CHAPTER 47: ECHINODERMS

CHAPTER SYNOPSIS

More advanced animals exhibit two different kinds of embryological patterns. Protostomes, including mollusks, annelids, and arthropods, exhibit the same pattern seen in noncoelomates; the mouth develops from the blastopore. In deuterostomes, echinoderms, chordates, and a few small phyla, the blastopore becomes the anus. Protostomes also exhibit spiral cleavage, deuterostomes radial cleavage. The developmental fate of a protostome cell is fixed when that cell first appears; a deuterostome cell's fate is not fixed until later in development. Finally, protostomes have a simple and direct development of the coelom from mesoderm tissue. Deuterostome coelomic development is more complex as groups of cells move around during development forming new tissue associations.

The phylum Echinodermata is unusual in that its larvae exhibit bilateral symmetry, while the adults are radially symmetrical. The secondary radial symmetry may be associated with the mobility of the phylum. Bilateral symmetry is very important for mobile organisms, in echinoderms the larval form. The adults are relatively sessile, appropriate for radial organisms. They possess an endoskeleton composed of calcium-plate ossicles covered by a thin epidermis. They have no head or brain and their bodies follow a five-part plan. Echinoderms have a unique water vascular system that controls the extension and contraction of flexible tube feet used in locomotion and/or feeding. Respiration and waste removal occurs across the skin through projections called skin gills. They are capable of extensive regeneration in addition to normal sexual reproduction.

Echinoderms are divided into six visually different classes. The class Crinoidea includes the sea lilies and feather stars, multi-armed filter feeders whose mouth and anus are located on the upper surface. Asteroidea includes the sea stars, active marine predators. Brittle stars, class Ophiuroidea, appear similar to sea stars, but their arms are set off more sharply from the central disk. Sea urchins and sand dollars lack arms and are members of the class Echinoidea. These latter three classes have mouths located on the under surface (thus the aboral surface). The class Holothuroidea least resembles the other echinoderms. Their body form is well described by their common name, sea cucumber. Their ossicles are microscopic plates embedded in a leathery skin and they lack spines. The most recently discovered Concentricycloidea are commonly called sea daisies. These disk-shaped animals have the typical five-part radial symmetry, but lack arms. Their tube feet are arranged along the edge of the disk, not along radial lines like the other classes of echinoderms. Both species are unusual with regard to their digestion. One has a saclike stomach without intestine or anus. The other completely lacks a digestive system, absorbing nutrients through a membrane on the mouth.

CHAPTER OBJECTIVES

- Differentiate between protostomes and deuterostomes.
- Describe the general body plan of an adult echinoderm.
- Understand the importance of the echinoderm water vascular system.
- Describe regeneration in echinoderms and how it relates to reproduction.
- Differentiate among the six classes of echinoderms in terms of body plan, locomotion, tube feet modifications, reproduction, and feeding strategy.
- Contrast the Holothuroidea and Concentricycloidea to the other classes of echinoderms.

KEY TERMS

ampulla
archenteron
cloaca
determinate
deuterostome
echinoderm
endoskeleton
indeterminate
madreporite
nerve ring
protostome
radial cleavage
radial canal
ring canal
secondary radial symmetry
spiral cleavage
tube foot
water vascular system

CHAPTER OUTLINE

47.0 Introduction

I. ECHINODERMS EXHIBIT BILATERAL AND RADIAL SYMMETRY AT DIFFERENT TIMES fig 47.1

A. Part of the Coelom Becomes the Water Vascular System

B. Some Have an Endoskeleton of Dermal Plates

47.1 The embryos of deuterostomes develop quite differently from those of protostomes

I. PROTOSTOMES AND DEUTEROSTOMES

A. Comparing Two Distinct Kinds of Coelomate Animals
1. Protostomes
   a. Include mollusks, annelids, arthropods
   b. Mouth (stoma) develops from or near blastopore fig 47.2
   c. Same pattern seen in all noncoelomates
   d. Anus develops in another region of embryo
   e. Original state was characteristic of common ancestor of all eumetazoans
2. Deuterostomes
   a. Includes echinoderms, chordates, few other related phyla
   b. Anus forms at or near blastopore
   c. Mouth develops from another region of blastula
   d. Derived from protostome pattern of development

