

Chapter Outline

31.1 Echinoderms

A. Echinoderms Have a Spiny Skin

1. About 6,000 species of echinoderms are in **phylum Echinodermata**.
2. Modern echinoderms (along with the phylum Chordata) are deuterostomes.
3. All echinoderms have an **endoskeleton** consisting of calcareous plates bearing spines.
4. Class **Crinoidea** includes 600 species of **crinoids**; includes stalked sea lilies and motile feather stars.
5. Class **Holothuroidea** has 1,500 species of **sea cucumbers**; they have a long leathery body and feed by tentacles about the mouth.
6. About 950 species of sea urchins and sand dollars are in the class **Echinoidea**; they possess spines for locomotion, defense, and burrowing.
7. About 2,000 species of brittle stars are in the class **Ophiuroidea**; they have a central disk from which long, flexible arms radiate.
8. Class **Asteroidea** contains 1,500 species of sea stars (starfishes).

B. Sea Stars

1. Sea stars are common along rocky coasts; they feed on clams, oysters, and other bivalves.
2. The five-rayed body has an oral (mouth) and aboral (upper) side.
3. Various structures project through the body wall.
 - a. Spines project from the endoskeletal plate through the thin dermis.
 - b. Pincerlike **pedicellariae** keep the surface free from particles.
 - c. Gas exchange is conducted by **skin gills**.
 - d. On the oral surface, each arm has a groove lined with **tube feet**.
4. Sea stars feed by everting the cardiac stomach.
 - a. A sea star positions itself over a bivalve and attaches tube feet to each side of the shell.
 - b. Working the tube feet alternatively, it pulls a shell open; a small crack allows it to insert a cardiac stomach.
 - c. Stomach enzymes begin digestion of a bivalve while it is trying to close its shell.
 - d. Partially digested food is taken into a pyloric stomach for full digestion.
 - e. A short intestine opens at the anus on the aboral side.
5. In each arm is a developed coelom containing paired digestive glands and male or female gonads.
6. The nervous system is a central ring with radial nerves extending into each arm.
7. A light-sensitive eyespot is at the tip of each arm.
8. Locomotion depends upon a **water vascular system**.
 - a. Water enters on the aboral side through a **sieve plate** (madreporite).
 - b. Water passes through a stone canal to a ring canal and into radial canals in each arm.
 - c. The radial canals feed into lateral canals extending into **tube feet**; each tube foot has an **ampulla**.
 - d. Contraction of an ampulla forces water into the tube foot, expanding it; when the foot touches a surface, the center withdraws forming a suction and adhering to surfaces.
9. Echinoderms lack a complex respiratory, excretory, or circulatory system.
 - a. Fluids within a coelomic cavity diffuse nutrients, wastes, and gases.
 - b. Gas exchange occurs across the skin gills and tube feet.
 - c. Nitrogenous wastes diffuse through the coelomic fluid and across a body wall.
 - d. Cilia on the peritoneum lining the coelom keep the coelomic fluid moving.

10. Sea stars reproduce both sexually and asexually.
 - a. If the sea star body is fragmented, each fragment can regenerate a whole animal.
 - b. Sea stars spawn and release either eggs or sperm at the same time.
 - c. The bilateral larvae undergoes a metamorphosis to become a radially symmetrical adult.

31.2 Chordates

A. The Chordates

1. Chordates include 45,000 species in the phylum **Chordata**.
2. At some time during their life, all chordates have four basic characteristics.
 - a. **Notochord**
 - 1) This supporting rod is located dorsally just below the nerve cord.
 - 2) It provides support and is replaced by the vertebral column in vertebrates.
 - b. **Dorsal Hollow Nerve Cord**
 - 1) This cord contains a fluid-filled canal.
 - 2) In vertebrates, this is the spinal cord and it is protected by vertebrae.
 - c. **Pharyngeal Pouches**
 - 1) These openings function in feeding, gas exchange, or both.
 - 2) They are seen only during embryonic development in most vertebrates.
 - 3) In invertebrate chordates, fish, and amphibian larvae, they become functioning gills.
 - 4) In terrestrial vertebrates, the pouches are modified for various purposes.
 - 5) In humans, the first pair of pouches become the auditory tubes, the second become tonsils, and the third and fourth pairs become the thymus and parathyroid glands.
 - d. A **postanal tail** extends beyond the anus; in some, this only appear in embryos.

