

# The Evolution of Animal Diversity

## Most known organisms are animals

- Of the 1.5 million known species, one-third are animals.
- Most animal species live on land, but the greatest diversity of animal phyla are marine. The most diverse communities of animals are tropical coral reefs; 27 of the 30 animal phyla may be found here
- These reefs are composed of lime from the skeletons of corals and the left over cell walls of coralline red algae.
- Corals feed on small food particles that they trap on their tentacles.

Coral Reef

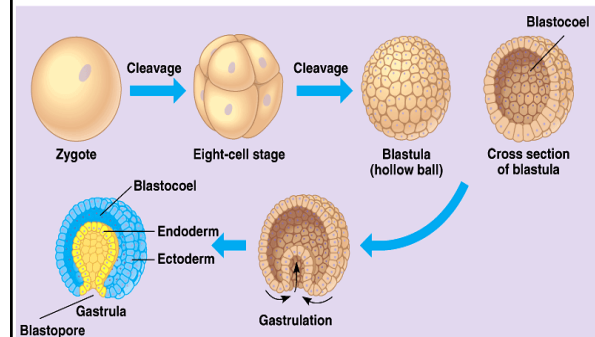


- Corals also receive food from photosynthesis of mutualistic dinoflagellates, in exchange for compounds the corals give off as wastes ( $\text{CO}_2$  and nitrogenous compounds).

- Zoologists distinguish between animals with internal skeletons (vertebrates) and those without internal skeletons (invertebrates). All but one animal phylum (our own, phylum Chordata) are invertebrate.

## What is an animal?

- Animals are eukaryotic, multicellular heterotrophs that lack cell walls.
- The life cycle of most animals includes a dominant, diploid adult that produces eggs or sperm by meiosis. These gametes fuse to form a zygote. The zygote develops into the adult animal, passing through a series of embryonic stages, many which are shared by most members of the animal kingdom.
- In all animals the embryonic stages include the **blastula** (hollow ball of cells) and, in most, a **gastrula** (a sac like embryo with one opening and two layers of cells). Most further develop an additional layer of cells.



•In many animals, the gastrula develops into one or more immature stages, larvae, that develop into the sexually mature adults only after metamorphosis.

**Note:** Larvae are dispersive stages that help an animal's offspring find suitable habitats before continuing to grow. These are also extremely important sources of food for many other animals in aquatic environments.

•Most animals digest food inside their multicellular bodies.

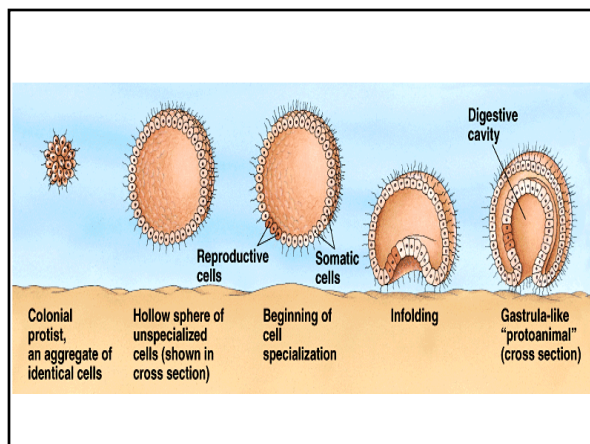
•Animals are, with the exception of the gametes, composed of diploid cells.

#### The animal kingdom probably originated from colonial protists

•Fossils of the oldest known animals date from the late Precambrian era, ≈700 mya.

•The modern animal phyla evolved during the Cambrian period ≈600 mya.

•A hypothetical evolutionary scenario leading to the first animal proceeds as follows (a) colonial protists of a few, identical, flagellated cells; (b) larger, hollow, spherical colonies that ingested organic materials suspended in the water around the colony; (c) colonies with cells specialized for somatic (movement, digestion, etc.) and reproductive functions; (d) differentiated entities with an infolded, temporary digestive region; and (e) "protoanimals," completely infolded, with two-layered body walls.



