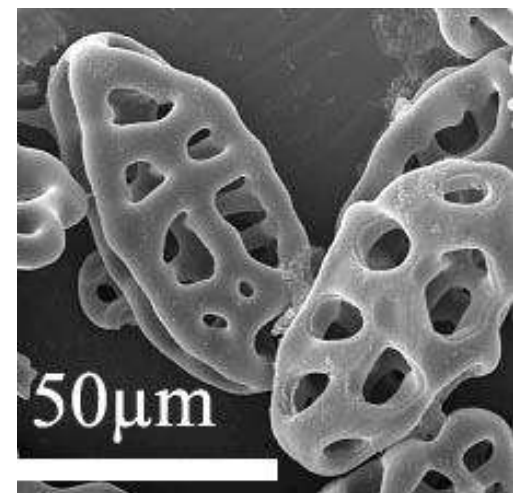
Common ossicle types



Button (German: *Schnalle*; French: *bouton* or *boucle*; Spanish: *botón*). Ossicle pierced by a variable number of regular to irregular holes that are usually arranged in pairs; rim of button may be smooth, spiny or knobbed, straight, undulating or irregular; surface of button smooth (occasionally with a median optical discontinuity) or knobbed; thickness of button variable.

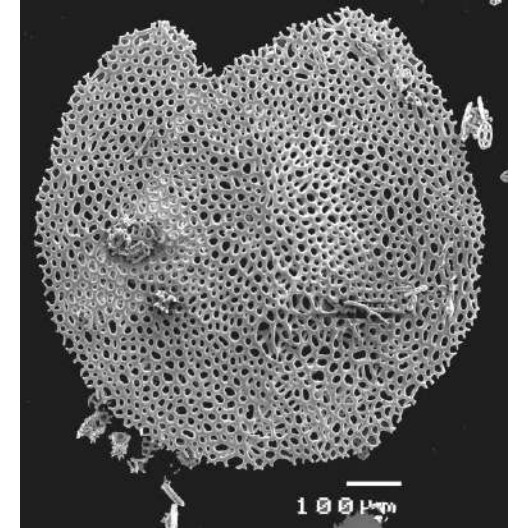
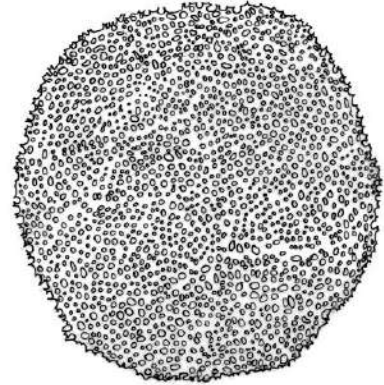


Fenestrated ellipsoid (German: *gefensterte* or *durchbrochene Hohlkugeln* or *Hohlkörper*; French: *ellipsoïde fenestré*; Spanish: *elipsoide festoneado*). Buttons with knobs interconnecting to form a three-dimensional fenestrated structure; number, size and arrangement of holes and knobs variable.

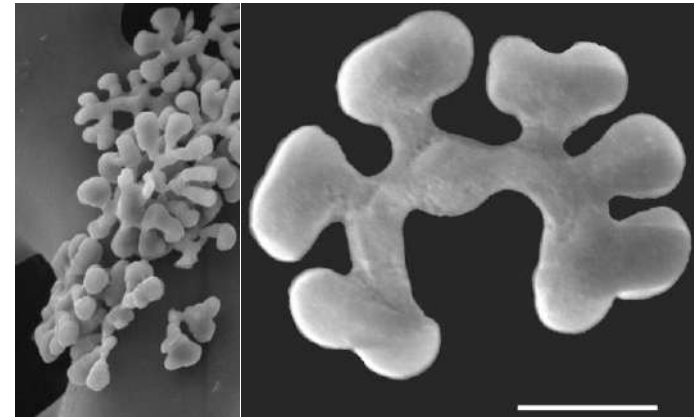
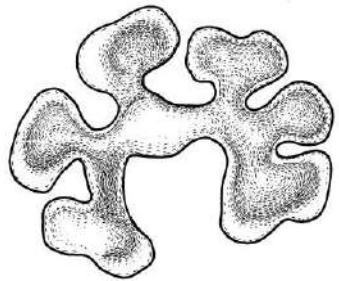


Common ossicle types

End-plate (German: *Endscheibe*; French: *plaque terminale*; Spanish: *placa de la ventosa*). An end-plate is a multiperforated ossicle found in the terminal part of tube feet. Fully formed end-plates are circular in outline and have their rim smooth or ragged; central part often slightly concave. Number, size, arrangement and regularity of the holes vary between higher-level taxa. Diameter of end-plate variable (75-500 μm in diameter), but species-specific in some groups. The large central holes can be overgrown by a secondary layer thus forming an irregular meshwork.



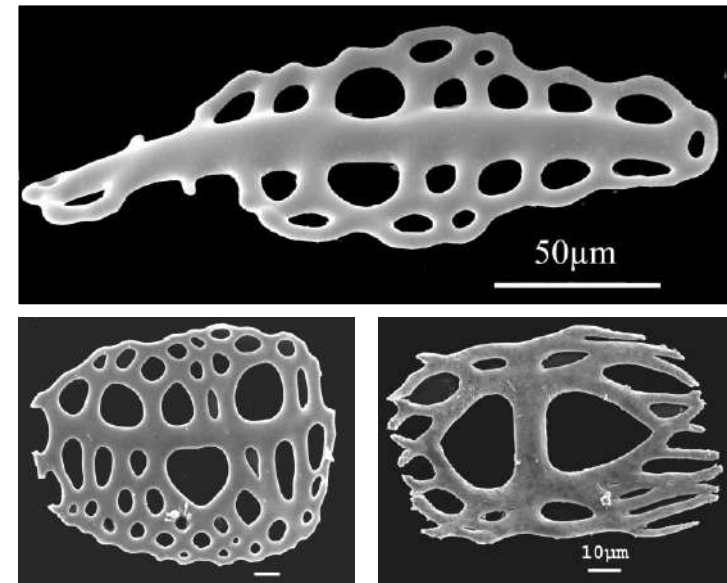
Miliary granule (German: *biscuitförmige Kalkkörper*; French: *corpuscules crépus*; Spanish: *gránulo miliar*) (see also plate 1K). Usually very small (5-30 μm in diameter) ossicles; shape from blebs to rods to rosette-alikes; they can be found in synaptids and chiridotids.



Common ossicle types

Perforated plate (German: *Gefensterte Platte*; French: *plaque perforé*; Spanish: *placa perforada*). Ossicles of various size and structure, commonly divided on the basis of the length-width ratio, the arrangement of the perforations, the rugosity and the thickness of the plate. The number of different types is almost proportional to the number of authors that described them.

Within the Aspidochirotida perforated plates can be divided into those derived from the button and those formed from the rosette-*bauplan*. The first type has its holes arranged in two or more rather regular rows (Holothuriidae), while the second type has its holes arranged more randomly (Stichopodidae).

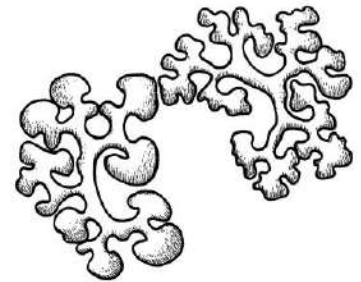
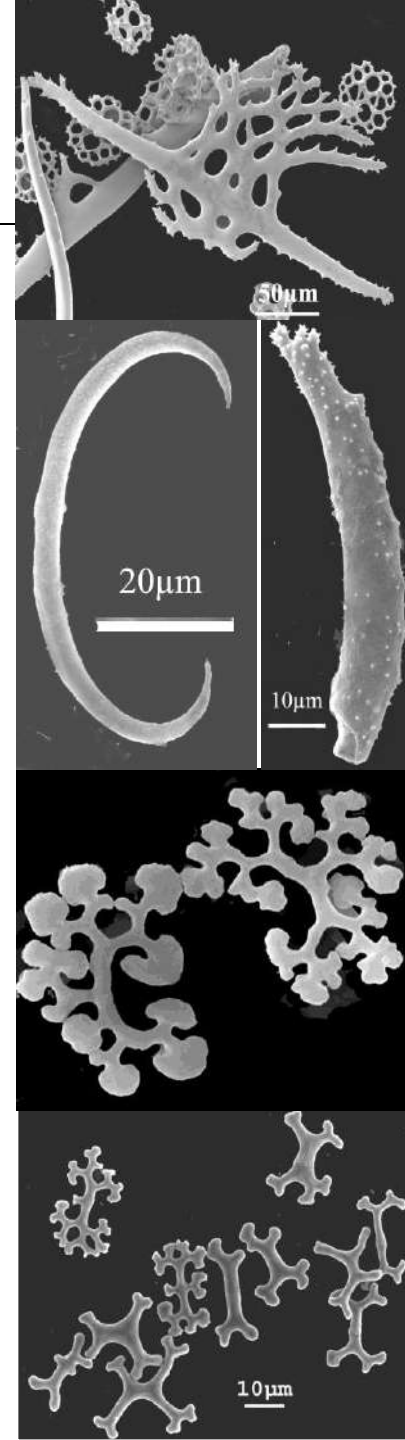


Common ossicle types

Rods (German: *Kalkstäbchen* or *Stützstäbe*; French: *bâtonnet*; Spanish: *barrotes*). Elongated bar-like ossicle which may be thickened centrally and/or distally; perforated or not; branching or not. Various types of rods can be discerned according to the taxon, e.g.:

- *Holothuriidae*: perforations are mostly two by two, giving rise to a regular perforated rod, which by many authors is called an elongated plate
- *Stichopodidae*: perforations are more random, giving rise to an irregular perforated rod (see also *plate*). In the dorsal papillae these rods typically have the central part expanded to one side; the perforations are found therein.

