ECHINODERMS

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ECHINODERM CHARACTERISTICS

Characteristics of the phylum Echinodermata include:

1) **Calcareous endoskeleton in the form of ossicles that arise from mesodermal tissue.**
2) **Adults with pentaradial symmetry and larvae with bilateral symmetry.**
3) **Water-vascular system composed of water-filled canals used in locomotion, attachment, and/or feeding.**
4) **Complete digestive tract that may be secondarily reduced.**
5) **Hemal system derived from coelomic cavities.**
6) **Nervous system consisting of a nerve net, nerve ring, and radial nerves**

Pentaradial Symmetry

- Approximately seven thousand species.
- Exclusively marine and occur at all depths in all oceans.
- Radial symmetry allows a uniform distribution of sensory, feeding, and other structures around the animal.
- body parts are arranged in fives, or a multiple of five, around an oral-aboral axis.
- The echinoderm skeleton consists of a series of calcium carbonate plates called ossicles.
- These plates are derived from mesoderm, held in place by connective tissues, and convered by an epidermal layer.

Fig: Pentaradial Symmetry. Echinoderms exhibit pentaradial symmetry, in which body parts are arranged in fives around an oral-aboral axis. Note the madreporite between the bases of the two arms in the foreground and the tube feet on the tips of the upturned arm.

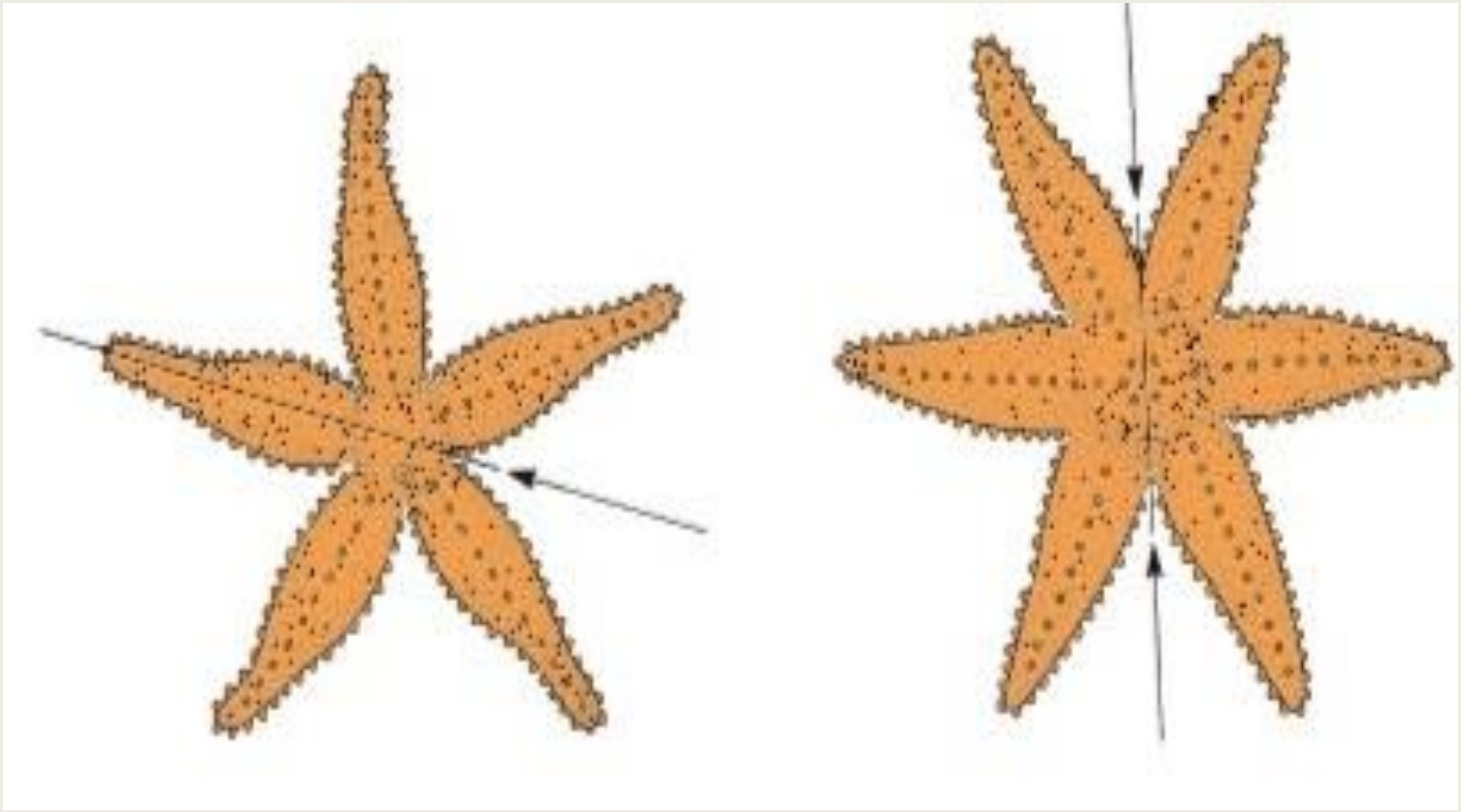


Fig: Pentaradial Symmetry (b) Comparison of hypothetical penta- and hexaradial echinoderms. The five-part organization may be advantageous because joints between skeletal ossicles are never directly opposite one another, as they would be with an even number of parts. Having joints on opposite sides of the body in line with each other (arrows) could make the skeleton weaker.

water-vascular system

- The water-vascular system includes a ring canal that surrounds the mouth.
- The madreporite may serve as an inlet to replace water lost from the water-vascular system and may help equalize pressure differences between the water-vascular system and the outside.
- Tiedemann bodies are sites for the production of phagocytic cells, called coelomocytes.
- Polian vesicles function in fluid storage for the water-vascular system.
- Five (or a multiple of five) radial canals branch from the ring canal.
- Many lateral canals branch off each radial canal and end at the tube feet.
- Internally, tube feet usually terminate in a bulblike, muscular ampulla.
- When an ampulla contracts, it forces water into the tube foot, which then extends.
- A tube foot often has a suction cup at its distal end.
- When the foot extends and contacts solid substrate, muscles of the suction cup contract and create a vacuum.

