Invertebrate Macrofossils

Lecture 13

Phylum Echinodermata

Echinodermata

- Cambrian—Recent
- Modern starfish, sea urchins, sea cucumbers and sea lilies
- Different from nearly all other invertebrate groups.
- Echinoderms have internal **mesodermal skeletons** of porous calcite plates, normally spiny and covered outside and in by a thin protoplasmic skin.
- skeletons usually have a five-rayed or **pentameral symmetry;** in some fossil groups this is not so and in some modern and fossil sea urchins a bilateral symmetry is superimposed upon the radial plan.

- Another important feature the **water—vascular system:** a complex internal apparatus of tubes and bladders containing fluid.
- This has extensions, the **tube feet or podia,** used for locomotion, respiration and feeding.
- Because of their calcitic skeleton echinoderms are very abundant in the fossil record
- i.e. crinoidal limestones (stem fragments of sea lilies)
- Echinoderms are entirely marine animals, and stenohaline (they tolerate only normal sea water salinities)

Classification (Sprinkle, 1976)

- SUBPHYLUM 1. ECHINOZOA: Radiate echinodenns, usually globose or discoidal.

  CLASS 1. ECHINOIDEA (Ord.-Rec.): Sea urchins.

  CLASS 2. HOLOTHUROIDEA (Ord.-Rec.): Sea cucumbers

  CLASS 3. EDRIOASTEROIDEA (L. Cam.-Carb.)

  There are several other extinct classes.
- SUBPHYLUM 2. ASTEROZOA.

  CLASS STELLEROIDEA (Ord.-Rec.).

  SUBCLASS 1. ASTEROIDEIA (Ord.-Rec.): Starfish.

  SUBCLASS 2. OPHIUROIDEA (Ord.-Rec.): Brittle stars.

  SUBCLASS 3. SOMASTEROIDEA (Ord.-Rec.).

- SUBPHYLUM 3. CRINOZOA: 'Pelmatozoans'

  CLASS CRINOIDEA (M. Cam.-Rec.): Sea-lilies.
- SUBPHYLUM 4. BLASTOZOA: 'Pelmatozoans‘.

  CLASSES 1 and 2. DIPLOPORITA and RHOMBIFERA (?Carb.-Dev.): 'Cystoids' — extinct groups

  CLASS 3. BLASTOIDEA (Sil.-Perm.): Extinct pelmatozoans with complex respirator)' structures.

  CLASS 4. EOCRINOIDEA (L. Cam.-Sil.): Primitive echinoderms with pores along the sutures.
- SUBPHYLUM 5. HOMALOZOA (Ord.): Rare peculiar organisms, calcite plated but with no planes of symmetry. The subject of much controversy and may be a separate chordate subphylum on their own: the CALCICHORDATA.

- Eleutherozoa (free living echinoderms)

Echinozoa, Asterozoa

- Pelmatozoa (fixed, sessile echinoderms)

Crinozoa, Blastozoa

- First echinoderms in Cambrian
- the epoch of their maximum proliferation (at class level) was the Ordovician
- At generic level, however, echinoderms were most abundant in the Carboniferous.
- A whole range of remarkable forms arose at that time in a great burst of adaptive radiation, but only some of these were successful; the others, to which the Cambrian classes belong, produced no new lines of descent and became extinct.

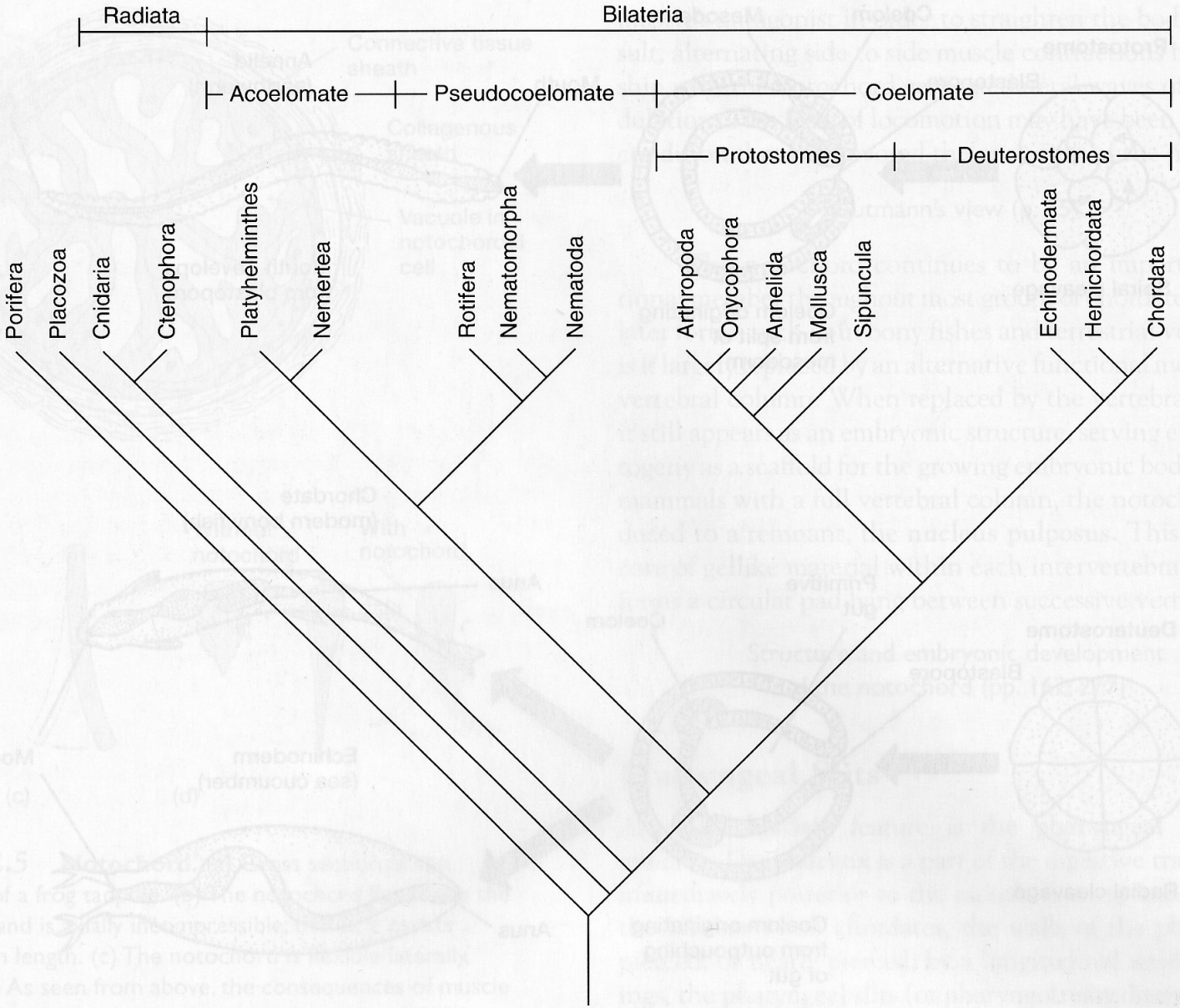


FIGURE 2.2 **Phylogenetic relationships within major animal groups.** Note that chordates are coelomate deuterostomes along with hemichordates and echinoderms. The protostomes are a separate lineage.

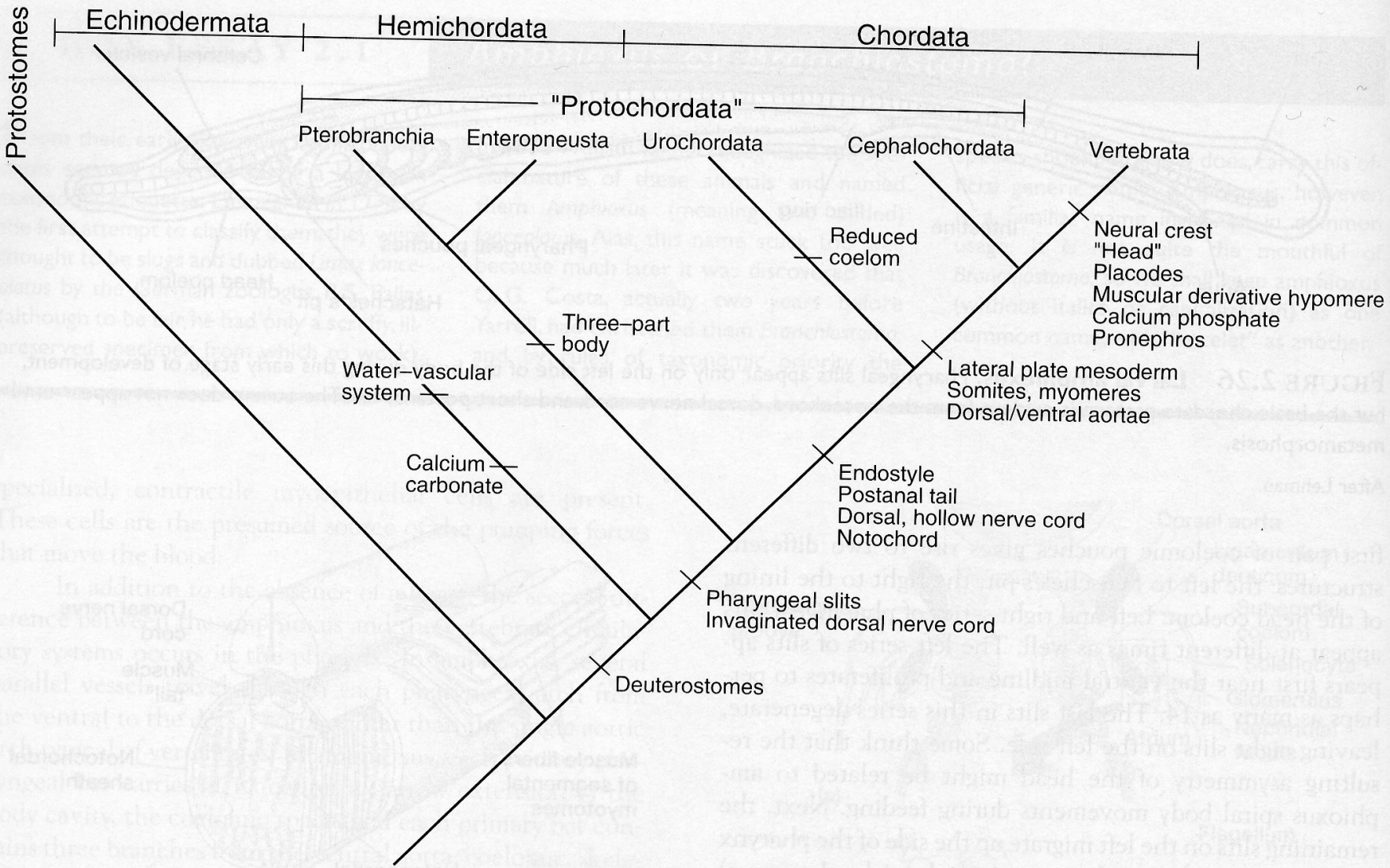


FIGURE 2.28 **Phylogenetic relationships within the "protochordates."** Protochordates are compared to echinoderms and, more distantly, to protostomes.

Class Echinoidea

- The echinoid skeleton is called the **test**
- A rigid globular, disc shaped or heart shaped
- Consists of several interlocking plates covered by skin, thus, an endoskeleton
- Externally, covered by spines; for protection as well as locomotion
- Benthic, epifaunal and infaunal (burrowing), in shallow marine waters

- Can be separated into:

1. **Regularia** (echinoids with a regular test)
   Perfect radial symmetry.
   Anus and mouth at opposite sides of body.

