CHAPTER 14 ECHINODERMATA STUDY GUIDE

14.1 A Design To Puzzle the Zoologists

A. Echinoderms confound the obvious advantages of bilateralism by becoming radial.

B. A compartment of the coelom has been transformed in echinoderms into a unique **water-vascular system.**

C. Echinodermata, along with Chordata and Hemichordata (acorn worms and pterobranchs) are **deuterostomes.**

D. Molecular evidence supports monophyly of the Deuterostomia.

14.2 Phylum Echinodermata: Diversity and Characteristics

A. Characteristics: (see **Characteristics of Phylum Echinodermata,** page 278).

1. All members of the phylum have a **calcareous skeleton**.
2. The spiny endoskeleton consists of **plates**.
3. They have a unique **water-vascular system.**
4. They possess **pedicellariae** and **dermal branchiae**.
5. They have secondary **radial or biradial symmetry;** larvae are bilateral.
6. **Position in animal kingdom:** page 274.
7. **Biological contributions:** page 274.

B. Diversity

1. Brittle stars, sea urchins, sea cucumbers, sea stars, and sea lilies are echinoderms.
2. Unique characteristics include:
   a. endoskeleton of ossicles
   b. water-vascular system
   c. pedicellariae
   d. dermal branchiae
   e. secondary radial or biradial symmetry

C. Ecological Relationships

1. All are marine with virtually no ability to osmoregulate.
2. Adults are benthic found in all oceans of the world.
3. Sea stars are particulate feeders and predators.
4. Brittle stars may scavenge, browse, deposit feed or filter feed; some are commensal with sponges.
5. Sea cucumbers are suspension or deposit feeders; regular sea urchins feed on algae or detritus.
6. Sand dollars and heart urchins are found on the sand and feed on small particles.
7. Sea lilies and feather stars stretch their arms to feed on plankton and suspended particles.

14.3 Class Asteroidea

A. Diversity

1. Sea stars are common along shorelines and may aggregate on rocks.
2. Some sea stars live on muddy or sandy bottoms, or among coral reefs.
3. They range from a centimeter across to about a meter across and may be brightly colored.

B. Form and Function

1. **External Features**
   a. Sea stars have a **central disc** with tapering arms extending outward.
   b. The body is flattened and flexible, with a pigmented and ciliated epidermis.
   c. The mouth is on the underside or oral side.
   d. The **ambulacrum** runs from the mouth to the tip of each arm.
   e. Usually there are five arms but there may be more (Figure 14.1D).
   f. The arms merge gradually with the central disc (Figure 14.2).
   g. Most species have a **pentamerous** form (Figure 14.1A,B, C, D).
   h. The ambulacral groove is bordered by rows of **tube feet**.
   i. A large radial nerve is in the center of each ambulacral groove.
   j. Under the nerve is an extension of the coelom and the radial canal of the **water-vascular system.**
   k. In all other cases except crinoids, ossicles or other dermal tissue covers these structures.
   l. The aboral surface is spiny; at the base of the spines are groups of pincer-like **pedicellariae**.
   m. Pedicellariae keep the body surface free of debris (Figure 14.4).
   n. **Papulae (dermal branchiae** or **skin gills)** are soft projections lined with peritoneum and serve in respiration.
   o. On the **aboral side** is a circular **madreporite** that is a sieve leading to the water-vascular system.
   p. The **ambulacral grooves** radiate out along the arms from the centrally located mouth (Figure 14.2B).
   q. Viewed from the oral side, a large **radial nerve** can be seen in the center of each ambulacral groove (Figure 14.3A,C).
   r. The ambulacral grooves in asteroids and crinoids are **open,** and those of the other groups are **closed** (Figure 14.3A).
2. **Endoskeleton and Coelom**
   a. Under the epidermis is the mesodermal endoskeleton of small calcareous plates or **ossicles.**
   b. Ossicles are penetrated by a meshwork of spaces filled with fibers and dermal cells, the **steroem** (see Figure 14.15).

c. The spacious body coelom filled with fluid is one coelomic compartment.
d. Ciliated peritoneal lining of the coelom circulates the fluid around the cavity and into papulae.
e. Respiratory gases and nitrogenous waste ammonia diffuse across the papulae and tube feet.