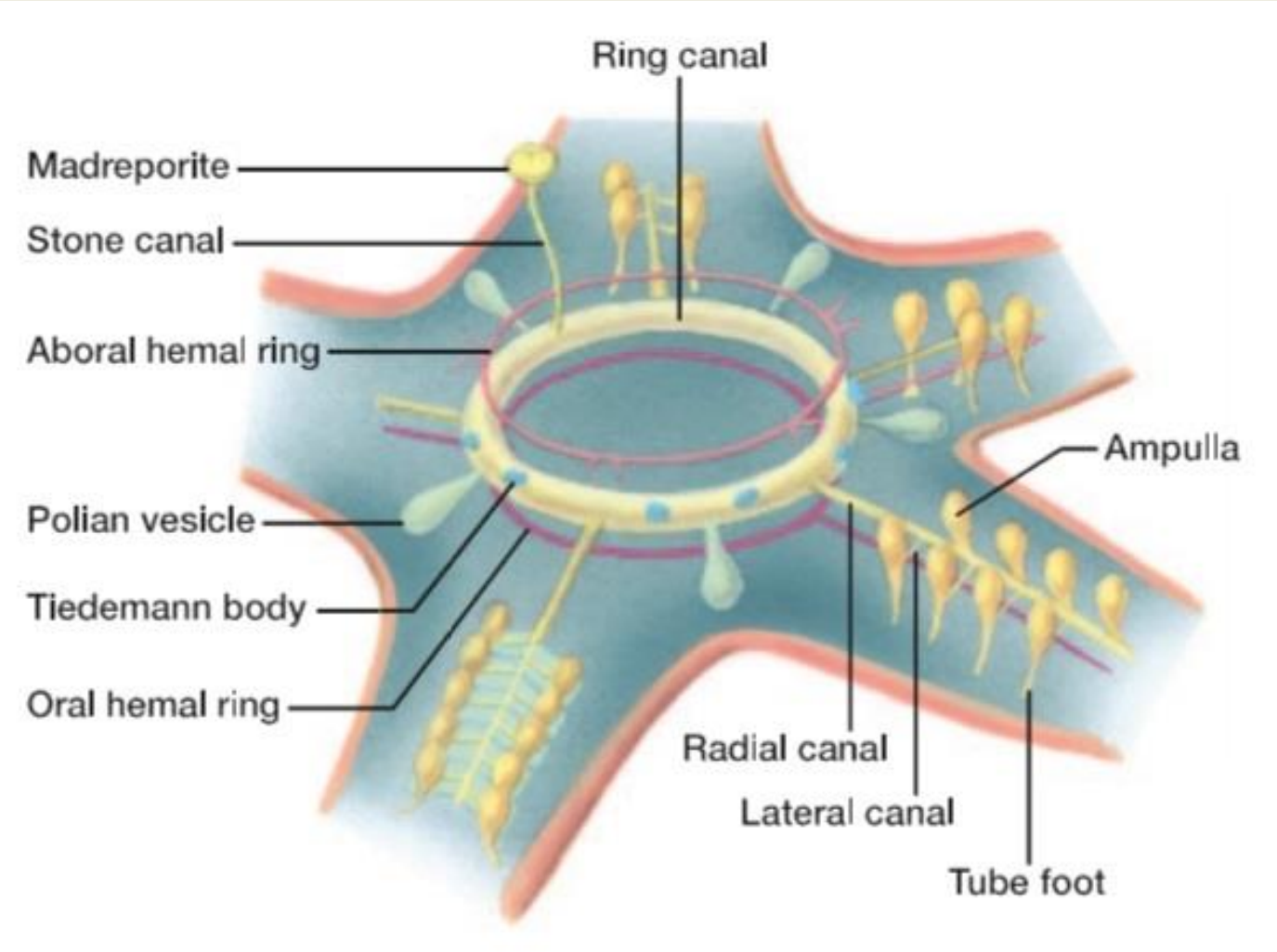


Fig: Water-Vascular System of a Sea Star. The ring canal gives rise to radial canals that lead into each arm. It opens to the outside or to the body cavity through a stone canal that ends at a madreporite on the aboral surface. Polian vesicles and Tiedemann bodies are often associated with the ring canal

Functions of water-vascular system

- The original function of water-vascular systems was probably feeding not locomotion
- The soft membranes of the water-vascular system permit diffusion of respiratory gases and nitrogenous wastes across the body wall.

hemal system

- Consist of strands of tissue encircle an echinoderm near the ring canal of the water-vascular system and run into each arm near the radial canals.
- The hemal system has been likened to a vestigial circulatory system; however, its function is largely unknown.
- It may aid in the transport of large molecules, hormones, or coelomocytes, which are cells that engulf and transport waste particles within the body.

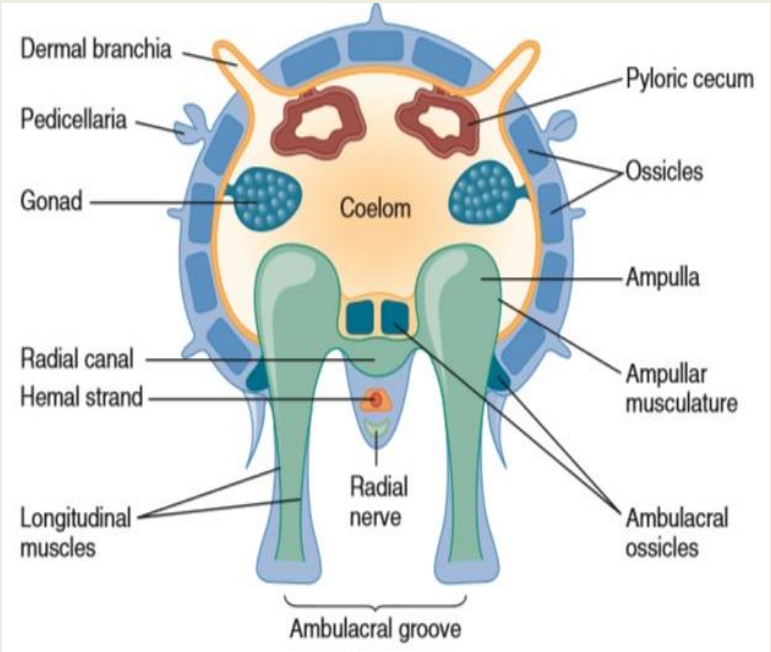


Fig: Body Wall and Internal Anatomy of a Sea Star. A cross section through one arm of a sea star shows the structures of the water-vascular system and the tube feet extending through the ambulacral groove.

CLASS ASTEROIDEA

- The sea stars make up the class Asteroidea.
- About 1,500 species.
- They often live on hard substrates in marine environments.
- Some species also live in sandy or muddy substrates.
- Sea stars may be brightly colored with red, orange, blue, or gray.
- Asterias is an orange sea star common along the Atlantic coast of North America.

Body Wall and Internal Anatomy of a Sea Star

- Sea stars usually have five arms that radiate from a central disk.
- The oral opening, or mouth, is in the middle of one side of the central disk.

❖ **Dermal branchiae**

- Thin folds of the body wall, called **dermal branchiae**, extend between ossicles and function in gas exchange.

❖ **Pedicellariae**

- In some sea stars, the aboral surface has numerous pincherlike structures
- Clean the body surface of debris and have protective functions.
- Pedicellariae may be attached on a movable spine.
- They may be immovably fused to skeletal ossicles.