1. **Irregularia** (echinoids with an irregular test)
   Perfect bilateral symmetry.
   Variously positioned ani and mouths

Regular echinoids

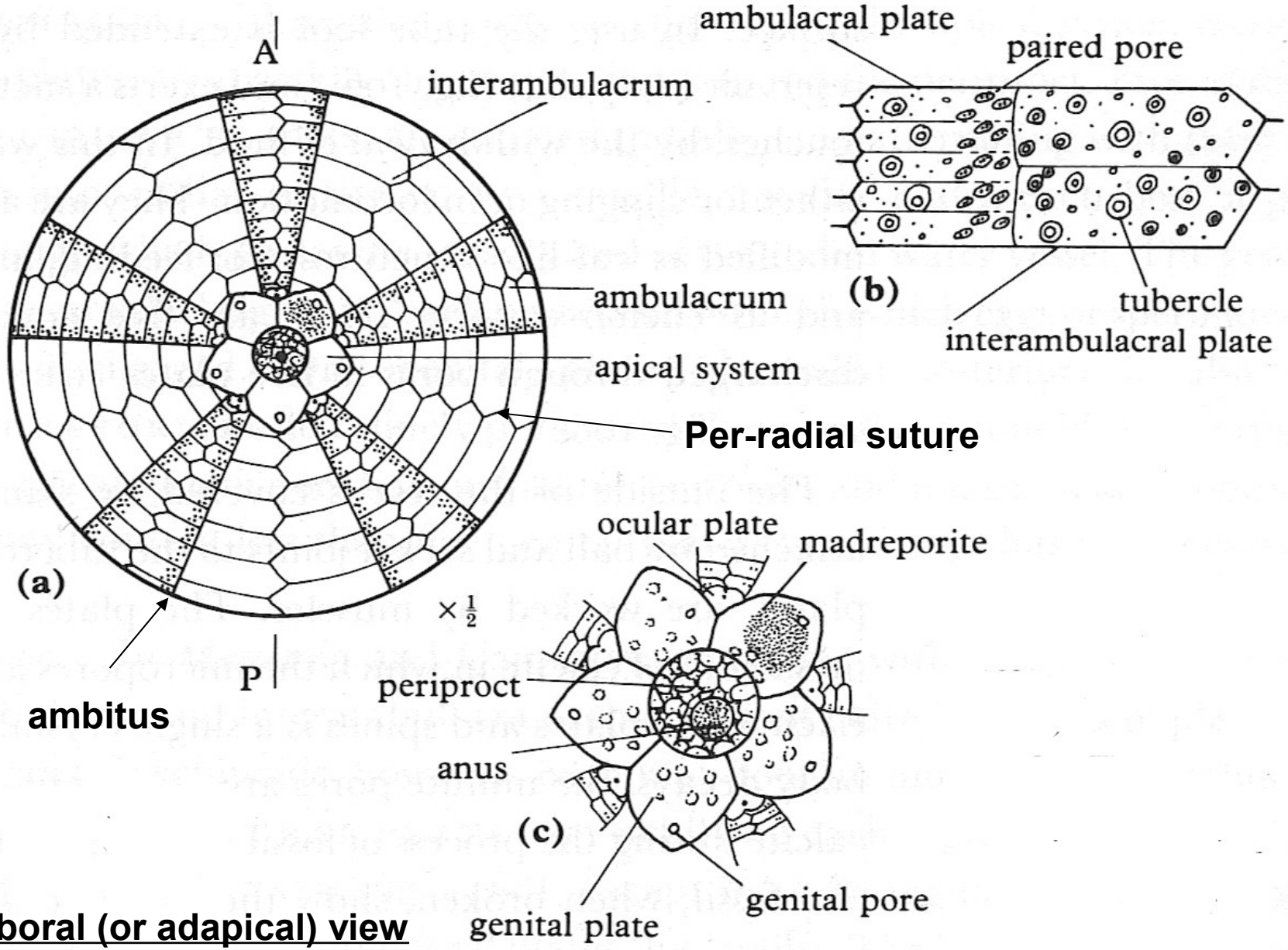
- On the upper **(aboral or adapical)** surface there is a central **apical disc:** a double ring of plates surrounding a central hole or **periproct,** which contains the anus.
- The apical disc is formed of two types of plates:

1. the larger **genital plates**
2. the smaller **ocular plates** which are usually outside the ring of genitals.

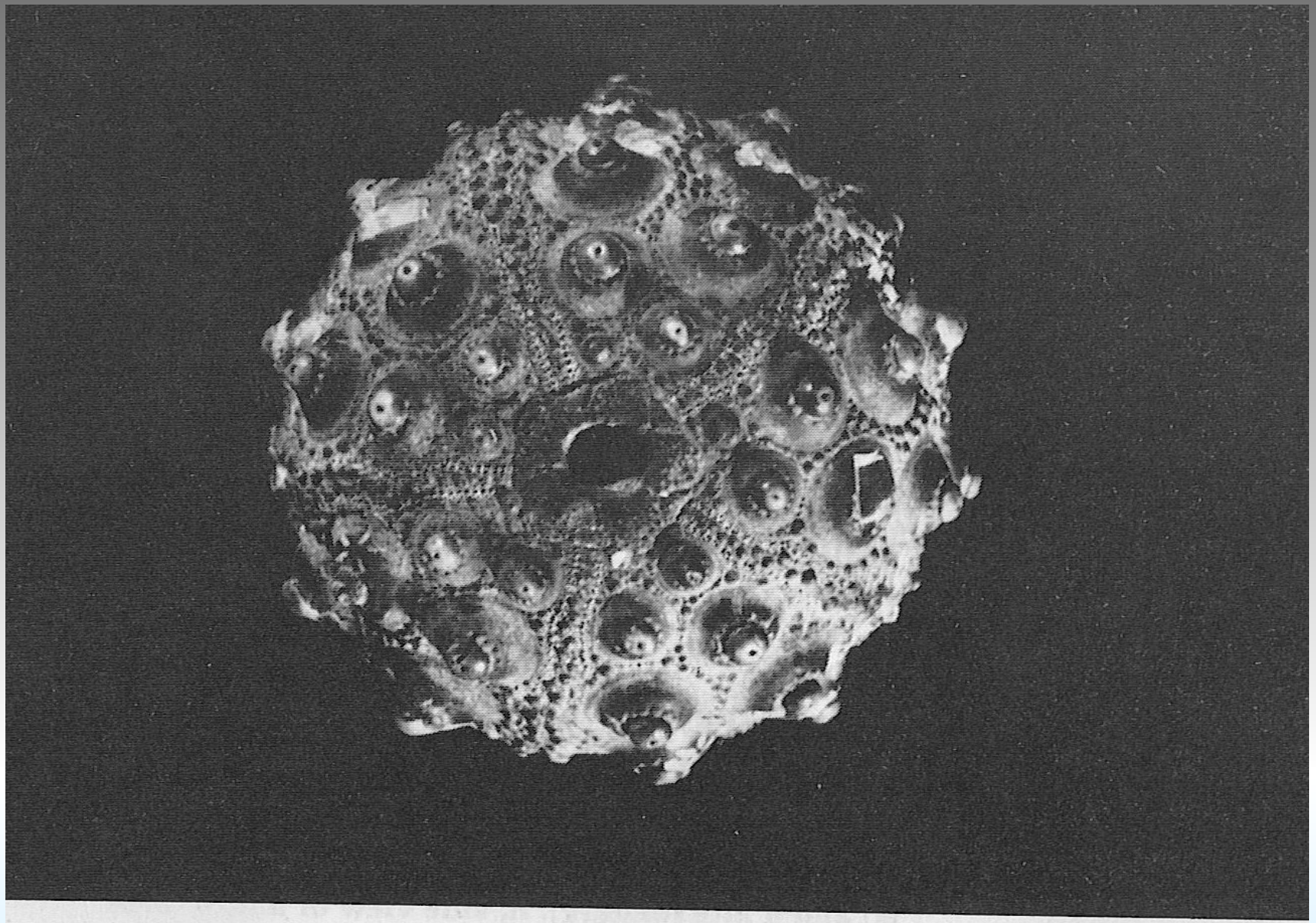
- Each is perforated by a pore.
- The **genital pores** are the outlets of the **gonads,** and the **ocular pores** are part of the water—vascular system.
- One genital plate (the **madreporite)** is larger than the others. It has numerous tiny perforations which lead into the water—vascular system below.
- The anus resides in the centre of a number of small plates attached to a flexible, rarely fossilized membrane extending across the periproct.

The test

- Divided into ten radial segments extending from the apical disc to the **peristome** which surrounds the mouth on the lower **(adoral)** surface.
- The five narrower segments are the **ambulacra** which connect with the ocular plates, whereas the broader **interambulacra** terminate against the genital plates.
- Both ambulacra and interambulacra consist of double columns of elongated plates which meet along a central suture in a zigzag pattern.
- In the ambulacrum this is the **per-radial suture.**
- The interambulacral plates are large and tubercular, without perforations, but the ambulacral plates each have three sets of paired pores near the outer edge of the plate.
- These **pore pairs** are the sites where the tube feet emerge through the test from the internal part of the water—vascular system.
- The ambulacra and interambulacra are widest at the **ambitus**, which is the edge of the specimen when seen from above or below