B. Invertebrate Chordates

1. The notochord persists and is never replaced by the vertebral column in these species.
2. Lancelets
 - a. 23 species of **lancelets** are in genus *Branchiostoma* in the subphylum **Cephalochordata**.
 - b. An elongated, lance-shaped body resembles the lancelet, a two-edged surgical knife.
 - c. They inhabit shallow coastal waters; they filter feed partly buried in sandy substrates.
 - d. They feed on microscopic particles filtered from a constant stream of water that enters the mouth and exits through gill slits into an atrium that opens at the atriopore.
 - e. Lancelets retain the four chordate characteristics as adults.
 - f. The notochord extends from head to tail, accounting for the name “Cephalochordata.”
 - g. They possess segmented muscles and the dorsal hollow nerve cord has periodic branches.
3. Tunicates
 - a. The subphylum **Urochordata** contains 1,250 species of **tunicates**.
 - b. Adults have a body composed of an outer tunic; an excurrent siphon squirts out water when it is disturbed.
 - c. The larvae are bilaterally symmetrical and have the four chordate characteristics.
 - d. The larvae undergo metamorphosis to develop into sessile adults.
 - e. Water passes into a pharynx and out numerous gill slits, the only chordate characteristic that remains in adults.
 - f. Beating cilia lining the inside of the pharynx create a current to move water through.
 - g. Microscopic particles adhere to a mucous secretion in the pharynx and are eaten.
 - h. If the larvae became sexually mature without developing tunicate characteristics, the urochordate larva may have been ancestral to vertebrates.

31.3 Vertebrates

A. Subphylum Vertebrata

1. The 43,700 species of vertebrates are in the subphylum **Vertebrata**.
2. Vertebrates have all four chordate characteristics at some time during their lives.
3. The embryonic notochord is replaced by a **vertebral column**.
 - a. The vertebral column is individual **vertebrae** that surround a dorsal hollow nerve cord.
 - b. The vertebral column is part of a flexible, strong **endoskeleton** that is also evidence of segmentation.
4. The vertebrate skeleton is living tissue (either cartilage or bone) that grows with the animal.
5. The endoskeleton and muscles together permit rapid and efficient movement.

6. The pectoral and pelvic fins of fish evolved into jointed appendages allowing vertebrates to move onto land.
 7. A **skull** is anterior component of main axis of vertebrate endoskeleton; it encases the brain.
 8. The high degree of cephalization in vertebrates is accompanied by complex sense organs.
 - a. The eyes developed as outgrowths of the brain.
 - b. The ears—equilibrium devices in water—function as sound-wave receivers in land vertebrates.
 9. Vertebrates possess a complete digestive system and a large coelom.
 10. The circulatory system is closed and the blood is contained within blood vessels.
 11. Gills or lungs provide efficient gas exchange.
 12. The **kidneys** efficiently excrete nitrogenous waste and regulate water.
 13. Reproduction is usually sexual with separate sexes.
 14. Evolution of the amnion allowed reproduction to take place on land.
 15. The development of the placenta in mammals allowed development in the uterus of the female.
- B. Fishes
1. **Fishes** are aquatic, gill-breathing vertebrates that usually have fins and skin covered with scales.
 2. Small, jawless, and finless **ostracoderms** are the earliest vertebrate fossils.
 - a. They were filter feeders also able to move water through their gills by muscular action.
 - b. Ostracoderms are dated from Cambrian to as late as Devonian; then they became extinct.
 - c. Although living jawless fishes lack protection, early jawless fishes had large defensive head shields.
- C. Jawless Fishes
1. Jawless fishes are **agnathans**; 63 species belong to superclass **Agnatha**.
 2. Lampreys and hagfishes are modern jawless fishes and they lack a bony skeleton.
 3. They have smooth nonscaly skin.
 4. They have cylindrical bodies and are up to a meter long.
 5. Hagfishes are scavengers feeding on soft-bodied invertebrates and dead fishes.
 6. Many lampreys are filter feeders similar to their ancestors.
 7. Parasitic lampreys have a round muscular mouth equipped with teeth; they attach themselves to fish and suck nutrients from the host's circulatory system.
 8. Marine parasitic lampreys entered the Great Lakes and devastated the trout population in the 1950s.
- D. Fishes with Jaws
1. Animals beyond this point are **gnathostomates**, animals with **jaws**, the tooth-bearing bones of the head.
 2. Jaws evolved from the first pair of gill arches of agnathans; the second pair of arches became support structures for the jaws.
 3. Placoderms are extinct jawed fishes of the Devonian period.
 - a. They were armored with heavy plates and had strong jaws.
 - b. Like extant fishes, they had paired pectoral and pelvic fins.
 - c. Paired fins allow a fish to balance and maneuver well in water; this helps predation.
- E. Cartilaginous Fishes
1. 850 species of sharks, rays, and skates are in the class **Chondrichthyes**, the **cartilaginous fishes**.
 2. They have a cartilaginous skeleton rather than bone.
 3. Five to seven gill slits are on both sides of the pharynx; they lack the gill covers found on bony fish.
 4. Their body is covered by epidermal **placoid** (toothlike) **scales**.
 5. The teeth of sharks are enlarged scales; there are many rows of replacement teeth growing behind the front teeth.
 6. They have three well developed senses to detect electric currents in water, pressure (a lateral line system), and smell.
 7. The largest sharks are filter feeders, not predators; the basking and whale sharks eat tons of crustacea.
 8. Most sharks are fast, open-sea predators; a great white shark eats dolphins, sea lions and seals.
 9. Rays and skates live on the ocean floor; their pectoral fins are enlarged into winglike fins and they swim slowly.
 10. Stingrays have a venomous spine.
 11. Electric rays feed on fish that have been stunned with an electric shock that may reach over 300 volts.
 12. Sawfish rays have a large anterior “saw” that they use to slash through schools of fish.