❖ **Ambulacral groove**

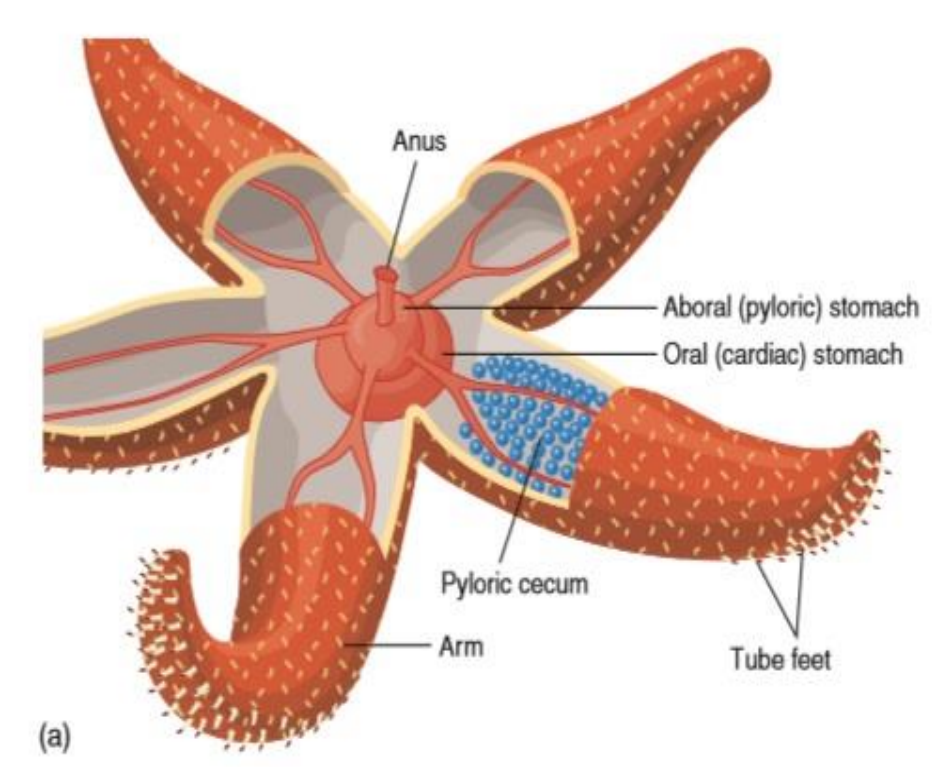
- A series of ossicles in the arm form an ambulacral groove.
- Houses the radial canal, and paired rows of tube feet protrude through the body wall on either side of the ambulacral groove.

- **Tube feet**
  - **Alternate extension, attachment, and contraction of tube feet move sea stars across their substrate.**
  - **The nervous system coordinates the tube feet.**
  - **The suction disks of tube feet are effective attachment structures.**

MAINTENANCE FUNCTIONS

1) Digestive structures in Sea star

- Sea stars feed on snails, bivalves, crustaceans, polychaetes, corals, detritus, and a variety of other food items.
- Mouth → Short esophagus → Large stomach.
- The stomach is divided into two regions.
- The larger, oral stomach → cardiac stomach
- The smaller, aboral stomach → pyloric stomach.
- Secretory and absorptive structures called **pyloric cecae**.
- Two pyloric cecae extend into each arm.
- **A short intestine** leads to rectal cecae and to a nearly nonfunctional anus, which opens on the aboral surface of the central disk.



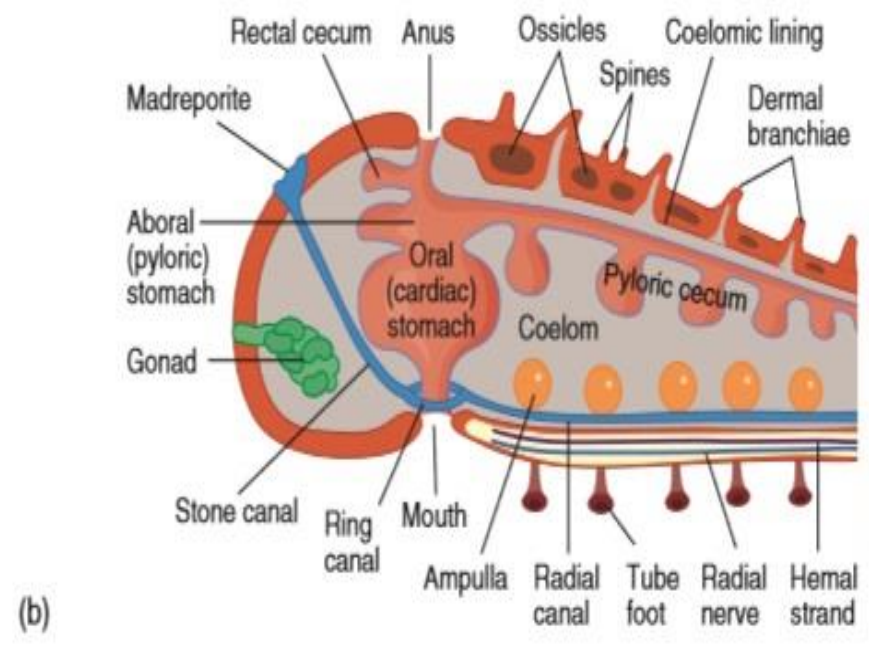


Fig: Digestive Structures in a Sea Star. A mouth leads to a large oral (cardiac) stomach and an aboral (pyloric) stomach. Pyloric cecae extend into each arm. (a) Aboral view. (b) Lateral view through central disk and one arm.

Digestion in a Sea Star

When a sea star feeds on a bivalve, it wraps itself around the bivalve's ventral margin

Tube feet attach to the outside of the shell, and the body-wall musculature forces the valves apart.

When the valves are opened, increased coelomic pressure everts the oral (cardiac) portion of the sea star's stomach into the bivalve shell

Digestive enzymes are released, and partial digestion occurs in the bivalve shell.

This digestion further weakens the bivalve's adductor muscles, and the shell eventually opens completely

Partially digested tissues are taken into the aboral (pyloric) portion of the stomach and into the pyloric cecae

After feeding and initial digestion, the sea star retracts the stomach, using stomach retractor muscles.

Gas Exchange

- Gases, nutrients, and metabolic wastes are transported in the coelom by diffusion and by the action of ciliated cells lining the body cavity.
- Gas exchange and excretion of metabolic wastes occur by diffusion across dermal branchiae, tube feet, and other membranous structures.
- A sea star's hemal system consists of strands of tissue that encircle the mouth near the ring canal, extend aborally near the stone canal, and run into the arms near radial canals

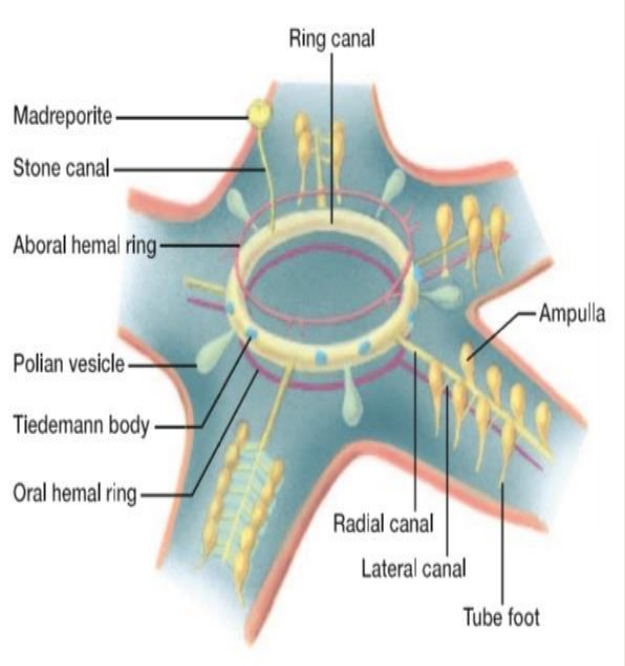


Fig: Water-Vascular System of a Sea Star

The nervous system

- The nervous system of sea stars consists of a nerve ring that encircles the mouth and radial nerves that extend into each arm.
- Radial nerves lie within the ambulacral groove, just oral to the radial canal of the water-vascular system and the radial strands of the hemal system.
- Radial nerves coordinate the functions of tube feet.
- Other nervous elements are in the form of a nerve net associated with the body wall.