Aboral (or adapical) view

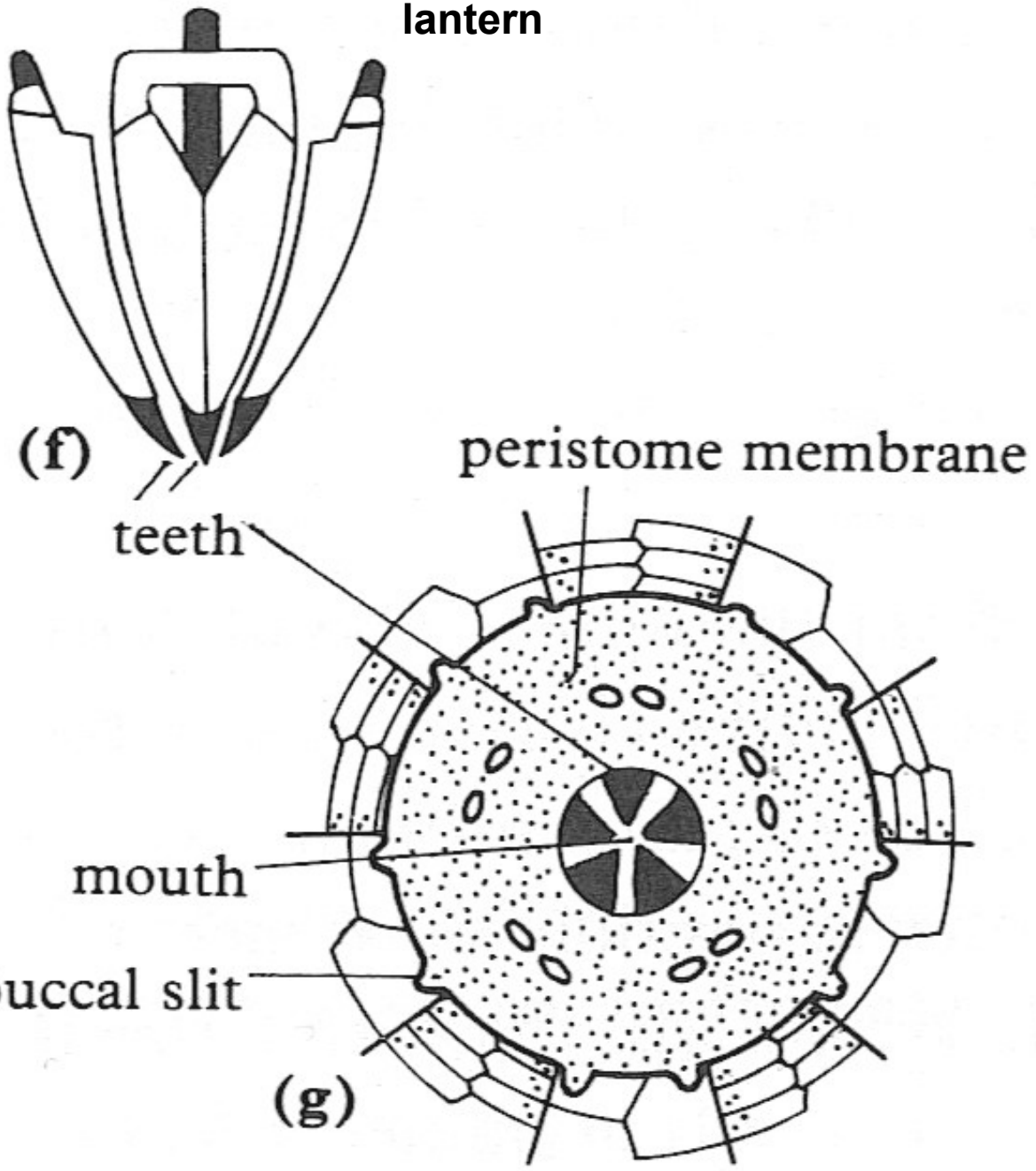


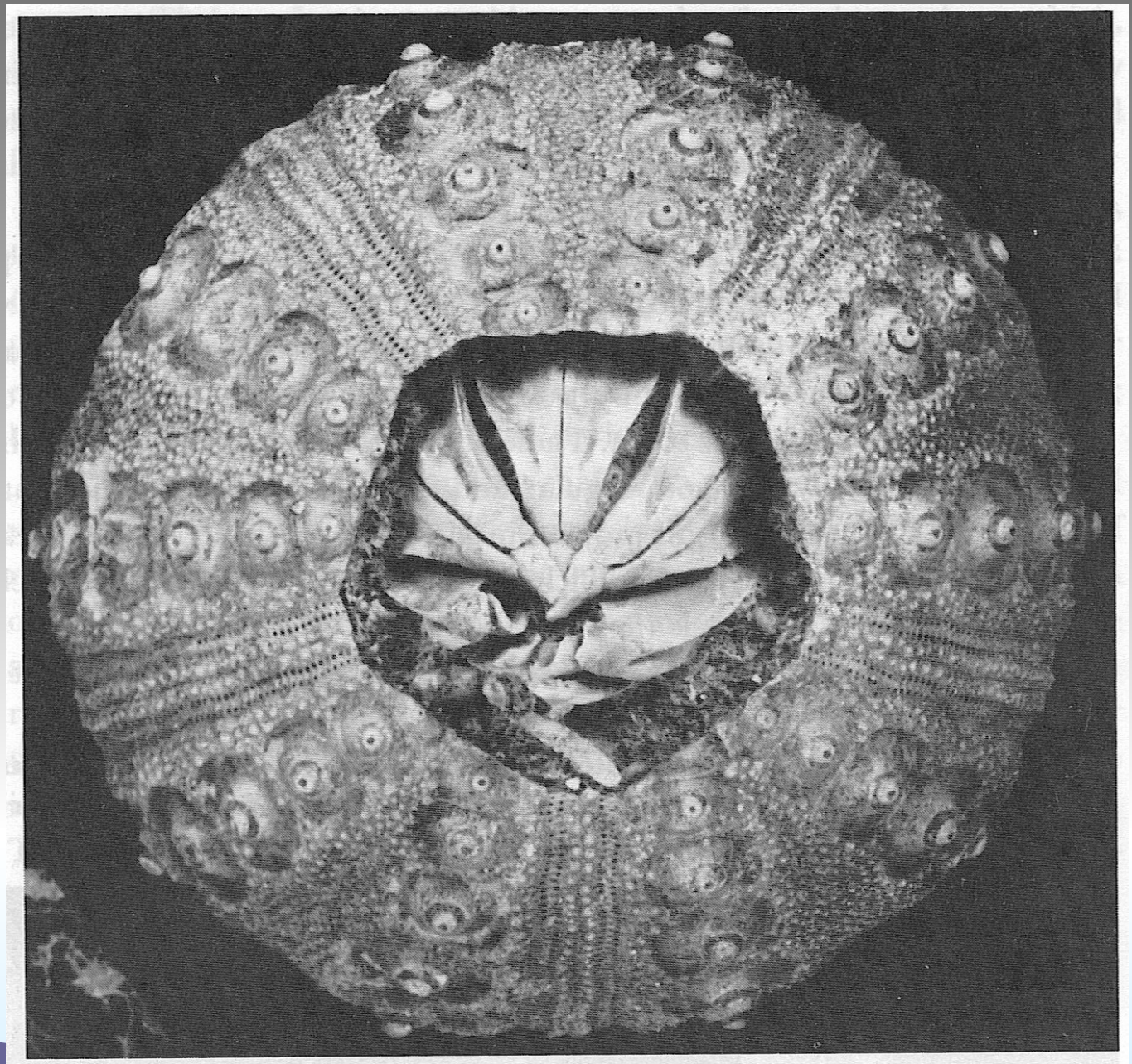
117 *Hemicidaris*, Coral Rag, U Jurassic, Wiltshire (× 3). Aboral view.

Adoral surface

- The peristome is a large adoral area, covered in life by a flexible plated membrane, which contains the mouth centrally.
- In fossil specimens, the membrane normally gone, leaving a large circular or pentagonal cavity.
- Five pairs of **gill notches** are found where the interambulacra at the edge of the peristome, and from these project feathery bunches of gills (provide surfaces for respiratory exchange additional to those of the tube feet)
- Inside the peristome the test is turned back into a perforated flange which is the **perignathic girdle**.
- This girdle forms a support for the masticatory apparatus of the echinoid: the **Aristotle's lantern (jaws)**. This lantern has five strong jaws, each with a single calcitic tooth.
- Ligaments and muscles attach it to the perignathic girdle.
- the teeth can rasp away at organic or algal material on the sea floor and pass it inward to the gut.

lantern





110 Echinoid jaws with teeth. An oral view of 'Cidaris', Coral Rag, U Jurassic (× 1.5).

Soft parts

- Inside the test is a thin layer of protoplasm
- the gut is only a simple tube running spirally round the inner wall from mouth to anus
- the body of the test is largely empty.
- At breeding time (summer) the gonads swell enormously before releasing their products through the genital pores.
- The ciliated **echinopluteus larvae** which grow from the zygotes originally plankton and undergo many transformations before finally settling down.

- The **coelom** has various tubular elements: the **haemal and perihaemal** systems involved in material transfer, and the **axial organ** associated with the repair of injury
- The water—vascular system of the echinoderms, resembles nothing else in the animal kingdom.
- Primary function is oper-ate the tube feet.
- In echinoids its only exit from the test is via the madreporite.
- From this a calcified tube (the **stone canal)** descends to near the top of the lantern. Here it joins the **circumoral ring,** from which five **radial water vessels** extend, one running up the centre of each ambulacrum.
- Each of these passes finally through an ocular pore, but it only forms a tiny closed tube. From the radial -water vessels there arise, at intervals, paired lateral tubes, each leading to a tube foot and associated apparatus

- At the base of each tube toot is an inflatable sac (the **ampulla),** and the tube foot leads outwards from this, dividing as it passes through the pore pair and reforming on the other side.
- This device prevents the tube foot from being withdrawn right inside the test when retracted
- one of the functions of the tube foot is respiration; it separates incoming oxygen-rich water from the outgoing fluid depleted in oxygen.
- The tube foot possesses longitudinal muscles and has a suction cup at the end, rendering it prehensile.
- Those on the lower part of the body are used also for locomotion