3. **Water-Vascular System**
   a. This system is another coelomic compartment and is unique to echinoderms.
   b. It consists of a system of canals, tube feet, and dermal ossicles that exploits hydraulics.
   c. This system functions in locomotion and food-gathering as well as respiration and excretion.
   d. It opens to the outside at the **madreporite** on the aboral side (Figure 14.3B).
   e. The madreporite leads to the **stone canal**, which joins the ring canal that encircles the **mouth** (Figure 14.3A,B).
   f. Radial canals diverge from the ring canal and extend into each ray.
   g. **Polian vesicles** may also be attached; they serve for fluid storage.
   h. Small **lateral canals**, each with a one-way valve, connect the radial canal to the tube feet (Figure 14.3C).
   i. The inner end of each tube foot or podium is an **ampulla** that lies within the body coelom.
   j. The outer end of each tube foot bears a sucker.
   k. The water-vascular system operates hydraulically; valves in lateral canals prevent backflow.
   l. Muscles in the ampulla contract forcing fluid into and extending the podium.
   m. Contraction of longitudinal muscles in the tube foot retracts it, forcing fluid back into the ampulla.
   n. Small muscles in the end of the tube foot raise the middle of the end, creating suction.
   o. The sea star can move while being firmly adhered to the substrate.

5. **Feeding and Digestive System**
   a. The mouth on the oral side leads through a short esophagus to a large central stomach.
   b. The lower cardiac part of the stomach can be **everted** through the mouth during feeding.
   c. The upper stomach is smaller and is connected by ducts to a pair of pyloric ceca in each arm.
   d. A short intestine joins the stomach to the anus.
   e. The anus is inconspicuous and empties on the center at the top; some lack an intestine and anus.
   f. Sea stars consume a wide range of food; some eat sea urchins and regurgitate undigestible parts.
   g. A sea star wraps itself around prey by attaching podia to valves then exerts a steady pull.
   h. They pull steadily until they can insert a stomach through the crack.
   j. In 30 minutes the adductor muscles of the bivalve prey fatigue and relaxes.
   i. Some sea stars feed on small particles that are carried up ambulacral grooves to the mouth.

6. **Hemal System**
   a. This system of tissue strands encloses unlined sinuses; it is itself enclosed in perihemal channels.
   b. It might be useful in distributing digested products but its function is unproven.

7. **Nervous and Sensory System**
   a. The nervous system is composed of three subsystems, each formed by a ring nerve and radial nerves.
   b. An epidermal nerve plexus coordinates responses of the dermal branchiae to tactile stimulation.
   c. Tactile organs are scattered over the surface and an ocellus is at the tip of each arm.

8. **Reproductive System, Regeneration, and Autonomy**
   a. Most have separate sexes; a pair of gonads is in each interradial space (see Figure 14.3).
   b. Fertilization is external.
   c. Echinoderms also regenerate lost parts; they can cast off injured arms and regenerate new ones.
   d. An arm can regenerate a new sea star if at least one-fifth of the central disc is present (Figure 14.5).

9. **Development**
   a. Some species brood eggs on the oral side or in arboreal structures.
   b. In most cases, embryonating eggs are dispersed in the water and hatch to free-swimming larvae.
   c. **Embryogenesis** shows a typical primitive **deuterostome pattern**: the coelomic cavity, which expands in a **U-shape** to fill the blastocoel, constricts at each end to become a separate vesicle which in turn produces the **metacoels**.
   d. In echinoderms the metacoel, mesocoel, and protocoel are called somatocoel, hydrocoel, and axocoel, respectively.
   e. The right axocoel and hydrocoel are lost, and the left axocoel and hydrocoel become the water vascular system and perihemal channels.
   f. The free-swimming larva has cilia arranged in bands and is called a **bipinnaria** (Figure 14.7).
   g. Ciliated tracts become larval arms during metamorphosis (Figure 14.6).
   h. When the larva grows three adhesive arms and a sucker at the anterior, it is called a **brachiolaria.**
   i. A brachiolaria then attaches to the substrate and undergoes metamorphosis into a radial juvenile.
   j. As its arms and tube feet appear, the animal detaches from its stalk and becomes a young sea star.
   k. Metamorphosis:
      1) Involves reorganization of a bilateral larva into a juvenile adult.
      2) The left larval side becomes the oral surface.
      3) The right larval side becomes the aboral surface.

4) A new mouth and anus form
5) Short stubby arms and the first podia appear.
6) The young sea star detaches from its stalk.

10. **Sea Daisies (Figure 14.8)**
    a. Disc-shaped animals less than 1 cm in diameter discovered off the coast of New Zealand in 1986.
    b. The two species have no arms but tubed feet are found around the periphery of the disc.
    c. Two ring canals are present; a hydropore connects the inner ring canal to the aboral surface.
    d. Analysis of rDNA places them in Asteroidea.