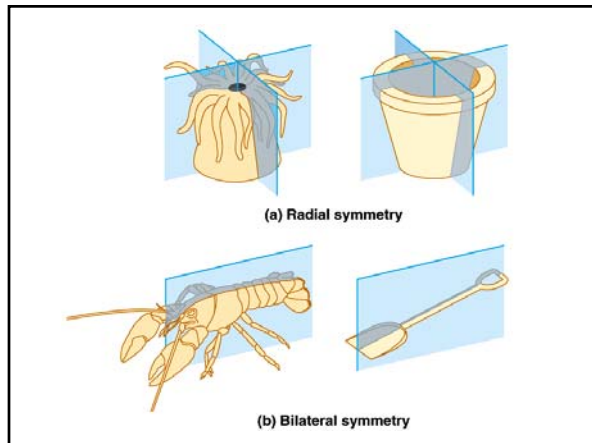
•These protoanimals probably "crawled," feeding on the ocean bottoms.

# Invertebrates

## Sponges have relatively simple, porous bodies

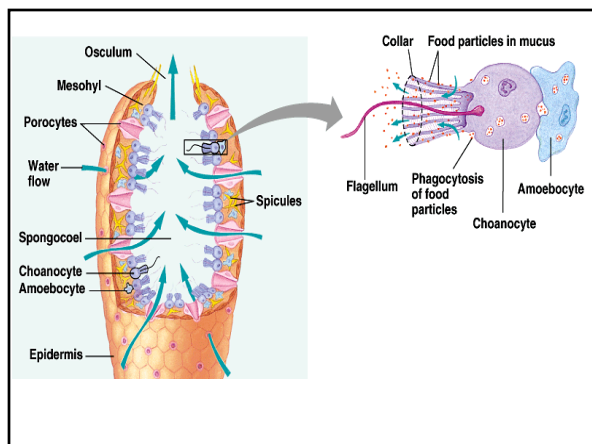
•Sponges are classified in the phylum *Porifera*. Most are marine and live singly, attached to a substrate, and range in height from 1 cm to 2 m.

•Many sponges are based on a body plan having radial symmetry, that is, similar shapes as mirror images around a central axis.



•The cell layers include an outer layer of flattened, pore-containing cells, a middle layer of noncellular skeletal elements and amoebocytes, and an inner layer of choanocytes, surrounding an inner chamber.

•Sponges feed when the choanocyte flagella beat, creating a flow of water in through the pores, through the collars, trapping bacteria in mucus, and out through the large, upper opening. The choanocytes then phagocytize the food and package it in vacuoles. Amoebocytes pick up the food vacuoles, digest the food, and carry nutrients to other cells.

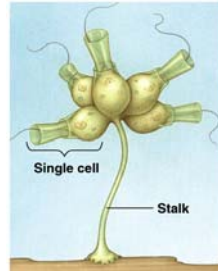


•In addition to digesting and distributing food, amoebocytes also transport oxygen, dispose of waste, and manufacture skeletal elements. Further amoebocytes can change into other cell types.

•Sponges are likely to have been a very early offshoot from the multicellular organisms that gave rise to the animals. Sponges retain several protists characteristics, including not having a digestive tract and having intracellular digestion. Developmentally sponges do not go through a gastrula stage and thus their three cell layers are not homologous to those of other animals. Sponges also lack nerves and muscles.

•Sponges likely descended from choanoflagellates in the late Precambrian. Choanoflagellates are colonial protists composed entirely of collar cells (choanocytes) but, as protists, they do not show cellular differentiation.

## Choanoflagellate Colony



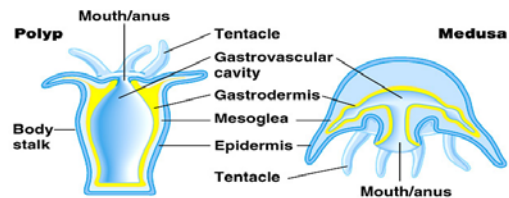
## Cnidarians



### Cnidarians are radial animals with stinging threads

•Cnidarians exhibit radial symmetry.

•These animals may be in the form of a polyp (relatively fixed in position) or a medusa (swimming), or they may alternate between polyp and medusa forms. Both body plans have a central tubular body (surrounding a gastrovascular cavity), one opening ("mouth") into this cavity, and tentacles arranged around the mouth.

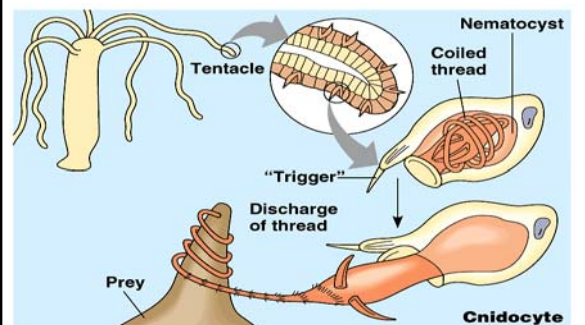


(a) Sea anemone: a polyp



(b) Jelly: a medusa

•Along the tentacles are cnidocytes (stinger cells) that function in defense and the capturing of food. The coiled thread in each cell is discharged, stinging or entangling the prey or predator as it brushes against the cnidocyte.