B. Other Fundamental Differences Between Deuterostomes and Protostomes
1. Present two different cleavage patterns fig 47.2
   a. Protostomes exhibit spiral cleavage
      1) New cell buds off at oblique angle
      2) Produces closely packed array of cells
      3) Line drawn through sequence of divisions produces a spiral from axis
   b. Deuterostomes exhibit radial cleavage
      1) Cells divide parallel to and at right angles to polar axis
      2) Produces loosely packed array of cells
      3) Line drawn through sequence of division produces a radius outward from axis
2. Differences in developmental fate of cells
   a. Protostome cell fate is fixed when that cell first appears, determinate development
      1) Individual cells will not develop into complete animal if separated
      2) Chemicals controlling developmental signals are localized early
   b. Deuterostome cell fate is fixed later in development, indeterminate development
      1) Daughter cells from early divisions are totally identical
      2) Cells from early stages can become complete individuals
      3) Commitment to developmental pathway occurs later
3. Differences in development of coelom from mesoderm

   a. Occurs simply and directly in protostomes
      1) Cells move away from one another
      2) Coelomic cavity expands within mesoderm
   b. Complex development in deuterostomes
      1) Groups of cells move around forming new tissue associations
      2) Coelom produced from invagination of archenteron
      3) Cavity opens outward via blastopore, becomes gut
4. Deuterostomes clearly derived from protostomes early in their evolution

47.2 Echinoderms are deuterostomes with an endoskeleton

I. DEUTEROSTOMES

A. The Echinoderms
1. Were the first deuterostomes, first animals with endoskeletons fig 47.3
2. Ancient group of exclusively marine animals, well-represented in fossil record
3. Name "spiny skin" refers to hard endoskeleton just beneath delicate skin fig 47.4
   a. Endoskeleton composed of calcium-rich plates
      1) Are totally encased in living skin when first formed
      2) Fuse forming hard shell in adults
4. Possess a unique water vascular system
   a. Hydraulic system to aid movement
   b. Central ring with five radial canals
5. Include sea stars, brittle stars, sea urchins, sand dollars, sea cucumbers
6. Echinoderms exhibit radial symmetry as adults
7. Other radial animals lack complex organ systems of adult echinoderms
8. Well represented in shallows and in deep sea
9. Origin of phylum is unclear
   a. Excellent fossil record
   b. May have evolved from bilateral ancestors since embryos are bilateral
   c. Radial symmetry develops only in adult form
   d. Symmetry may be related to mobility
      1) Bilateral symmetry is important to highly motile organisms
      2) Early forms were probably sessile, radial symmetry is valuable
   e. Early echinoderms attached to the sea floor with a stalk

II. ECHINODERM BODY PLAN

A. Body Plans Shift During Development
1. Echinoderms exhibit secondary radial symmetry
   a. Are bilaterally symmetrical as larva
   b. Become radially symmetrical as adults
2. Body references in terms of mouth position: oral, aboral
   a. Most echinoderms crawl along on oral surface
   b. Axis of sea cucumbers is horizontal, radial symmetry not as obvious
3. Have a five-part body plan
4. Adults have no head or brain
   a. Nervous system composed of circular nerve ring and its branches
   b. Capable of complex response patterns, but lack centralized functions

B. Endoskeleton
1. Have epidermis stretched over an internal skeleton
2. Endoskeleton composed of ossicles: Movable or fixed calcium plates
3. Plates enclosed within living tissue when first formed

   a. Ossicles widely scattered in asteroids and holothuroids, body flexible
   b. Ossicles fused in echinoids, form rigid shell
4. Bear spines as indicated by phylum's name, also covered with skin
5. Posses mutable collagenous tissue
   a. Tough and rubbery in some, weak and fluid in others
   b. Accounts for ability to rapidly autotomize body parts
6. Have perforations in plates through which tube feet extend

C. The Water Vascular System
1. Five radial canals extend from a ring canal around the esophagus
2. Radial canals determine basic five-part symmetry fig 47.5
   a. Water enters through madreporite, a sieve-like plate
   b. Flows to ring canal through the tubular stone canal
   c. Radial canals extend out into hollow tube feet fig 47.6
   d. Some echinoderms have suckers at end of tube feet, others do not
   e. Each tube foot has a muscular fluid-filled ampulla at its base
3. Operation of the water vascular system
   a. Ampulla contracts, fluid can't enter ring canal due to one-way valve
   b. Fluid forced into tube foot, extends it
   c. Foot can attach to substrate
   d. Longitudinal muscles contract and bend tube foot
   e. Water forced back into ampulla
   f. Repeated movement results in locomotion
4. Special adaptations in some classes
   a. Sea cucumbers fig 47.3b
      1) Have five rows of tube feet along body for locomotion
      2) Tube feet around mouth are modified for feeding
   b. Sea lilies
      1) Tube feet arise from branched arms
      2) Take food from surrounding water
   c. Brittle stars
      1) Tube feet pointed
      2) Specialized for feeding fig 47.1