F. Bony Fishes

1. About 20,000 species of bony fishes are in the class **Osteichthyes**.
2. Bony fishes have a bony skeleton; most are ray-finned with thin, bony rays supporting the fins.
3. A few lobe-finned fishes are related to ancestors of amphibians.
4. The ray-finned fishes include our familiar fishes.
 - a. They are the most successful and diverse of vertebrates.
 - b. They vary from filter feeders to predaceous carnivores.
 - c. Their skin is covered by scales formed of bone.
 - d. The gills do not open separately but instead are covered by an **operculum**.
 - e. The **swim bladder** is a gas-filled sac whose pressure can be altered to regulate buoyancy and depth.
 - f. Salmon, trout, and eels migrate between fresh and salt water but adjust their kidney and gill function.
 - g. Fish sperm and eggs are usually shed into water.
 - h. For most fish, the fertilization and embryonic development occur outside the female's body.
5. The **lobe-finned fishes** include six species of lungfishes and one species of coelacanth.
 - a. Their fleshy fins are supported by central bones.
 - b. Lungfishes live in stagnant water or ponds that dry up; found in Africa, South America and Australia.
 - c. Coelacanths live in deep oceans; once considered extinct, more than 200 have been captured since 1938 near the Comoros Islands, with recent finds near Malaysia.

G. Amphibians

1. All animals studied from this point on have four limbs and are **tetrapods**.
2. The lobe-finned fishes of Devonian are ancestral to amphibians.
3. Land animals use limbs to support their body since the air is less buoyant than water.
4. Some lobe-finned fishes and the early amphibians had lungs and internal nares to breathe air.
5. 3,900 species of amphibians belong to class **Amphibia**.
6. Two hypotheses describe evolution of amphibians from lobe-finned fishes.
 - a. Lobe-finned fishes that could move from pond-to-pond had an advantage over those that could not.
 - b. The supply of food on land and the absence of predators promoted adaptation to land.
7. The first amphibians diversified during Carboniferous period which is known as the Age of the Amphibians.
8. Diversity of Amphibians
 - a. Modern amphibians include three groups: frogs and toads, salamanders and newts, and the caecilians.
 - b. Salamanders and newts have a long body and tail, and two pairs of legs; they resemble the earliest fossil amphibians.
 - c. Their S-shaped locomotion is similar to fish movements.
 - d. Salamanders and newts are carnivorous, feeding on insects, snails, etc.
 - e. Salamanders practice internal fertilization; the males produce a spermatophore that females pick up with the **cloaca**.
 - f. Frogs and toads are tailless as adults; the hind limbs are specialized for jumping.
 - g. Frogs and toads have the head and trunk fused; frogs live near or in fresh water while toads live in damp places away from water.
 - h. Caecilians are legless; most burrow in soil and feed on worms, etc.
 - i. Reproduction involves a return to the water; "amphibian" refers to this need to return to water from land.
 - 1) They shed eggs into the water for external fertilization.
 - 2) Generally, amphibian eggs are protected by a coat of jelly but not by a shell.
 - 3) The young hatch into aquatic larvae with gills (tadpoles).
 - 4) The aquatic larvae usually undergo **metamorphosis** to develop into a terrestrial adult.

