Biological Diversity

Review

In **taxonomy,** organisms are classified into categories called **taxa** (singular, **taxon**). A **species** is given a name consisting of a species name and a **genus** (plural, **genera**) name. For example, the domesticated dog is categorized into the genus *Canis* and is given the name *Canis familiaris.* Closely related animals are grouped in the same genus. Thus, the wolf, *Canis lupis,* and the coyote, *Canis latrans,* share the same genus with the domesticated dog. Genera that share related features are grouped in a **family.** Related families, in turn, are grouped in **orders,** which are grouped successively in **classes, phyla** (singular, **phylum**) (or **divisions** for fungi and plants), **kingdoms,** and finally, **domains.** A good way to remember the successional order of taxa is to remember the phrase "Dumb Kings Play Chess On Fine Green Sand," in which each word gives the first letter of each taxon from kingdom to species.

To prepare for the AP exam, you should not be concerned with knowing which organism is placed into which taxon. Rather, you need to know the important characteristics that define a particular taxon. These are the characteristics used to put a particular organism into a particular taxon and thus describe features that are common to all the organisms within a taxon. A major goal of classification is to organize taxa on the basis of **phylogeny,** or evolutionary relationships. Thus, by knowing the characteristics that define organisms within a taxon, you are aware of the evolutionary relationships among these organisms. The study of the evolutionary relationships among organisms is called **systematics.**

All living things consist of one or more cells. All cells have a plasma membrane, genetic material in the form of DNA, and a mechanism, using RNA and ribosomes, for translating the genetic material into proteins and enzymes. The classification of living things begins with a description of two kinds of cells, as follows.

1. **Eukaryotic cells** (eukaryotes) have the following characteristics.
   - Chromosomes consist of a very long, linear DNA molecule package with histone proteins.
   - The chromosomes are enclosed in a nucleus.
   - Specialized membrane-enclosed bodies serve to isolate metabolic activities. These bodies, or **organelles**, include mitochondria, chloroplasts, the endoplasmic reticulum, and the Golgi apparatus.
   - Flagella and cilia, when present, are made of the protein tubulin arranged in "9 + 2" microtubule arrays.
2. **Prokaryotic cells** (prokaryotes) have the following characteristics.
   - There is a single chromosome consisting of a short, circular DNA molecule. Histone proteins may or may not be present. In addition, some cells contain **plasmids**, smaller circular DNA molecules, in addition to the major chromosome.
   - There is no nucleus.
   - There are no organelles, although various membranes might serve similar functions.
   - Flagella, when present, consist of the globular protein **flagellin**.

Before a review of the major features of various taxa, it is important to know the various methods that organisms use to obtain energy. For many organisms, especially the prokaryotes, their method of energy acquisition is an important descriptive tool. There are two basic methods, as follows.

1. **Autotrophs** manufacture their own organic molecules. To do this, **photoautotrophs** use light energy (as in photosynthesis) and **chemoautotrophs** use energy obtained from inorganic substances (as in chemosynthesis). Examples of inorganic substances used by chemoautotrophs are hydrogen sulfide (H_2S), ammonia (NH_3), and other nitrogen compounds (NO_2^-, NO_3^-).
2. **Heterotrophs** must obtain their energy by consuming organic substances produced by autotrophs. Some heterotrophic organisms are **parasites**, obtaining their energy from the living tissues of a host. Others are **saprobes** (or **saprophytes**), obtaining their energy from dead, decaying matter. Since saprobes contribute to the decay of organic matter, they are called **decomposers**.

Another feature important in describing organisms is their ability to survive in the presence or absence of oxygen. **Obligate aerobes** must have oxygen to live, while **obligate anaerobes** can survive only in the absence of oxygen. A **facultative anaerobe** grows in the presence of oxygen but, when oxygen is absent, can switch to an anaerobic metabolism.

All living things are classified into three domains. The characteristics of each of the three domains and important taxa within these domains are described below.

Domain Archaea

The Archaea (also called archaebacteria) are prokaryotes. They *differ* from other prokaryotes (bacteria) and from eukaryotes by the following features.

1. Archaeal cell walls contain various polysaccharides, but *not* peptidoglycans (as in bacteria), cellulose (as in plants) or chitin (as in fungi).
2. Archaeal plasma membranes contain phospholipids that differ from the phospholipids of bacteria and eukaryotes. For example, the glycerol component of archaea phospholipids is an isomer of the glycerol in bacteria and eukaryotes. Also, in Archaea, the hydrocarbon chains of the phospholipids attach to the glycerol with ether-linkages and the hydrocarbon chains are branched. Among bacteria and eukaryotes, in contrast, the hydrocarbon chains (fatty acids) attach with ester linkages and do not branch.