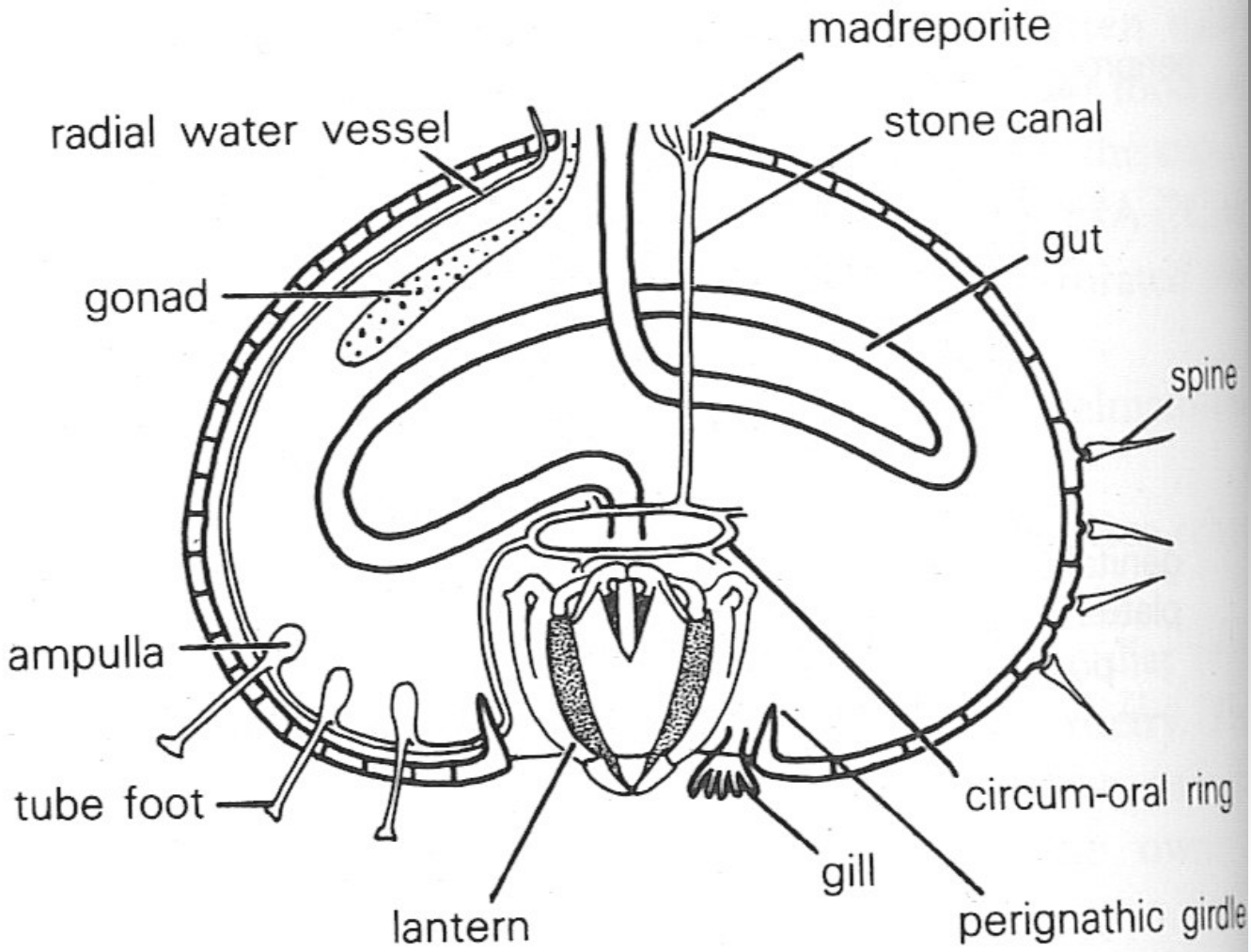
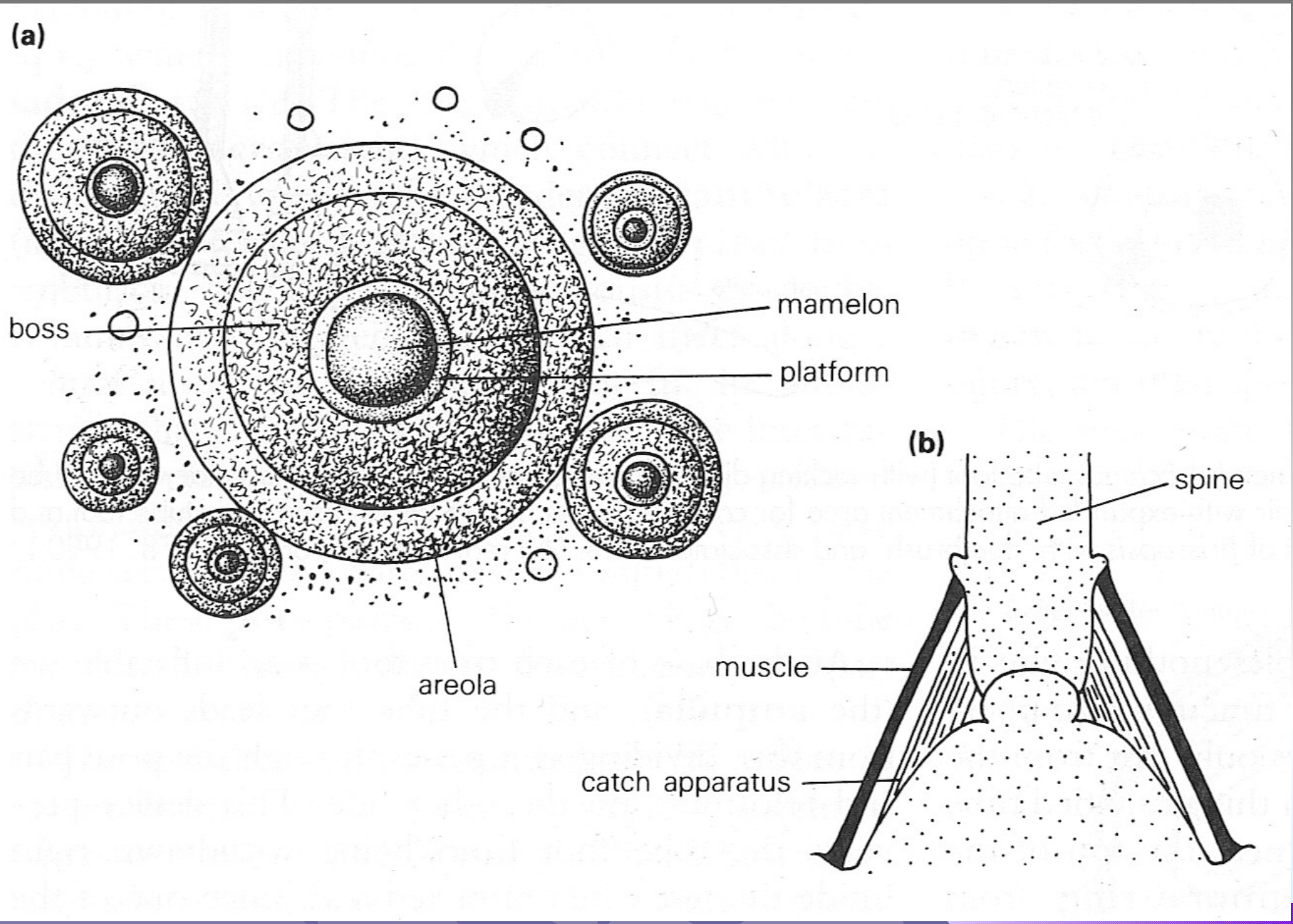


Figure 9.2 Internal morphology of *Echinus* (simplified) passi through an ambulacrum (left side) and interambulacrum (rig side).

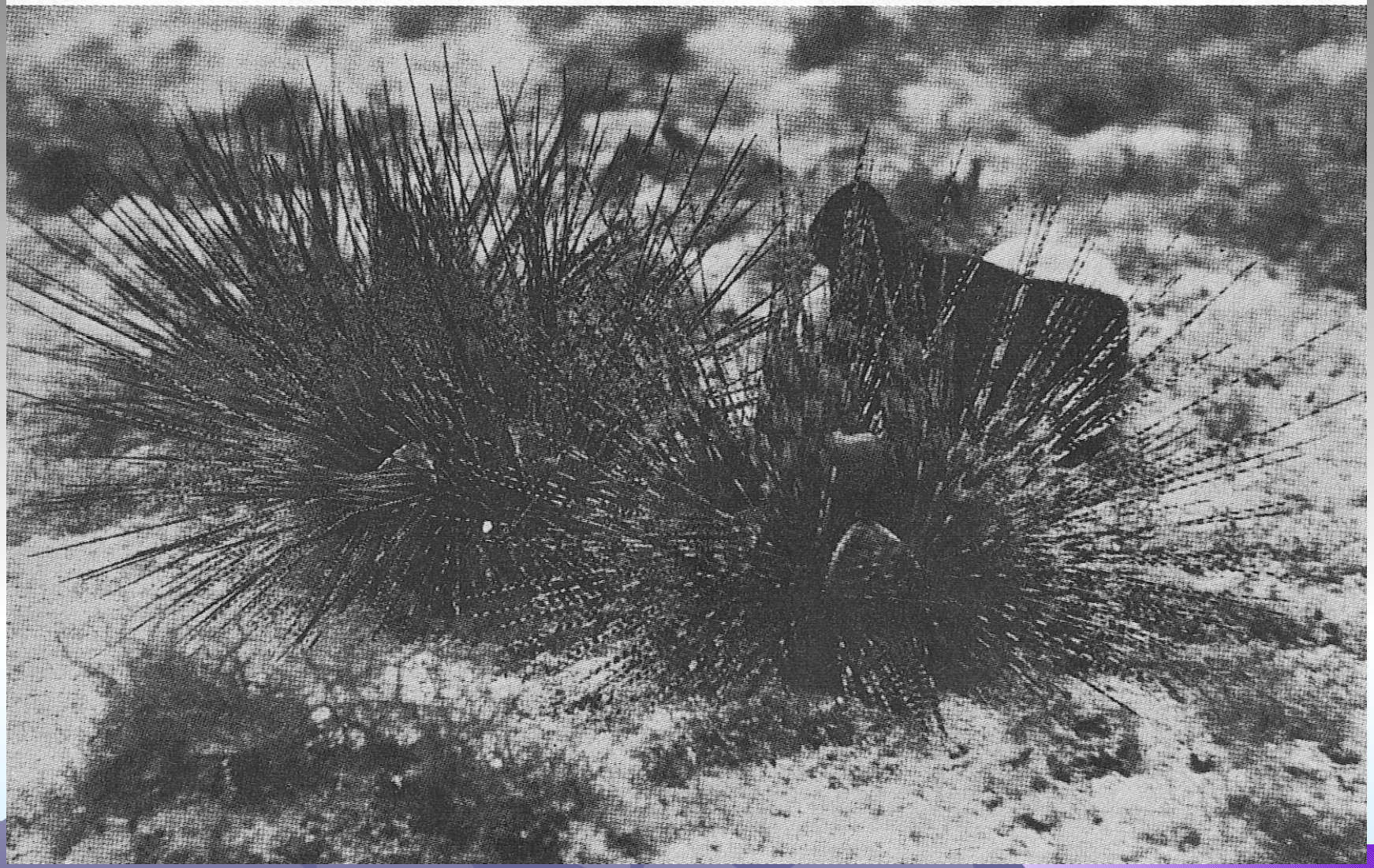
spines

- The interambulacral plates are covered by **tubercles** (they can occur in ambulacral plates but more scarce)
- In life on these movable spines are attached by muscles
- They are rarely preserved in situ
- A tubercle consists of a shallow mound, the **boss**, topped by a knob, the **mamelon**, and surrounded by a shallow groove the **areola**

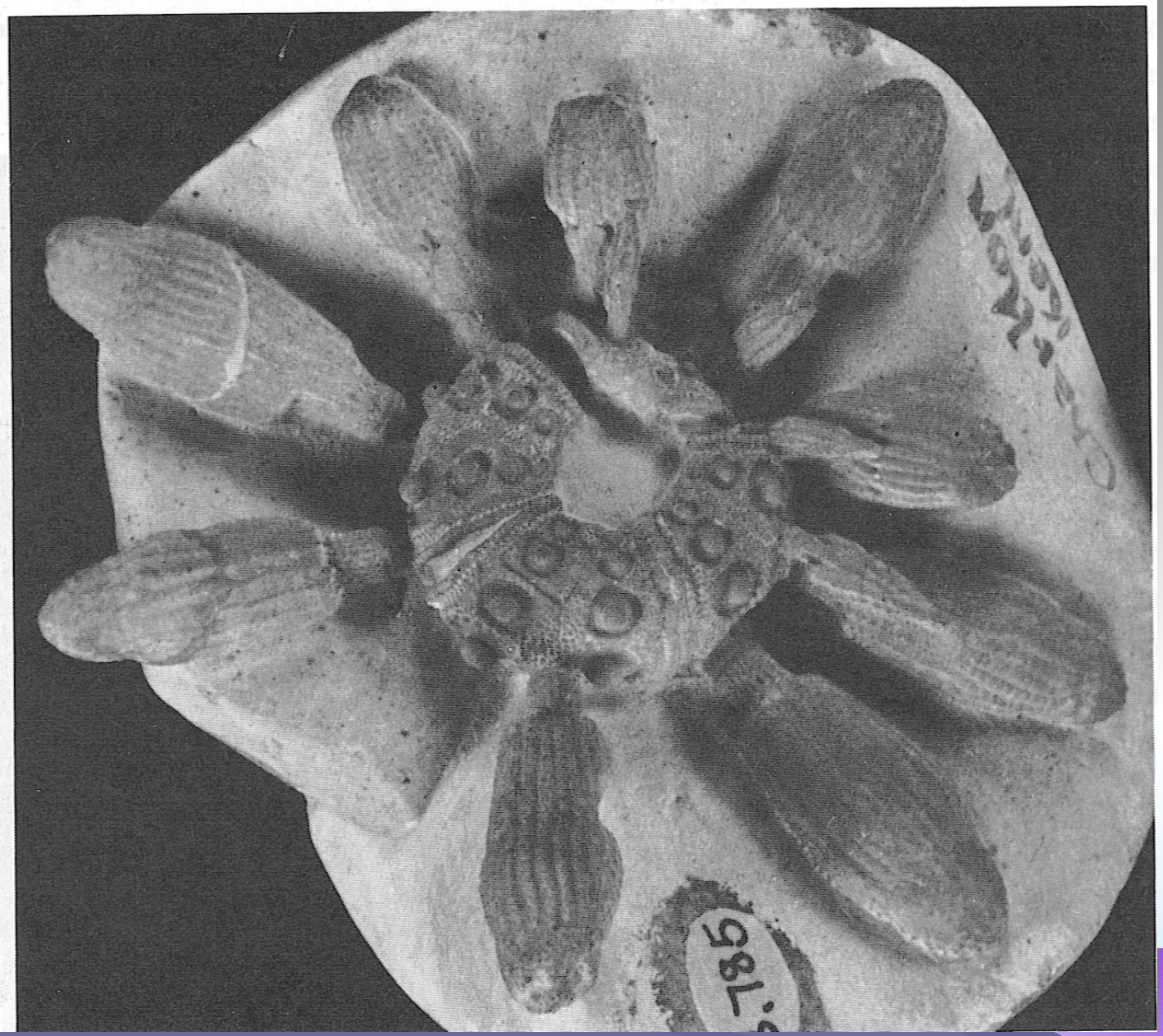

(a)
boss
mamelon
platform
areola
(b)
spine
muscle
catch apparatus

- Each spine, like the individual plates of echinoids, is a single crystal of calcite.
- The spine consists of a shaft and its base forms a socket which articulates with the mamelon
- Round the tubercle is a ring of muscles, attached to the spine base so that the spine can be moved in any direction.
- Spines used for protection, locomotion, burrowing
- Various shapes: needle like, rod-shaped, club-shaped, spatulate

107 A modern regular sea-urchin with long spines, up to about 75 mm, *Astropyga magnifica*, underwater photograph at 26 m off Florida Keys, USA.