Rosette (German: *Rosette*; French: *rosette*; Spanish: *roseta*). Rosettes form from dichotomously (terminal & lateral) branched rods; branches may variously anastomose to form perforated deposits. Often the general appearance is rather button-like, though rosettes differ from buttons in having the holes of various sizes and in having a single terminal perforation.



Common ossicle types

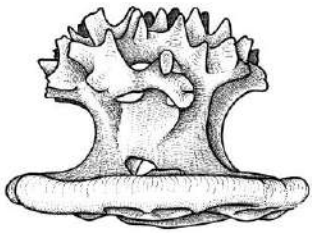
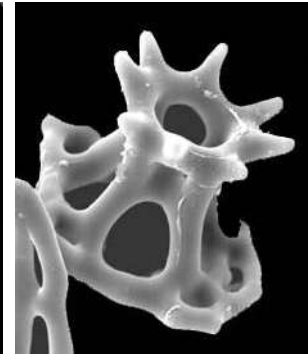
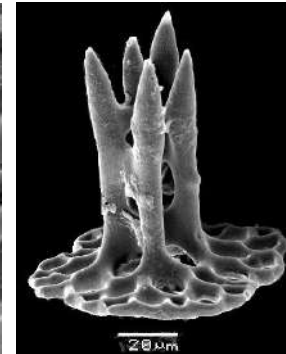
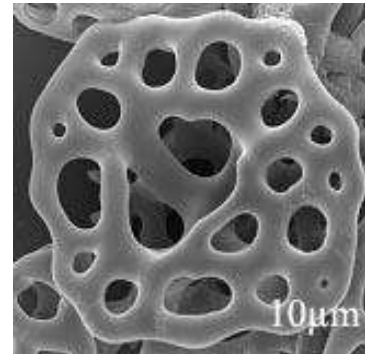
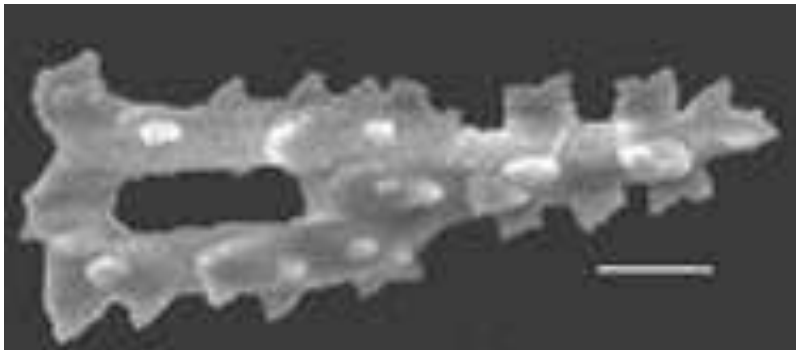
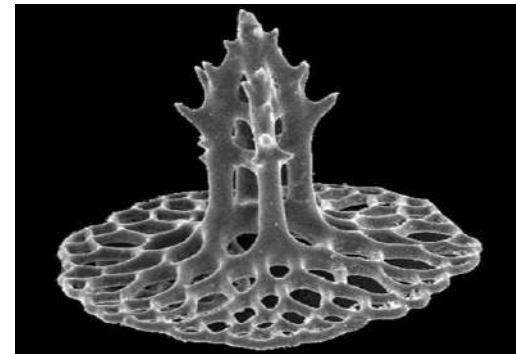
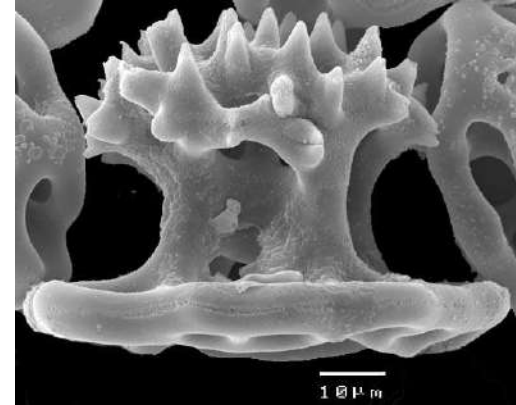
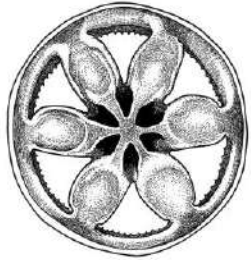


Table (German: *Türme*; French: *table*; Spanish: *tabla*) (see also plate 2L); tables originate from multi-armed (usually four) deposits which branch distally. These branches anastomosing to form a perforated disc, on which arise a variable number of vertical pillars; these pillars can be variously connected to each other (cross-beam or bridge) to form the spire; the spire ends in a cluster of spines or in a crown.

Special kinds of tables exist (e.g. *Pearsonothuria*, *Thelenota*,...)