Archaea are *similar* to eukaryotes in the following respects.

1. The DNA of both archaea and eukaryotes are associated with histone proteins. Bacterial DNA is not.
2. Ribosome activity in both archaea and eukaryotes is *not* inhibited by the antibiotics streptomycin and chloramphenicol. In bacteria, ribosome activity *is* inhibited by these antibiotics.

Some major groups of archaea follow.

1. **Methanogens** are obligate anaerobes that produce methane (CH_4) as a by-product of obtaining energy from H_2 to fix CO_2. They live in mud, swamps, and the guts of cows, humans, termites, and other animals.
2. **Extremophiles** live in environments where environmental conditions are extreme. They include:
   - **Halophiles** ("salt lovers") live in environments with high salt concentrations, such as in the Great Salt Lake and the Dead Sea, or in salted foods, where they can cause spoilage. Most are aerobic and heterotrophic, while others are anaerobic and photosynthetic with the pigment **bacteriorhodopsin.**
   - **Thermophiles** ("heat lovers") live in hot (60 to 80°C) environments such as hot springs or geysers. Most are sulfur-based chemoautotrophs.
   - Others extremophiles live in high acid environments (pH 0.7 to 4), high base environments (pH 9 to 11), or under high pressures (such as at hydrothermal vents in the deep ocean).

Domain Bacteria

The Bacteria (also called eubacteria, or true bacteria) are prokaryotes. They are distinct from archaea and eukaryotes by the following features.

1. Bacterial cell walls are made with peptidoglycan, a polymer of a monosaccharide with amino acids.
2. Bacterial DNA is not associated with histone proteins.
3. Ribosome activity is inhibited by the antibiotics streptomycin and chloramphenicol.

It is difficult to classify bacteria on the basis of phylogeny because they originated so long ago that features characteristic of closely related groups may no longer be distinct. It is apparent that many features have evolved independently in unrelated groups. In addition, transformation, the uptake of free DNA, and transduction, the transport of DNA by viruses, may have scrambled the genomes of unrelated prokaryotes.

Five kingdoms are currently used to categorize all organisms. The characteristics of each of these kingdoms, and important taxa within these kingdoms, are described below.

The following features have been traditionally used to categorize bacteria.

1. Many bacteria are categorized by their mode of nutrition, or how they metabolize resources.
2. Some bacteria are distinguished by their ability to produce **endospores,** resistant bodies that contain the genetic material and a small amount of cytoplasm surrounded by a durable wall.
3. Bacteria are distinguished by their means of motility, whether by flagella, corkscrew motion, or gliding through slimy material that they secrete. When flagella are present, they can be apical or posterior, or they can completely cover the cell.
4. Bacteria are classified into one of three shapes: **cocci** (spherical), **bacilli** (rod shaped), and **spirilla** (spirals).
5. The cell wall distinguishes two broad groups of bacteria. Bacteria that stain positive with the **Gram stain technique** have a thick peptidoglycan cell wall, while Gram-negative bacteria have a thin peptidoglycan wall covered with a layer of lipopolysaccharides.

Some of the more common groups of bacteria follow:

1. **Cyanobacteria** are photosynthetic, using chlorophyll *a* to capture light energy, splitting H_2O, and releasing O_2 as do plants. They also contain accessory pigments called **phycobilins.** Some have specialized cells called **heterocysts** that produce **nitrogen-fixing** enzymes. When nitrogen is fixed, inorganic, unreactive nitrogen gas is converted into ammonia (NH_3), which can then be used for making nitrogen-containing amino acids and nucleotides.
2. **Chemosynthetic bacteria** are autotrophs. Some of these are called **nitrifying** bacteria because they convert nitrite (NO_2^-) to nitrate (NO_3^-).
3. **Nitrogen-fixing bacteria** are heterotrophs that fix nitrogen. Many of these bacteria have **mutualistic** relationships with plants; that is, both the bacteria and the host plant benefit from an interdependent relationship. The bacteria live in **nodules,** specialized structures in plant roots.
4. **Spirochetes** are coiled bacteria that move with a corkscrew motion. Their flagella are internal, positioned within the layers of the cell wall.

Domain Eukarya

There are four kingdoms in the Eukarya (eukaryotes). Their characteristics and some important taxa are described in the following discussion.

Kingdom Protista

Organisms in this kingdom may be algaelike, animallike, funguslike, unicellular, or multicellular. In many cases, the evolutionary relationships among the various groups are either very weak, poorly understood, or both. Thus, this kingdom is artificial and is used more for convenience than to present actual evolutionary relationships. Features shared by two or more groups may represent **convergent evolution;** that is, the features arose among the groups independently. Nevertheless, the groupings given below present this varied kingdom with a degree of organization that will help you remember them.