D. Body Cavity
1. Large coelom
   a. Interconnected with complicated system of tubes
   b. Helps provide for circulation and respiration
2. Respiration and waste removal occur through papulae fig 47.5

E. Reproduction
1. Capable of extensive regeneration
   a. Sea and brittle stars may drop parts when attacked
   b. May reproduce asexually by splitting into parts
2. Sexual reproduction and fertilization is external
   a. Sexes are separate, but difficult to distinguish externally
   b. Develop into free-swimming, bilaterally symmetrical larvae fig 47.7
   c. Significantly different from annelid/mollusk trochophore larvae
   d. Larvae are free swimming, metamorphose into more sedentary adults

47.3 The six classes of echinoderms are all radially symmetrical as adults

I. DIVERSE EXTINCT AND LIVING GROUPS

A. Twenty Extinct Classes

B. Six Living Classes
1. Crinoidea includes sea lilies and feather stars
2. Asteroidea includes sea stars
3. Ophiuroidea includes brittle stars
4. Echinoidea includes sea urchins and sand dollars
5. Holothuroidea includes sea cucumbers
6. Concentricycloidea includes recently discovered sea daisies

II. CLASS CRINOIDEA: THE SEA LILIES AND FEATHER STARS

A. Basic Biology
1. Mouth and anus located on upper surface in an open disk
2. Simple excretory and reproductive systems
3. Extensive water vascular system
4. Large numbers of highly branched arms located around central disk
   a. Species may have 5 to 200 arms
   b. Smaller pinnules branch from each arm
5. Filter feeders, food collected by mucus from tube feet on pinnules
6. Common ancestor of echinoderms may have resembled crinoids
   a. Sessile, sedentary radial animals
   b. Fossils abundant, ten times more than living species

B. Sea Lilies
1. One of two basic crinoid body plans
   a. Flower-shaped body attached to a substrate by a stalk — fig 47.8
   b. Stalk is usually 15 to 30 cm, may be as long as 1 meter
2. May move slowly with feather-like arms if detached from stalk
3. All species found deeper than 100 meters
4. Only fully sessile living echinoderms

C. Feather Stars
1. Second of two basic body plans
   a. Disks detach from stalks early in development — fig 47.9
   b. Attach to substrate by claw-like structures on branched arms
2. May swim short distances and move along substrate
   a. Found in shallower waters
   b. Abundant, with sea cucumbers, in warm waters and coral reefs in Pacific Ocean
3. Sexes separate, external fertilization
   a. Sex organs within cavities on arms and pinnules
   b. Females occasionally brood young

III. CLASS ASTEROIDEA: THE SEA STARS

A. General Biology
1. Most familiar echinoderms, the starfish — fig 47.10
   a. Active, important marine predators
   b. Abundant in intertidal zone, also found at great depths

2. Arms prominent, merge gradually with disk
   a. Generally five in number, or multiples of five
   b. Body flattened, flexible, covered with pigmented epidermis

B. Endoskeleton
1. Calcium-containing plates found beneath epidermis
   a. Called ossicles
   b. Bound together with connective tissue
2. Spines project from ossicles
   a. Minute pincer-like pedicellariae surround base of spines
   b. Possess tiny muscle-operated jaws
   c. Keep body free of debris, may help capture food particles

C. The Water Vascular System
1. Underside of each arm has deep groove running along its length
   a. Bordered by rows of locomotive tube feet
   b. Radial canal connects tube feet to ring canal in central disk
2. Unique hydraulic system
   a. Ampulla contracts and forces water into tube foot
   b. Extends podium by force of water
   c. Muscles in tube foot contract and force water back into ampulla
   d. Small muscles at end of tube foot contract forming suction cup structure
3. Tube feet contracting or extending in unison move arm along surface

D. Feeding
1. Mouth located in center of the lower surface
2. Often feed on bivalve mollusks fig 47.11
   a. Grasp shell with tube feet
   b. Extrude stomach into opening between shells
   c. Secretes enzymes, digests soft parts of bivalve
   d. Retracts stomach when finished

E. Reproduction
1. Sexes separate, external fertilization
2. Pair of gonads located within ventral regions of each arm
3. Some species brood young in special cavities or underneath adult
4. Larvae possess conspicuous bands of cilia