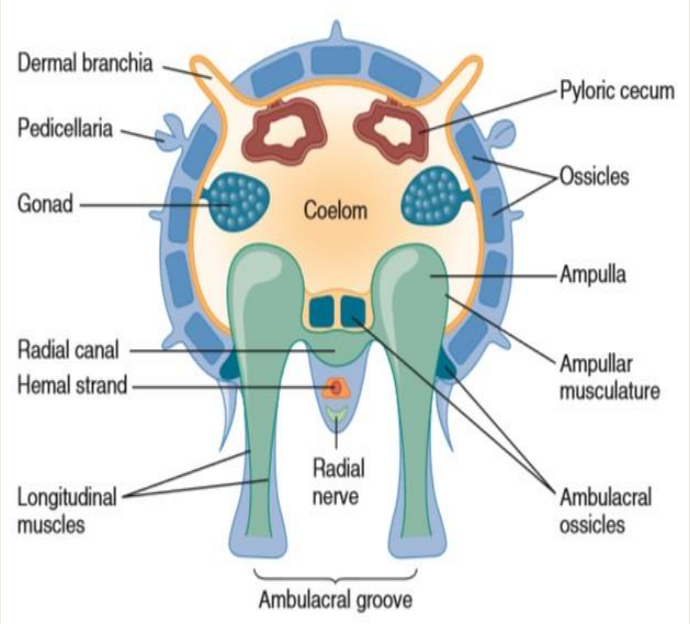


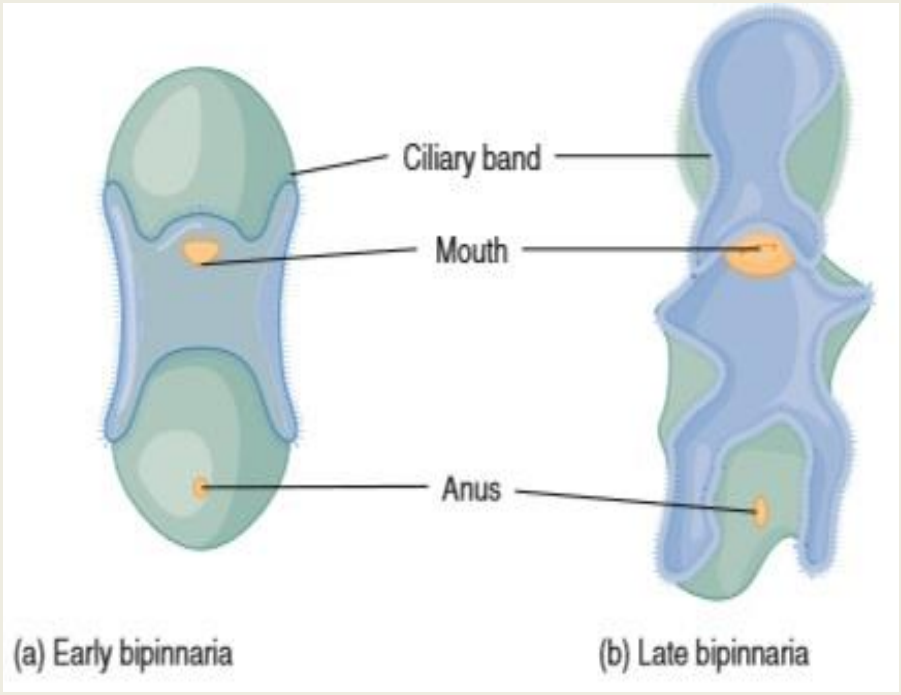
Fig: Body Wall and Internal Anatomy of a Sea Star

Sensory organs

- Most sensory receptors are distributed over the surface of the body and tube feet.
- Sea stars respond to light, chemicals, and various mechanical stimuli.
- They often have specialized photoreceptors at the tips of their arms.
- These are actually tube feet that lack suction cups but have a pigment spot surrounding a group of ocelli.

REGENERATION, REPRODUCTION, AND DEVELOPMENT

- Sea stars are well known for their powers of **regeneration.**
- **Asexual reproduction** involves division of the central disk, followed by regeneration of each half.
- Sea stars are **dioecious**, but sexes are indistinguishable externally.
- **Two gonads** are present in each arm. **Gonopores** open between the bases of each arm.
- **External fertilization** is the rule.
- The **photoperiod** and **temperature** are environmental factors used to coordinate sexual activity.
- **Spawning pheromones**, which induce other sea stars in the area to spawn, increasing the likelihood of fertilization.
- After gastrulation, bands of cilia differentiate, and a bilaterally symmetrical larva, called a **bipinnaria larva**, forms.
- The development of larval arms results in a **brachiolaria larva**, which settles to the substrate, attaches, and metamorphoses into a **juvenile sea star**.



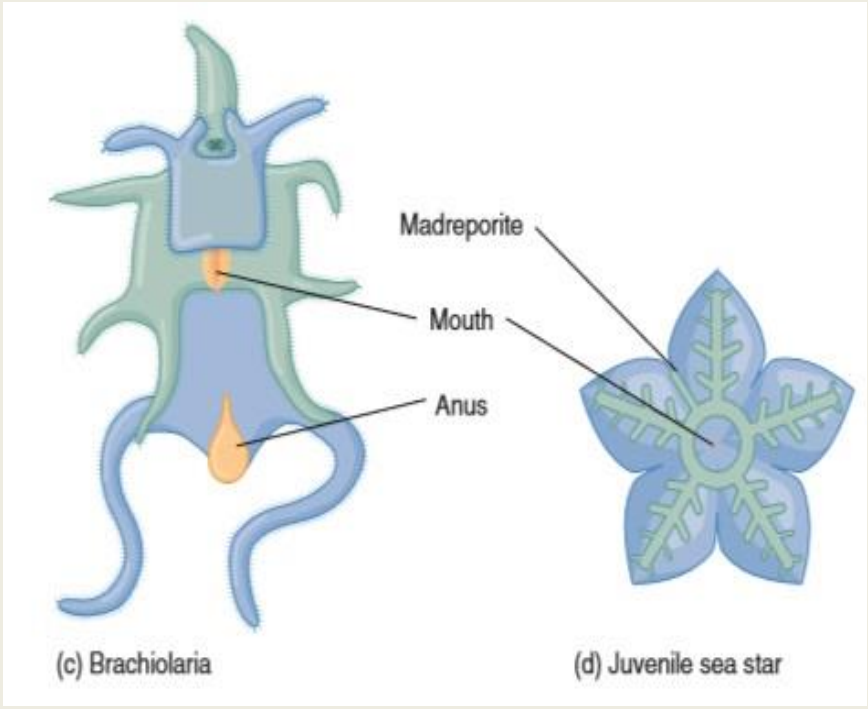


Fig: Development of a Sea Star. Later embryonic stages are ciliated and swim and feed in the plankton. In a few species, embryos develop from yolk stored in the egg during gamete formation. Following blastula and gastrula stages, larvae develop. (a) Early bipinnaria larva (0.5 mm). (b) Late bipinnaria larva (1 mm). (c) Brachiolaria larva (1 mm). (d) Juvenile sea star (1 to 2 mm).