Algaelike (or plant-like) members of the Protista all obtain energy by photosynthesis. All have chlorophyll *a* but may have various other chlorophylls and different accessory pigments. The main features used to categorize them are their chlorophylls and accessory pigments, the form of carbohydrate used to store energy, the number of flagella (if present), and the makeup of the cell walls. Some distinguishing characteristics of the important taxa follow.

1. **Euglenoids** have one to three flagella at their apical (leading) end. Instead of a cellulose cell wall, they have thin, protein strips called **pellicles** that wrap over their cell membranes. They can become heterotrophic in the absence of light. Some have an **eyespot** that permits **phototaxis,** the ability to move in response to light.

2. **Dinoflagellates** have two flagella. One flagellum is posterior, while the second flagellum is transverse and rests in an encircling mid groove perpendicular to the first flagellum. Some of these are bioluminescent. Others produce nerve toxins that concentrate in filter-feeding shellfish, which then cause illness in humans when eaten.
3. **Diatoms** have **tests** (shells) that fit together like a box with a lid. The tests consist of silica (SiO_2).
4. **Brown algae** are multicellular and have flagellated sperm cells. Some brown algae are giant seaweeds, or kelps.
5. **Rhodophyta,** or red algae, contain red accessory pigments called **phycobilins.** They are multicellular, and their gametes do not have flagella.
6. **Chlorophyta,** or green algae, have both chlorophyll *a* and *b,* have cellulose cell walls, and store their carbohydrates as starch. There is considerable variation in sexuality. For example, some species have **isogamous** gametes, where both sperm and eggs are motile and equal in size, while in others, the gametes are **anisogamous,** where the sperm and egg differ in size. In still others, the gametes are **oogamous,** where a large egg cell remains with the parent and is fertilized by a small, motile sperm. In addition, there are examples of trends toward multicellularity. In one group of closely related species, there is a succession from unicellular organisms (*Chlamydomonas*), to colonies of four to thirty-two cells (*Gonium* and *Pandorina*), to a colony with hundreds of cells (*Volvox*). Because of these various characteristics and evolutionary trends, a lineage of the Chlorophytes, the **charophytes,** are believed to be the ancestors of plants.

The **protozoa,** or **animal-like** protists, are heterotrophs. They consume either living cells (thus being predatory or parasitic) or dead organic matter. Some important taxa follow.

1. **Rhizopoda** are amoebas that move by extensions of their cell body called **pseudopodia.** Pseudopodia encircle food and absorb it by phagocytosis.
2. **Foraminifera,** or forams, have tests usually made of calcium carbonate. Many ancient marine sediments consisting of certain foram tests are good indicators of underlying oil deposits.
3. **Apicomplexans** are parasites of animals. They are characterized by an **apical complex,** a complex of organelles located at an end (apex) of the cell. They have no physical means of motility. However, they form spores which are dispersed by one or more hosts that participate in the completion of their life cycles. The sporozoan that causes malaria, for example, spends part of its life cycle in mosquitos and part in humans.
4. **Ciliates** are distinguished by their cilia, which they use for moving and other functions. Because of specialized structures, such as mouths, anal pores, contractile vacuoles (for water balance), two kinds of nuclei (one large macronucleus and several small micronuclei), and other features, they are perhaps the most complex of all cells. *Paramecium* is this phylum's most notable member.

The **fungus-like** protists resemble fungi because they form either filaments or spore-bearing bodies similar to the fungi.

1. The **cellular slime molds** exhibit both funguslike and protozoalike characteristics during their life cycle. Spores germinate into amoebas which feed on bacteria. When food sources are depleted, the amoebas aggregate into a single unit, which migrates as a slug. The individual cells of the slug then mobilize to form a stalk with a capsule at the top similar to the spore-bearing bodies of many fungi. Spores are then released, which repeat the cycle when they germinate. The stimulus for aggregation is **cyclic AMP** (cAMP), which is secreted by the amoebas that experience food deprivation first.
2. The **plasmodial slime molds** grow as a single, spreading mass (or **plasmodium**) feeding on decaying vegetation. When food becomes unavailable or when the environment desiccates (dries up), stalks bearing spore capsules form. Haploid spores released from the capsule germinate into haploid amoeboid or flagellated cells, which fuse to form a diploid cell. The diploid cell grows into the spreading plasmodium.
3. **Oomycota** include the water molds, downy mildews, and white rusts. They are either parasites or saprobes. They are much like fungi in that they form filaments (**hyphae**) which secret enzymes that digest the surrounding substances. The breakdown products of digestion are then absorbed. The filaments of the Oomycota lack **septa,** or **cross walls,** which in many of the true fungi partition the filaments into compartments. Because they lack septa, they are **coenocytic,** containing many nuclei within a single cell. Also, the cell walls of the Oomycota are made of cellulose, rather than the chitin found in the true fungi.