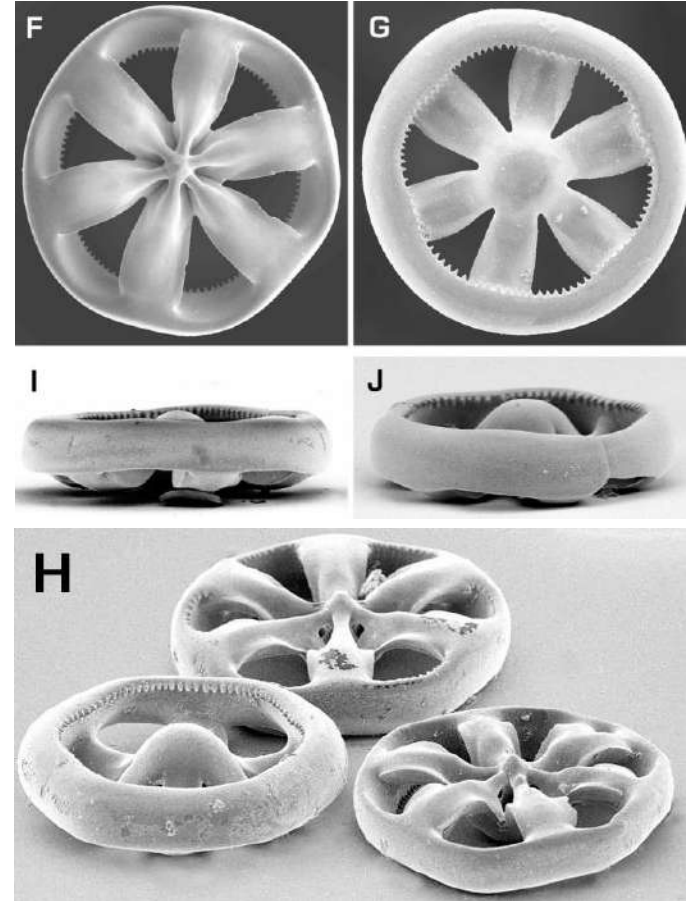


Common ossicle types

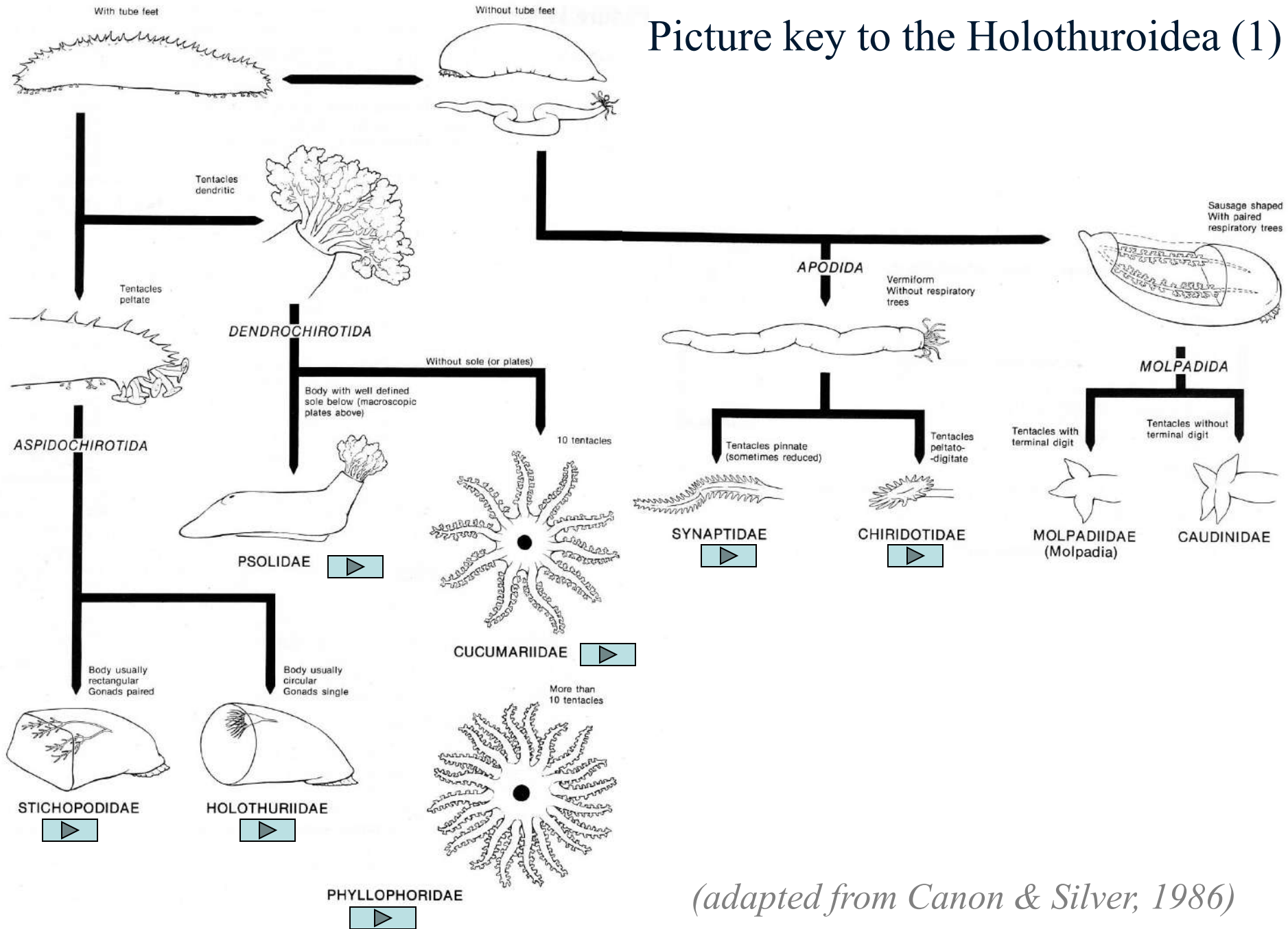


Wheels (German: *Rädchen*; French: *roue*; Spanish: *rueda*). Circular ossicles with six or more spokes leading to the peripheral rim; restricted to the Chiridotidae and Myriotrochidae (Apodida).

Round concavo-convex wheels, similar to chiridotids wheels, can be found in the auricularia larvae of synaptids.



Picture key to the Holothuroidea (1)

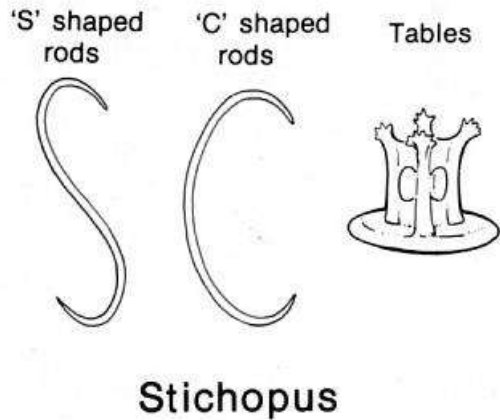


(adapted from Canon & Silver, 1986)

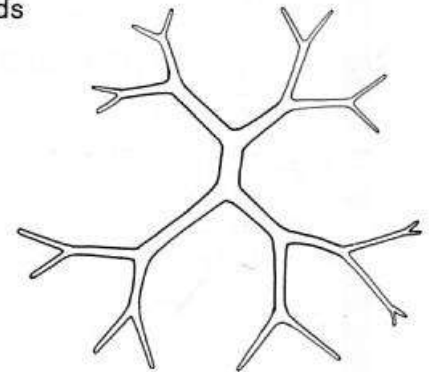
Picture key to the Holothuroidea (2)



STICHOPODIDAE



Dichotomously branched rods



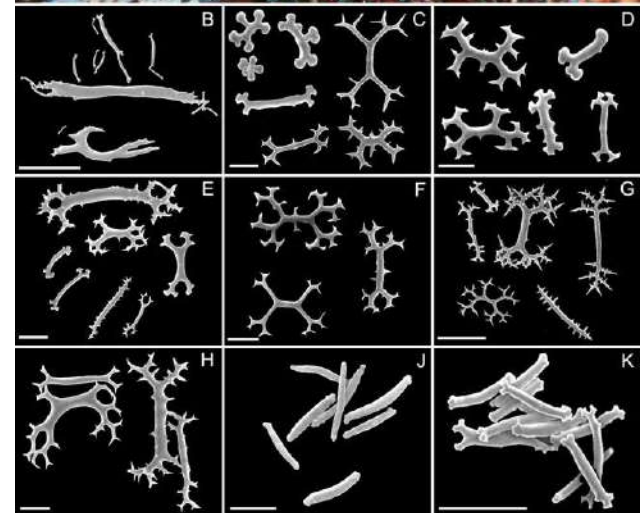
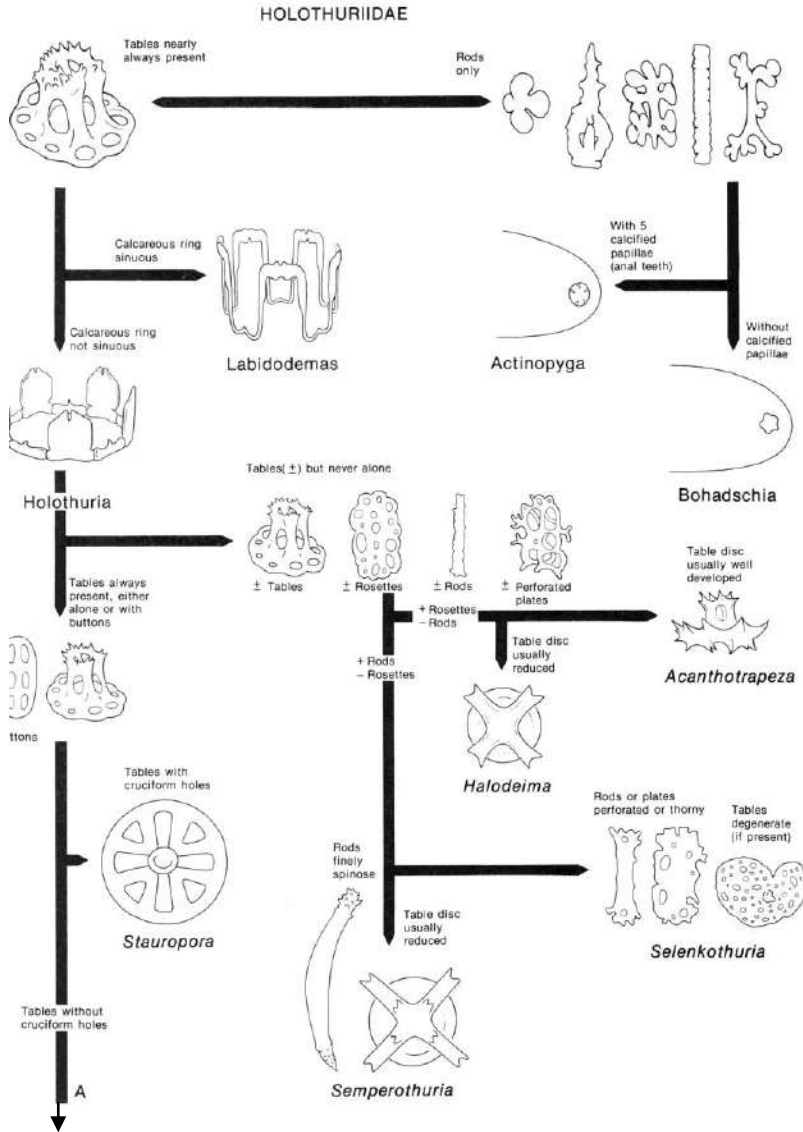
Thelenota