•Cnidarians trap food with their tentacles, then maneuver it into a gastrovascular cavity where it is digested and distributed throughout the body. Undigested food is eliminated through the mouth.

•Cnidarians are built at the tissue level of construction, with several different cell types arranged in layers and having common functions. Muscle cells are arranged in groups that allow the body to extend, move tentacles, and contract. Nerve tissue coordinates this movement.

•Development includes the gastrula stage, like all the remaining animal phyla.

### Most animals are bilaterally symmetrical

•Bilateral symmetry means that an animal can be divided into mirror images (left and right sides) by a single plane.

•Associated with bilateral symmetry is the division of the animal into head (anterior), tail (posterior), back (dorsal), bottom (ventral), and side (lateral) surfaces.

•The head houses sensory structures and the brain.

•Bilateral animals are fundamentally different from radial animals. In contrast to radial animals that sit or drift passively, bilateral animals actively move through their environment headfirst.

## Flatworms

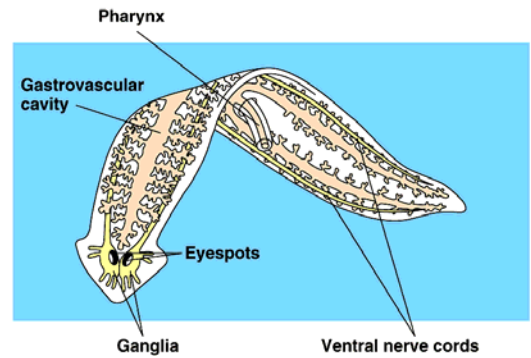


### Flatworms are the simplest bilateral animals

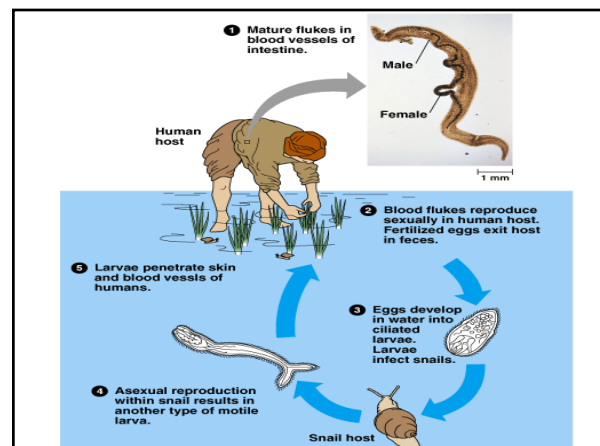
•Flatworms are classified in the phylum *Platyhelminthes*. There are three major groups of flatworms: free-living planarians that live on rocks in marine and fresh water, parasitic flukes, and tape worms.

•Like cnidarians, planarians and most flukes have a gastrovascular cavity and no other body cavities. The body normally has a head end with a concentration of sensory nerves. The mouth opens from the ventral surface, and the gastrovascular cavity runs and branches through the entire length of the body.

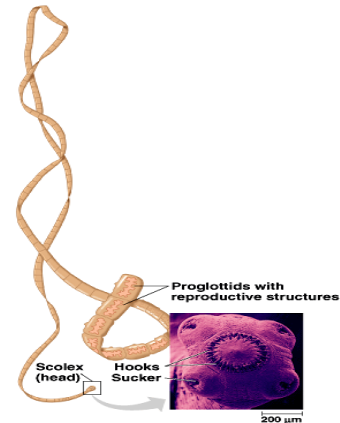
**NOTE:** Flatworms are not quite on the organ level of construction.



•Most **flukes** have a complex life cycle, including reproduction in more than one host and one or more larval stages. *Schistosoma* (blood flukes) adults live and permanently mate inside blood vessels, where they feed on blood. As many as 1000 fertilized eggs a day are produced, and they leave through the host's intestine. The eggs grow into larvae that infect snails. Asexual reproduction in the snail produces different larvae that infect humans.

