<u>Adv. Biology: Classification Unit Study Guide</u>

- Chapter 17 and 24.1-24.2
- All notes/handouts/activities from class
- Early taxonomists: Aristotle/Linnaeus
  - Aristotle (394-32 B.C.) – a Greek Philosopher, who over two thousand years ago developed the first widely accepted system of biological classification. Aristotle classified organisms as either animals or plants. Animals were classified according to the presence or absence of "red blood." Aristotle's "bloodless" and "red-blooded" animals nearly match the modern distinction of invertebrates and vertebrates. Animals were further grouped according to their habitats and morphology. Plants were classified by average size and structure as trees, shrubs, or herbs. The table shows how Aristotle might have divided some of his groups.

Table 17.1 Aristotle's Classification System

Concepts In Motion — Interactive Table To explore more about classification systems, visit biologygmh.com.

Plants		
Herbs	**Shrubs**	**Trees**
Violets Rosemary Onions	Blackberry bush Honeysuckle Flannelbush	Apple Oak Maple
Animals with red blood		
Land	**Water**	**Air**
Wolf Cat Bear	Dolphin Eel Sea bass	Owl Bat Crow

Aristotle's system was useful for organizing, but it had many limitations. Aristotle's system was based on his view that species are distinct, separate, and unchanging. The idea that species are unchanging was common until Darwin presented his theory of evolution. Because of his understanding of species, Aristotle's classification did not account for evolutionary relationships. Additionally, many organisms do not fit easily into Aristotle's system, such as birds that don't fly or frogs that live both on land and in water. Nevertheless, many centuries passed before Aristotle's system was replaced by a new system that was better suited to the increased knowledge of the natural world.

- Carolus Linnaeus (1707-1778)– An eighteen century Swedish naturalist who broadened Aristotle's classification method and formalized it into a scientific system. Like Aristotle, he based his system on observational studies of the morphology and the behavior of organisms. For example, he organized birds into three major groups depending on their behavior and habitat. The birds in Figure 17.1 illustrate these categories. The eagle is classified as a bird of prey, the heron as a wading bird, and the cedar waxwing is grouped with the perching birds.

tific name that has two parts. The first part is the genus (JEE nus) name, and the second part is the specific epithet (EP uh thet), or specific name, that identifies the species. Latin is the basis for binomial nomenclature because Latin is an unchanging language, and, historically, it has been the language of science and education.

■ **Figure 17.1** Linnaeus would have classified these birds based on their morphological and behavioral differences.
Infer ***In what group might Linnaeus have placed a robin?***

American bald eagle
Bird of prey

Great blue heron
Wading bird

Cedar waxwing
Perching bird

- Classification/taxonomy
  - Classification – the grouping of objects or organisms based on a set of criteria.
  - Taxonomy – a disciplined of biology primarily concerned with identifying, naming, and classifying species based on natural relationships. Taxonomy is part of the larger branch of biology called systematics. Systematics is the study of biological diversity with an emphasis on evolutionary history. Linnaeus's system of classification was the first formal system of taxonomic organization.
- Binomial Nomenclature – gives each species a scientific name that has two parts. The first part is the genus name, and the second part is the specific epithet, or specific name , that identifies the species (common name).
  - Greek/Latin – Latin is the basis for binomial nomenclature because Latin is an unchanging language, and, historically, it has been the language of science and education.
  - Rules for writing – see below
  - Explain scientific names – see below

Biologists use scientific names for species because common names vary in their use. Many times the bird shown in **Figure 17.2** is called a redbird, sometimes it is called a cardinal, and other times it is called a Northern cardinal. In 1758, Linnaeus gave this bird its scientific name, *Cardinalis cardinalis*. The use of scientific names avoids the confusion that can be created with common names. Binomial nomenclature also is useful because common names can be misleading. If you were doing a scientific study on fish, you would not include starfish in your studies. Starfish are not fish. In the same way, great horned owls do not have horns and sea cucumbers are not plants.

When writing a scientific name, scientists follow these rules.

