BLY 122

Chapter 33 Deuterostome Animals

I. Why Do Biologists Study Deuterostome Animals?

A. Because Humans Are Deuterostomes
1. We identify with other vertebrates because they are like us.
2. Other mammals affect our lives since we interact with them as livestock and pets.

B. Deuterostomes play important roles in our ecological community and our human economy.
1. Most large deuterostomes dominate the upper food chains in most ecosystems. (**Fig. 33.1**)
a. Fish and echinoderms are important herbivores and predators in marine environments.
b. Reptiles and mammals are important herbivores and predators in terrestrial environments.
2. Humans depend on vertebrates for food and power.
a. Fish and livestock are key sources of protein in many cultures.
b. Many cultures still depend on horsepower and oxpower for transportation and agriculture.

II. How Do Biologists Study Deuterostomes?

A. Biologists investigate three central issues while studying deuterostomes.
1. Understanding the diversity of body plans in the three deuterostome phyla, echinoderms, hemichordates, and chordates
2. Exploring how vertebrates evolved from vertebrates
3. Grasping how vertebrates made the transition from water to land

B. Analyzing Morphological Traits
1. What do all deuterostomes have in common?
a. They are triploblastic and have a coelom.
b. They have similar patterns of embryonic development.
c. They differ in that echinoderms reverted to radial symmetry. (**Fig. 33.2**)
(1) Their ancestors are bilaterally symmetrical.
(2) Adults have five-sided radial symmetry. (**Fig. 33.2b**)
(3) Larvae are bilaterally symmetrical (**Fig. 33.2a**)
2. The water vascular system of echinoderms; body organization without a head and tail
a. Echinoderms consist of a body with a number of fluid-filled tubes and chambers called the water vascular system. (**Fig. 33.3a**)
(1) One of the tubes is open to the exterior so seawater can flow into and out of the system.
(2) These tubes and chambers form a sophisticated hydrostatic skeleton.
b. One part of the fluid-filled structure is called the tube foot.
(1) Podia are sections to the tube feet that extend outside the body and contact substrate. (**Fig. 33.3b**)
(2) Podia extend and shorten via muscle contractions that move water within the tube feet.
(3) These podia movements allow the animal to alternately grab and release the substrate, thus moving along it.
c. Echinoderms have a hard, supportive endoskeleton inside the body. (**Fig. 33.4**)
(1) During development, internal cells release calcium carbonate in plate form inside the skin.
(2) The plates may remain separate, resulting in a flexible body; or they may fuse, resulting in a rigid body.
3. The origin of chordates illustrates the evolution of several unique traits.
a. Chordates are characterized by the presence of four distinct features that appear at some point during their life cycle.
(1) Pharyngeal gill slits in the throat
(2) A stiff, but flexible notochord that runs the length of the body
(3) A bundle of nerves that runs the length of the body, called the dorsal hollow nerve cord
(4) A muscular tail that extends past the anus

b. Hemichordates are members of the phylum Chordata, but lack a notochord and a tail. (**Fig. 33.5a**)
   (1) They do have pharyngeal gill slits and a dorsal nerve cord.
   (2) Most live in the ocean and are sessile suspension feeders.

c. The rest of Chordata can be divided into three major subgroups. (**Fig. 33.5b**)
   (1) Urochordata (tunicates and sea squirts) are small suspension feeders that live attached to hard substrates in the ocean.
   (2) Cephalochordates (lancelets or amphioxus) are small, mobile, suspension feeders.
   (3) Vertebrates include sharks, bony fishes, reptiles, and mammals.

d. These three subgroups have all four chordate features at some point during their development.
   (1) Urochordates have pharyngeal gill slits in both larvae and adults, but have only a dorsal nerve cord, notochord, and tail as larvae.
   (2) Cephalochordates have pharyngeal gill slits that aid in gas exchange and suspension feeding, and they have a notochord that facilitates swimming movements.
   (3) In vertebrates, the dorsal nerve cord is the spinal cord, the pharyngeal gill slits are pouches present in embryos, and a notochord helps organize the body plan into somites during embryogenesis.