14.4 Class Ophiuroidea

A. Form and Function

1. This group has over 200 extant species.
2. The arms of the **brittle stars** are slender and distinct from the central disc (Figure 14.10).
3. They lack pedicellariae or papulae and the ambulacral groove is closed and coated with ossicles.
4. Tube feet lack suckers.
5. The madreporite is on the oral surface (Figure 14.10).
7. Each jointed arms has a column of articulated ossicles called vertebrae.
8. Arms are moved in pairs for locomotion.
9. Five movable plates act as jaws and surround the mouth; there is no anus.
10. Skin is leathery and surface cilia are mostly lacking.
11. Visceral organs are all in the central disc; the arms are too slender to accommodate them.
12. The stomach is saclike; there is no intestine.
13. The water-vascular, nervous and hemal systems resemble those of sea stars.
14. Brittle stars are secretive and live on hard or sandy bottoms where little light penetrates, often under rocks or in kelp holdfasts (Figure 14.9).
15. They browse on food or suspension feed.
    a. Podia transfer food to the mouth.
    b. Some catch suspended particles in mucus strands on extended arms
    c. Basket stars perch on corals to feed.

B. Reproduction

1. Five invaginations called **bursae** open to the oral surface by genital slits at the bases of the arms.
2. Gonads on the wall of each bursa discharge ripe sex cells into the water for external fertilization.
3. Sexes are usually separate but a few are hermaphroditic.
4. The larva is an **ophiopluteus** (Figure 14.7).
5. The larva has ciliated bands that extend onto delicate and beautiful larval arms.
6. In contrast to sea stars, they lack any attached phases during metamorphosis.
7. Regeneration and autotomy are more pronounced than in sea stars; they are very fragile.

14.5 Class Echinoidea: Sea Urchins, Sand Dollars, and Heart Urchins

A. Diversity

1. Sea urchins lack arms but their endoskeletal **tests** show the five-part symmetry.
2. **Dermal ossicles** make up the test; echinoids lack arms.
3. The ambulacral areas follow test contours and end up close to the anus **(periproct).**
4. Most sea urchins have a hemispherical shape with radial symmetry and long spines (Figure 14.11).
5. Sand dollars and heart urchins (irregular echinoids) have become bilateral with short spines.
6. Regular urchins move by tube feet; **irregular urchins** move by their spines (Figure 14.12).
7. Echinoids occur from intertidal regions to deep oceans.

B. Form and Function (Figure 14.13)

1. The echinoid test has ten double rows of plates with movable, stiff spines.
2. The **tube feet** extend along the five ambulacral rows.
3. The spines articulate on "ball-and-socket" joints moved by small muscles at the bases.
4. Among the several kinds of pedicellaria, the three-jawed variety on long stalks is most common.
5. Some species have pedicellariae with poison glands that secrete a toxin that paralyzes small prey. (Figure 14.13B)
6. Five converging teeth and sometimes branched gills encircle the peristome.
7. The anus, genital pores, and madreporite are aboral and in the periproct region.
8. Sand dollars and heart urchins have shifted the anus to the posterior and can be defined bilaterally.
9. Inside the test is **Aristotle's lantern**, a complex set of chewing structures (Figure 14.14).
10. A ciliated siphon connects the esophagus to the intestine; food can be concentrated in the intestine.
11. Sea urchins eat algae; sand dollars filter particles through their spines.
12. Hemal and nervous systems resemble those in asteroids.
13. Ambulacral grooves are closed and radial canals run just beneath the test in each radii.

C. Reproduction

1. Sexes are separate; both eggs and sperm are shed into the sea for **external fertilization.**
2. Echinopluteus larvae of nonbrooding echinoids live a planktonic existence before becoming young urchins.

14.6 Class Holothuroidea

A. Diversity

1. As their name suggests, these odd animals resemble cucumbers (Figure 14.15).
2. They are greatly elongated in the oral-aboral axis.
3. Ossicles are very reduced and the body is soft; they are microscopic and important taxonomically (Figure 14.15).
4. Some species crawl on the ocean bottom; others are found under rocks or burrow.