Kingdom Fungi

Fungi grow as filaments called **hyphae** (singular, **hypha**). A mass of hyphae is called **mycelium** (plural, **mycelia**). Some fungi have **septa** (singular, **septum**), or cross walls, which divide the filament into compartments containing a single nucleus. When filaments lack septa, they are multinucleate, or **coenocytic.** The cell walls of fungi consist of **chitin,** a nitrogen-containing polysaccharide.

Fungi are either parasites or saprobes, absorbing the breakdown products from the action of digestive enzymes that they secrete. Many parasitic fungi have hyphae called **haustoria** that penetrate their host.

Fungi are dominantly haploid, but most form temporary diploid structures for sexual reproduction. The following stages occur during sexual reproduction.

1. **Plasmogamy** is the fusing of cells from two different fungal strains to produce a single cell with nuclei from both strains. A pair of haploid nuclei, one from each strain, is called a **dikaryon.** A hypha containing a dikaryon is called a **dikaryotic** hypha.
2. **Karyogamy** is the fusing of the two haploid nuclei of a dikaryon to form a single diploid nucleus.
3. **Meiosis** of the diploid nucleus restores the haploid condition. Daughter cells develop into haploid spores, which germinate and form haploid hyphae.

Fungi reproduce asexually by various means, including **fragmentation** (the breaking up of hyphae), **budding** (the pinching off of a small hyphal outgrowth), and **asexual spores.** Two kinds of asexual spores are described below:

1. **Sporangiospores** are produced in saclike capsules called **sporangia** (singular, **sporangium**) that are each borne on a stalk called a **sporangiophore.**
2. **Conidia** (singular, **conidium**) are formed at the tips of specialized hyphae, not enclosed inside sacs. Hyphae bearing conidia are called **conidiophores.**

Six fungus groups are described. Depending upon the classification scheme, the groups are considered either divisions (and bear the "-mycota" suffix) or classes ("-mycete" suffix). As a result, division and class names are often used interchangeably (Zygomycota and zygomycetes, for example).

1. **Zygomycota** lack septa, except when filaments border reproductive filaments. Zygomycetes reproduce sexually by fusion of hyphae from different strains, followed by plasmogamy, karyogamy, and meiosis. Haploid **zygospores** are produced, which germinate into new hyphae. Bread mold is a typical zygomycete.
2. **Glomeromycota** lack septa, but do not produce zygospores. They are a small group of fungi that occur only in mutualistic associations with roots of plants. In these fungus-root relationships, called **mycorrhizae**, the plant provides carbohydrates to the fungus and the fungus increases the ability of the plant roots to absorb nutrients, especially phosphorus.
3. **Ascomycota** have septa and reproduce sexually by producing haploid **ascospores.** After plasmogamy of hyphae from unlike strains, a dikaryotic hypha produces more filaments by mitosis. Karyogamy and meiosis subsequently occur in terminal hyphal cells producing four haploid cells. These four cells divide by mitosis to produce *eight* haploid ascospores in a sac called an **ascus** (plural, **asci**). In many ascomycetes, the asci are grouped together into a specialized fruiting body, the **ascocarp.** The ascomycetes include yeasts, powdery mildews, and truffles.
4. **Basidiomycota** have septa and reproduce sexually by producing haploid **basidiospores.** Plasmogamy between two unlike hyphae is followed by mitosis and the growth of dikaryotic hyphae to form a fruiting body called a **basidiocarp.** A mushroom, for example, is a basidiocarp. Karyogamy occurs in terminal hyphal cells called **basidia** (singular, **basidium**), followed by meiosis and the production of *four* haploid basidiospores.
5. **Deuteromycota,** or imperfect fungi, is an artificial group comprising fungi for which no sexual reproductive cycle has been observed. *Penicillium,* from which penicillin is obtained, is a deuteromycete.
6. **Lichens** are mutualistic associations between fungi and algae. The algae, which is usually a chlorophyta or cyanobacteria, provides sugar from photosynthesis. Nitrogen compounds are also provided if the algae is nitrogen-fixing. The fungus, which is most often an ascomycete, provides water and protection from the environment. Some fungi produce pigments that shield algae from ultraviolet radiation or excess light, or toxic substances that discourage algae consumption by grazers.