C. The fossil record documents several key chordate innovations.

1. Echinoderms and vertebrate fossils have been discovered in the Burgess Shale deposits from the Cambrian explosion (544–515 mya). (**Fig. 33.6**)
   a. Earliest vertebrates appear to have lived in the ocean and looked like fish; they seem to have had a skull, a notochord, and an endoskeleton made of cartilage.
   b. Fossils that date about 480 mya are the first fossil evidence of bone.
      (1) Bone tissue consists of cells and blood vessels entrapped in a matrix of calcium carbonate and protein fibers.
      (2) The first animals to have bones did not have an endoskeleton, but they had bone plates that formed an exoskeleton.
   c. The first vertebrates with jaws show up in the fossil record about 430 mya.
      (1) Jaws gave vertebrates the ability to bite, allowing them to diversify their diet to herbivory or carnivory.
      (2) The evolution of teeth within the bony jaw occurred not long after the appearance of the jaw.
   d. Vertebrates seem to have moved to land about 357 mya, evidenced by the appearance of tetrapods in the fossil record.
   e. Vertebrate fossils dating 330 mya show the first known presence of an amniotic egg.
      (1) These eggs have watertight shells that enclose the embryo, a membrane-bound food supply, water supply, and waste depository.
      (2) This innovation was significant because it allowed vertebrates to lay eggs on land that would not dry out.

D. Evaluating molecular phylogenies allows biologists to build a phylogenetic tree for deuterostomes.

1. The phylogenetic tree built from molecular sequence data concurs with the order of appearance observed in the fossil record. (**Fig. 33.7**)
2. The three groups of deuterostomes (Echinodermata, Hemichordata, and Chordata) are all monophyletic groups.

III. What Themes Occur in the Diversification of Deuterostomes?

A. Echinoderms and vertebrates are the most successful deuterostome lineages.

1. Echinoderms are widespread in all marine habitats.
2. Ray-finned fishes and tetrapods are the most diverse of the vertebrates. (**Fig. 33.8**)
   a. Ray-finned fishes live in a vast array of marine and freshwater environments.
   b. Tetrapods are the dominant herbivores and predators in terrestrial environments around the globe.
   c. A variety of echinoderms and vertebrates have been important model organisms in biology. (**Box 33.1, Fig. 33.9**)

B. Feeding

1. Feeding strategies in echinoderms
   a. Echinoderms either suspension feed, deposit feed, or harvest algae or other animals.
   b. They use their podia to gather food.
      (1) For example, sea stars eat bivalves by using their podia to pry the bivalve's shell open. (**Fig. 33.10a**)
      (2) They then extrude their stomach into the shell and externally digest the visceral mass.
      (3) Then they absorb the small molecules released by the digestion.
      (4) Other species use their podia to move food toward cilia that then move the food to the mouth. (**Fig. 33.10b**)
2. The vertebrate jaw
   a. Ancient vertebrates like hagfish and lampreys do not have jaws; therefore, they are deposit feeders or ectoparasites.
   b. Biologists hypothesized that jaws evolved from cartilaginous tissue that supports gill arches in ancient vertebrates.
      (1) This hypothesis suggests that mutation and natural selection increased the size and orientation of the arch to form a working jaw. (**Fig. 33.11**)
      (2) Three lines of evidence support this hypothesis.
         (*a*) Both gill arches and jaws consist of flattened bars of bone or cartilage that is hinged.
         (*b*) Both gill arches and jaws are derived from neural crest cells.
         (*c*) Muscles that move gill arches and jaws are derived from the same population of cells.
   c. Modifications in the jaw structure make ray-finned fishes particularly diverse in their eating habits.
      (1) In most species, the jaw protrudes to be able to nip out or bite food.
      (2) Most species also have a pharyngeal jaw that functions as a second set of jaws located at the back of the mouth that makes food processing more efficient.

