Chapter 22

Phylum Echinodermata

Characteristics

• All members of the phylum have a calcareous skeleton.
• The spiny endoskeleton consists of plates.
• They have a unique water-vascular system.
• They possess pedicellariae and dermal branchiae.
• They have radial or biradial symmetry.

Diversity

• They are an ancient group extending back to the Cambrian period.
• They likely descended from bilateral ancestors; their larvae are bilateral.
• One theory is that they evolved radiality as an adaptation to sessile existence.
• The body plan is derived from crinoid-like ancestors that became free-moving descendants later.
• They lack ability to osmoregulate and this restricts them to marine environments.
• No parasitic echinoderms are known; a few are commensals.

Group Diversity

• Asteroids or sea stars are mostly predators.
• Ophiuroids or brittle stars move by active arms and may be scavengers, browsers or commensals.
• Holothurians or sea cucumbers are mostly suspension or deposit feeders.
• Echinoids or sea urchins are found on hard bottoms while sand dollars prefer sand substrate; they feed on detritus.
• Crinoids are sessile and flower-like as young and detach as adults; they are suspension feeders.

Ecology, Economics, and Research

• Due to their spiny structure, echinoderms are not often preyed upon.
• A few fish and otters are adapted to feed on sea urchins.
• Humans sometimes eat the sea urchin gonads and the body wall of certain holothurians.
• Sea stars feed on molluscs, crustaceans and other invertebrates; they may damage oyster beds.
• The embryology of sea urchin eggs is very observable.
• Artificial parthenogenesis was first described for sea urchin eggs; they develop without fertilization if treated with hypertonic seawater or subjected to other stimuli.

Class Asteroidea

Diversity

• Sea stars are common along shorelines and may aggregate on rocks.
• Some sea stars live on muddy or sandy bottoms, or among coral reefs.
• They range from a centimeter across to about a meter across and may be brightly colored.
• Asterias is common on the east coast of the U.S.; Pisaster is common on the west coast.
Form and Function

External Features
- Sea stars have a central disc with tapering arms extending outward.
- The body is flattened and flexible, with a pigmented and ciliated epidermis.
- The mouth is on the underside or oral side.

External Features
- The ambulacrum runs from the mouth to the tip of each arm.
- Usually there are five arms but there may be more.
- The ambulacral groove is bordered by rows of tube feet.

External Features
- A large radial nerve is in the center of each ambulacral groove. Under the nerve is an extension of the coelom and the radial canal of the water-vascular system.
- In all other cases except crinoids, ossicles or other dermal tissue covers these structures.

External Features
- The aboral surface is spiny; at the base of the spines are groups of pincer-like pedicellariae. Pedicellariae keep the body surface free of debris.
- Papulae (dermal branchiae or skin gills) are soft projections lined with peritoneum and serve in respiration.

External Features
- On the aboral side is a circular madreporite that is a sieve leading to the water-vascular system.
- From the madreporite, water drains from the stone canal that leads to the ring canal. This leads into radial canals connected to ampullae that lead to tube feet.

Endoskeleton
- Under the epidermis is the mesodermal endoskeleton of small calcareous plates or ossicles.
- Ossicles are penetrated by a meshwork of spaces filled with fibers and dermal cells.
- Muscles in the body wall move the rays and partially close the ambulacral grooves.
Coelom, Excretion, and Respiration

- The spacious body coelom filled with fluid is one coelomic compartment.
- The fluid contains amebocytes (coelomocytes).
- Ciliated peritoneal lining of the coelom circulates the fluid around the cavity and into papulae.
- Respiratory gases and nitrogenous waste ammonia diffuse across the papulae and tube feet.
- Some wastes are picked up by coelomocytes, which migrate to the tips of papulae to be pinched off.

Water-Vascular System

- This system is another coelomic compartment and is unique to echinoderms.
- It consists of a system of canals, tube feet, and dermal ossicles.
- This system functions in locomotion and food-gathering as well as respiration and excretion.
- The system opens to the outside at the madreporite on the aboral side.

Water-vascular System

- Polian vesicles may also be attached; they serve for fluid storage.
- Small lateral canals, each with a one-way valve, connect the radial canal to the tube feet.
- The inner end of each tube foot or podium is an ampulla that lies within the body coelom.
- The outer end of each tube foot bears a sucker.
- The water-vascular system operates hydraulically; valves in lateral canals prevent backflow.