CLASS OPHIUROIDEA

External Features

- Includes the basket stars and the brittle stars.
- Over two thousand species, this is the most diverse group of echinoderms.
- The arms of ophiuroids are long and, unlike those of asteroids, are sharply set off from the central disk, giving the central disk a pentagonal shape.
- Brittle stars have unbranched arms, and most have a central disk that ranges in size from 1 to 3 cm.

Class Ophiuroidea. This brittle star (*Ophiopholis aculeata*) uses its long, snakelike arms for crawling along its substrate and curling around objects in its environment.

External Features

- Basket stars have arms that branch repeatedly.
- Neither dermal branchiae nor pedicellariae are present in ophiuroids.
- The tube feet of ophiuroids lack suction disks and ampullae, and the contraction of muscles associated with the base of a tube foot extends the tube foot.
- Unlike the sea stars, the madreporite of ophiuroids is on the oral surface

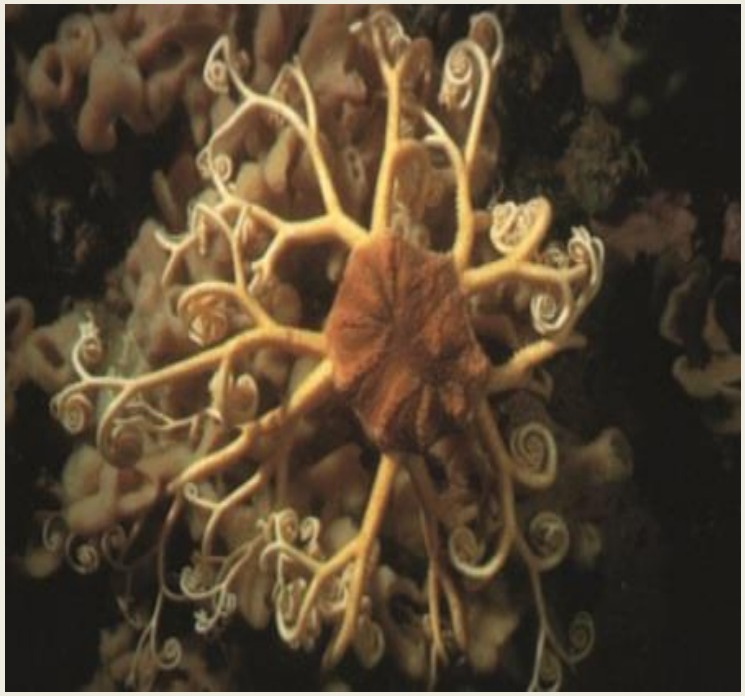


Fig: Class Ophiuroidea. Basket stars have five highly branched arms. They wave the arms in the water and with the mucus-covered tube feet capture planktonic organisms.

water-vascular system of ophiuroids

- The ambulacral groove—containing the radial nerve, hemal strand, and radial canal—is thus said to be “closed.”
- Ambulacral ossicles are in the arm, forming a central supportive axis.
- Successive ambulacral ossicles articulate with one another and are acted upon by relatively large muscles to produce snakelike movements that allow the arms to curl around a stalk of algae or to hook into a coral crevice.
- During locomotion, the central disk is held above the substrate, and two arms pull the animal along, while other arms extend forward and/or trail behind the animal.

MAINTENANCE FUNCTIONS

- Ophiuroids are predators and scavengers.
- Some ophiuroids are filter feeders that wave their arms and trap plankton on mucuscovered tube feet.
- The mouth is in the center of the central disk, and five triangular jaws form a chewing apparatus.
- The mouth leads to a saclike stomach and there is no intestine.
- The coelom is reduced and is mainly confined to the central disk.
- Coelom serves as the primary means for the distribution of nutrients, wastes, and gases.
- Coelomocytes aid in the distribution of nutrients and the expulsion of particulate wastes.
- Ammonia is the primary nitrogenous waste product, and it is lost by diffusion across tube feet and membranous sacs, called bursae.
- Slits in the oral disk, near the base of each arm, allow cilia to move water into and out of the bursae.