- The first letter of the genus name always is capitalized, but the rest of the genus name and all letters of the specific epithet are lowercase.
- If a scientific name is written in a printed book or magazine, it should be italicized.
- When a scientific name is written by hand, both parts of the name should be underlined.
- After the scientific name has been written completely, the genus name often will be abbreviated to the first letter in later appearances. For example, the scientific name of *Cardinalis cardinalis* can be written *C. cardinalis*.

- Benefits of classification

Modern classification systems The study of evolution in the 1800s added a new dimension to Linnaeus's classification system. Many scientists at that time, including Charles Darwin, Jean-Baptiste Lamarck, and Ernst Haekel, began to classify organisms not only on the basis of morphological and behavioral characteristics. They also included evolutionary relationships in their classification systems. Today, while modern classification systems remain rooted in the Linnaeus tradition, they have been modified to reflect new knowledge about evolutionary ancestry.

- Classification groups – The taxonomic categories used by scientists are part of a nested-hierarchal system-each category is contained within another, and they are arranged from broadest to most specific.

Species and genus A named group of organisms is called a **taxon** (plural, taxa). Taxa range from having broad diagnostic characteristics to having specific characteristics. The broader the characteristics, the more species the taxon contains. One way to think of taxa is to imagine nesting boxes—one fitting inside the other. You already have learned about two taxa used by Linnaeus—genus and species. Today, a **genus** (plural, genera) is defined as a group of species that are closely related and share a common ancestor.

Note the similarities and differences among the three species of bears in **Figure 17.3.** The scientific names of the American black bear *(Ursus americanus)* and Asiatic black bear *(Ursus thibetanus)* indicate that they belong to the same genus, *Ursus.* All species in the genus *Ursus* have massive skulls and similar tooth structures. Sloth bears *(Melursus ursinus),* despite their similarity to members of the genus *Ursus,* usually are classified in a different genus, *Melursus,* because they are smaller, have a different skull shape and size, and have two fewer incisor teeth than bears of the genus *Ursus.*

Family All bears, both living and extinct species, belong to the same family, Ursidae. A **family** is the next higher taxon, consisting of similar, related genera. In addition to the three species shown in **Figure 17.3,** the Ursidae family contains six other species: brown bears, polar bears, giant pandas, Sun bears, and Andean bears. All members of the bear family share certain characteristics. For example, they all walk flatfooted and have forearms that can rotate to grasp prey closely.

grasp prey closely.

Figure 17.3 All species in the genus *Ursus* have large body size and massive skulls. Sloth bears are classified in the genus *Melursus*.

Ursus americanus **American black bear**

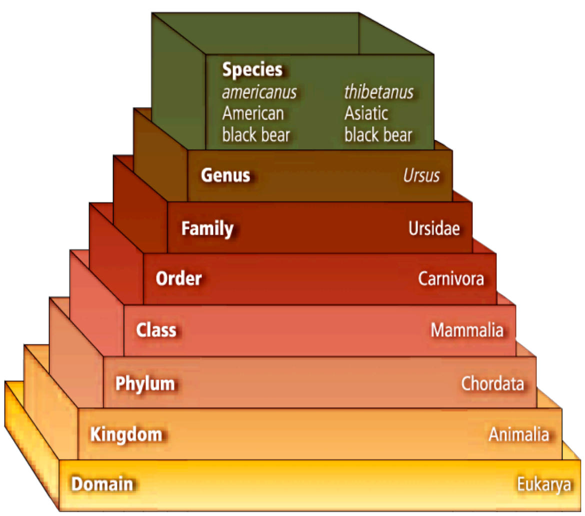
Ursus thibetanus **Asiatic black bear**

Melursus ursinus **Sloth bear**

Higher taxa An **order** contains related families. A **class** contains related orders. The bears in **Figure 17.3** belong to the order Carnivora and class Mammalia. A **phylum** (FI lum) (plural, phyla) or **division** contains related classes. The term *division* is used instead of *phylum* for the classification of bacteria and plants. Sometimes scientists break the commonly used taxa into subcategories, such as subspecies, subfamilies, infraorders, and subphyla.