Locomotion

- Muscles in the ampulla contract forcing fluid into and extending the podium.
- Contraction of longitudinal muscles in the tube foot retracts it, forcing fluid back into the ampulla.
- Small muscles in the end of the tube foot raise the middle of the end, creating suction.
- The sea star can move while being firmly adhered to the substrate.
- Tube feet are innervated by a central nervous system; they move in one direction but not in unison.
- Cutting a radial nerve ends coordination in one arm; cutting a circumoral nerve ring stops all movement.

Feeding and Digestive System

- The mouth on the oral side leads through a short esophagus to a large central stomach.
- The lower cardiac part of the stomach can be everted through the mouth during feeding.
- The upper stomach is smaller and is connected by ducts to a pair of pyloric ceca in each arm.
- The anus is inconspicuous and empties on the center at the top; some lack an intestine and anus.

Feeding

- Sea stars consume a wide range of food; some eat sea urchins and regurgitate undigestible parts.
- Some feed on molluscs; they pull steadily until they can insert a stomach through the crack.
- Some sea stars feed on small particles that are carried up ambulacral grooves to the mouth.

http://dereila.ca/dereilaimages/Marine2.html
Nervous System

- The oral system of a nerve ring and radial nerves coordinate the tube feet.
- A deep hyponeural system aboral to the oral system forms a ring around the anus and extends into the roof of each ray.
- The epidermal nerve plexus coordinates responses of the dermal branchiae to tactile stimulation.
- Tactile organs are scattered over the surface and an ocellus is at the tip of each arm.
- They react to touch, temperature, chemicals and light intensity; they are mainly active at night.

Reproductive System, Regeneration, and Autonomy

- Most have separate sexes; a pair of gonads is in each interradial space.
- Fertilization is external; in early summer, eggs and sperm are shed into the water.
- Echinoderms also regenerate lost parts; they can cast off injured arms and regenerate new ones.
- An arm can regenerate a new sea star if at least one-fifth of the central disc is present.

http://www.vsf.capec.com/~jdale/science/regeneration.htm

Development

- In most cases, embryonating eggs are dispersed in the water and hatch to free-swimming larvae.
- Embryogenesis shows a typical primitive deuterostome pattern.
- The left hydrocoel becomes the water-vascular system; the left axocoel becomes the stone canal and perihemal channels.
- The free-swimming larva has cilia arranged in bands and is called a bipinnaria.
- Ciliated tracts become larval arms.

Class Ophiuroidea

Form and Function

- Each jointed arm has a column of articulated ossicles called vertebrae.
- Arms are moved in pairs for locomotion.
- Five movable plates act as jaws and surround the mouth; there is no anus.
- Skin is leathery and surface cilia are mostly lacking.
- Visceral organs are all in the central disc; the arms are too slender to accommodate them.
- The stomach is saclike; there is no intestine.
- The water-vascular, nervous and hemal systems resemble those of sea stars.
Reproduction
- Five invaginations called bursae open to the oral surface by genital slits at the bases of the arms.
- Gonads on the wall of each bursa discharge ripe sex cells into the water for external fertilization.
- Sexes are usually separate but a few are hermaphroditic.
- The larva has ciliated bands that extend onto delicate and beautiful larval arms.
- In contrast to sea stars, they lack any attached phases during metamorphosis.
- Regeneration and autotomy are more pronounced than in sea stars; they are very fragile.

Biology
- Brittle stars are secretive and live on hard or sandy bottoms where little light penetrates, often under rocks or in kelp holdfasts.
- They browse on food or suspension feed.

Class Echinoidea
Diversity
- Sea urchins lack arms but their tests show the five-part symmetry.
- The up-folding brings the ambulacral areas up to the area of the anus.
- Most sea urchins have a hemispherical shape with radial symmetry and long spines.
- Sand dollars and heart urchins (irregular echinoids) have become bilateral with short spines.
- Regular urchins move by tube feet; irregular urchins move by their spines.
- Echinoids occur from intertidal regions to deep ocean.

Form and Function
- The echinoid test has ten double rows of plates with movable, stiff spines.
- The tube feet extend along the five ambulacral rows.
- The spines articulate on “ball-and-socket” joints moved by small muscles at the bases.
- Among the several kinds of pedicellaria, the three-jawed variety on long stalks is most common.
- Some species have pedicellariae with poison glands that secrete a toxin that paralyzes small prey.
- Five converging teeth and sometimes branched gills encircle the peristome.
- The anus, genital pores, and madreporite are aboral and in the periproct region.
Form and Function

- Sand dollars and heart urchins have shifted the anus to the posterior and can be defined bilaterally.