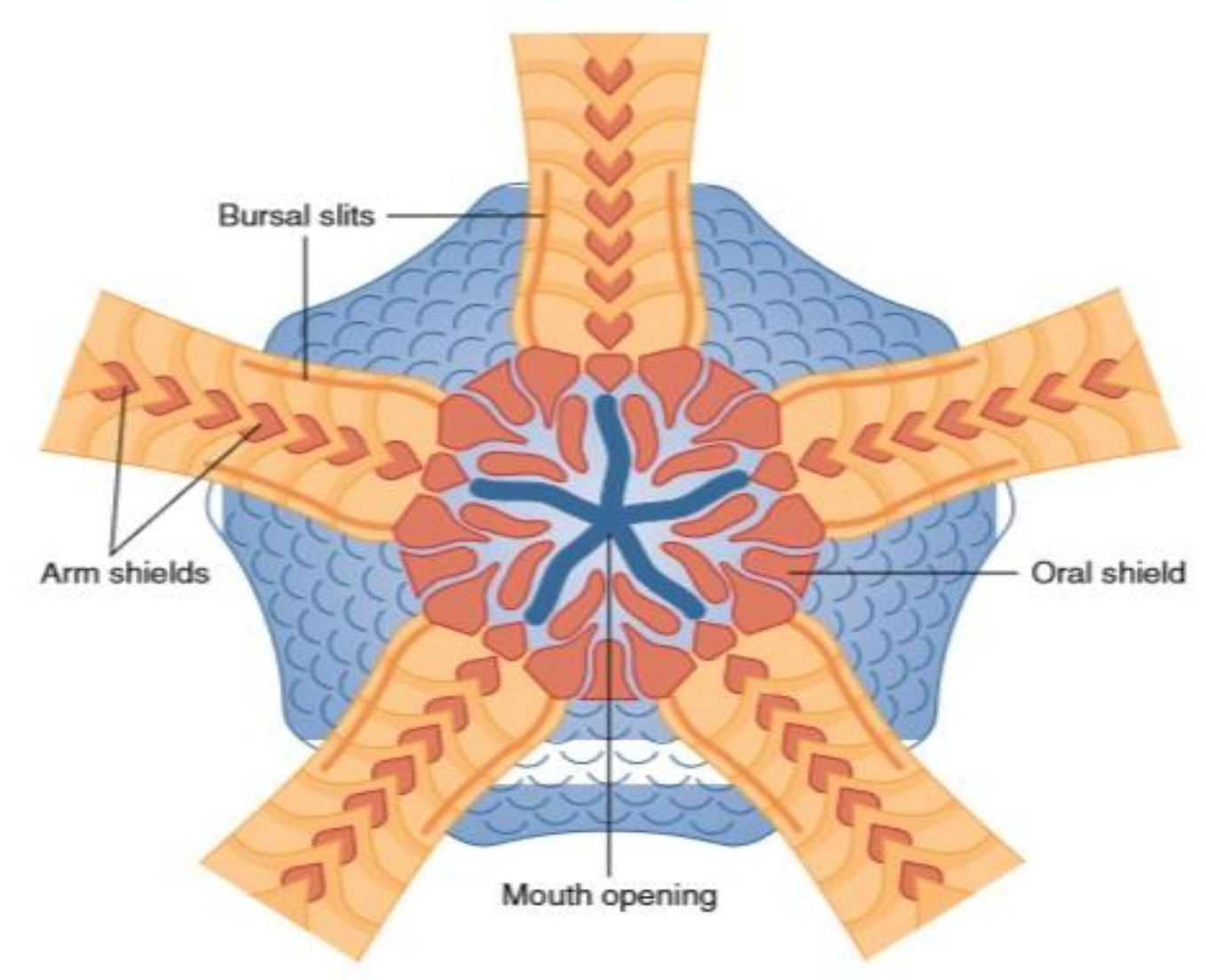


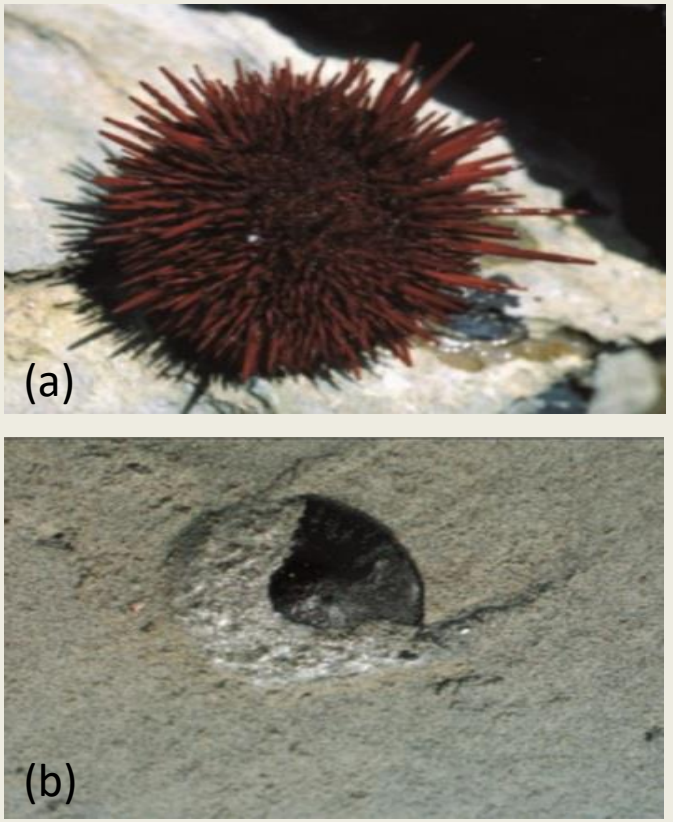
Fig: Class Ophiuroidea. Oral view of the disk of the brittle star, *Ophiomusium*

REGENERATION, REPRODUCTION, AND DEVELOPMENT

- Ophiuroids can regenerate lost arms.
- The process, called autotomy, is used in escape reactions.
- Some species also have a fission line across their central disk.
- Ophiuroids are dioecious.
- The gonads are associated with each bursa, and gametes are released into the bursa.
- Eggs may be shed to the outside or retained in the bursa, where they are fertilized and held through early development.
- Embryos are protected in the bursa and are sometimes nourished by the parent.
- A larval stage, called an ophiopluteus, is planktonic. It undergoes metamorphosis before sinking to the substrate.

CLASS ECHINOIDEA

- The sea urchins, sand dollars, and heart urchins make up the class Echinoidea.
- The approximately one thousand species are widely distributed in nearly all marine environments.
- Sea urchins are specialized for living on hard substrates, often wedging themselves into crevices and holes in rock or coral.
- Sand dollars and heart urchins usually live in sand or mud, and burrow just below the surface.
- They use tube feet to catch organic matter settling on them or passing over them.



Class Echinoidea. (a) A sea urchin (*Strongylocentrotus*) (b) Sand dollars are specialized for living in soft substrates, where they are often partially buried.

CLASS ECHINOIDEA

- Sea urchins are rounded, and their oral end is oriented toward the substrate.
- Their skeleton, called a test, consists of 10 closely fitting plates that arch between oral and aboral ends.
- Five rows of ambulacral plates have openings for tube feet, and alternate with five interambulacral plates, which have tubercles for the articulation of spines.
- Spines are often sharp and sometimes hollow, and they may contain venom dangerous to swimmers.
- The pedicellariae of sea urchins have either two or three jaws and connect to the body wall by a relatively long stalk.

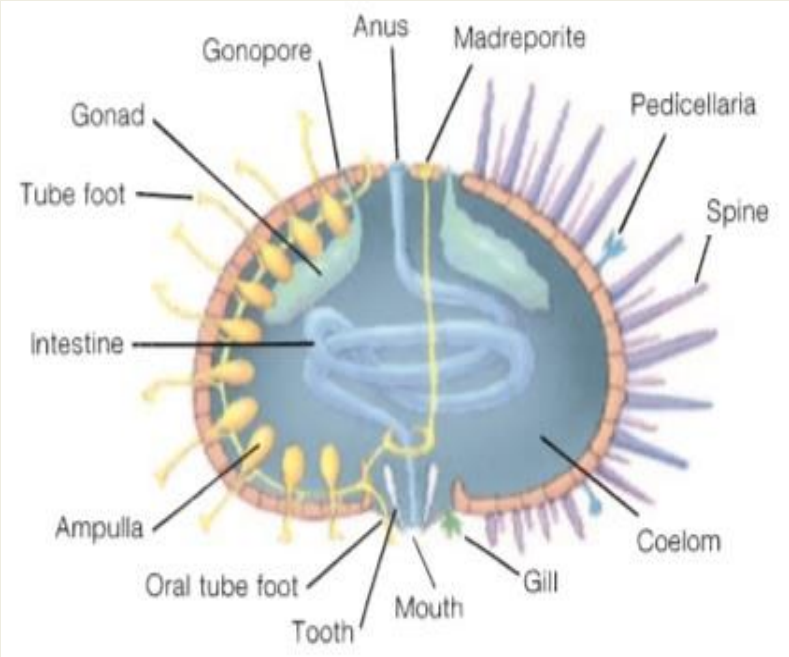


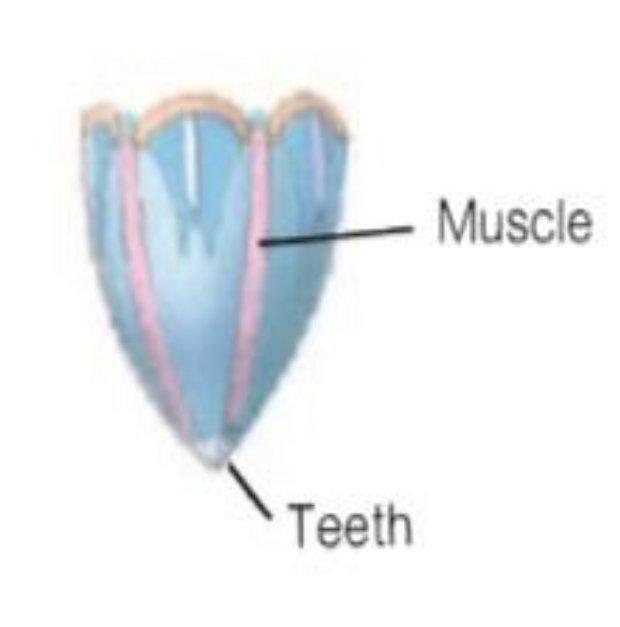
Fig: Internal Anatomy of a Sea Urchin. Sectional view

CLASS ECHINOIDEA

- The water-vascular system is similar to that of other echinoderms.
- Echinoids move by using spines for pushing against the substrate and tube feet for pulling.
- Sand dollars and heart urchins use spines to help burrow in soft substrates.
- Some sea urchins burrow into rock and coral to escape the action of waves and strong currents.
- They form cup-shaped depressions and deeper burrows, using the action of their chewing Aristotle's lantern.