Kingdom Plantae

In order to survive the transition from water to land, it was necessary for plants to make adaptations for obtaining water and to prevent its loss by desiccation (drying out). Water was also required to provide a medium for the fertilization of eggs by flagellated sperm. In addition, once plants emerged from the protective cover of water, genetic material was more susceptible to damage by ultraviolet radiation. The following list summarizes the major plant adaptations for survival on land.

1. Except for the primitive bryophytes (mosses, liverworts, and hornworts), the dominant generation of all plants is the diploid sporophyte generation. A diploid structure is more apt to survive genetic damage because two copies of each chromosome allow recessive mutations to be masked.
2. All plants possess a **cuticle,** a waxy covering on aerial parts that reduces desiccation.
3. The development of a vascular system in plants further reduced their dependency on water. Without a vascular system, all cells must be reasonably close to water. A vascular system reduced this dependency by providing a system for water to be distributed throughout the plant. Once cells were relieved of their dependency upon water, tissues specialized for specific tasks evolved. True leaves developed as centers for photosynthesis, true stems developed to provide a framework to support leaves, and true roots developed to obtain water and anchor the plant. Two groups of vascular tissues evolved, **xylem** and **phloem.** Xylem is specialized for water transport, and phloem is specialized for sugar transport.
4. In the more primitive plant divisions, flagellated sperm require water to swim to the eggs. In the more advanced divisions (Coniferophyta and Anthophyta), the sperm, packaged as pollen, are adapted for delivery by wind or animals.
5. In the most advanced division, the Anthophyta, the gametophytes are enclosed (and thus protected) inside an **ovary.**
6. Plants of the Coniferophyta and Anthophyta have developed adaptations to seasonal variations in the availability of water and light. For example, some trees are **deciduous;** that is, they shed their leaves to minimize water loss during slow-growing (or dormant) seasons. In contrast, desert annuals will germinate, grow, flower, and produce seeds within brief growing periods in response to a spring rain.

A list of the major plant divisions follows. Of particular importance is how each division shows an increasingly greater adaptation to survival on land.

1. The **bryophytes** consist of three groups of unspecified plants: the mosses, liverworts, and hornworts. Gametes are produced in protective structures called **gametangia** on the surface of the gametophytes, the dominant haploid stage of the life cycle of bryophytes. The male gametangium, or **antheridium** (plural, **antheridia**), produces flagellated sperm that swim through water to fertilize the eggs produced by the female gametangium, or **archegonium** (plural, **archegonia**). The resulting zygote grows into a diploid structure, still connected to the gametophyte. In mosses, this structure is a stalk bearing a capsule which contains haploid spores produced by meiosis. The spores are dispersed by wind, germinate, and grow into haploid gametophytes. Since bryophytes lack the specialized vascular tissues xylem and phloem, they do not have true roots, true stems, or true leaves. Thus, bryophytes must remain small, and water must be readily available for absorption through surface tissues and as a transport medium for sperm.

The following divisions of plants are informally categorized as **tracheophytes,** or **vascular plants,** because they possess xylem and phloem. As a result, they have true roots, true stems, and true leaves. The **Lycophyta** and **Pterophyta** produce spores that germinate into small gametophytes. Like the bryophytes, the gametophytes produce antheridia and archegonia, which produce sperm and eggs, respectively. The flagellated sperm swim to the archegonia to fertilize the eggs. Successful fertilization produces a diploid zygote which grows into the sporophyte. Unlike the bryophytes, however, the sporophyte is the dominant generation.

2. **Lycophyta** include the club mosses, spike mosses, and quillworts. These are herbaceous plants, usually less than 30 cm (1 foot). The club mosses and spike mosses produce clusters of spore-bearing sporangia in conelike structures called **strobili**. The "resurrection plant," a plant that recovers from a deadlike appearance when watered, is a spike moss.
3. **Pterophyta** include three groups.
   - **Ferns** produce clusters of sporangia called **sori** (singular, **sorus**) that develop on the undersurface of fern fronds. The sporangia undergo meiosis and produce the spores.
   - **Horsetails** include extinct woody trees common during the Carboniferous period and extant herbaceous plants. Horsetails have hollow, ribbed stems that are jointed at **nodes**. The nodes occur at intervals along the stem and produce small, scalelike leaves and, in some species, branches. The bushy branches give the appearance of a horsetail. The stems, branches, and leaves are green and photosynthetic and have a rough texture due to the presence of silica (silicon dioxide, SiO_2). Strobili bear the spores.
   - **Whisk ferns** are plants that consist of branching stems without roots. Leaves are either reduced to small appendages or are absent. The absence of roots and leaves is considered a **secondary loss**—that is, these structures were lost as whisk ferns diverged from their ancestors.