9. Anatomy and Physiology of Amphibians
 - a. A tongue is used for catching prey.
 - b. The eyelids keep their eyes moist.
 - c. Amphibian ears are adapted for detecting sound waves; in turn, the **larynx** produces calls.
 - d. The amphibian brain is larger than that of fishes; their cerebral cortex is more developed.
 - e. Amphibians usually have small lungs supplemented by gas exchange across porous skin.
 - f. The single-loop circulatory path of fish is replaced by a closed double-loop circulatory system; however oxygen-rich blood mixes with some oxygen-poor blood.
 - g. A **three-chambered heart** with a single ventricle pumps mixed blood before and after it has gone to the lungs.
 - h. Amphibian skin is thin, smooth, and nonscaly, and contains numerous mucous glands; this skin plays an active role in osmotic balance and respiration.
 - i. Some skin glands secrete poisons; those tropical species often have brilliant warning coloration.
 - j. Amphibians are **ectothermic**, depending upon the environment to regulate body temperature.
 - k. If winter temperature drops too low, temperate ectotherms become inactive and enter **torpor**.

H. Reptiles

1. Reptiles were the first vertebrates to practice internal fertilization through copulation and to lay eggs that are protected by a leathery shell.
2. The **amniote egg** contains **extraembryonic membranes**.
3. **Extraembryonic** membranes are not a part of the embryo and are disposed of after development.
4. They protect the embryo, remove nitrogenous wastes, and provide oxygen, food, and water.
5. The **amnion** is one extraembryonic membrane; it fills with fluid to provide a “pond” for embryo to develop.
6. About 6,000 species of reptiles are in the class **Reptilia**.
7. Reptiles evolved from amphibian ancestors by Permian period.
8. The first reptiles (stem reptiles) gave rise to several lineages; each was adapted to a different way of life.
 - a. The pelycosaurs or sail lizards are related to **therapsids**, mammallike reptiles ancestral to mammals.
 - b. Some lineages returned to aquatic environments; the ichthyosaurs were fishlike and plesiosaurs had a long neck.
 - c. The pterosaurs of the Mesozoic era had a keel for attachment of flight muscles and air spaces in bones to reduce weight.
9. Dinosaurs varied in size and behavior; some had a bipedal stance and gave rise to birds.
10. Reptiles dominated earth for about 170 million years during the Mesozoic era; then most died out.
11. Luis and Walter Alvarez proposed the impact theory of dinosaur extinction.
 - a. A large meteorite or comet at the end of the Cretaceous period could have set off earthquakes and fires, raising enough dust and smoke to block out the sun.
 - b. An iridium layer, a mineral common in meteorites, occurs in rocks at the end of this period.
12. Diversity of Reptiles
 - a. Most reptiles today live in the tropics or subtropics; lizards and snakes live on soil; turtles, crocodiles and alligators live in water.
 - b. Tuataras are lizardlike and identical to fossils 200 million years old.
 - c. Crocodiles and alligators are largely aquatic, feeding on fishes and other animals.
 - 1) Their powerful jaws have numerous teeth; a muscular tail is both a paddle to swim and a weapon.
 - 2) Male crocodiles bellow to attract mates; males of some species protect the eggs and young.
 - d. Turtles have a heavy shell fused to the ribs and to the thoracic vertebrae.
 - 1) Turtles lack teeth but use a sharp beak.
 - 2) Sea turtles must return to lay eggs onshore.
 - e. Lizards have four clawed legs and are carnivorous.
 - 1) Marine iguanas on the Galapagos are adapted to spend long times in the sea.
 - 2) Chameleons live in trees, have a long sticky tongue to catch insects, and change color.
 - 3) Australian frilled lizards have a collar to scare predators.