108 A fossil echinoid with spines preserved *in situ*: *Cidaris clavigera*, Upper Chalk, U Cretaceous (× 1.6).



pedicellariae

- Amongst the spines are small organs of balance **(spheridia),** on the adoral part of the per-radial suture,
- and **ophicephalous pedicellariae,** which are tiny spines with their heads modified as pincers (some with poison glands)
- these clean the surface, discourage predators and prevent larvae from settling.
- Normally pedicellariae lie recumbent on the surface, but they can be erected and will snap shut on any extraneous object.
- New pedicellariae are formed when any are dislodged in defence.

orientation

- Regular echinoids are normally illustrated according o a conventional orientation
- madreporite is always shown at the right anterior and its dependent interambulacrum is numbered 2.
- The numbering proceeds anticlock-wise so that genital 5 is always posterior.
- Roman numerals designate the oculars and ambulacra, likewise numbered anti-clockwise, but starting to the right of the genitals.
- The same system is used in numbering the plates of irregular echinoids: those with a dominant bilateral symmetry, marked particularly by the position of the periproct which is no longer within the apical system **(exocyclic).**

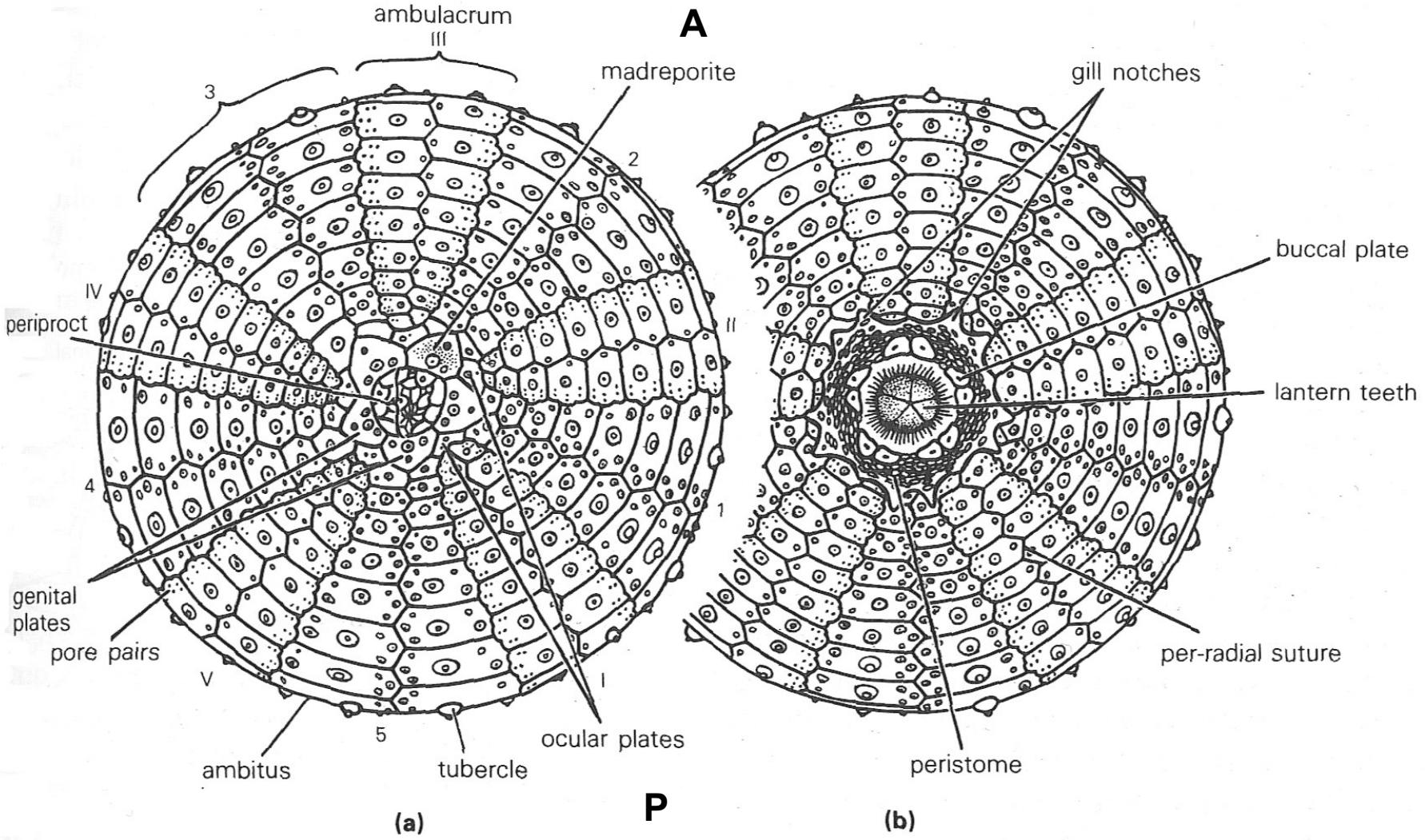


Figure 9.1 *Echinus esculentus* (Rec.), test deprived of spines: (a) aboral (adapical) surface: (b) adoral surface (× 0.8). (Redrawn from Durham in *Treatise on Invertebrate Paleontology*, Part U.)

Irregular echinoids

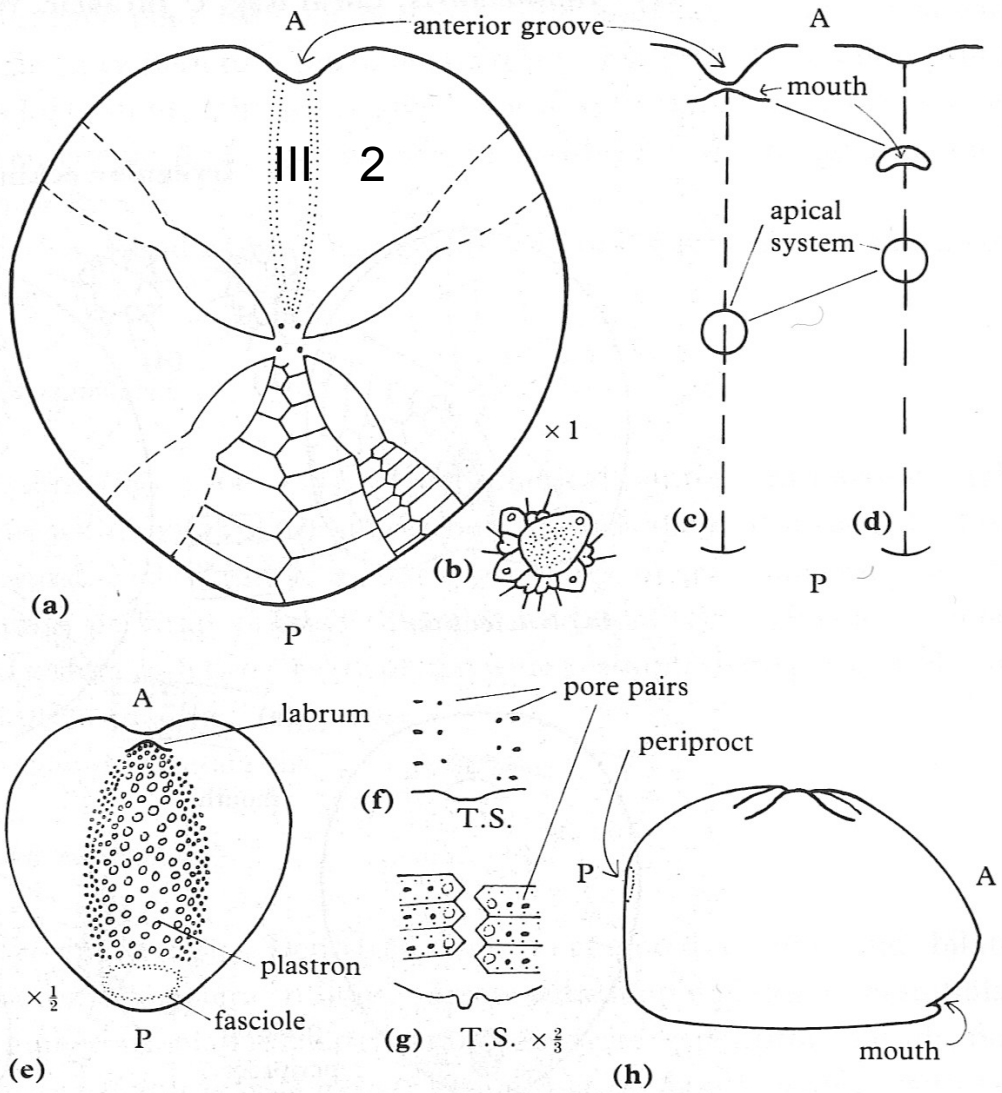
- a bilateral symmetry is superimposed upon the radial symmetry.
- The test is covered with a mat of short spines
- The aboral surface possesses an elongate apical disc from which the periproct is absent; the latter is located on the nearly vertical posterior wall of the test.
- A single ambulacrum (III), dissimilar to the others, is located in a deep anterior groove and goes straight towards the peristome.
- The other ambulacra are paired (II + IV; I + V). Each of these is in two parts.
- The aboral parts are expanded into four recessed leaf-like **'petals',** which terminate above the ambitus.
- The ambulacra continue below this level but are of more normal form, flush with the surface and less pronounced.
- In the petals the outer pore of each pore pair is elongated, slit-like and widely separated from the round inner pore.

- From these emerge flattened respiratory tube feet, leaf-like and rectangular.
- Adorally the peristome is located far forwards and has a project-ing lip (or **labrum)** below.
- There is no lantern.
- Adorally the plates are enlarged, and from their large pore pairs emerge sticky food-gathering tube feet.
- Behind the mouth is a flattened area (the **plastron)** formed from the modified posterior interambulacrum and densely covered with flat, paddle-shaped spines.