The next two plant divisions produce seeds. In addition, two kinds of spores are produced, male spores and female spores. Structures relating to the production of these spores are prefixed with "micro" and "macro," respectively. Thus, the **microsporangia** produce the **microspores** (male spores), and the **macrosporangia** produce the **macrospores** (female spores). A summary of reproduction in seed plants follows:

- The microsporangium produces numerous **microspore mother cells,** which divide by meiosis to produce four haploid cells, the microspores. The microspores mature into **pollen grains.** A pollen grain represents the male gametophyte generation. The pollen grain further divides into three cells (in flowering plants) or four cells (in conifers). One of these cells is a **vegetative,** or **tube,** cell that controls the growth of the pollen tube. Other cells become the sperm cells.
- The megasporangium, called the **nucellus,** produces a **megaspore mother cell,** which divides by meiosis to produce four haploid cells. One of these cells survives to become the megaspore and represents the female gametophyte generation. The megaspore divides by mitosis to produce one egg (in flowering plants) or two eggs (in conifers). Other accessory cells, in addition to the eggs, may also be produced. One to two tissue layers called **integuments** surround the megasporangium. The integuments, nucellus, and megaspore daughter cells are collectively called the **ovule.** An opening through the integuments for pollen access to the egg is called the **micropyle.**
- When a pollen grain contacts the megasporangium, the tube cell directs the growth of a **pollen tube** through the micropyle and toward the egg. After fertilization by the sperm cells, the zygote divides to form an embryo, the beginning of the sporophyte generation. The integuments develop into the seed coat.

There are two groups of seed plants, as follows:

4. **Coniferophyta** are the familiar conifers (literally, "cone-bearing"). They include pines, firs, spruces, junipers, redwoods, cedars, and others. The male and female reproductive structures are borne in pollen-bearing male cones and ovule-bearing female cones. The conifers, together with several other minor divisions (not discussed here), make up a group informally called the **gymnosperms.** The term gymnosperms (literally, "naked-seeds") refers to seeds produced in unprotected megaspores near the surface of the reproductive structure. Fertilization and seed development is lengthy, requiring one to three years.