- f. Snakes evolved from lizards and lost legs as an adaptation to burrowing.
 - 1) Their jaws can readily dislocate to engulf large food.
 - 2) A tongue collects airborne molecules to transfer them to Jacobson's organ for tasting.
 - 3) Some snakes are poisonous and have special fangs to inject venom.
- g. Reptiles have a thick, scaly skin that is keratinized and is impermeable to water.
 - 1) Keratin is the protein that is also found in hair, fingernails, and feathers.
 - 2) Reptile's protective skin prevents water loss but it also requires several molts a year.
- h. Reptile lungs are more developed than in amphibians; air rhythmically moves in and out of the lungs due to an expandable rib cage, except in turtles.
- i. Most have a nearly **four-chambered heart**, except in the crocodile it is completely four-chambered; oxygen-rich blood is more fully separated from oxygen-poor blood.
- j. Well-developed kidneys excrete uric acid; therefore, less water is lost in excretion.
- k. Reptiles are ectothermic.
 - 1) They require a fraction of the food per body weight of birds and mammals.
 - 2) They are behaviorally adapted to warm their body temperature by sunbathing.

I. Birds

- 1. About 9,000 species of birds are in the **class Aves**.
- 2. Birds lack teeth and have only a vestigial tail but their relationship to reptiles shows in the scales on their legs, claws on their toes, and a horny beak.
- 3. Birds also lay an egg, but it is hard-shelled rather than leathery.
- 4. The ancestry of birds is in dispute; some biologists consider them related to bipedal dinosaurs.
- 5. Bird anatomy is closely related to its ability to fly.
- 6. Bird forelimbs are modified as wings for flying with hollow, light bones laced with air cavities.
- 7. A beak composed of keratin has replaced jaws equipped with teeth.
- 8. A keeled breastbone anchors muscles used in flight.
- 9. Bird respiratory air sacs are extensive, even extending into some larger bones.
 - a. Using a one-way flow of air, air sacs maximize gas exchange and oxygenation of blood.
 - b. Efficient supply of oxygen to muscles is vital for level of muscle activity needed for flight.
- 10. Birds possess a four-chambered heart; this double-loop circulatory system separates oxygen-rich and oxygen-poor blood.
- 11. Birds are **endothermic**; they have ability to maintain a constant, relatively high body temperature.
 - a. Homeothermy enables an animal to be continuously active in cold weather.
 - b. Feathers may have evolved for insulation and secondarily became adapted for flight.
- 12. Flight requires well-developed sense organs and nervous system.
 - a. Birds have very acute vision and excellent muscle reflexes.
 - b. Bird muscle reflexes are excellent.
 - c. Bird migration allows use of widespread food sources; an enlarged portion of the brain is responsible for instinctive behaviors.
- 13. Bird classification is based on beak and foot types, and some on habitats and behaviors.
 - a. Birds of prey have notched beaks and sharp talons.
 - b. Shorebirds have long slender bills and long legs.
 - c. Waterfowl have webbed toes and broad bills.

J. Mammals

- 1. Over 4,800 species of mammals belong to the class **Mammalia**.
- 2. Mammals evolved during the Mesozoic era from **therapsids**, extinct mammallike reptiles.
- 3. The mammal skull is bigger, their teeth are differentiated into molars and premolars, and the vertebral column provides more movement.
- 4. True mammals appeared during the Jurassic period, about the same time as the first dinosaurs.
 - a. The first mammals were small, about the size of mice.
 - b. Some of the earliest mammalian groups were **monotremes** and **marsupials**.
 - c. Placental mammals evolved later to occupy habitats vacated by dinosaurs.
- 5. The chief characteristics of mammals are **hair** and **mammary glands**.
- 6. Mammals are **endothermic**; they produce heat and maintain a constant body temperature.
- 7. Many adaptations of mammals are related to temperature control.