The taxon composed of related phyla or divisions is a **kingdom**. Bears are classified in phylum Chordata, Kingdom Animalia, and Domain Eukarya. The **domain** is the broadest of all the taxa and contains one or more kingdoms. The basic characteristics of the three domains and six kingdoms are described later in this chapter.

Figure 17.4 shows how the taxa are organized into a hierarchical system. The figure also shows the complete classification from domain to species for the American black bear and the Asiatic black bear. Notice that although these bears are classified as different species, the rest of their classification is the same.



- Order of hierarchy -
- Taxa: domain, kingdom, phylum, class, order, family, genus, species
    - Evolutionary relationships that determine classification groups

- Phylogeny – the evolutionary history of a species.

Phylogenetic species concept In the 1940s, the evolutionary species concept was proposed as a companion to the biological species concept. The evolutionary species concept defines species in terms of populations and ancestry. According to this concept, two or more groups that evolve independently from an ancestral population are classified as different species. More recently, this concept has developed into the phylogenetic species concept. **Phylogeny** (fi LAH juh nee) is the evolutionary history of a species. The phylogenetic species concept defines a species as a cluster of organisms that is distinct from other clusters and shows evidence of a pattern of ancestry and descent. When a phylogenetic species branches, it becomes two different phylogenetic species. For example, recall from Chapter 15 that when organisms become isolated—geographically or otherwise—they often evolve different adaptations. Eventually they might become different enough to be classified as a new species.

This definition of a species solves some of the problems of earlier concepts because it applies to extinct species and species that reproduce asexually. It also incorporates molecular data. **Table 17.2** summarizes the three main species concepts.

Concepts in Motion

Interactive Table To explore more about species concepts, visit biologygmh.com.

Table 17.2 Species Concepts

Species Concept	Description	Limitation	Benefit
Typological species concept	Classification is determined by the comparison of physical characteristics with a type specimen.	Alleles produce a wide variety of features within a species.	Descriptions of type specimens provide detailed records of the physical characteristics of many organisms.
Biological species concept	Classification is determined by similar characteristics and the ability to interbreed and produce fertile offspring.	Some organisms, such as wolves and dogs that are different species, interbreed occasionally. It does not account for extinct species.	The working definition applies in most cases, so it is still used frequently.
Phylogenetic species concept	Classification is determined by evolutionary history.	Evolutionary histories are not known for all species.	Accounts for extinct species and considers molecular data.

- Cladistics – The most common systems of classification today are based on a method of analysis called cladistics. Cladistics is a method that classifies organisms according to the order that they diverged from a common ancestor.

Character types Scientists consider two main types of characters when doing cladistic analyses. An ancestral character is found within the entire line of descent of a group of organisms. Derived characters are present members of one group of the line but not in the common ancestor. For example, when considering the relationship between birds and mammals, a backbone is an ancestral character because both birds and mammals have a backbone and so did their shared ancestor. However, birds have feathers and mammals have hair. Therefore, having hair is a derived character for mammals because only mammals have an ancestor with hair. Likewise, having feathers is a derived character for birds.

- Cladograms – a branching diagram that represents the proposed phylogeny or evolutionary history of a species or group.

Cladograms Sytematists use shared derived characters to make a cladogram. A **cladogram** (KLAD uh gram) is a branching diagram that represents the proposed phylogeny or evolutionary history of a species or group. A cladogram is a model similar to the pedigrees you studied in Chapter 11. Just as a pedigree's branches show direct ancestry, a cladogram's branches indicate phylogeny. The groups used in cladograms are called clades. A clade is one branch of the cladogram.

Constructing a cladogram **Figure 17.11** is a simplified cladogram for some major plant groups. This cladogram was constructed in the following way. First, two species were identified, conifers and ferns, to compare with the lily species. Then, another species was identified that is ancestral to conifers and ferns. This species is called the outgroup. The outgroup is the species or group of species on a cladogram that has more ancestral characters with respect to the other organisms being compared. In the diagram below, the outgroup is moss. Mosses are more distantly related to ferns, conifers, and lilies.