More detail about this family in:
H.L. Clark (1922) & Massin *et al* (2004)

(adapted from Canon & Silver, 1986)

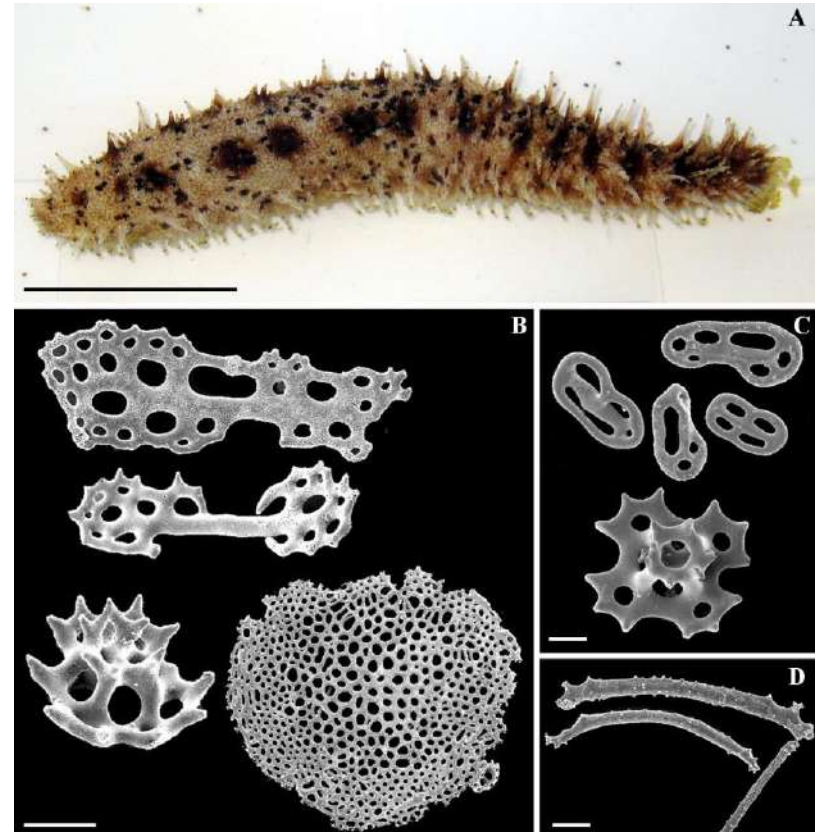
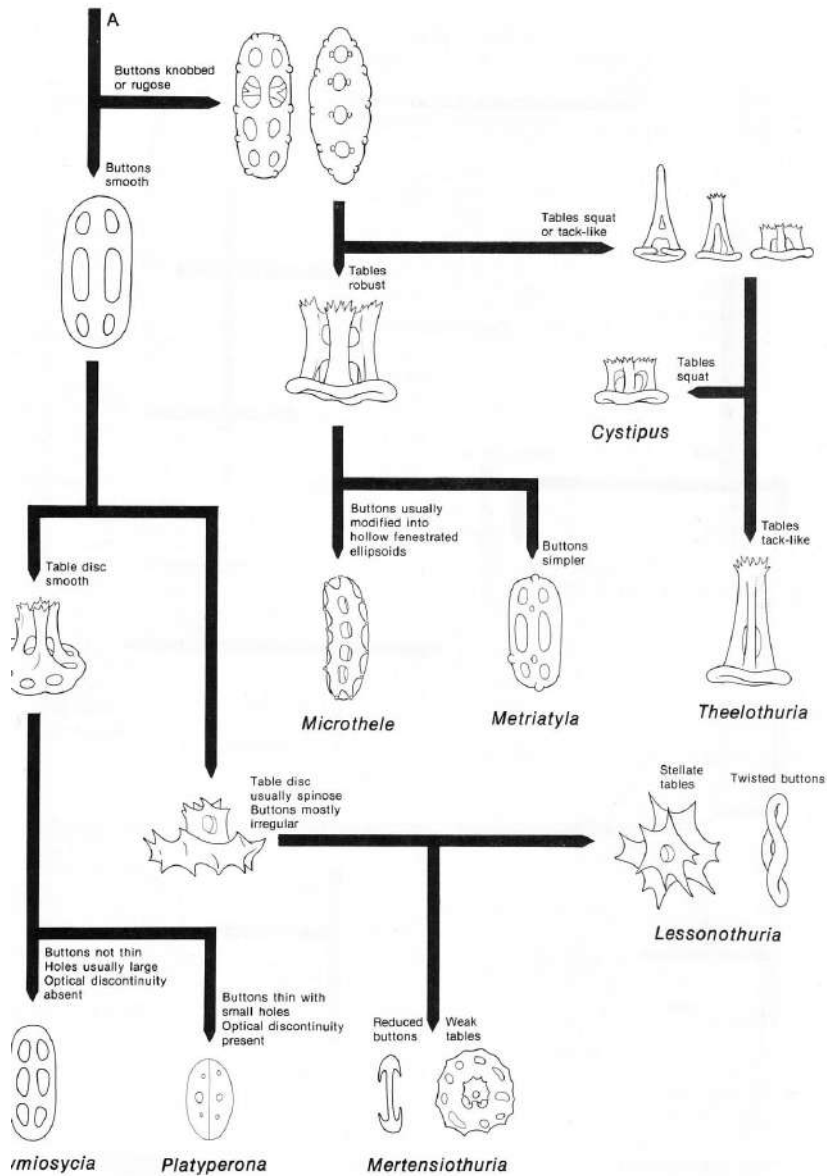
Picture key to the Holothuroidea (3)



To 3'

(adapted from Canon & Silver, 1986)

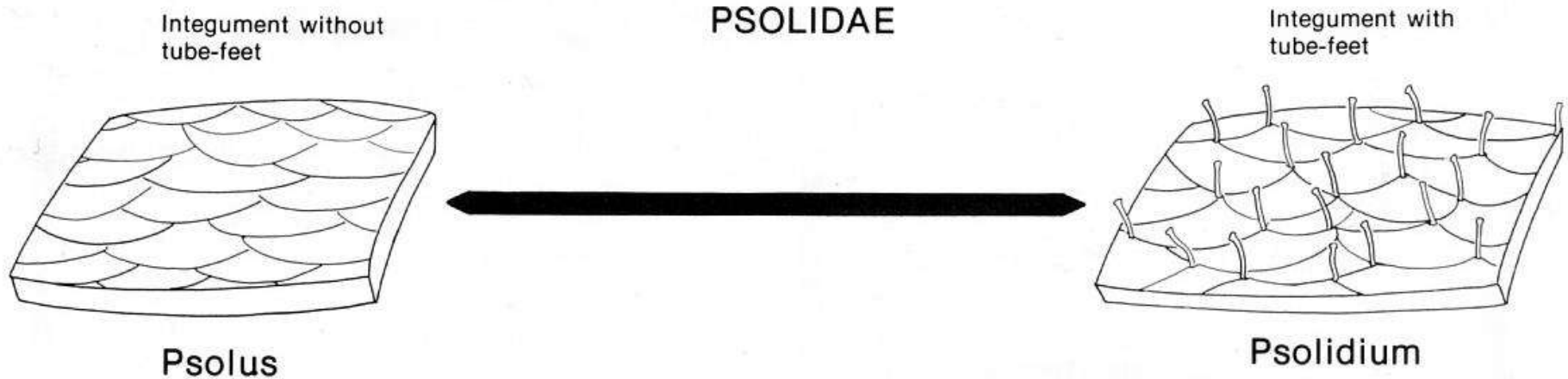
Picture key to the Holothuroidea (3)



More detail about this family in:
Rowe (1969)

(adapted from Canon & Silver, 1986)