MAINTENANCE FUNCTIONS

- Echinoids feed on algae, bryozoans, coral polyps, and dead animal remains.
- Oral tube feet surrounding the mouth manipulate food.
- A chewing apparatus, called Aristotle's lantern, can be projected from the mouth.
- It consists of about 35 ossicles and attached muscles and cuts food into small pieces for ingestion.
- The mouth cavity leads to a pharynx, an esophagus, and a long, coiled intestine that ends aborally at the anus.



Internal Anatomy of a Sea Urchin. Aristotle's lantern is a chewing structure consisting of about 35 ossicles and associated muscles.

MAINTENANCE FUNCTIONS

- Echinoids have a large coelom
- Small gills, found in a thin membrane surrounding the mouth, are outpockets of the body wall and are lined by ciliated epithelium.
- Gas exchange occurs by diffusion across this epithelium and across the tube feet.
- Coelomic fluids move into and out of gills by:
  - Ciliary currents
  - Changes in coelomic pressure
  - Contraction of muscles associated with Aristotle's lantern.
- Excretory and nervous functions are similar to those described for asteroids.

REPRODUCTION AND DEVELOPMENT

- Echinoids are dioecious.
- Gonads are on the internal body wall of the interambulacral plates.
- During breeding season, they nearly fill the spacious coelom.
- One gonopore is in each of five ossicles, called genital plates, at the aboral end of the echinoid.
- the sand dollars usually have only four gonads and gonopores.
- Gametes are shed into the water, and fertilization is external.
- Development eventually results in a pluteus larva that spends several months in the plankton and eventually undergoes metamorphosis to the adult.

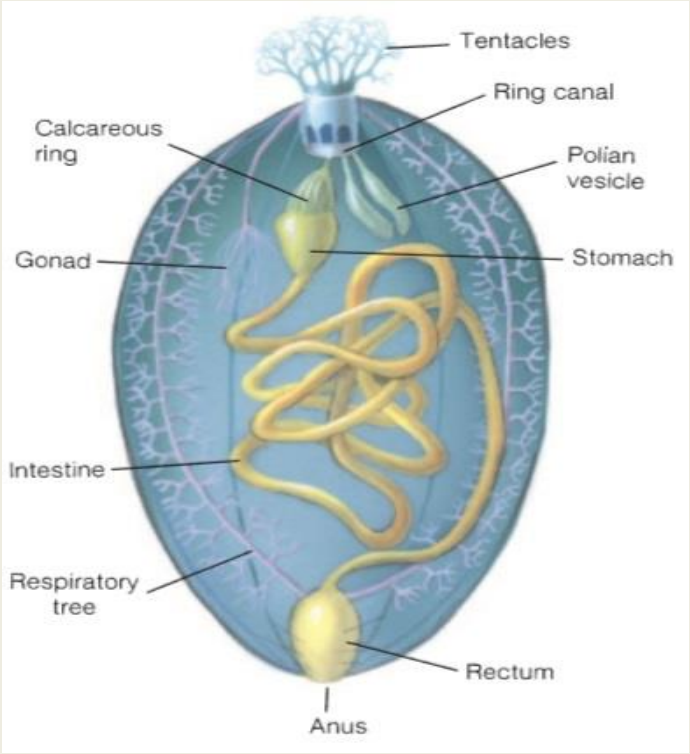
CLASS HOLOTHUROIDEA

- Approximately 1,500 species
- members are commonly called sea cucumbers.
- Sea cucumbers are found at all depths in all oceans
- They crawl over hard substrates or burrow through soft substrates.
- Sea cucumbers have no arms
- they are elongate along the oral-aboral axis.
- They lie on one side, which is usually flattened as a permanent ventral side, giving them a secondary bilateral symmetry.
- Most adults range in length between 10 and 30 cm.
- Their body wall is thick and muscular, and it lacks protruding spines or pedicellariae.

Class Holothuroidea. A sea cucumber (*Parastichopus californicus*).

CLASS HOLOTHUROIDEA

- Beneath the epidermis is the dermis
- Dermis is a thick layer of connective tissue with embedded ossicles.
- Larger ossicles form a calcareous ring
- Beneath the dermis is a layer of circular muscles overlying longitudinal muscles.
- The body wall of sea cucumbers, when boiled and dried, is known as trepang in Asian countries.
- It may be eaten as a main-course item or added to soups as flavoring and a source of protein.



Internal Structure of a Sea Cucumber, *Thyone*.

CLASS HOLOTHUROIDEA

- The madreporite of sea cucumbers is internal
- Water-vascular system is filled with coelomic fluid
- The ring canal encircles the oral end of the digestive tract and gives rise to one to ten Polian vesicles.
- Five radial canals and the canals to the tentacles branch from the ring canal.
- Radial canals and tube feet, with suction cups and ampullae, run between the oral and aboral poles.
- Sea cucumbers are mostly sluggish burrowers and creepers, although some swim.
- Locomotion more commonly results from contractions of body-wall muscles

MAINTENANCE FUNCTIONS

- Most sea cucumbers ingest particulate organic matter using their tentacles.
- Mucus covering the tentacles traps food as the tentacles sweep across the substrate or are held out in seawater.
- The digestive tract consists of a stomach; a long, looped intestine; a rectum; and an anus.
- Sea cucumbers thrust tentacles into the mouth to wipe off trapped food.
- During digestion, coelomocytes move across the intestinal wall, secrete enzymes to aid in digestion, and engulf and distribute the products of digestion.

MAINTENANCE FUNCTIONS

The coelom

- Coelme of sea cucumbers is large
- Cilia of the coelomic lining circulate fluids throughout the body cavity
- Distributing respiratory gases, wastes, and nutrients.

The hemal system

- Sea cucumbers is well developed, with relatively large sinuses
- a network of channels containing coelomic fluids.
- Its primary role is food distribution.

- A pair of tubes called respiratory trees attach at the rectum and branch throughout the body cavity of sea cucumbers.
- The pumping action of the rectum circulates water into these tubes.
- When the rectum dilates, water moves through the anus into the rectum.
- Contraction of the rectum, along with contraction of an anal sphincter, forces water into the respiratory tree.
- Water exits the respiratory tree when tubules of the tree contract.
- Respiratory gases and nitrogenous wastes move between the coelom and seawater across these tubules.

Nervous system and sensory structures

- The nervous system of sea cucumbers has additional nerves supplying the tentacles and pharynx.
- Some sea cucumbers have statocysts, and relatively complex photoreceptors.

Defensive adaptation

Toxins

- Many sea cucumbers, however, produce toxins in their body walls that discourage predators.

Cuverian tubules

- Tubules of the respiratory tree, called Cuverian tubules, through the anus contain sticky secretions and toxins capable of entangling and immobilizing predators.