B. Form and Function

1. The body wall is **leathery** with tiny ossicles buried in it; a few have dermal armor (Figure 14.16).
2. In some, locomotor tube feet are distributed to all five ambulacral areas; most have them only on the ambulacra that faces the substratum.
3. The side that faces the substratum (the sole) has three ambulacra, adding a **secondary bilaterality.**
4. Burrowing species move by contraction of longitudinal and circular muscles.
5. Oral tentacles are 10-30 tube feet surrounding the mouth.
6. The **coelomic cavity** serves as hydrostatic skeleton.
7. The digestive system opens into a cloaca; a respiratory tree also empties into the cloaca (Figure 14.17).
8. A madreporite lies free in the coelom; the hemal system is more developed than in other echinoderms.
9. The **respiratory tree** also serves for excretion.

C. Reproduction

1. Sexes are separate but some are **hermaphroditic.**
2. Sea cucumbers have a single gonad; this is considered a primitive character.
3. Fertilization is external.

D. Biology

1. Sea cucumbers are sluggish and use both ventral tube feet and muscular body waves to move.
2. Some trap particles on the mucus of their tentacles and suck off the food particles in their pharynx.
3. Others graze the sea bottom with their tentacles.
4. Sea cucumbers make up 90% of the biomass on deep-sea floor surfaces.
5. Long, sticky, and sometimes toxic structures called **Cuvierian tubles** may be discharged to entangle an enemy (Figure 14.15B.
6. These tubules are attached to the respiratory tree and can be regenerated.
7. Some species discharge their digestive tract, respiratory tree, and gonads.

14.7 Class Crinoidea

A. Diversity

1. Crinoids include both sea lilies and feather stars; they have primitive characteristics.
2. Crinoids are far more numerous in the fossil record.
3. They are unique in being deep water forms and **attached** for most of their life.
4. Sea lilies have a flower-shaped body at the tip of a stalk (Figure 14.18).
5. Feather stars have long, many-branched arms; adults are free-moving but may be sessile.
6. Many crinoids are deep-water species; feather stars are found in more shallow water.

B. Form and Function (Figure 14.19)

1. The body disc or calyx is covered with a leathery skin or tegmen of **calcareous plates.**
2. The five arms branch to form more arms, each with lateral **pinnules** as in a feather.
3. The **calyx** and arms form a **crown.**
4. Sessile forms have a stalk formed of **plates**; it appears jointed and may bear **cirri.**
5. A madreporite, spines and pedicellariae are absent.
6. The upper surface has a mouth and anus.
7. Tube feet and mucous nets allow it to feed on small organisms in the ambulacral grooves.
8. It has a water-vascular system, an oral ring and a radial nerve to each arm.
9. Ambulacral grooves are open and ciliated and serve to carry food to the mouth.
10. During metamorphosis feather stars also become sessile and attached, but after several months they detach and become free moving. They swim by alternate sweeping of their long, feathery arms.

C. Reproduction

1. Sexes are separate; gonads are merely masses of cells in the genital cavity of the arms and pinnules.
2. Larvae are **free-swimming** before they become attached and metamorphose.
3. Most living crinoids are 15-30 centimeters long; some fossil species had stalks 25 meters long.

14.9 Phylogeny and Adaptive Radiation (Figure 14.20)

A. Phylogeny

1. The fossil record is extensive but there are still many theories about their evolution.
2. From the larvae, we know the **ancestor was bilateral** and the **coelom had three pairs of spaces.**
3. One theory states sessile groups derived independently from free-moving adults with radial symmetry.
4. Traditional views consider the **first echinoderms sessile and radial**, giving rise to free-swimming forms.
5. Early forms may have had endoskeletal plates with stereom structure and external ciliary grooves.
6. **Carpoids** may be an extinct variation, or a separate subphylum of echinoderms.

7. Fossil helicoplacoids show evidence of three true ambulacral arms and mouth placement on the side of the body.
8. Attachment by the aboral surface would give rise to radial symmetry and the Pelmatozoa.
9. A free-living ancestor that attached with its oral surface would give rise to Eleutherozoa.
10. Echinoids and holothuroids are probably related; the relationship of ophiuroids and asteroids is controversial.

B. Adaptive Radiation

1. Radiations of echinoderms were influenced by radial symmetry, water-vascular system, and the dermal endoskeleton.
2. If their ancestors had a brain and sense organs, these were lost in adoption of **radial symmetry.**
3. There is a large number of creeping, benthic forms, perhaps because of having no brain.
4. Predatory success may be partly due to hydraulic tubed feet.

C. Classification

Subphylum Pelmatozoa

Class Crinoidea

Subphylum Eleutherozoa

Class Asteroidea
Class Ophiuroidea
Class Echinoidea
Class Holothuroid