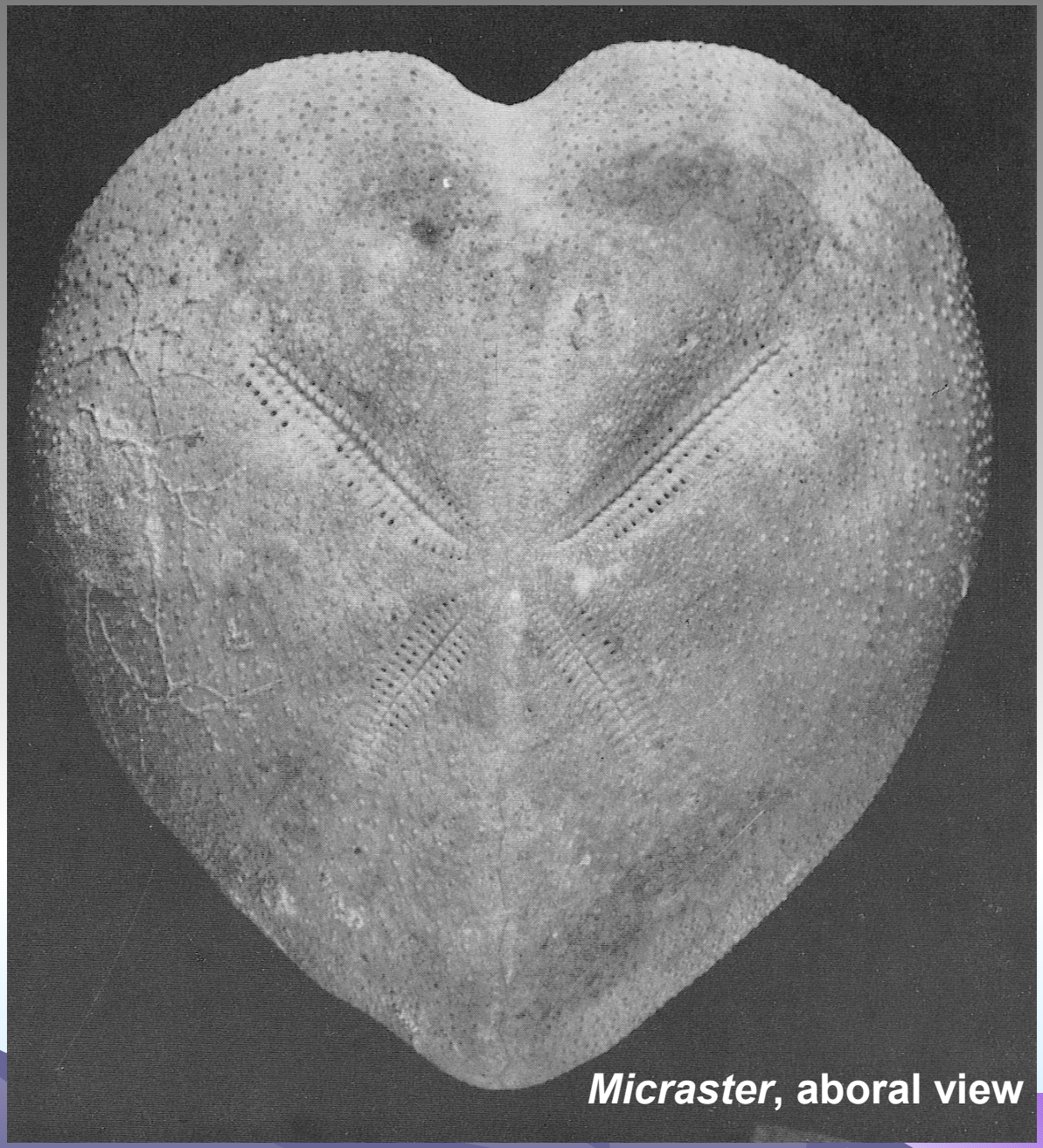
- Two regions of the test known as **fascioles** generate currents.
- The larger fasciole surrounds the anterior ambulacrum as a ribbon-like strip
- the smaller (**sub-anal**) fasciole is an elliptical ribbon located below the anus.
- In both the surface is covered with small vertical spines (the **clavulae),** each of which is covered by innumerable cilia, as in the intervening epithelium; it is the coordinated beat of these cilia that produces the currents

119 Changes in the test in *Micraster*.

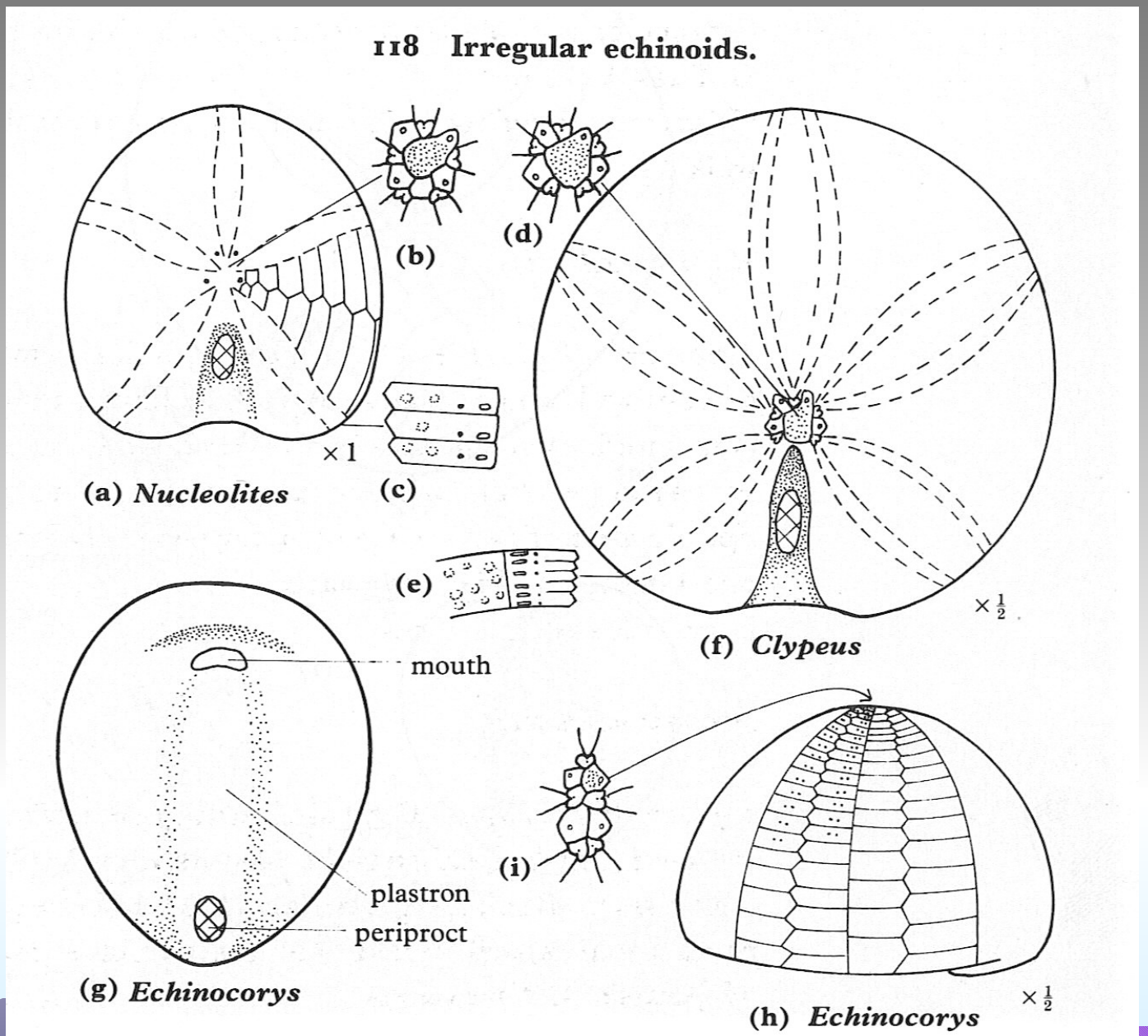
a, aboral view of a late form. b, apical system. c, d, a comparison of the positions of the apical system and the mouth, and also the depth of the anterior groove, in a late *Micraster* (c) and an early *Micraster* (d). e, oral surface of a late form. f, g, pore pairs and cross-section of an ambulacrum of an early form (f) and a late form (g). h, side view of a late form.



Micraster



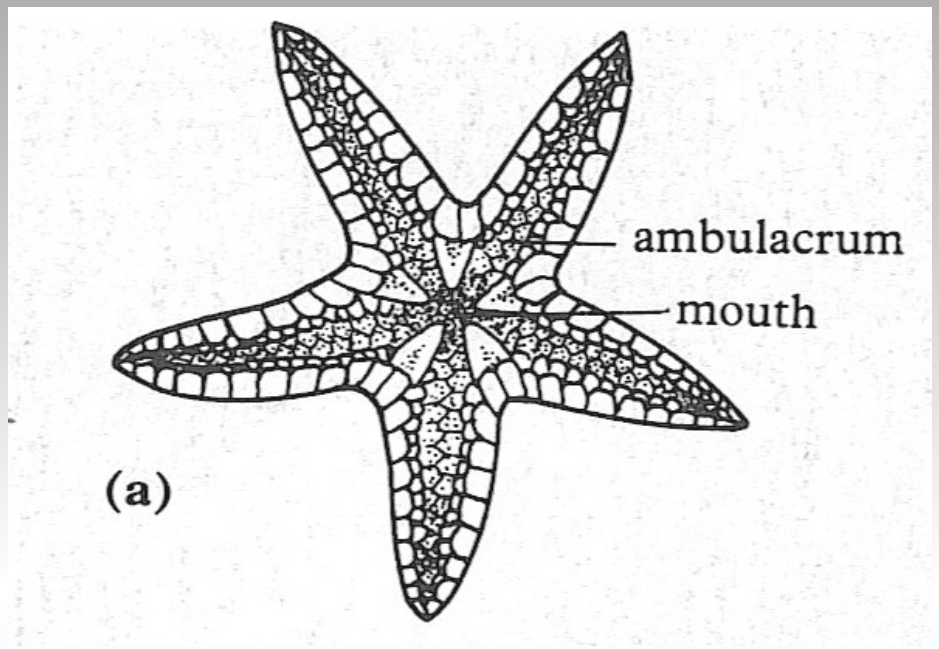
Micraster, aboral view


118 Irregular echinoids.
(b)
(d)
× 1
(a) Nucleolites
(c)
(e)
× ½
(f) Clypeus
mouth
plastron
periproct
(g) Echinocorys
(i)
× ½
(h) Echinocorys