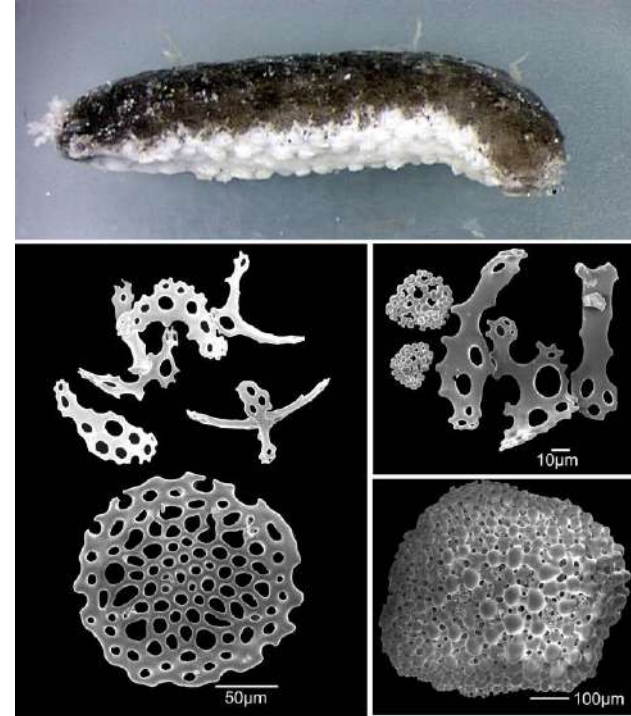
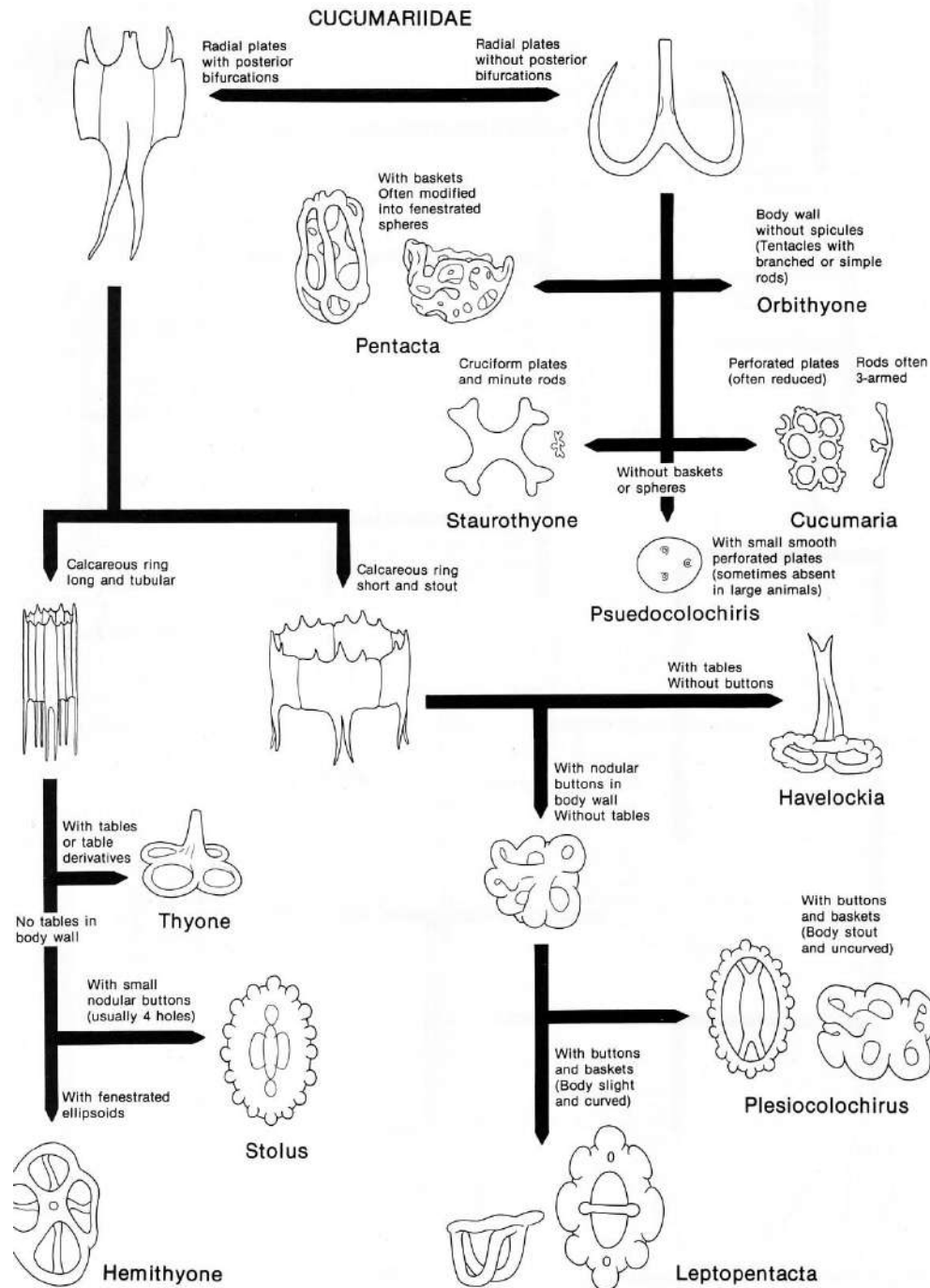
Picture key to the Holothuroidea (4)



More detail about this family in:
ad hoc literature

(adapted from Canon & Silver, 1986)

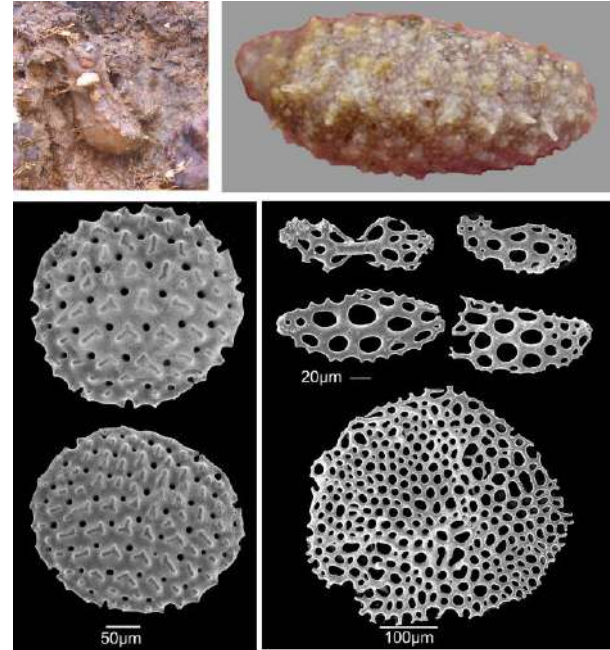
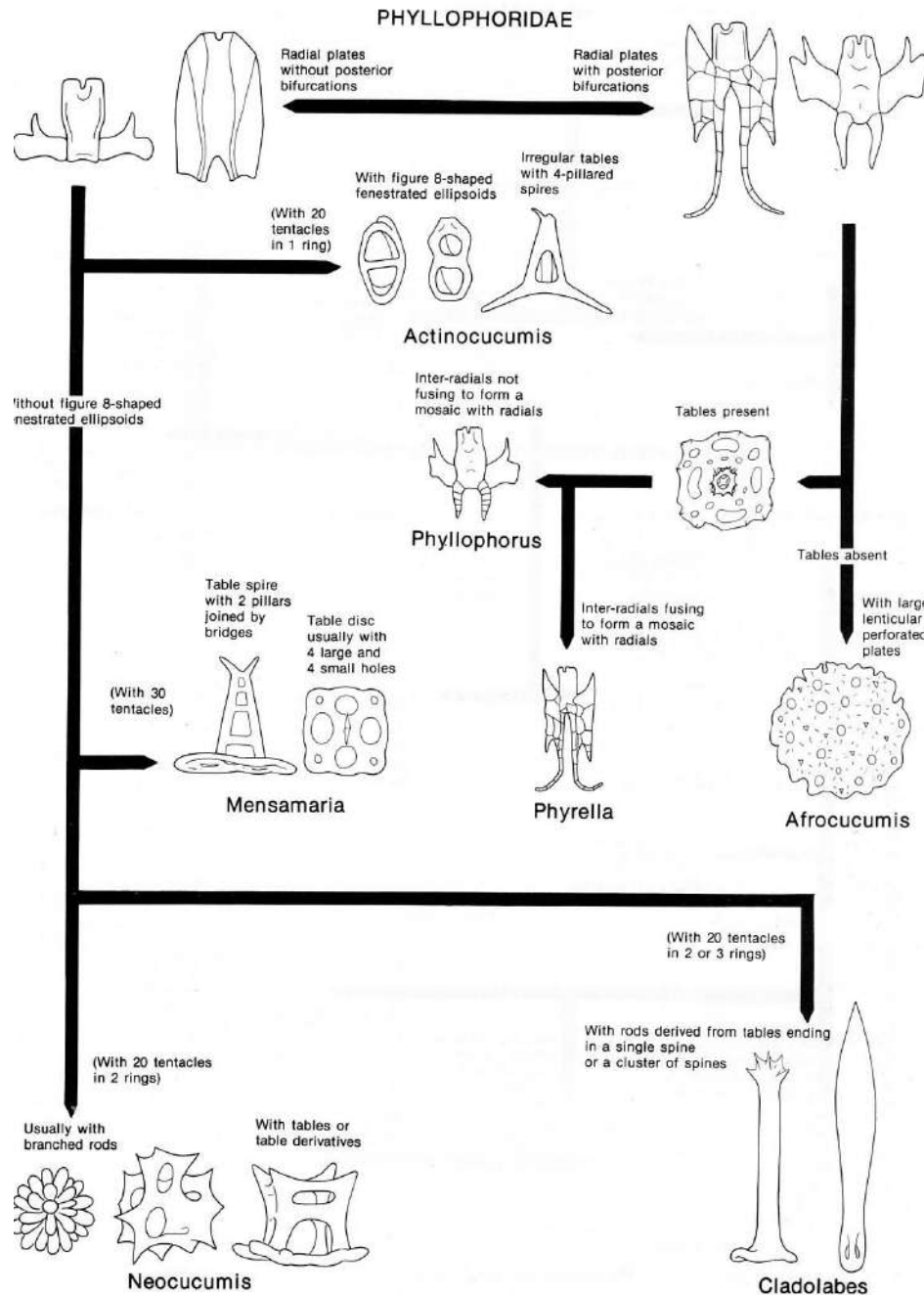
Picture key to the Holothuroidea (5)