The cladogram is then constructed by sequencing the order in which derived characters evolved with respect to the outgroup. The closeness of clades in the cladogram indicate the number of characters shared. The group that is closest to the lily shares the most derived characters with lilies and thus shares a more recent common ancestor with lilies than with the groups farther away. The nodes where the branches originate represent a common ancestor. This common ancestor generally is not a known organism, species, or fossil. Scientists hypothesize its characters based on the traits of its descendants.

The primary assumption The primary assumption that systematists make when constructing cladograms is that the greater the number of derived characters shared by groups, the more recently the groups share a common ancestor. Thus, as shown in **Figure 17.11,** lilies and conifers have three derived characters in common and are presumed to share a more recent common ancestor than lilies and ferns, which share only two characters.

A cladogram also is called a phylogenetic tree. Detailed phylogenetic trees show relationships among many species and groups of organisms. **Figure 17.12** illustrates a phylogenetic tree that shows the relationships among the domains and kingdoms of the most commonly used classification system today.

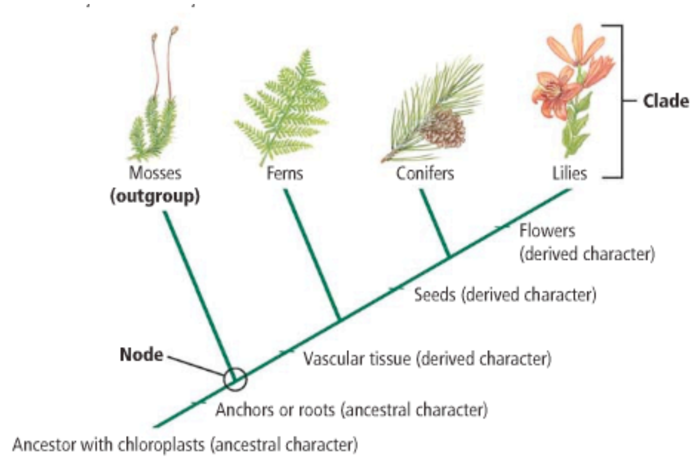


Figure 17.11 This cladogram uses the derived characters of plant taxa to model its phylogeny. Groups that are closer to the lily on the cladogram share a recent common ancestor.
Identify ***which clades have chloroplasts but do not produce seeds.***

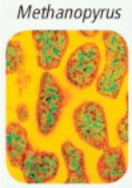
Concepts In Motion

Interactive Figure To see an animation of the cladistic method of classification, visit biologygmh.com.

- Dichotomous Keys – consists of a series of choices that lead the used to the correct identification of an organisms. Scientists group organisms based on their characteristics. These groups are the basis for classification tools called dichotomous keys.
- 3 Domains and examples – **See pages 1119-1123**
    - Domain Bacteria
    - Kingdom Achaea
    - Kingdom Eukarya
- 6 Kingdoms

Table 17.3 **Kingdom Characteristics**

Concepts in Motion Interactive Table To explore more about the six kingdoms, visit biologygmh.com.

Domain	Bacteria	Archaea	Eukarya			
Kingdom	Bacteria	Archaea	Protista	Fungi	Plantae	Animalia
Example	*Pseudomonas*  SEM Magnification: 5500×	*Methanopyrus*  TEM Magnification: 25,000×	*Paramecium*  LM Magnification: 150×	Mushroom 	Moss 	Earthworm 
Cell type	Prokaryote		Eukaryote			
Cell walls	Cell walls with peptidoglycan	Cell walls without peptidoglycan	Cell walls with cellulose in some	Cell walls with chitin	Cell walls with cellulose	No cell walls
Number of cells	Unicellular		Unicellular and multicellular	Most multicellular	Multicellular	
Nutrition	Autotroph or heterotroph			Heterotroph	Autotroph	Heterotroph