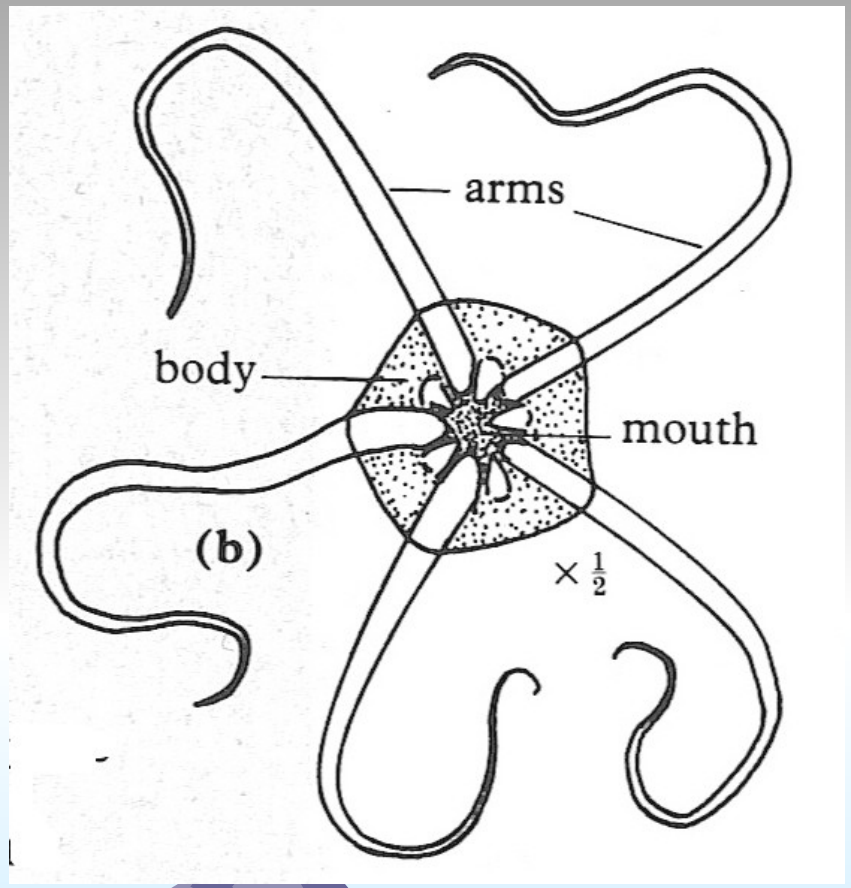
Asterozoa

- They are relatively rare in the fossil record since they break up very easily after death, and the paucity of their fossil remains is no guide to their former abundance.
- Nevertheless they are amongst the most abundant of animals living today on rocky shores of continental shelves and in the deep sea.
- In all asterozoans the central part of the body (disc) extends laterally into five or more **arms,** the mouth faces downwards and the anus, where present, is aboral.
- In asteroids the arms are not sharply marked off from the central disc, whereas in ophiuroids the central disc is clearly delimited and bears five flexible snake-like arms (Greek: ophis = snake).
- Most of the visceral elements in asterozoans, such as the intestine and gonads, are broadly homologous with those in other echinoderms.
- The water-vascular system resembles that of crinoids in that the radial water vessels lie in deep grooves in the ventral (adoral) surface.
- This is one of the many features that suggest a relationship with crinoids rather than echinoids.

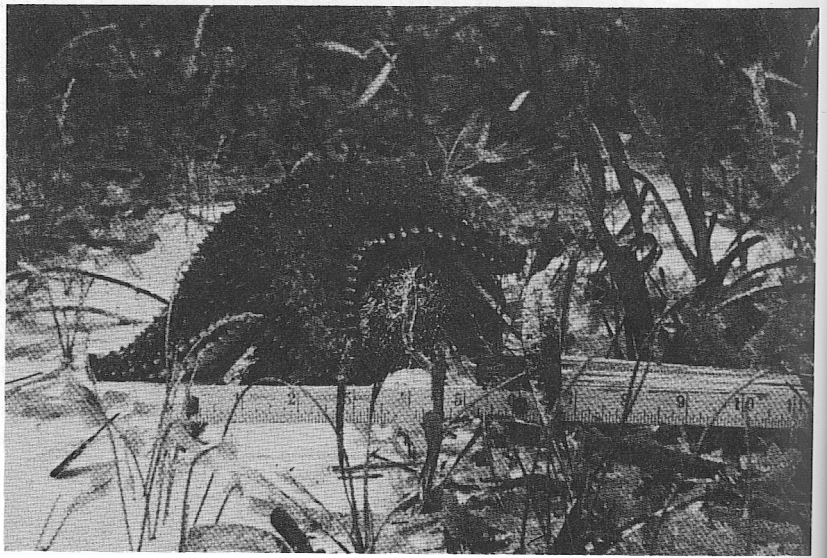
Asteroid



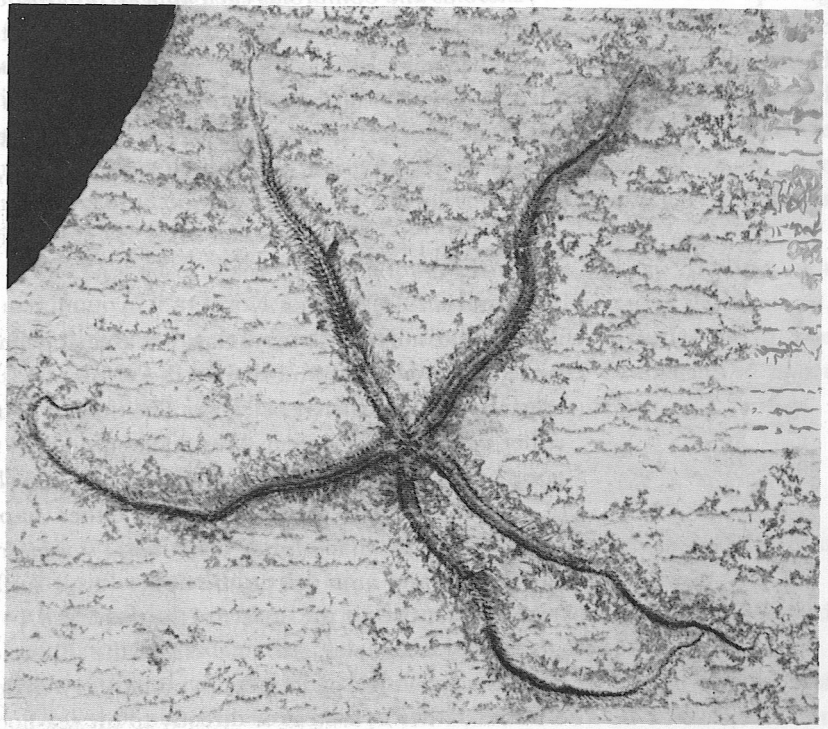
Ophiuroid



129 **A starfish, *Oreaster reticulatus*, preying on an echinoid, *Meoma ventricosa*.**
Photographed underwater at 3 m depth off the Florida Keys, USA.



131 **An ophiuroid, *Ophiurella speciosa*, Solnhofen Limestone, U Jurassic, Bavaria** (× 0.7).

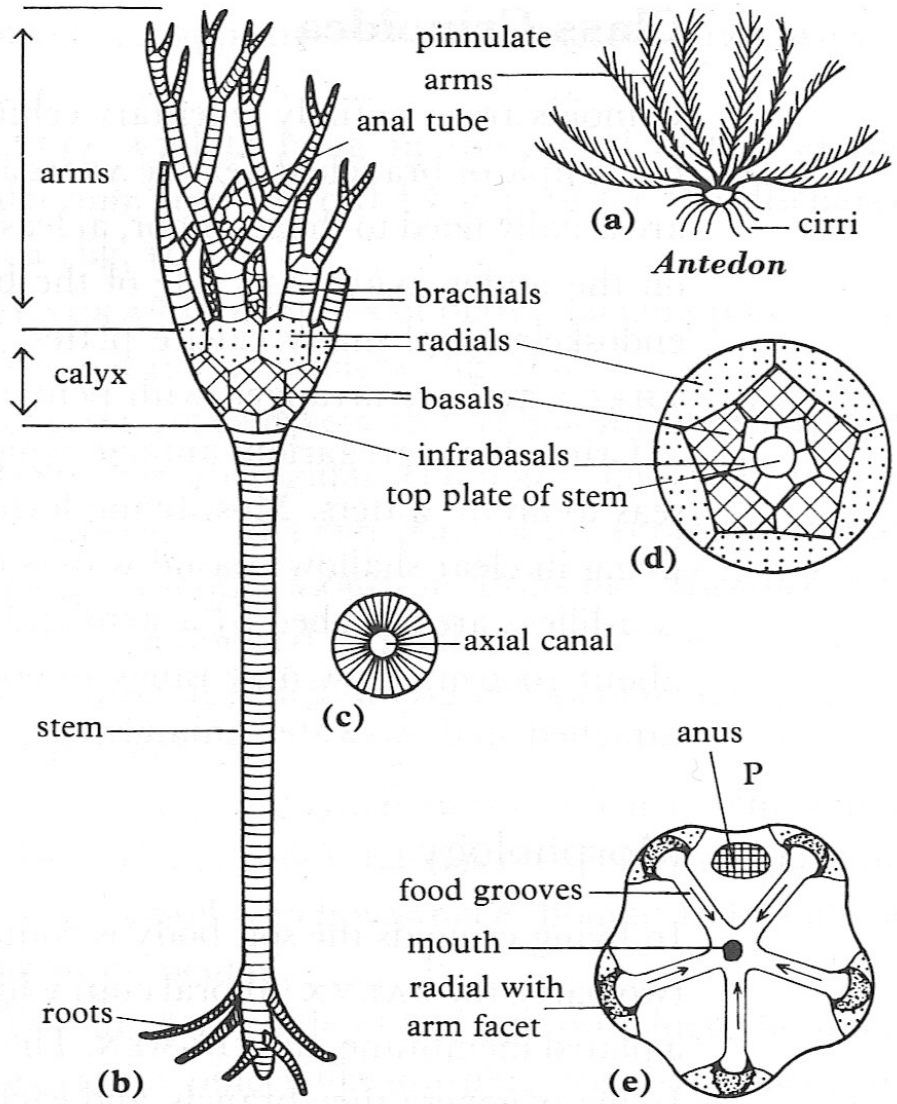


Class **Crinoidea**

- Crinozoans are primitively stalked echinoderms with long arms and normally lack complex respiratory structures. The comatulid crinoids have, lost their stalks and become secondarily free.
- Crinoids are very diverse and important in Palaeozoic faunas, and their remains have contributed substantially to Palaeozoic limestones. Complete crinoids, rarely preserved.
- Crinoids are less abundant than they were, but at the present they are represented by 25 stalked genera and by some 90 genera of free comatulids, which are the dominant group of modern oceans..

- have a **crown** which has a pentameral symmetry and **arms** which extend from the crown.
- Most are affixed to the sea floor by a **stem** formed of columnar **plates**
- The skeleton & stem are comprised of many calcareous plates.
- The body consists of a globular plated cup (the **theca**) from which long plated arms **(brachia)** arise (5 simple or branched).
- The theca has two parts: a lower region of thick rigid plates (**calyx**), pentamerally symmetrical, and a domed flexible roof (**tegmen**) with a central mouth and lateral anus.
- Inside the theca is a spirally twisted gut and a circumoral ring as in echinoids, but the madreporite is replaced by ciliated funnels. The gonads are borne not within the theca but on the arms.

- The calyx consists of two rings of five plates, the **basals** below and the **radials** above
- In some forms extra ring of 5 plates between basals and stem, the **infrabasals**
- The arm plates articulate freely with the radial plates
- They are cylindrical with a V-shaped incision on the oral side to accommodate the **food grooves**
- The stem plates also articulate freely,
- They are discoidal or star-shaped with a central hole for soft parts



123 Morphology of the crinoids.

a, a free-swimming crinoid. b, an attached crinoid showing the disposition of the main parts of the body (the arms are incomplete). c, the articular surface of a stem plate (columnal). d, aboral view of the dorsal cup. e, oral view of the calyx to show the food grooves converging on the mouth.