More detail about this family in:
Panning (1949), Clark & Rowe (1971),
Thandar (1991).

adapted from Canon & Silver, 1986)

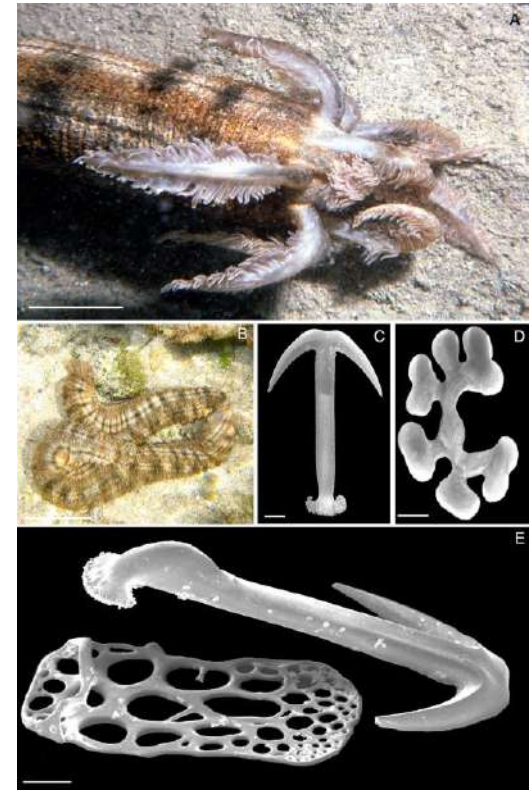
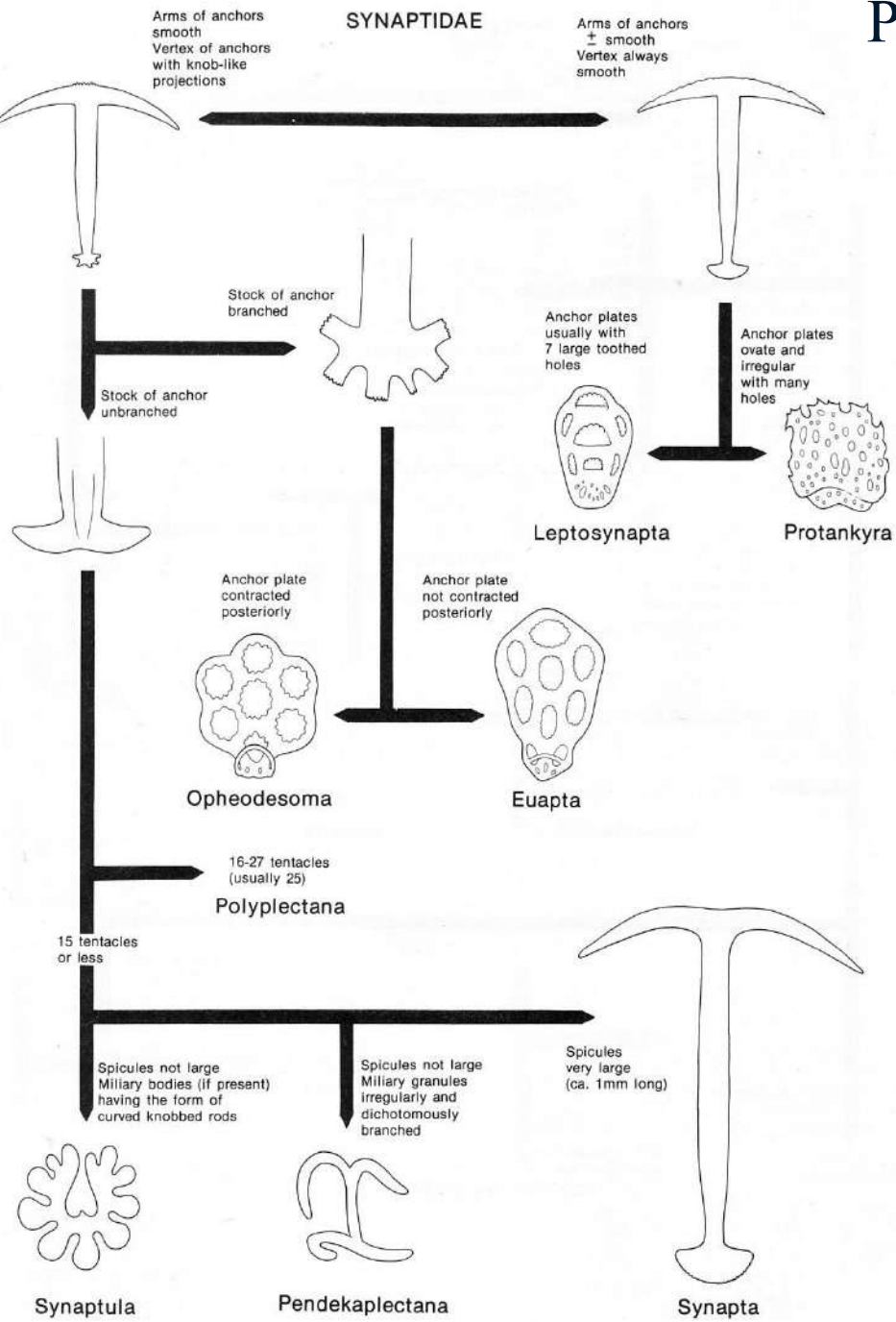
Picture key to the Holothuroidea (6)



More detail about this family in:
 Heding & Panning (1954); Samyn &
 Thandar (2003); Samyn & Thandar
 (in press)

(adapted from Canon & Silver, 1986)

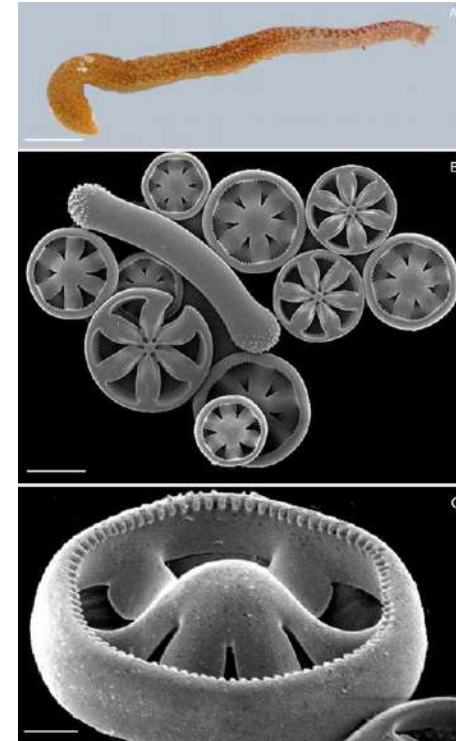
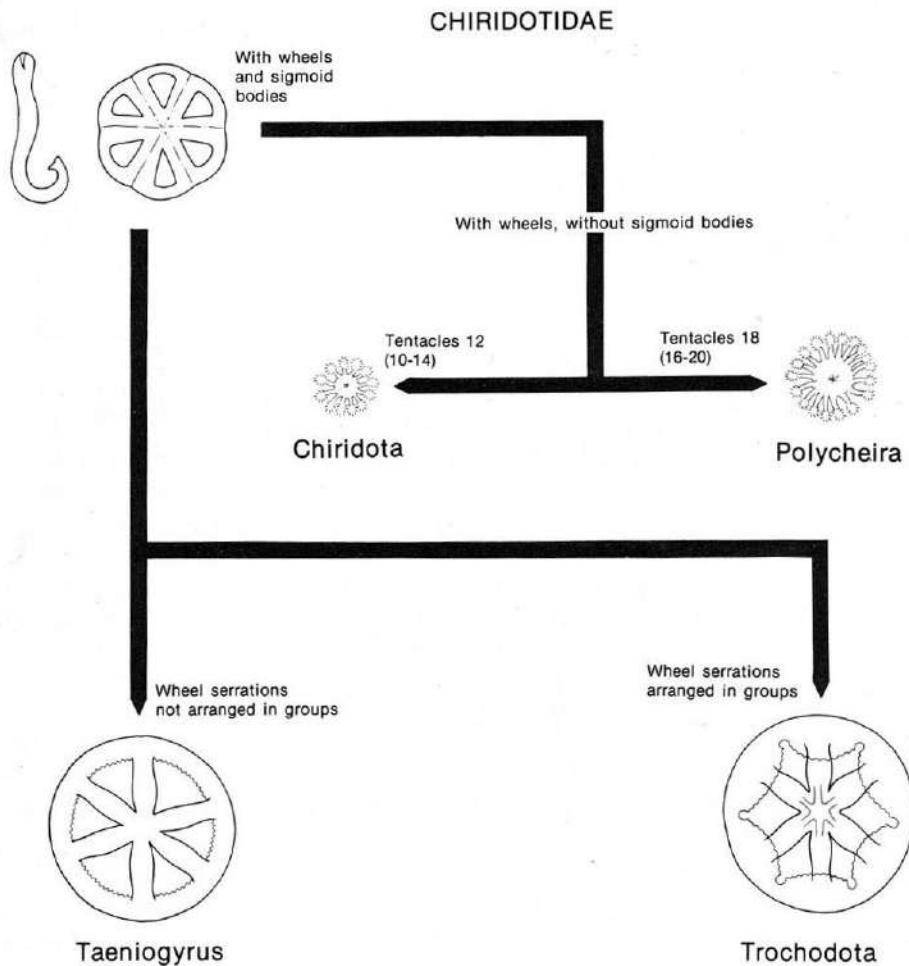
Picture key to the Holothuroidea (7)