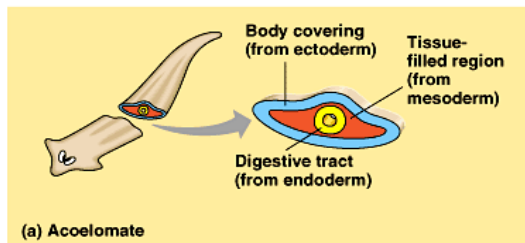


• **Tapeworms** are highly adapted parasites that inhabit the digestive tracts of their hosts. Unlike other flatworms, tapeworms are segmented and lack a gastrovascular cavity, absorbing their predigested food directly. The anterior end attaches to the host with hooks and suckers, and a region behind generates segments. Sexual reproduction occurs in each segment; the oldest segments break off and leave the host via the feces. Many tapeworms produce larvae that infect the prey animal, while the adult tapeworms infect that prey animal's predator.

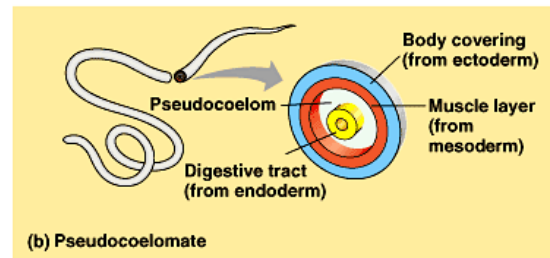


#### Most animals have a body cavity

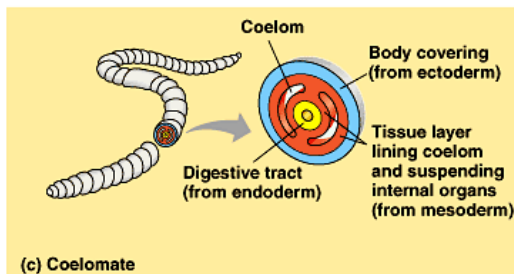
• Depending on how tissue regions develop from the gastrula stage, three body plans exist among animal phyla: (a) The body is solid, except for the gastrovascular cavity (**Acoelomate**), as in flatworms and cnidaria.



(b) The body contains a **pseudocoelom**, an internal space in direct contact with the inner layer of the digestive tract, as in roundworms.



(c) The body contains a **coelom**, an internal space completely lined by tissue of the middle layer, as in all other animals.



• Advantages of having a body cavity include having greater flexibility, cushioning of internal organs, and providing room for internal organ growth.

• In some animals (like earthworms), body cavities under pressure function as a skeleton.

• The fluid in the cavity circulates nutrients and oxygen and aids in waste collection and disposal.



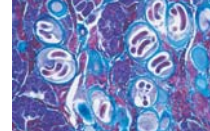
### Roundworms have a pseudocoelom and a complete digestive system

- Roundworms, classified in the phylum *Nematoda*, are numerous and diverse in most environments. Most are important decomposers or parasites of plant or animals.
- The roundworm body is cylindrical, includes a complete intestinal tract, and is covered by a tough, nonliving cuticle.
- Food passes in one direction along a digestive tract that includes regions specialized for certain functions: food intake, breakup, digestion, absorption, and waste elimination.

**Note:** Round worms are tending toward the organ level of construction.



- One free-living species, *Caenorhabditis elegans*, is an important organism for genetic research and one of the best-understood organisms. Researchers have been able to trace the developmental lineage of each of an adult's 1000 cells.
- Trichinosis is a disease caused by the roundworm *Trichinella spiralis*. Humans get this parasite by eating uncooked pork.

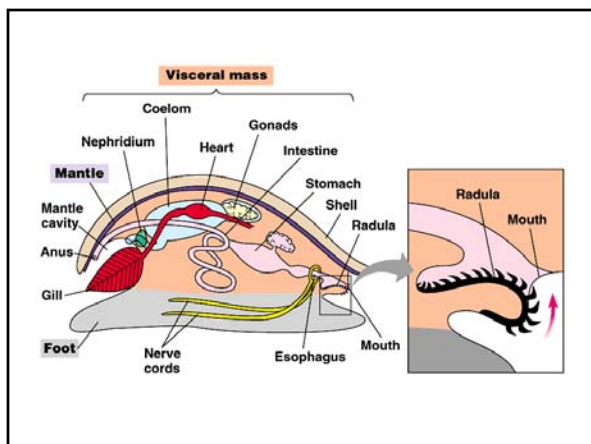


### Diverse mollusks are variations on a common body plan

- Mollusks are classified in the phylum *Mollusca*.
- The basic body plan of a mollusk includes bilateral symmetry, a complete digestive tract, a coelom, and many internal organs.
- Two distinctive characteristics of the phylum are a muscular "foot" and a mantle, an outgrowth of the body surface that drapes over the animal, functions in sensory reception, often secretes a shell, and usually houses gills that function in gas exchange and waste removal.