C. The evolution of the tetrapod limb allowed for movement on land.
1. Lungfish morphology provides clues for how vertebrates may have made the transition from water to land.
   a. Because lungfish inhabit shallow, oxygen-poor water, they have lungs (in addition to gills) that allow them to breathe air in addition to water. (**Fig. 33.12**)
   b. Some also have fleshy fins supported by bones that allow them to walk over mudflats or the bottom of ponds.
   c. The fossil record shows strong links between lungfishes and ancient terrestrial vertebrates.
      (1) Morphological comparison shows similarities in fin and limb bone arrangement. (**Fig. 33.13**)
      (2) The similarity is strong and unique and thus provides evidence for homology between the vertebrate limb and the fish fin.
   d. Genetic data also indicate that vertebrate limbs evolved from fish fins.
      (1) Studies of zebrafish development have shown that *Hox* gene products and *Sonic hedgehog* gene products are important in fin development.
      (2) These proteins are found at the same developmental stage and in the same locations in both fin and limb development, implying that these structures are under the same genetic control.
      (3) Biologists hypothesize that mutation and natural selection gradually transformed fins into limbs.
   e. Once limbs evolved, they diversified in their morphological detail.
      (1) This diversification facilitated a variety of movements, including running, gliding, crawling, burrowing, and swimming.
      (2) Wings are a stunning limb modification that arose independently in three groups of tetrapods. (**Box 33.2, Fig. 33.14–33.16**)

D. Three major innovations in tetrapod reproduction allowed them to generate and rear offspring in a variety of habitats.
1. Amniotic eggs allow reptiles and some mammals to lay their eggs on land.
   a. These eggs have shells that minimize water loss.
   b. They also contain a membrane-bound food and water supply called the albumin. (**Fig. 33.17**)
   c. The embryo is bathed in fluid and is protected by a membrane called the amnion.
   d. The yolk sac contains nutrients for the embryo and the allantois in a membranous pouch that accumulates waste.

e. The chorion separates the embryo from these other compartments and facilitates gas exchange through the shell.

2. The placenta allows mammals to retain the embryo as it develops.
   a. The placenta is an organ that is rich in blood vessels and facilitates the flow of oxygen and nutrients from the mother to the embryo. (**Fig. 33.18**)
   b. Once a developmental period called gestation is complete, a live offspring is born.
   c. How did this viviparous condition evolve?
      (1) Every female has a trade-off between the number of offspring she produces and the size of the offspring she produces.
      (2) In some lineages, natural selection has favored the production of a small number of large, well-developed offspring.
      (3) Viviparity and the placenta are traits that allow for that reproductive strategy.
3. Parental care of offspring after birth increases the ability of those few, larger offspring to survive.
   a. Parental care involves supplying food, warmth, and protection.
   b. Some parental care is seen in ray-finned fishes, but the most extensive parental care habits are observed in mammals and birds.
      (1) These species feed their young after birth (lactation in mammals). (**Fig. 33.19**)
      (2) The evolutionary success of mammals and birds has been attributed to the time and energy they invest in parental care.

IV. Key Lineages of Echinodermata (**Fig. 33.20**)

A. Asteroidea (Sea Stars) (**Fig. 33.21**)
1. Feeding:
   a. Most species are predators or scavengers.
   b. Some species pull bivalves apart with their tube feet and eat their visceral mass.
   c. The crown of thorns sea star eats coral and, with the removal of its greatest predator, is destroying coral reefs.
2. Movement: Crawl with the aid of their tube feet
3. Reproduction:
   a. Sexes are separate, and reproductive organs are localized in one arm where egg or sperm are made.
   b. Most species lay eggs in the water, but some retain the eggs until they hatch.
   c. Most species can regenerate lost limbs, but only a few species can reproduce asexually by dividing in two.