More detail about this family in:
H.L. Clark (1907) and Heding (1928)

(adapted from Canon & Silver, 1986)

Picture key to the Holothuroidea (8)



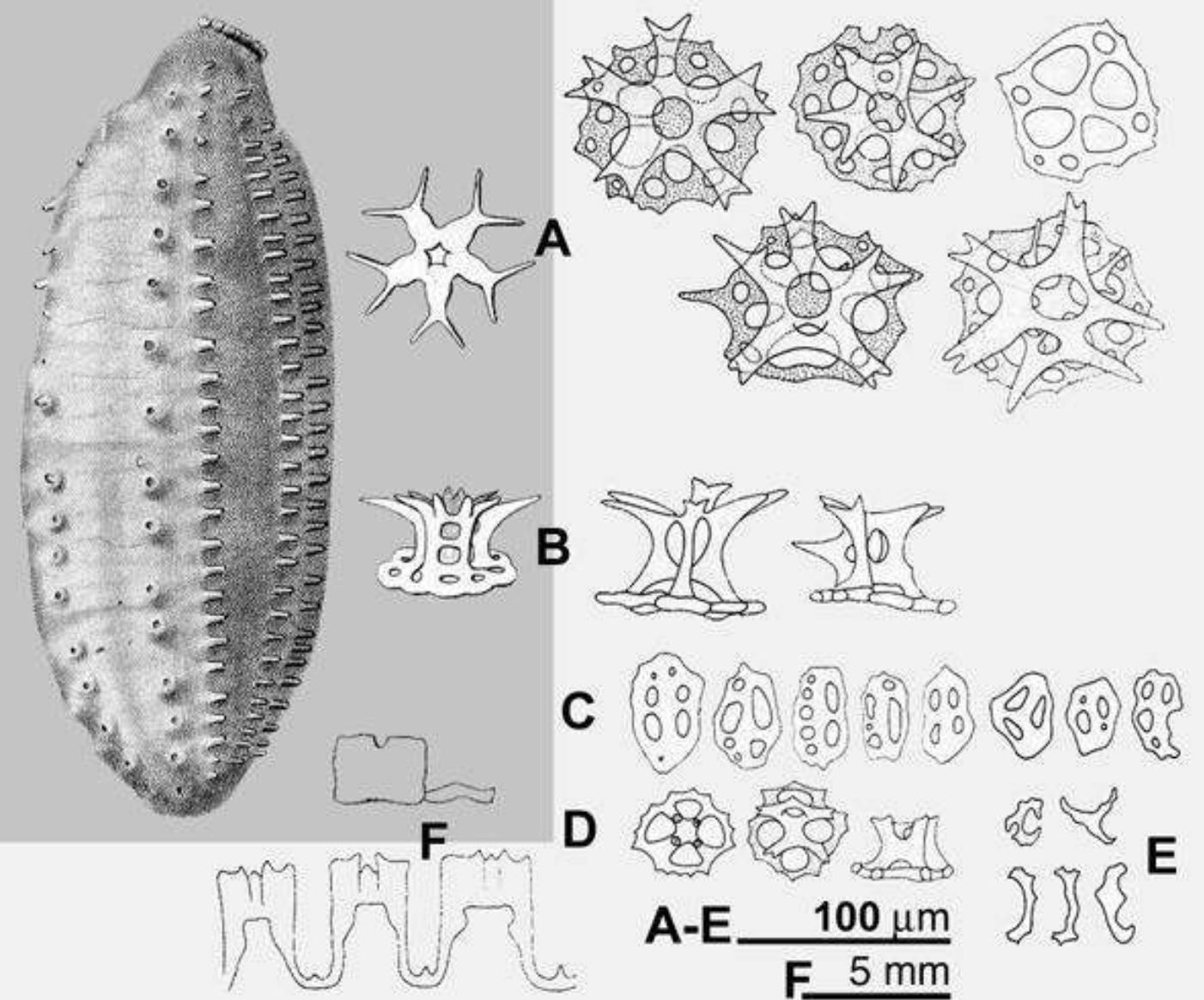
More detail about this family in:
H.L. Clark (1907) and Heding
(1928)

(adapted from Canon & Silver, 1986)

Descriptions always to be approached with care

Selenka, 1867

Cherbonnier, 1970



Descriptions always to be approached with care



Descriptions always to be approached with care

Ontogeny & ossicles...