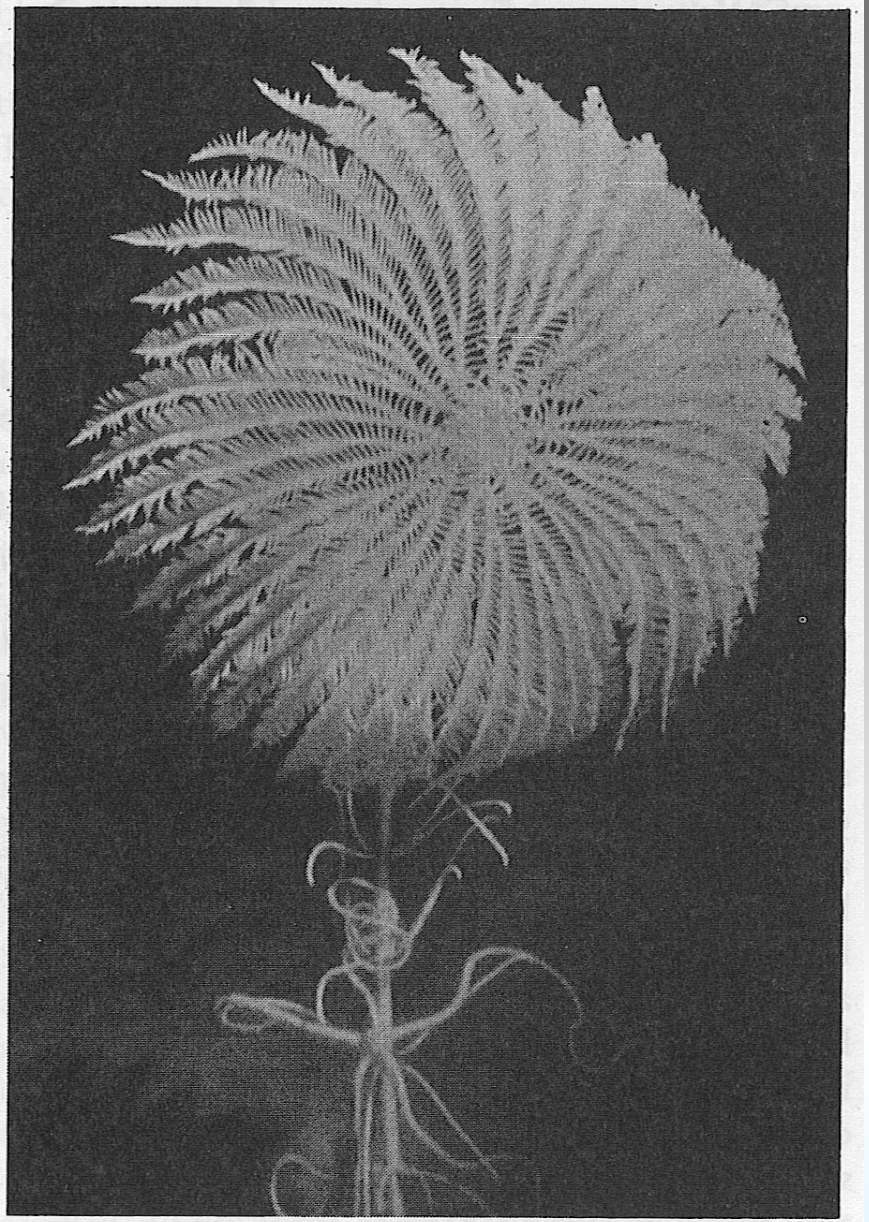
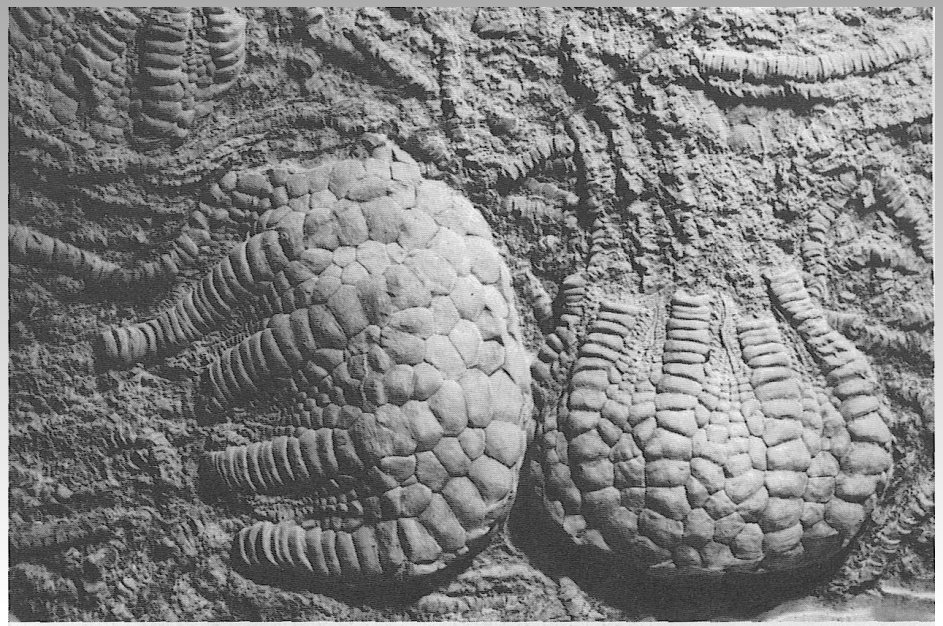


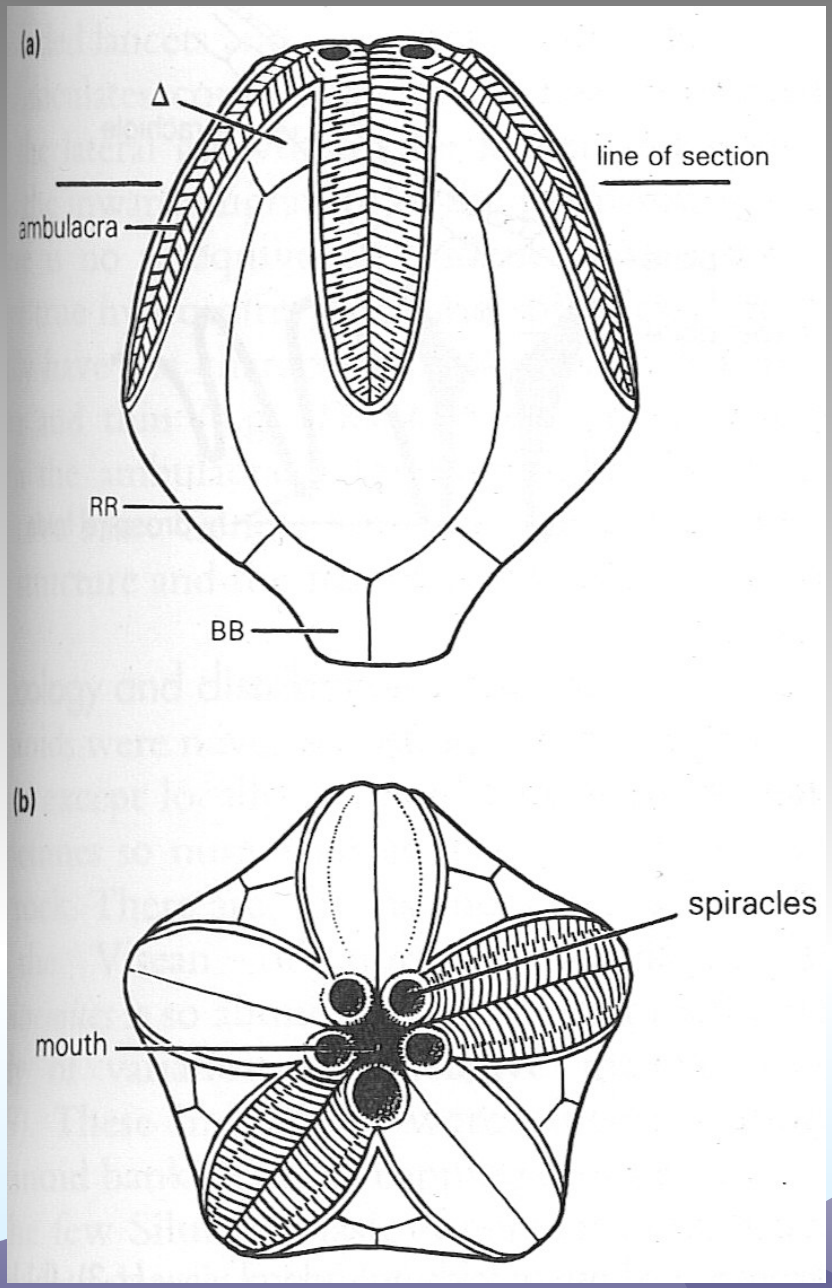
Figure 9.42 *Cenocrinus asterius* Linné; a Recent rheophilic crinoid living at depth of 200–300 m of the north coast of Jamaica. The arms are of radius 20–30 cm and form a vertical filtration fan. (Photograph reproduced by courtesy of Dr D.B. Macurda.)

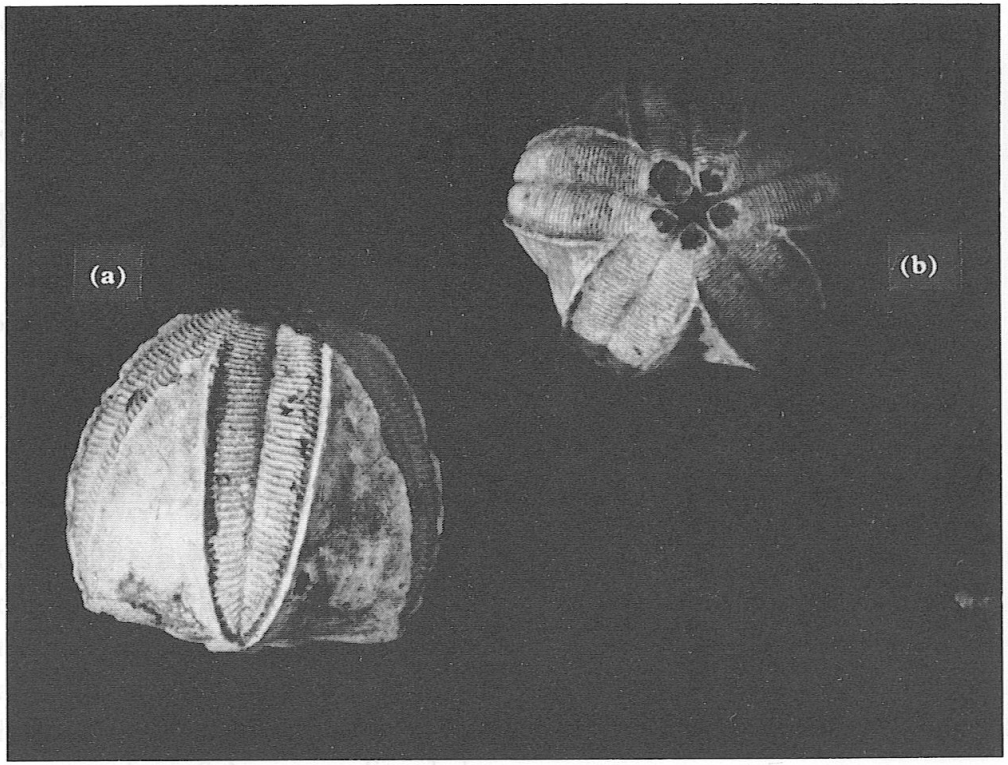
125 *Gissocrinus*, Wenlock Limestone, Silurian (× 2).



127 *Uintacrinus*, a stemless crinoid, U Cretaceous (× 1).

Blastozoa





133 **A blastoid, *Pentremites*, L Carboniferous (× 2.7).**
a, lateral view of calyx. b, oral view.