B. Echinoidea (Sea Urchins and Sand Dollars) (**Fig. 33.22**)
1. Feeding:
   a. Sand dollars use mucus-coated podia to collect food in sand.
   b. Most sea urchins are herbivores, and graze on kelp and algae.
   c. Most echinoids have a jaw-like structure in their mouths with five calcium carbonate teeth.
2. Movement:
   a. Sea urchins crawl via their podia and movement of their spines.
   b. Sand dollars burrow via podia.
3. Reproduction: Sexual reproduction predominates, and sexes are separate.

V. Key Lineages of Chordata

A. Myxinoidea (Hagfish) and Petromyzontoidea (Lamprey) (**Fig. 33.23**)
1. Feeding:
   a. Hagfish are scavengers and predators that deposit feed on dead fish and whales. (**Fig. 33.23a**)
   b. Lampreys are ectoparasites that attach to the sides of fishes, rasp a hole in their victims, and suck blood and other bodily fluids. (**Fig. 33.23b**)
2. Movement:
   a. All species have a well-developed notochord that is attached to muscles.
   b. Muscle contraction generates an undulating movement that results in swimming.
3. Reproduction:

a. Lampreys are anadromous, meaning that they spend their adult life in large bodies of water, but swim up streams to breed.
b. Fertilization is external, and adults die after breeding once.
c. Lamprey eggs hatch into lancelet-looking larvae that burrow into sediments and suspension feed until metamorphosing into adults.

B. Chondrichthyes (Sharks, Rays, and Skates) (**Fig. 33.24**)
1. Feeding:
a. A few species are suspension feeders of plankton.
b. Skates and rays are sit-and-wait predators at the bottom of the ocean floor.
c. Electric rays shock their prey.
d. Most sharks are hunters that chase down their prey and bite them; they are the top predator in marine ecosystems.
2. Movement:
a. Rays and skates swim by flapping their large pectoral fins.
b. Sharks swim by undulating their bodies and beating their large tails.
3. Reproduction:
a. Sharks fertilize internally; most lay fertilized eggs in the water that hatch into well-developed young.
b. Skates are oviparous, while rays are viviparous.

C. Actinopterygii (Ray-Finned Fishes) (**Fig. 33.25**)
1. Feeding:
a. Teleosts suck food toward their mouths and grasp it with their large jaws.
b. They have teeth and pharyngeal jaws that are used to process the food.
c. Ray-finned fish are important herbivores in marine environments.
2. Movement:
a. Ray-finned fish have a swim bladder that can change in volume to keep the fish afloat.
b. Fish swim by contracting muscles on each side of their bodies from head to tail, resulting in fast, undulating movements.
3. Reproduction:
a. Most species fertilize externally and are oviparious.
b. Although rare, parental care does occur in some species.

D. Dipnoi (Coelacanths) and Actinistia (Lungfish or Lobe-Finned Fishes) (**Fig. 33.26**)
1. Feeding:
a. Coelacanths prey on fish.
b. Lungfish are omnivorous and eat plants, algae, and other animals.
2. Movement:
a. Have fins that are supported by bones and muscles
b. Coelacanths swim by waving their pectoral and pelvic fins in the same sequence that tetrapods use to walk.
c. Lungfish swim by waving their body, or can walk by using their fins.
3. Reproduction:
a. Coelacanths fertilize internally and are ovoviviparous.
b. Lungfish fertilize externally and are oviparious.

E. Amphibia (Frogs, Salamanders, and Caecilians) (**Fig. 33.27**)
1. Feeding:
a. Adult amphibians are carnivores.
b. Frogs and salamanders use their tongue to capture prey.
c. Caecilians prey on earthworms.
2. Movement:
a. Most amphibians are tetrapods.
b. Frogs hop on land; salamanders walk.
c. Frogs use their hind legs to kick while swimming; salamanders undulate their bodies to swim.
d. Caecilians do not have limbs, so they burrow.

3. Reproduction:
    a. Frogs fertilize externally and are oviparious.
    b. Salamanders and caecilians fertilize internally.
    c. Salamanders are oviparious; caecilians are viviparous.