- Mollusks have a true circulatory system.

- Most have **radula**, an organ used to scrape food, such as algae, off surfaces in the environment.



- Evolution has modified the basic body plan in different groups of mollusks. **Gastropods** include snails and slugs.



- **Bivalves** include clams, scallops, and oysters.



- **Cephalopods** include octopuses and squids.

- Cephalopods have large brains and sophisticated sense organs.



### Most animals have segmented bodies

- Segmentation is the subdivision of the body into repeated parts.

- In an earthworm, the segments are clearly visible from the outside, outlining the repeated pattern of organs inside. The nervous, circulatory, and excretory systems all have repeating, mostly identical parts in each segment.

- In other animals, segmentation may involve fewer segments or be less obvious.

- Advantages of segmentation include greater body flexibility and mobility. For example, in the earthworm, rhythmic alternating contractions and elongations of segments propel the worm into or along the ground. In many animals, the segments are sites of insertion of walking legs or muscles.

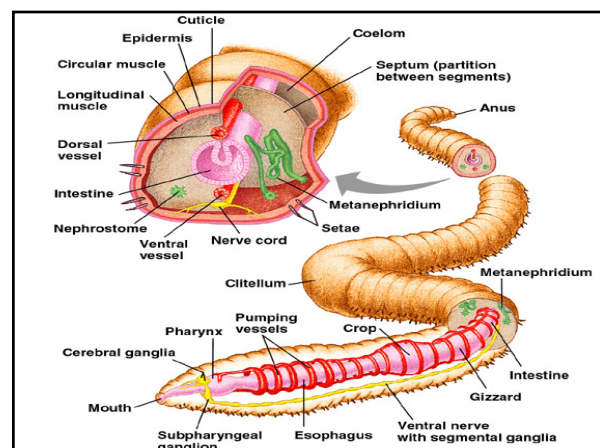
- Genetically speaking, it is easier to build large, complex animal by repeating a single developmental sequence in many smaller units.

- During evolution segments specialized into different functional regions, working from a basic pattern; segments are often fused.

### Earthworms and other annelids are segmented worms

- These worms are in the phylum *Annelida*. They live in the sea, in most freshwater habitats, and in damp soil. Annelids usually have one or more anterior segments specially modified into a head region.

- Earthworms are one group of annelids adapted to life in soil. They consume the soil, digest the organic parts, and eliminate the undigested soil and other waste products in their feces.





• **Polychaete** are mostly marine. They are characterized by segmental appendages with broad paddle like appendages and bristles. Some polychaetes show modification of anterior segments.



• Leeches are free-living carnivores of aquatic animals or blood-sucking parasites non vertebrates. A blood-sucking leech cuts the skin with razor-sharp jaws and secretes an anesthetic and an anticoagulant. Leeches are still used in medicine, and their anticoagulants are being produced by genetic engineering.



**Arthropods are the most numerous and widespread of all animals**

• In terms of diversity, geographical distribution, and sheer numbers, the phylum *arthropoda* is the most successful that has ever lived.

• Based on the presence of Cambrian fossils that display characteristics of both annelids and arthropods, it has been thought that arthropods evolved from annelids or segmented ancestors of annelids.

• Arthropods are segmented (often fused), have jointed appendages, and have an exoskeleton composed of chitin and proteins.

• To grow arthropods molt (ecdysis) their exoskeletons, swell in size, and thicken a new developing exoskeleton.

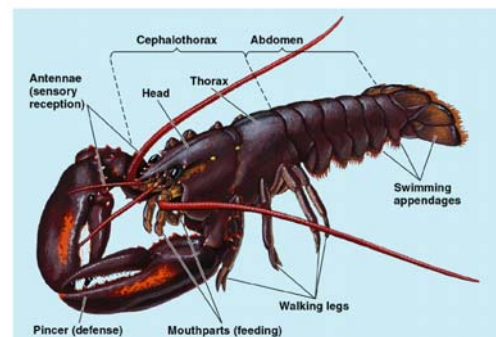
• Horseshoe crabs are "living fossil" life forms that have survived for hundreds of millions of years with little change.