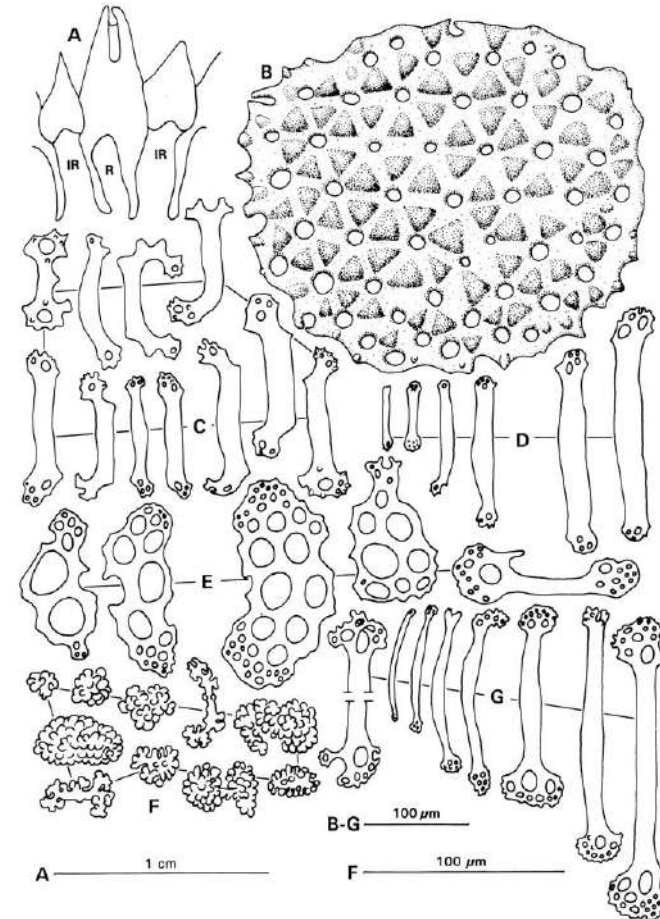
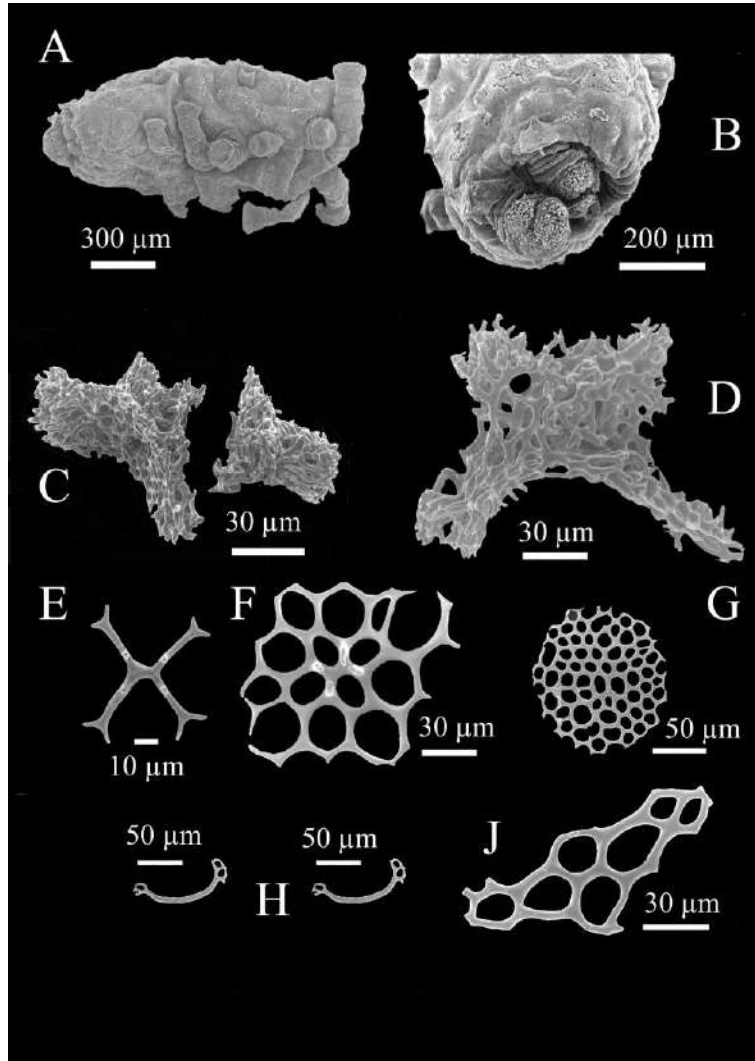
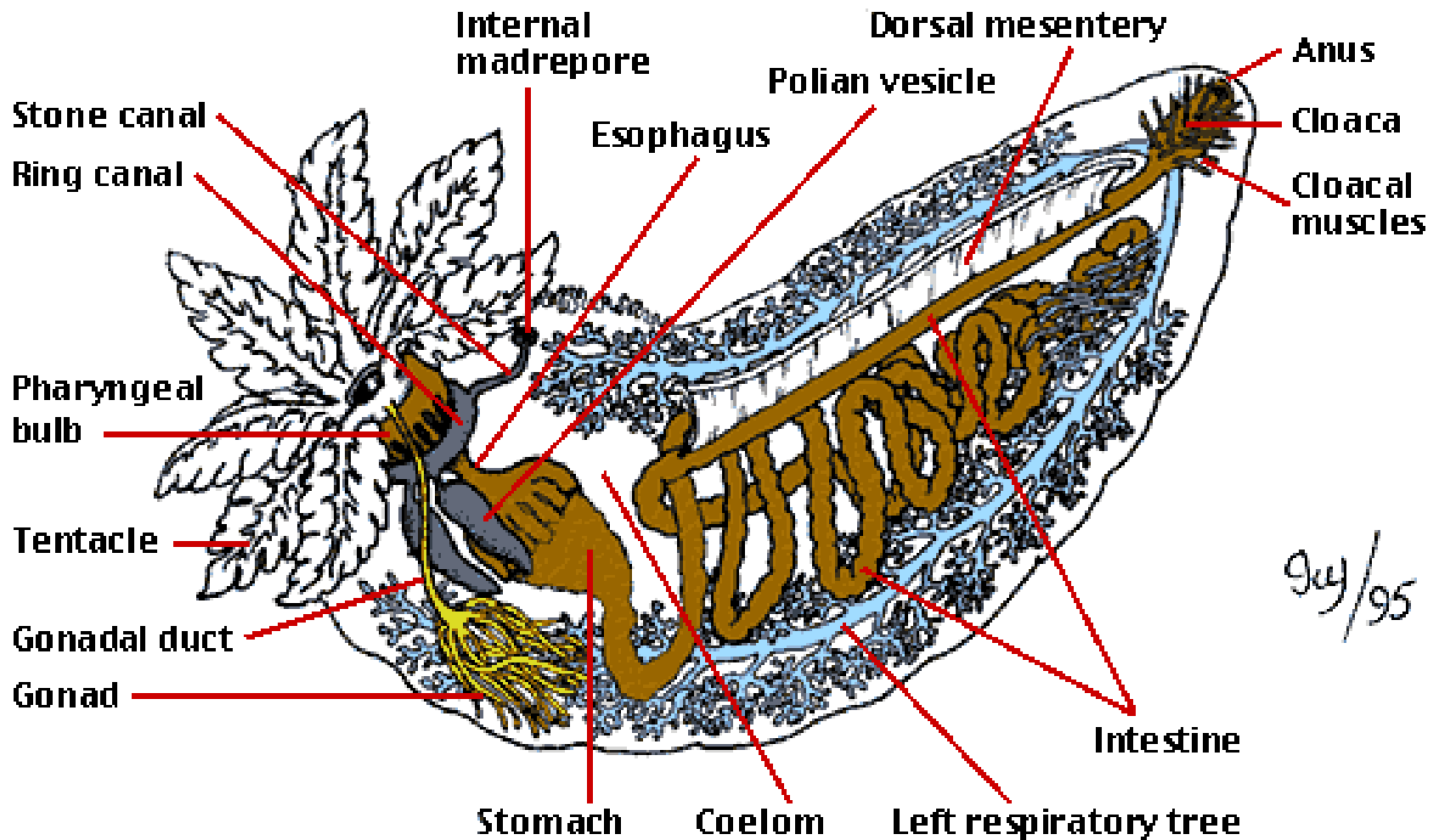


Fig. 28. *Afrocucumis stracki* spec. nov. A: calcareous ring (R: radial piece; IR: interradial piece); B: lenticular plate of the body wall; C: rods of the body wall; D: rods of the tube feet; E: perforated plates of the tube feet; F: miliary granules of the tube feet; G: rods of the tentacles.

Internal anatomy



Sea cucumber fisheries



Much more under <http://www.spc.int/coastfish/News/BDM/bdm.htm>

Interesting websites

<http://www.ucmp.berkeley.edu/echinodermata/echinodermata.html>

<http://www.tolweb.org/tree/phylogeny.html>

<http://www.calacademy.org/research/izg/echinodem/classify.html>

<http://www.echinodermata.be>

Systema naturae Holothuroidea

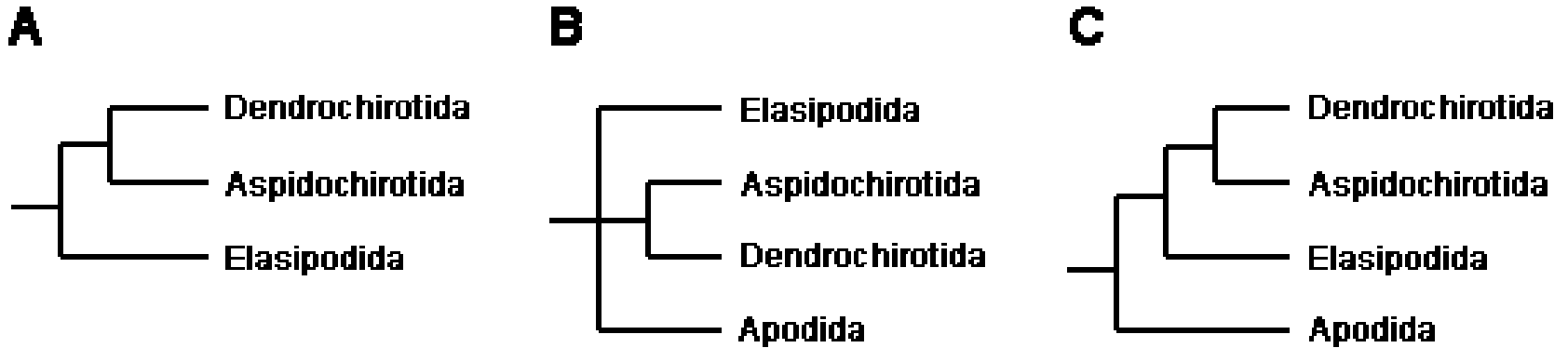
World register of Marine Species

And further links on these sites



Thank you for your attention

Systematics



Recent hypotheses about holothuroid relationships.

A. Tree based on complete 18S rDNA sequences (Littlewood et al., 1997).

B. Tree based on partial 28S rDNA sequences (Littlewood et al., 1997).

C. Interpretation of the 18S and 28S rDNA data favored by Smith (1997).

More information on Kerr & Kim, 2001(class); Kerr 2001 (Apoda); Samyn et al, 2005 (Holothuriidae, morphological); Kerr et al, 2005 (Holothuriidae, molecular).

Thank you for your attention