IV. CLASS OPHIUROIDEA: THE BRITTLE STARS

A. General Ecology
1. Largest class by number of species, most abundant fig 47.12
2. Found in shallow water and deep in seas
   a. One of most abundant animals in deep seas
   b. Secretive, avoid light, active in dark

B. General Biology
1. Slender, often branched, arms more sharply set off from central disk than sea stars
2. Move by active movement of their arms along the substrate
   a. Arms may be covered with spines that aid in movement
   b. May use arms to swim through water
3. Capture suspended particles with tube feet, long spines, or arms
   a. Tube feet are important sensory organs
   b. Tube feet may help move food to mouth

4. Arms detach readily, helping protect animals from predators
5. Related to, but distinctly different from, sea stars
   a. Lack pedicellariae
   b. Groove on arm is closed and covered with ossicles
   c. Tube feet lack ampullae and suckers, used for feeding not locomotion
6. Reproduction
   a. Separate sexes, gametes released into water, external fertilization
   b. Some may brood young and release larval stages
   c. Larvae are free-swimming with bands of cilia

V. CLASS ECHINOIDEA: THE SEA URCHINS AND SAND DOLLARS

A. Comparison to Other Echinoderms

1. Lack distinct arms, still have five-part body plan fig 47.13
2. Five rows of tube feet protrude from plates of skeleton
3. Possess distinct openings for mouth and anus
4. Endoskeletons are made up of fused calcareous plates
   a. Sea urchins are globular in shape
   b. Sand dollars are flattened

B. General Biology

1. Walk along substrate with tube feet or movement of spines
2. Feed on algae, debris scraped off the surfaces by triangular teeth
3. Reproduction similar to other echinoderms
   a. Some brood young, others have free-swimming larvae
   b. Larvae have cilia on long arms, unlike those of other classes

VI. CLASS HOLOTHUROIDEA AND CONCENTRICYCLOIDEA: THE SEA CUCUMBERS AND SEA DAISIES

A. Sea Cucumbers

1. Soft, slug-like organisms with tough, leathery outer skin fig 47.14
2. Most lie on sides at the bottom of the ocean
3. Mouth is located on one end, anus on other
   a. Mouth surrounded by tube feet modified into tentacles
   b. Tentacles secrete mucus to trap food particles
4. Calcareous skeleton reduced to widely separated, microscopic plates
5. Have highly branched respiratory trees that originate from cloaca
   a. Water brought into and out of cloaca by muscular contractions
   b. Gas exchange occurs across the respiratory trees
6. Most have separate sexes, some forms are hermaphroditic
7. Have tube feet on body, may be restricted to five grooves
   a. Move by tube feet or wriggling of the entire body
   b. Most are sluggish, some swim actively
8. May eject portion of intestines when irritated

B. Sea Daisies

1. Most recently discovered echinoderms
2. Disc-shaped animals less than 1 cm in diameter
3. Two species found in deep waters off New Zealand fig 47.15
4. Five-part radial symmetry, lack arms
5. Tube feet located along edge of disk, not along radial lines
6. Unusual digestive systems
   a. One species has sac-like stomach, no intestine or anus
   b. Other species lacks digestive tract, absorbs nutrients via membrane on mouth

INSTRUCTIONAL STRATEGY

PRESENTATION ASSISTANCE:

Compare the growth of the echinoderm endoskeleton to that of the arthropod exoskeleton. Discuss the advantages associated with the echinoderms not having to molt periodically.

Discuss the lack of fresh water echinoderms in relation to the osmolarity of sea water versus fresh water.

Sea stars and brittle stars are relatively easy to maintain in a salt water aquarium, they eat almost anything. One afternoon I watched a palm-sized sea star evert its stomach on the side wall of the aquarium – it was feeding on the algae on the glass! I've also raised baby brittle stars, I'm not sure if they came from eggs of the adults or came in as larvae in some marine sample.

Buy a "living rock community" even if you don't have a permanent marine aquarium. Most supply companies sell them. They have myriads of marine plants and animals from protists to microscopic sea cucumbers. Using a dissecting microscope, watch a sea cucumber project its mucus-covered tentacles through the sand particles and sweep them through its mouth!

VISUAL RESOURCES:

Show lots of slides to indicate the diversity of this phylum. Most students in non-coastal regions know echinoderms only from the hard, dry specimens found in lab or as decorations. They are amazingly flexible, colorful organisms, readily seen in slides or films.

Help students visualize the typical echinoderm form in the horizontally positioned sea cucumbers by projecting a slide or overhead improperly – with the tentacles and mouth facing downward.