Domain Bacteria

Connection to Chemistry Bacteria, members of Domain and Kingdom Bacteria, are prokaryotes whose cell walls contain peptidoglycan (pep tih doh GLY kan). Peptidoglycan is a polymer that contains two kinds of sugars that alternate in the chain. The amino acids of one sugar are linked to the amino acids in other chains, creating a netlike structure that is simple and porous, yet strong. Two examples of bacteria are shown in **Figure 17.14.**

Figure 17.14 Bacteria vary in their habitats and their methods of obtaining nourishment. The bacteria *Mycobacterium tuberculosis* that cause tuberculosis are heterotrophs. Cyanobacteria, such as *Anabaena*, are autotrophs.

Color-Enhanced SEM Magnification: 15,000×

Mycobacterium tuberculosis

LM Magnification: 450×

Anabaena

Bacteria are a diverse group that can survive in many different environments. Some are aerobic organisms that need oxygen to survive, while others are anaerobic organisms that die in the presence of oxygen. Some bacteria are autotrophic and produce their own food, but most are heterotrophic and get their nutrition from other organisms. Bacteria are more abundant than any other organism. There are probably more bacteria in your body than there are people in the world. You can view some different types of bacteria in **MiniLab 17.2.**

Domain Archaea

Archaea (ar KEE uh), the species classified in Domain Archaea, are thought to be more ancient than bacteria and yet more closely related to eukaryote ancestors. Their cell walls do not contain peptidoglycan, and they have some of the same proteins that eukaryotes do. They are diverse in shape and nutrition requirements. Some are autotrophic, but most are heterotrophic. Archaea are called extremophiles because they can live in extreme environments. They have been found in boiling hot springs, salty lakes, thermal vents on the ocean's floor, and in the mud of marshes where there is no oxygen. The archaea *Staphylothermus marinus*, shown in **Figure 17.15,** is found in deep ocean thermal vents and can live in water temperatures up to 98°C.

  - Know differences between eubacteria and archeabacteria (especially where they live!) - archeabacteria live in extreme environments, while most eubacteria don't
  - Identify the kingdom the organism is from
- 6 Kingdoms and examples, cell walls/cell types/prokaryotic/eukaryotic/mode of nutrition/environments that they live in – **see above**
- Germ Layers: endo, ecto and mesoderm

Early development In most animals, the zygote undergoes mitosis and a series of cell divisions to form new cells. After the first cell division, in which the zygote forms two cells, the developing animal is called an embryo. The embryo continues to undergo mitosis and cell division, forming a solid ball of cells. These cells continue to divide, forming a fluid-filled ball of cells called the **blastula** (BLAS chuh luh), as shown in **Figure 24.5.** During these early stages of development, the number of cells increases, but the total amount of cytoplasm in the embryo remains the same as that in the original cell. Therefore, the total size of the embryo does not increase during early development.

In animals such as lancelets, the outer blastula is a single layer of cells, while in animals such as frogs, there might be several layers of cells surrounding the fluid. The blastula continues to undergo cell division. Some cells move inward to form a **gastrula** (GAS truh luh)—a two-cell-layer sac with an opening at one end. A gastrula looks like a double bubble—one bubble inside another bubble.