F. Mammalia (Mammals)
  1. Monotremata (Platypuses and Echidnas) (**Fig. 33.28**)
    a. Feeding: Have leathery beaks and bills for feeding on insects, crustaceans, and earthworms
    b. Movement: Walk on four legs, swim with webbed feet
    c. Reproduction: Oviparious
  2. Marsupiala (Marsupials) (**Fig. 33.29**)
    a. Feeding: Herbivores, carnivores, and omnivores
    b. Movement: Walking, running, gliding, crawling, or hopping
    c. Reproduction: Viviparous; carry young in pouch after birth until mature
  3. Eutheria (Placental Mammals) (**Fig. 33.30**)
    a. Feeding:
      (1) Size and structure of teeth correspond with diet.
      (2) Hebivores have broad, flat teeth for crushing and grinding.
      (3) Predators have sharp teeth for biting and tearing flesh.
      (4) Omnivores have both types of teeth.
    b. Movement: Varies; Limb morphology corresponds with movement type.
    c. Reproduction: Internal fertilization and development

G. Reptilia (Turtles, Snakes, Lizards, Crocodiles, and Birds)
  1. Testudinia (Turtles and Tortoises) (**Fig. 33.31**)
    a. Feeding: Can be herbivorous, detrivorous or carnivorous
    b. Movement: Swim, walk or burrow
    c. Reproduction: Oviparious; no parental care
  2. Lepidosaura (Lizards, Snakes) (**Fig. 33.32**)
    a. Feeding:
      (1) Lizards eat insects or plants.
      (2) Snakes are carnivorous; swallowing their prey whole.
    b. Movement:
      (1) Lizards crawl on four limbs.
      (2) Snakes are limbless and burrow and crawl by undulating their body.
    c. Reproduction:
      (1) Most are oviparious, although some are ovoviviparous.
      (2) Asexual reproduction via parthenogenesis is known in some species.
  3. Crocodilia (Crocodiles, Alligators) (**Fig. 33.33**)
    a. Feeding: Predators that eat amphibians, turtles, fish, birds, and mammals
    b. Movement: Walk, gallop with their limbs; swim with their tail.
    c. Reproduction: Oviparious with extensive parental care.
  4. Aves (Birds) (**Fig. 33.34**)
    a. Feeding:
      (1) Herbivorous birds feed on nectar or seeds.
      (2) Omnivorous birds eat plants, insects, fish, small mammals, lizards, or crustaceans.
      (3) Bill size and shape are specialized for their food source.
    b. Movement:
      (1) Almost all species can fly; wing size and shape are specialized for the type of flying done by each species.
      (2) Aquatic birds have webbed feet for swimming.
      (3) Flightlessness has evolved several times in birds.
    c. Reproduction: Oviparious with extensive parental care

VI. Key Lineages: The Hominin Radiation

A. The Primates
   1. The Primate lineage contains two groups. (**Fig. 33.35c**)
      a. Prosimians include lemurs, tarsiers, pottos, and lorises; most live in trees and are nocturnal. (**Fig. 33.35a**)
      b. Anthropoids include New World and Old World monkeys, the great apes, and humans. (**Fig. 33.35b**)
   2. Primate morphological features
      a. Eyes located on the front of the face that look forward and provide good depth perception.
      b. Have grasping hands and feet
         (1) The anthropoids have a fully opposable thumb for extensive grasping.
         (2) The prosimians do not have an opposable thumb.
      c. Have large brains, complex social behavior, and extensive parental care.
   3. Hominids, or great apes, includes humans.
      a. DNA sequence studies have illustrated that humans are most closely related to chimpanzees. (**Essay, Fig. 33.39**)
      b. Our next closest living relative is the gorilla.