Evisceration

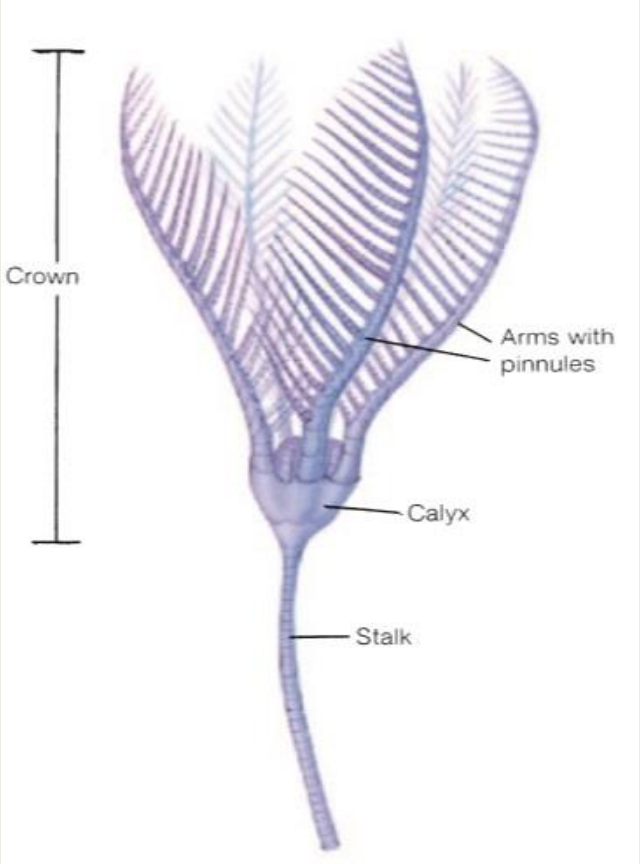
- Contractions of the body wall may result in expulsion of one or both respiratory trees, the digestive tract, and the gonads through the anus. This process, called evisceration. Regeneration of lost parts follows

REPRODUCTION AND DEVELOPMENT

- Sea cucumbers are dioecious.
- They possess a single gonad, located anteriorly in the coelom
- a single gonopore near the base of the tentacles.
- Fertilization is usually external, and embryos develop into planktonic larvae.
- Metamorphosis precedes settling to the substrate.
- After fertilizaiton, eggs are transferred to the body surface, where they are brooded.
- Eggs are released into the body cavity, where fertilization and early development occur.
- Sea cucumbers can also reproduce by transverse fission, followed by regeneration of lost parts.

CLASS CRINOIDEA

- Members of the class Crinoidea include the sea lilies and the feather stars.
- They are the most primitive of all living echinoderms and are very different from any covered thus far.
- Approximately 630 species are living today.
- An extensive fossil record indicates that many more were present during the Paleozoic era, 200 to 600 million years ago.
- Sea lilies attach permanently to their substrate by a stalk.



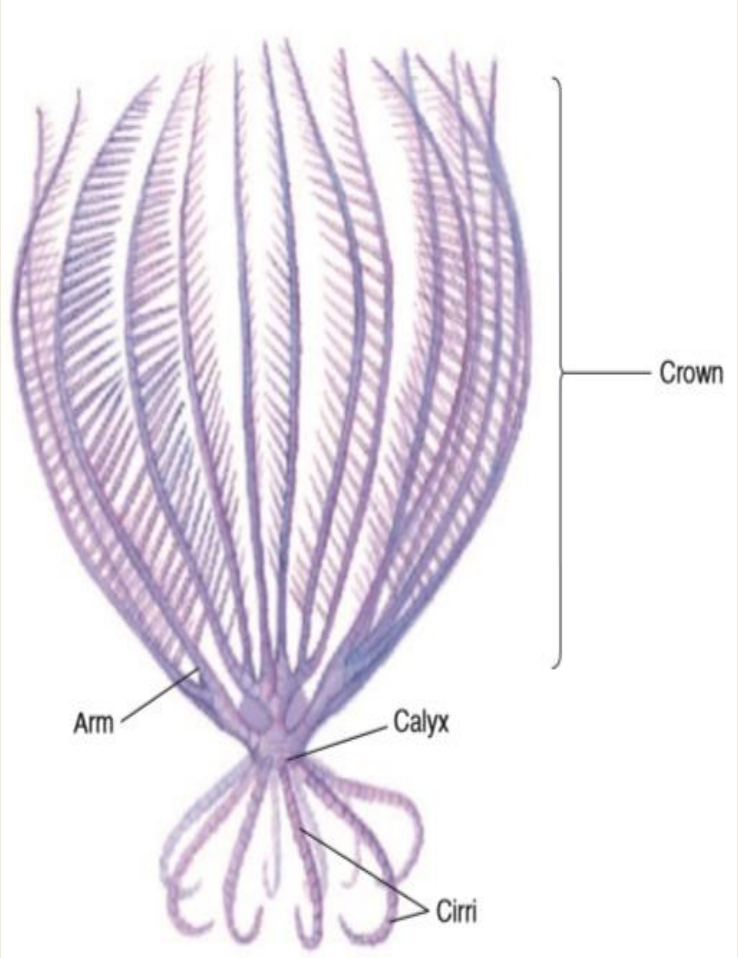
Class Crinoidea. A sea lily (*Ptilocrinus*).

CLASS CRINOIDEA

- Disklike ossicles of the stalk appear to be stacked on top of one another and are held together by connective tissues, giving a jointed appearance.
- The stalk usually bears projections, or cirri, arranged in whorls.
- The unattached end of a sea lily is called the crown.
- The aboral end of the crown attaches to the stalk and is supported by a set of ossicles, called the calyx.
- Five arms also attach at the calyx. They are branched, supported by ossicles, and bear smaller branches (pinnules)—giving them a featherlike appearance.
- Ambulacral grooves on the arms lead toward the mouth.
- The mouth and anus open onto the upper (oral) surface.

CLASS CRINOIDEA

- Ambulacral grooves on the arms lead toward the mouth.
- The mouth and anus open onto the upper surface.
- Feather stars are similar to sea lilies, except they lack a stalk and are swimming and crawling animals.
- The aboral end of the crown bears a ring of rootlike cirri
- Feather stars swim by raising and lowering the arms, and they crawl over substrate by pulling with the tips of the arms.



Class Crinoidea. A feather star (*Neometra*)

MAINTENANCE FUNCTIONS

- Circulation, gas exchange, and excretion in crinoids are similar to these functions in other echinoderms.
- In feeding, however, crinoids use outstretched arms for suspension feeding.
- A planktonic organism that contacts a tube foot is trapped, and cilia in ambulacral grooves carry it to the mouth.
- Crinoids lack the nerve ring found in most echinoderms.
- A cup-shaped nerve mass below the calyx gives rise to radial nerves.

REPRODUCTION AND DEVELOPMENT

- Crinoids, like other echinoderms, are dioecious.
- Gametes form from germinal epithelium in the coelom and are released through ruptures in the walls of the arms.
- Some species spawn in seawater, where fertilizaition and development occur.
- Other species brood embryos on the outer surface of the arms.
- Metamorphosis occurs after larvae attach to the substrate.
- Like other echinoderms, crinoids can regenerate lost parts.