Look again at **Figure 24.5.** Notice how the diagrams of the two-cell

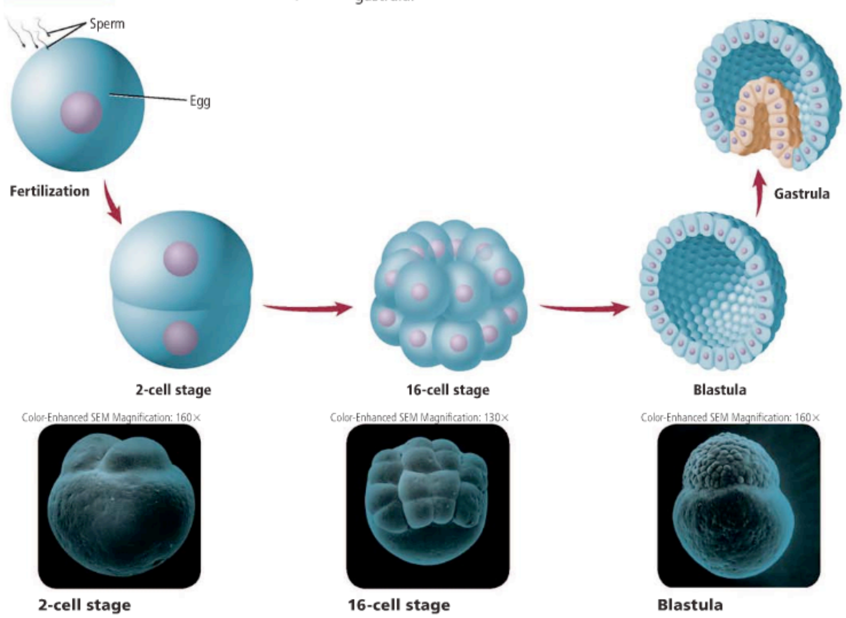
Look again at **Figure 24.5.** Notice how the diagrams of the two-cell
stage, the 16-cell stage, and the blastula differ from the photographs of these same stages. The diagrams illustrate early development in embryos that develop inside the adult animal. The photographs illustrate early development in embryos that develop outside of the adult animal. The large ball that does not divide is the yolk sac. It provides food for the developing embryo.

Reading Check **Explain** the differences between the blastula and the gastrula.

Figure 24.5 The fertilized eggs of most animals follow a similar pattern of development. Beginning with one fertilized egg cell, cell division occurs and a gastrula is formed.

Concepts In Motion

Interactive Figure To see the development of a zygote into specialized cells, visit biologygmh.com.



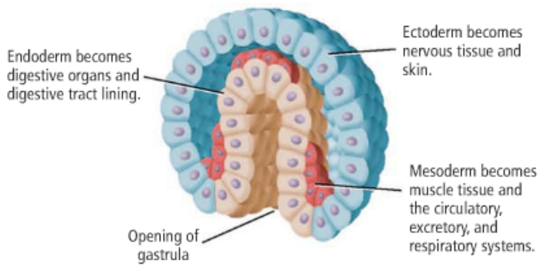


Figure 24.6 As development continues, each cell layer differentiates into specialized tissues.

Tissue development Notice in **Figure 24.6** that the inner layer of cells in the gastrula is called the **endoderm.** The endoderm cells develop into the digestive organs and the lining of the digestive tract. The outer layer of cells in the gastrula is called the **ectoderm.** The ectoderm cells in the gastrula continue to grow and become the nervous tissue and skin.

Cell division in some animals continues in the gastrula until another layer of cells, called the **mesoderm,** forms between the endoderm and the ectoderm. In some animals, the mesoderm forms from cells that break away from the endoderm near the opening of the gastrula. In more highly evolved animals, the mesoderm forms from pouches of endoderm cells on the inside of the gastrula. As development continues, mesoderm cells become muscle tissue, the circulatory system, the excretory system, and, in some species of animals, the respiratory system.

Recall from Chapter 12 that Hox genes might be expressed in ways that give proteins new properties that cause variations in animals. Much of the variation in animal bodies is the result of changes in location, number, or time of expression of Hox developmental genes during the course of tissue development.

LAUNCH Lab

Review Based on what you've read about animal characteristics, how would you now answer the analysis questions?

- Body Cavities: coelomate, acoelomate, pseudocoelomates

Body Cavities

In order to understand the next branching point on the evolutionary tree, it is important to know about certain features of animals with bilateral symmetry. Body plans of animals with bilateral symmetry include the gut, which is either a sac inside the body or a tube that runs through the body, where food is digested. A saclike gut has one opening—a mouth—for taking in food and disposing of wastes. A tube-like gut has an opening at both ends—a mouth and an anus—and is a complete digestive system that digests, absorbs, stores, and disposes of unused food.