8. **Hair** provides insulation against heat loss and allows mammals to be active in cold weather.
9. Gas exchange is efficiently accomplished by lungs.
10. Mammals possess a four-chambered heart and a double-loop circulatory system.
11. **Mammary glands** enable females to feed young without deserting them to obtain food.
12. Nursing creates a bond between mother and offspring to ensure parental care while the young are helpless.
13. In most mammals, the young are born alive after a period of development in uterus.
14. Mammals That Lay Eggs
 - a. **Monotremes** are mammals that have a cloaca and lay hard-shelled amniote eggs.
 - b. They are represented by the duckbill platypus and the spiny anteater of Australia.
 - c. A female duckbill platypus lays her eggs in a burrow in the ground where she incubates them.
 - d. After hatching, young lick milk seeping from modified sweat glands on the abdomen.
 - e. The spiny anteater has a pouch formed by swollen mammary glands and muscle; the egg moves from cloaca to pouch and hatches; the young remain for 53 days and live in burrow where the mother feeds them.
15. Mammals That Have Pouches
 - a. **Marsupials** begin development inside the mother's body but are then born in a very immature state.
 - b. The newborns crawl up into a **pouch** on their mother's abdomen.
 - c. Inside a pouch they attach to the nipples of the mother's mammary glands and continue to develop.
 - d. Today, most marsupials are found in Australia where they underwent adaptive radiation for several million years without competition from the placental mammals, only introduced recently.
16. Mammals That Have Placentas
 - a. **Placental mammals** use a **placenta**, an organ of exchange between maternal and fetal blood.
 - b. The placenta supplies nutrients to and removes wastes from the blood of developing offspring.
 - c. A placenta also allows a mother to move about while the offspring develop.
 - d. The placenta enables young to be born in a relatively advanced stage of development.
 - e. Placental mammals are very active animals; they possess acute senses and a relatively large brain.
 - f. The brains of placental animals have cerebral hemispheres proportionately larger than other animals.
 - g. The young go through a long period of dependency on their parents after birth.
 - h. Today, placental mammals populate all of the continents except Antarctica.
 - i. Most are terrestrial, but some are aquatic, and bats can fly.
17. Classification of mammals is based on mode of locomotion and the method of obtaining food.
 1. The order **Perissodactyla** includes 17 species of horses, zebras, tapirs, and rhinoceroses and the order **Artiodactyla** includes 185 species of pigs, cattle, deer, buffaloes, giraffes, etc.
 - a. Both orders are hoofed animals.
 - b. They have elongated limbs adapted for running across open grassland.
 - c. They are herbivorous and have large grinding teeth.
 2. About 270 species are in order **Carnivora**.
 - a. Carnivores include the dogs, cats, bears, raccoons, and skunks.
 - b. The canines of meat eaters are large and conical.
 - c. Aquatic carnivores such as seals and sea lions must return to land to reproduce.
 3. The order **Primates** contains 180 species of lemurs, monkeys, gibbons, chimpanzees, gorillas, and humans.
 - a. Typical primates are tree-dwelling fruit eaters; some are ground dwellers.
 - b. Their digits have nails, not claws; the thumb is more opposable.
 - c. Primates, particularly humans, have well-developed brains.
 4. The order **Cetacea** includes about 80 species of **whales** and **dolphins**.
 - a. They lack substantial hair or fur.
 - b. Blue whales are the largest animal ever to live on this planet are baleen whales that strain plankton from the water.
 - c. Toothed whales feed on fish and squid.

5. The order **Chiroptera** contains 925 species of **nocturnal bats**.
 - a. Wings are layers of skin and connective tissue stretched between the elongated bones of all fingers but first.
 - b. Many species use echolocation to locate their usual insect prey.
 - c. Some bats also eat birds, fish, frogs and plant tissues.
6. The order **Rodentia** contains **rodents** (e.g., mice, rats, squirrels, beavers, and porcupines).
 - a. This is largest order with 1,760 species.
 - b. Rodents have incisors that grow continuously.
 - c. Most rodents eat seeds but some are omnivorous or eat mainly insects.
7. Only two extant species are in order **Proboscidea**: the **elephants**.
 - a. Upper lip and nose are elongated and muscularized forming a prehensile trunk.
 - b. They are herbivores and are largest living land mammals.
8. Order **Lagomorpha** includes 65 species of rabbits, hares, and pikas.
 - a. They resemble rodents but have two pairs of continuously growing incisors.
 - b. Their hind legs are longer than their front legs and they are herbivores.