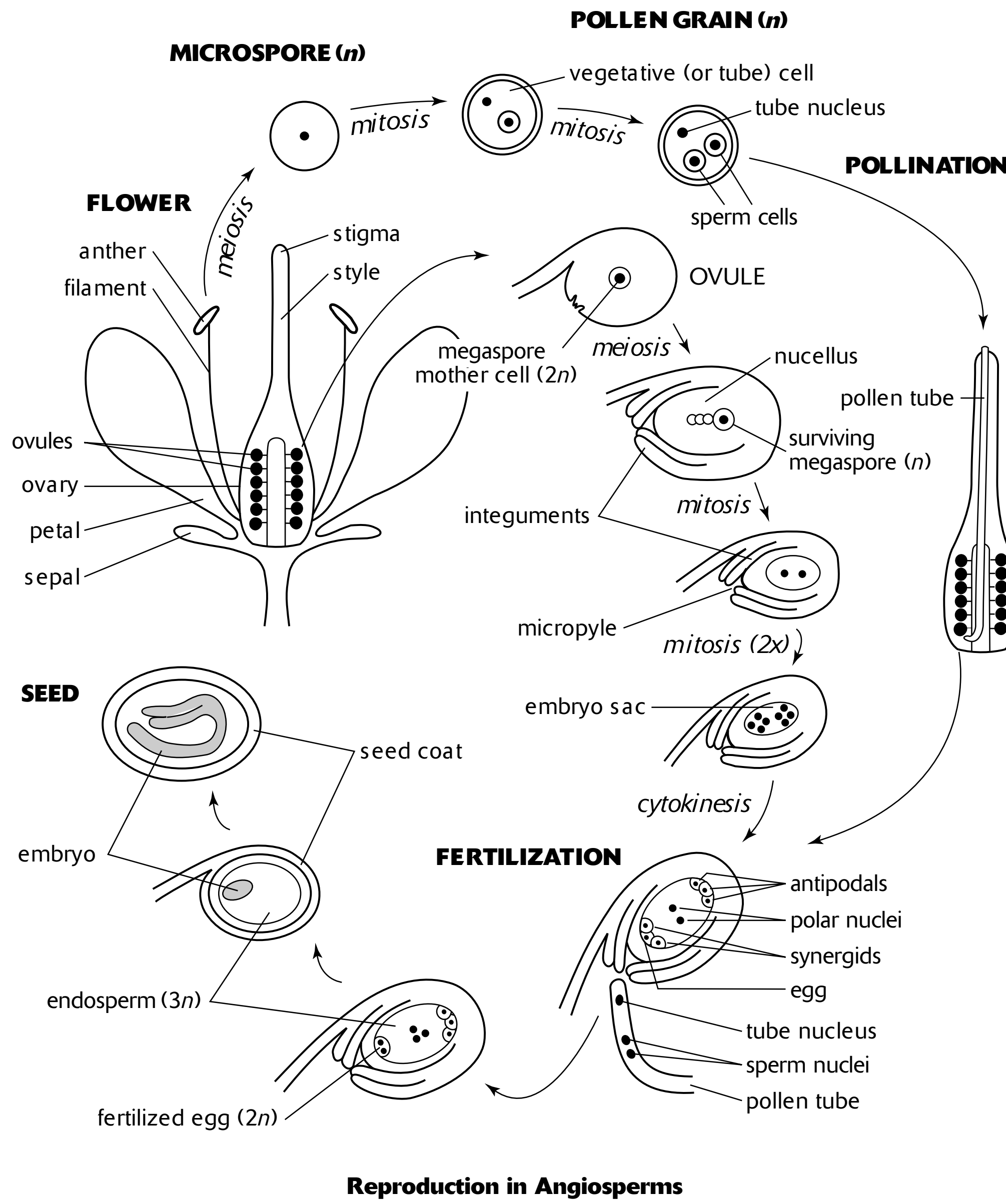

Figure 10-1

5. **Anthophyta,** or **angiosperms,** consist of the flowering plants. Major parts of the flower (Figure 10-1) are as follows:
   - The **pistil** is the female reproductive structure and consists of three parts: an egg-bearing **ovary,** a **style,** and a **stigma.**
   - The **stamen** is the male reproductive structure and consists of a pollen-bearing **anther** and its stalk, the **filament.**
   - **Petals,** and sometimes **sepals,** function to attract pollinators.

   The flower is a major evolutionary advancement for the following reasons:
   - The flower is a special adaptation to attract **pollinators,** such as insects and birds.
   - The ovules are protected inside an **ovary.**
   - The ovary develops into a **fruit** which fosters the dispersal of seeds by wind, insects, birds, mammals, and other animals.

Details of fertilization typical in many angiosperms are as follows (Figure 10-1):

- Pollen lands on the sticky stigma. A pollen tube, an elongating cell that contains the **vegetative nucleus** (or **tube nucleus**) grows down the style toward an ovule. There are two sperm cells inside the pollen tube.
- Ovules within the ovary consist of a megaspore mother cell surrounded by the nucellus and integuments. The megaspore mother cell divides by meiosis to produce four haploid cells, the megaspores. One surviving megaspore divides (three times) by mitosis to produce eight nuclei. Six of the nuclei undergo cytokinesis and form plasma membranes. The result is an **embryo sac.** At the micropyle end of the embryo sac are three cells, an **egg** cell and two **synergids.** At the end opposite the micropyle are three **antipodal cells.** In the middle are two haploid nuclei, the **polar nuclei.**
- When the pollen tube enters the embryo sac through the micropyle, one sperm cell fertilizes the egg, forming a diploid zygote. The nucleus of the second sperm cell fuses with both polar nuclei, forming a triploid nucleus. The triploid nucleus divides by mitosis to produce the **endosperm,** which provides nourishment for subsequent development of the embryo and seedling. The fertilization of the egg and the polar nuclei each by a separate sperm nucleus is called **double fertilization.**

Other evolutionary advancements among the angiosperms, including more specialized vascular tissues and numerous variations in habit and growth, developed to advance survival in a variety of environmental conditions.

The characteristics of the divisions of the plant kingdom are summarized in Table 10-1. Additional detail with respect to plant structure, transport, reproduction, and development is given in the section on plants.

Table 10-1

Phylum or Group	***Common Names***	***Dominant Generation***	***Fluid Transport***	***Sperm Transport***	***Dispersal Unit***
Bryophytes	mosses, liverworts, hornworts	gametophyte	nonvascular	flagellated sperm	spores
Lycophyta	club mosses, spike mosses, quillworts	sporophyte	vascular	flagellated sperm	spores
Pterophyta	ferns, horsetails, whisk ferns	sporophyte	vascular	flagellated sperm	spores
Coniferophyta	conifers	sporophyte	vascular	wind-dispersed pollen	seeds
Anthophyta	flowering plants	sporophyte	vascular	wind- or animal-dispersed pollen	seeds

Kingdom Animalia

Although the animal kingdom is extremely diverse, its members share a number of characteristics, as follows:

1. All animals are multicellular.
2. All animals are heterotrophic.
3. The dominant generation in the life cycle of animals is the diploid generation.
4. Most animals are motile during at least some part of their life cycle.
5. Most animals undergo a period of embryonic development during which two or three layers of tissues form.