• *Arachnids* include scorpions, spiders, ticks, and mites. Their ancestors were among the first terrestrial carnivores. Except for mites, arachnids are carnivores.



• *Crustaceans* include crabs, shrimps, lobsters, crayfish, and barnacles; they are mostly aquatic.



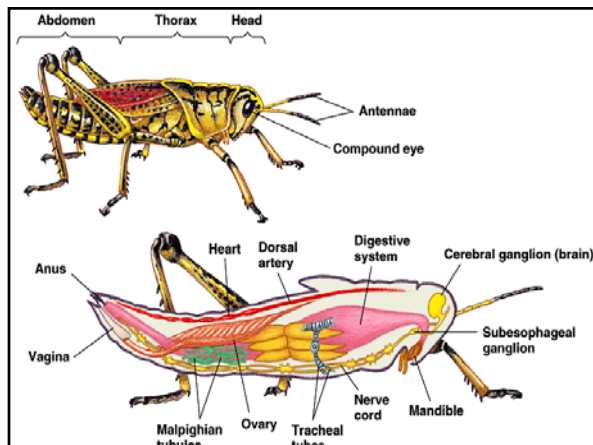
•Millipedes have segments with two pairs of appendages each and feed on decaying plants. Centipedes have segments with one pair of appendages each and are carnivorous. Both groups are terrestrial.



### Insects are the most diverse group of organisms

•About one million insect species are known to biologists, perhaps half of those that exist. They have been important aspects of terrestrial life for 400 million years, but less so in aquatic and, especially marine habitats.

•Insects are united as a group in having a three-part body plan with head, thorax, and abdomen. The head has sensory appendages and mouthparts specialized for a particular diet.



•Metamorphosis is common to many insects. Incomplete metamorphosis (Orthoptera, Odonata, and Hemiptera) results in an adult that resembles the young but are larger and have different proportions.

•Complete metamorphosis (Coleoptera, Lepidoptera, Diptera, Hymenoptera) occurs when a larval form specialized for eating and growing develops into a very different adult form which is specialized for reproduction and dispersal.

•Grasshoppers (order Orthoptera) have biting and chewing mouthparts. Most species are herbivorous (mantids are an exception). They have two pairs of wings.



•Damselflies and dragonflies (order Odonata) have biting mouthparts and are carnivorous. They have two identical pairs of wings.



•True bugs (order Hemiptera) have piercing, sucking mouthparts, and most species feed on plant sap (bed bugs feed on blood). They have two pairs of wings.



•Beetles make up the largest order (Coleoptera) in the animal kingdom, with some 500,000 known worldwide from all types of habitats. They have biting and chewing mouthparts, and are carnivorous, omnivorous, or herbivorous. They have two pairs of wings, and the forewings (elytra) serve as a protective covering for the hindwings.



•Moths and butterflies (order Lepidoptera) are the second most numerous insects. They have drinking-tube mouthparts for sipping nectar or other liquids, and have two pairs of scale-covered wings.



•Flies, gnats, and mosquitoes (order Diptera) have lapping mouthparts and feed on nectar or other liquids (mosquitoes have piercing, sucking mouthparts and suck blood). They have a single pair of functional wings, with the hindwings reduced to halteres to maintain balance.



•Ants, bees, wasps (order Hymenoptera) are the third most numerous insects. They have chewing and sucking mouthparts, and many are herbivorous. They have two pairs of wings. Many in this group display complex behavior and social organization.



Photo by Otto Rogge

**Echinoderms have spiny skin, an endoskeleton, and a water vascular system for movement**

•The phylum *Echinodermata* includes sea stars and sea urchins (all marine) and represents a second branch of evolution in the animal kingdom. Similarities in embryonic development suggest that this phylum is closely related to our own, the phylum *Chordata*.

•Echinoderms lack segmentation and bilateral symmetry as adults, but larvae are bilaterally symmetrical. Members of this phylum are noted for their regenerative capacity. Most have tubular endoskeletons composed of fused plates lying under the skin. Unique to this phylum is the presence of a water vascular system. This network of water-filled canals that branch into extensions called tube feet.

•Sea stars have flexible “arms” that bear the tube feet. They wrap these arms around bivalve prey, pull the valves apart, extrude their stomach out their mouth and into the opening, and digest the soft parts.