Coelomates Between the gut and the outside body wall of most animals with bilateral symmetry is a fluid-filled body cavity. One type of fluid-filled cavity, the **coelom** (SEE lum), shown in **Figure 24.10,** has tissue formed from mesoderm that lines and encloses the organs in the coelom. You have a coelom, as do insects, fishes, and many other animals, therefore, you are a coelomate. The coelom was a key adaptation in the evolution of larger and more specialized body structures. Specialized organs and body systems that formed from mesoderm developed in the coelom. As more efficient organ systems evolved, such as the circulatory system and muscular system, animals could increase in size and become more active.

Pseudocoelomates Follow the body cavity branch on the evolutionary tree in **Figure 24.8** until you come to the pseudocoelomates—animals with pseudocoeloms. A **pseudocoelom** (soo duh SEE lum) is a fluid-filled body cavity that develops between the mesoderm and the endoderm rather than developing entirely within the mesoderm as in coelomates. Therefore, the pseudocoelom, as shown in **Figure 24.10,** is lined only partially with mesoderm. The body cavity of pseudocoelomates separates mesoderm and endoderm, which limits tissue, organ, and system development.

Acoelomates Before the body cavity branch on the evolutionary tree in **Figure 24.8,** notice that the branch to the left takes you to the acoelomate animals. **Acoelomates** (ay SEE lum ayts), such as the flatworm in **Figure 24.10,** are animals that do not have a coelom. The body plan of acoelomates is derived from ectoderm, endoderm, and mesoderm—the same as in coelomates and pseudocoelomates. However, acoelomates have solid bodies without a fluid-filled body cavity between the gut and the body wall. Nutrients and wastes diffuse from one cell to another because there is no circulatory system.

Personal Tutor

To learn about body cavities, visit biologygmh.com.

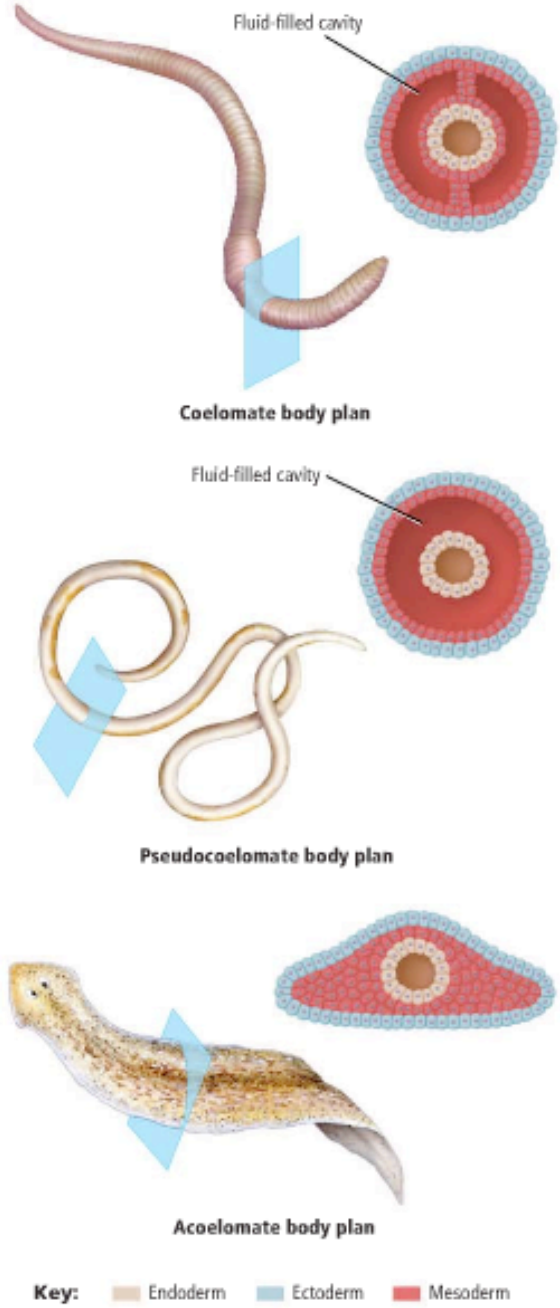
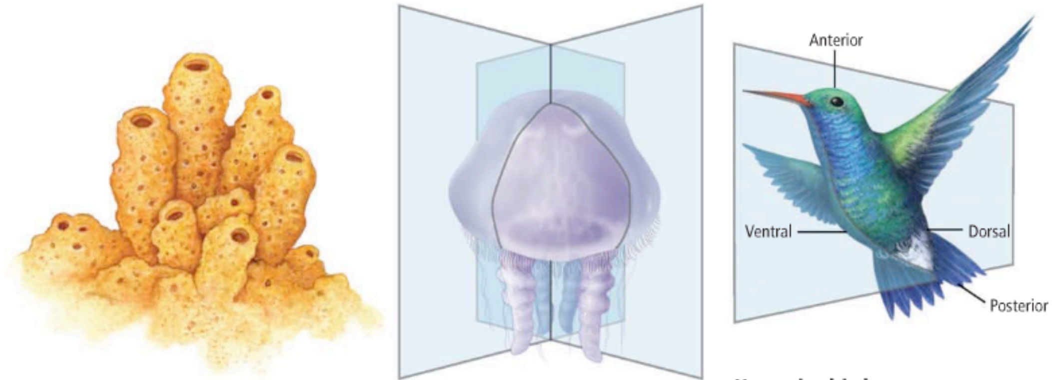