B. Fossil Humans: The Homonins
   1. *Australopithecus* (**Fig. 33.36a**)
      a. Gracile australopithecines include four species of slender, small-framed organisms that were originally identified in South Africa.
      b. Evidence supports the hypothesis that they were bipedal.
         (1) The hole in their skull from which their spinal cord extends points downward, as it does in humans.
         (2) That hole points to the back in species that walk on all four limbs.
   2. *Paranthropus* (**Fig. 33.36b**)
      a. Robust australopithecines include three species of bipedal hominins that had more robust skull morphology than that of the *Australopithecus*.
      b. The jaw morphology of these fossil skulls suggests that they fed on nuts and seeds.
   3. Early *Homo* (**Fig. 33.36c**)
      a. These species have flatter and narrower faces, smaller jaws and teeth, and larger braincases.
      b. The fossilized bones of these species coincide with appearance of tools, leading the hypothesis that these species used tools.
   4 Recent *Homo* (**Fig. 33.36d**)
      a. These species have even flatter faces, smaller teeth and larger braincases.
      b. One population of *Homo sapiens* called Cro-Magnons had an even larger braincase than that of humans today.
      c. There is evidence that Cro-Magnons and Neanderthals made art and buried their dead in carefully prepared graves.
   5. What does the fossil record tell us about the hominin radiation? (**Fig. 33.37**)
      a. All hominins appeared to have been bipedal.
      b. Some coexisted or existed at the same time in different geographical locations. (**Table 33.1**)
      c. *Homo* species have large brains relative to body size.
         (1) Tool use and language development are thought to have triggered natural selection for the capacity to reason and communicate.
         (2) Speaking hominids have a differently shaped hyphoid bone than that of apes that do not talk.
         (3) *Homo sapiens* colonized Australia by boat 40,000–60,000 years ago; that type of journey must have required communication.

C. Where did we come from? The Out-of-Africa Hypothesis
   1. DNA sequence data indicate that the ancestral population of modern humans lived in Africa. (**Fig. 33.38a**)
   2. Three monophyletic lineages seem to represent three waves of migration from Africa to . . . (**Fig. 33.38b**)
      a. Southeast and Central Asia
      b. Central Asia and Europe
      c. Northeast Asia and the Americas
   3. What happened to the Neanderthals and *Homo erectus* as *Homo sapiens* began to migrate?

a. The assimilation hypothesis: *H. sapiens* interbred with these two groups as it moved into Europe and Asia.
b. The out-of-Africa hypothesis: *H. sapiens* did not interbreed, but *H. sapiens* evolved independently in Africa and spread all over the world.
c. DNA sequence data (mitochondrial DNA) indicate that *H. sapiens* did not interbreed with Neanderthals.

Chapter Vocabulary

deuterostomes

vertebrates
invertebrates
water vascular system
tube feet
podia
endoskeleton
pharyngeal gill slits
notochord
dorsal hollow nerve cord
tail
Urochordates
Cephalochordates
gills
somites

cartilage
bone
exoskeleton
jaws
tetrapods
Amniota

amniotic egg

gill arches
neural crest cells
pharyngeal jaw

Sonic hedgehog

endothermic

albumin
amnion
yolk sac
allantois
chorion
oviparious
viviparous
placenta
gestation
parental care
lactate

Echinodermata
Asteroidea
Echinoidea

Hemichordata

Chordata
vertebrae
cranium
Myxinoidea
Petromyzontoidea
Chondrichthyes
Actinopterygii
Swim bladder
Dipnoi
Actinistia
lobe-fined fishes
omnivorous
Amphibia
Reptilia
Testudinia
Lepidosaura
Crocodilia
Aves
feathers
endotherms
Mammalia
mammary glands
Monotremata
Marsupiala
Eutheria

Primates
prosimians
anthropoids
opposable thumb
great apes
hominids
bipedal
Australopithecus
Great australopithecines
Paranthropus
robust australopithecines
Early *Homo*
humans
braincase
Recent *Homo*
Cro-Magnons
Neanderthal
Homo sapiens
assimilation hypothesis
out-of-Africa hypothesis