•Sea urchins are spherical, with five double rows of tube feet running radially, with which they pull themselves along. They eat seaweeds.



**Our own phylum, *Chordata*, is distinguished by four features**

- A dorsal, hollow nerve cord.
- A notochord: a flexible, longitudinal rod located between the digestive tract and the nerve cord.
- Gill structures (slits and supports) in the pharynx region behind the mouth.
- A post-anal tail.
- The most diverse chordates are vertebrates. However there are several invertebrates in this kingdom.

•**Lancelets** are small, bladelike chordates that live anchored by their tails in marine sands and expose their head and mouths, filtering and trapping organic materials in mucus around the gill slits. These animals show the clearest presentation of the chordate body plan. Molecular indicates that lancelets are the closest living relatives of vertebrates.



•**Tunicates** (sea squirts) are another group of marine chordates. As adults, they do not exhibit the chordate pattern of notochord and nerve cord. As stationary filter feeders, they use gill slits much like lancelets. It is most likely during the Cambrian (500 mya), by paedomorphosis, vertebrates evolved from chordates similar to larval tunicates.



# Vertebrates



### A skull and backbone are hallmarks of vertebrates

- A skull forms a case for the brain.
- A segmented backbone composed of vertebrae encloses the nerve cord.
- Most vertebrates have skeletal support for paired appendages (fins, arms, legs, wings).
- The vertebrate skeleton is an endoskeleton of cartilage or bone. These nonliving materials contain living cells and grow as the animal grows, unlike the exoskeleton of arthropods, which must be molted prior to growth.

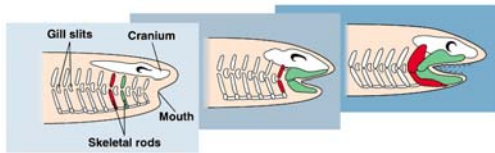
### Most vertebrates have hinged jaws

- One group of vertebrates, the lampreys (class Agnatha), lack jaws but have skeletal supports between gill slits, and they lack paired appendages. Otherwise they are superficially similar to fishes. Most are parasites on fish, boring a hole in the host and sucking its blood.



- Jaws evolved from modification of the first two pairs of skeletal supports of the gill slits. Similar events occur during the embryonic development of all fishes today.

- The oldest fossils of jawed vertebrates appear in rocks that were formed 450 mya. Jaws enable the vertebrates to catch and consume a wider variety of foods than were available to filter feeders.



### Fishes are jawed vertebrates with gills and paired fins

- Fish extract oxygen from water with their gills. Their paired fins help stabilize their bodies.
- The cartilaginous fishes (class Chondrichthyes) include sharks and rays and have skeletons of flexible cartilage. Sharks have a keen sense of smell and can sense minute vibrations with a pressure-sensitive lateral line system. Because they cannot pump water through their gills, they must swim in order to move the water.



- Bony fishes (class Osteichthyes) are more common and diverse and have a stiff skeleton of bone reinforced by hard calcium salts. Like sharks they have a keen sense of smell and a lateral line system. In addition they have a keen sense of sight, and a bony flap over the gills helps move water through the gills when the fish is stationary.



- Bony fish also have a swim bladder that can act as a buoyant counter balance to their heavier bones. Sometimes this is connected to the digestive tract, enabling some species to gulp air to increase oxygen intake.

- Bony fish, the largest class of vertebrates, are divided into two groups, the ray-finned fish and the lobe-finned fish. The fins of ray-finned fishes are supported by thin flexible skeletal rays. The fins of lobed finned fishes are muscular and supported by bones.





### Amphibians were the first land vertebrates

- Amphibians include frogs, toads, and salamanders.
- Most amphibians are tied to water because their eggs and larvae (tadpoles) develop there.
- Tadpoles are aquatic, legless scavengers with gills, a tail, and a lateral line system.
- They undergo a radical metamorphosis to change into an adult that is often a terrestrial hunter, with paired legs, external eardrums, air-breathing lungs, and no lateral line.

•Amphibians evolved about 400 mya from either lobe-finned fishes or lung-fishes. Structurally, ancestral lobe-finned fishes have strong fins, which may have been used to wriggle over mud flats. And saclike lungs (and gills). Molecular evidence indicates that ancestral lungfishes, which also have saclike lungs, gave rise to the first land vertebrates.

•Early amphibians thrived on insects and other invertebrates in coal-producing forests of the Carboniferous period. This period is known as the Age of Amphibians.