Figure 24.10 An earthworm has a coelom, a fluid-filled body cavity surrounded completely by mesoderm. The pseudocoelom of a roundworm develops between the mesoderm and endoderm. A flatworm has a solid body without a fluid-filled cavity.

• Symmetry: radial, bilateral, asymmetrical



Sponge—asymmetry **Jellyfish—radial symmetry** **Hummingbird—bilateral symmetry**

Figure 24.9 Animals have different arrangements of body structures. The sponge has an irregular shape and is asymmetrical. The jellyfish has radial symmetry, and the hummingbird has bilateral symmetry.
List *objects you see in the room that have bilateral symmetry.*

Personal Tutor
To learn about symmetry, visit biologygmh.com.

Symmetry

Move along the tissue branch on the evolutionary tree in **Figure 24.8** and you will find the next branching point to be symmetry. **Symmetry** (SIH muh tree) describes the similarity or balance among body structures of organisms. The type of symmetry an animal has enables it to move in certain ways.

Asymmetry The sponge in **Figure 24.9** has no tissue and has asymmetry—it is irregular in shape and has no symmetry or balance in its body structures. In contrast, animals with tissues have either radial or bilateral symmetry.

Radial symmetry An animal with **radial** (RAY dee uhl) **symmetry** can be divided along any plane, through a central axis, into roughly equal halves. The jellyfish in **Figure 24.9** has radial symmetry. Its tentacles radiate from its mouth in all directions—a body plan adapted to detecting and capturing prey moving in from any direction. Jellyfishes and most other animals with radial symmetry develop from only two embryonic cell layers—the ectoderm and the endoderm.

Bilateral symmetry The bird in **Figure 24.9** has bilateral symmetry. In contrast to radial symmetry, **bilateral** (bi LA tuh rul) **symmetry** means the animal can be divided into mirror image halves only along one plane through the central axis. All animals with bilateral symmetry develop from three embryonic cell layers—the ectoderm, the endoderm, and the mesoderm.

Cephalization Animals with bilateral symmetry also have an **anterior,** or head end, and a **posterior,** or tail end. This body plan is called **cephalization** (sef uh luh ZA shun)—the tendency to concentrate nervous tissue and sensory organs at the anterior end of the animal. Most animals with cephalization move through their environments with the anterior end first, encountering food and other stimuli. In addition to cephalization, animals with bilateral symmetry have a **dorsal** (DOR sul) surface, also called the backside, and a **ventral** (VEN trul) surface, also called the underside or belly.