Form and Function

- Inside the test is Aristotle’s lantern, a complex set of chewing structures.

Form and Function

- A ciliated siphon connects the esophagus to the intestine; food can be concentrated in the intestine.
- Sea urchins eat algae; sand dollars filter particles through their spines.
- Hemal and nervous systems resemble those in asteroids.
- Ambulacral grooves are closed and radial canals run just beneath the test in each radii.
- In irregular urchins, respiratory podia are arranged in fields called petaloids on the aboral surface.

Reproduction

- Sexes are separate; both eggs and sperm are shed into the sea for external fertilization.
- Some, including pencil urchins, brood young in depressions between the spines.
- Larvae of nonbrooding echinoids live a planktonic existence before becoming urchins.

Class Holothuroidea

Diversity

- As their name suggests, these animals resemble cucumbers.
- They are greatly elongated in the oral-aboral axis.
- Ossicles are very reduced and the body is soft.
- Some species crawl on the ocean bottom, others are found under rocks or burrow.

Form and Function

- The body wall is leathery with tiny ossicles buried in it; a few have dermal armor.
- In some, locomotor tube feet are distributed to all five ambulacral areas, most have them only on the ambulacra that faces the substratum.
- The side that faces the substratum (the sole) has three ambulacra, adding a secondary bilaterality.
Form and Function
- All tube feet, except oral tentacles, are absent in burrowing forms.
- Oral tentacles are 10-30 tube feet surrounding the mouth.
- The coelomic cavity has many coelomocytes.
- The digestive system opens into a cloaca; a respiratory tree also empties into the cloaca.
- A madreporite lies free in the coelom; the hemal system is more developed than in other echinoderms.
- The respiratory tree also serves for excretion; gas exchange also occurs through the skin and tube feet.

Reproduction
- Sexes are separate but some are hermaphroditic.
- Sea cucumbers have a single gonad; this is considered a primitive character.
- Fertilization is external and produces free-swimming larvae.
- A few brood their young inside the body or on the body surface.

Biology
- Sea cucumbers use both ventral tube feet and muscular body waves to move.
- Some trap particles on the mucus of their tentacles and suck off the food particles in their pharynx.
- Others graze the sea bottom with their tentacles.

Defense
- Sea cucumbers cast out part of their viscera when irritated; they must regenerate these tissues.
- The organs of Cuvier are expelled in the direction of an enemy; they are sticky and have toxins.

Commensal Relationship
One small fish, Carapus, uses the cloaca and respiratory tree of a sea cucumber for shelter.

Class Crinoidea

Diversity
Crinoids include both sea lilies and feather stars; they have primitive characters.
Crinoids are far more numerous in the fossil record.
They are unique in being attached for most of their life.
Sea lilies have a flower-shaped body at the tip of a stalk.
Feather stars have long, many-branched arms; adults are free-moving but may be sessile.
Many crinoids are deep-water species; feather stars are found in more shallow water.
Form and Function

- The body disc or calyx is covered with a leathery skin or tegmen of calcareous plates.
- The five arms branch to form more arms, each with lateral pinnules as in a feather.
- The calyx and arms form a crown.
- Sessile forms have a stalk formed of plates; it appears jointed and may bear cirri.

A madreporite, spines and pedicellariae are absent.

- The upper surface has a mouth that opens into an esophagus and intestine; it then exits the anus.
- Tube feet and mucous nets allow it to feed on small organisms in the ambulacral grooves.
- It has a water-vascular system, an oral ring and a radial nerve to each arm.

Reproduction

- Sexes are separate; gonads are merely masses of cells in the genital cavity of the arms and pinnules.
- Gametes escape through ruptures in the pinnule wall; some brood their eggs.
- Larvae are free-swimming before they become attached and metamorphose.
- Most living crinoids are 15-30 cm long; some fossil species had stalks 20 meters long.

Phylogeny

- The fossil record is extensive but there are still many theories about their evolution.
- From the larvae, we know the ancestor was bilateral and the coelom had three pairs of spaces.
- One theory states sessile groups derived independently from free-moving adults with radial symmetry.
- Traditional views consider the first echinoderms sessile and radial, giving rise to free-swimming forms.
- Early forms may have had endoskeletal plates and external ciliary grooves.
- Echinoids and holothuroids are related; the relationship of ophiuroids and asteroids is controversial.

![Fig. 22.28]