### Reptiles have more terrestrial adaptations than do amphibians

- Reptiles include snakes, lizards, turtles, and crocodilians.
- Reptiles have skin protected with protein (keratin), eggs with coatings that retain water, an internal fluid sac (amnion) that bathes the embryo, a food supply (yolk). The young hatches as juveniles, bypassing the need for free-living larvae.
- Most modern reptiles are ectothermic. They warm by absorbing external heat rather than generating much of their own metabolic heat.

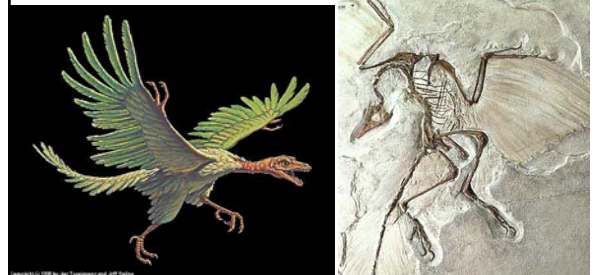
•Following the decline of prehistoric amphibians, reptilian lineages expanded and dominated Earth during the Age of Reptiles (200-65mya). The dinosaurs may have been endothermic.

•When dinosaurs died off ≈65 mya, one line survived and evolved into birds.

### Birds share many features with their reptilian ancestors

- Birds ( class Aves) have amniotic eggs, scales on their legs, and a reptilian body form. They evolved from one line of dinosaurs 150-200 mya.
- Feathers, the most distinctive characteristic of birds, are derived from scales. Feathers that shape bird wings are into airfoils that create lift and enable birds to maneuver in the air.

•*Archaeopteryx* is an extinct bird, with feathers and characteristics of bipedal dinosaurs such as teeth, claws, and a tail with many vertebrae. With its heavy body *Archaeopteryx* is more likely to have been a glider than a flier. *Archaeopteryx* is not the ancestor of modern birds.



- Many bird groups became extinct about 65 mya, along with the rest of the dinosaurs. Thus the bird lineages appear to have gone through a bottleneck about 65 mya (mass extinction) and modern birds evolved from a very few surviving groups.

- Modern birds have additional adaptations for flight, including an absence of teeth, no claws on their wings, very short tailbones, hollow bones, large breast muscles, efficient lungs, and an extremely high rate of metabolism to provide energy.

#### Mammal evolved from reptiles

- Mammals evolved from early reptiles, about 225 mya, but were minor parts of habitats during the age of reptiles. Once the dinosaurs died off, the mammalian lineages underwent adaptive radiation.

- Most mammals are terrestrial, with a number of winged and totally aquatic species. The largest animal that has ever existed is the blue whale, a species that can reach 30 m in length.

- Mammals are endothermic, and they have hair and mammary glands.

- The **monotremes**, such as the platypus, are egg-laying mammals that live in Australia and Tasmania.



- The marsupials, such as the American opossum and the kangaroo, give birth to embryonic young that complete development in the mother's pouch. Most marsupials live in Australia, on neighboring islands, and in Central and South America.

**NOTE:** Both groups evolved in isolation from other mammals in areas that were part of the Pangaeon supercontinent Gondwana.

- The **eutherians** (placentals) include nearly 95% of all mammalian species. Their embryos are nurtured inside the mother by a placenta, an organ that includes both maternal and embryonic vascular tissue.

- Humans are eutherian mammals belonging to the order Primates

#### A phylogenetic family tree gives animal diversity an evolutionary perspective

- Colonial protists were ancestors of the animal kingdom.

- Sponges may be a separate line of evolution, or a very early side lineage.

- Two-lines of tissue level animals evolved: those with pseudocoeloms, represented by roundworms, and those with coeloms, the most primitive of these represented by mollusks.

•Among coelomate animals, two-lines evolved: those whose coeloms developed from hollow outgrowths of the digestive tube, the echinoderms and chordates (deuterostomes); and those whose coelom develops from solid masses of cells, the mollusks, annelids, and arthropods (protostomes).

•Echinoderms which are not segmented, and chordates may have diverged prior to segmentation; or segmentation may have been lost in the echinoderms as they evolved radial symmetry.

•Likewise, segmentation may have evolved in annelids and arthropods after the mollusks diverged; or segmentation may have been lost during the evolution of the mollusk lineage.

•Segmentation itself may have evolved independently in deuterostomes and protostome lineages.