The diversity of animals originates from variations in the following characteristics:

1. **Tissue complexity.** Most animals, collectively called the **eumetazoa,** have closely functioning cells organized into tissues. Two (**diploblastic**) or three (**triploblastic**) layers of tissue called germ layers may be present. The three germ layers, the ectoderm, mesoderm, and endoderm (outer, middle, and inner layers, respectively), develop into various organs during embryonic development. In another group of animals, the **parazoa,** cells are not organized into true tissues, and organs do not develop.
2. **Body symmetry.** Animals have either **radial symmetry** or **bilateral symmetry.** In radial symmetry, organisms have only one orientation, front and back (or top and bottom). They display a circular body pattern. Organisms with bilateral symmetry have a top (**dorsal** side), bottom (**ventral** side), head (**anterior** end), and tail (**posterior** end).
3. **Cephalization.** In animals with bilateral symmetry, there is a progressively greater increase in nerve tissue concentration at the anterior end (head) as organisms increase in complexity. For example, brains have developed with accessory sensory organs for seeing, smelling, tasting, and feeling (antennae).
4. **Gastrovascular cavity.** Gastrovascular cavities, or **guts,** are areas where food is digested. If they have one opening, they are saclike, and the types of processes that can occur are limited. Two openings designate a **digestive tract,** allowing specialized activities to occur as food travels from beginning to end.
5. **Coelom.** During the embryonic development in more advanced animals, a cavity called a coelom develops from tissue derived from the mesoderm germ layer. The fluid-filled coelom cushions the internal organs and allows for their expansion and contraction. **Acoelomate** animals lack a coelom, while **pseudocoelomate** animals have a cavity that is not completely lined by mesoderm-derived tissue.
6. **Segmentation.** Many animals, such as insects and certain worms, have segmented body parts. In some cases the body parts are the same and repeat, while in other cases, the body parts are modified and adopt specialized functions.
7. **Protostomes** and **deuterostomes.** During the early development of the zygote, cell divisions, or **cleavages,** take place in an orderly fashion. Specific cleavage patterns emerge that result in the development of particular embryonic features. Two markedly different developmental patterns occur producing two groups of animals, the protostomes and deuterostomes. Three major differences between these two groups are evident as described below and outlined in Table 10-2.
   - Early cleavages either are at a slight angle (spiral cleavage) or are parallel (radial cleavage) to the vertical axis of the embryo.
   - When the embryo is configured as a sphere of cells (called a blastula), there is an infolding in the sphere that forms an internal cavity called the **archenteron.** The opening to the archenteron becomes either the mouth or the anus.
   - The coelum can develop either from a splitting of the mesodermal tissue at each side of the archenteron or directly from outpouching in the wall of the archenteron.

Table 10-2

Characteristic	*Protostome*	*Deuterostome*
Early cleavages	slight angle (spiral cleavage)	straight down (radial cleavage)
First infolding of archenteron forms	mouth	anus
Coelom develops from	split in tissue at sides of archenteron	outpouching (hollowing out) of archenteron wall

A list of animal phyla with short descriptions follows. Major evolutionary trends are summarized in Table 10-3.

1. **Porifera** are the sponges. They feed by filtering water drawn through the sponge wall by flagellated cells called **choanocytes.** Water exits through an opening called the **osculum.** Choanocytes pass the food to **amoebocytes,** which wander between the two cell layers of the sponge wall, digesting and distributing nutrients. The sponge wall contains **spicules,** skeletal needles made from either $CaCO_3$ or SiO_2. Since the cells of the Porifera are not organized in a coordinated fashion to form tissues, they are classified with the parazoa.

2. **Cnidaria** include hydrozoans, jellyfish, sea anemones, and corals. There are two body forms. One is the **medusa,** a floating, umbrella-shaped body with dangling tentacles typical of jellyfish. The second is the **polyp,** a sessile, cylinder-shaped body with rising tentacles typical of sea anemones. The medusa is much like an upside-down polyp. In some Cnidaria, the medusa and polyp body forms alternate between the two stages of their life cycle.
3. **Platyhelminthes** consist of three kinds of acoelomate **flatworms. Free-living flatworms,** such as planarians, are carnivores or scavengers that live in marine or freshwater. **Flukes** are internal animal parasites or external animal parasites that suck tissue fluids or blood. **Tapeworms** are internal parasites that often live in the digestive tract of vertebrates. The tapeworms appear segmented, but since the segments, called **proglottids,** develop secondarily for reproduction and function independently, the tapeworm is not considered a true segmented animal. Tapeworms do not have a digestive tract themselves, as they need only absorb the predigested food around them. Other Platyhelminthes, however, have a saclike gut.
4. **Nematoda** are **roundworms.** They have pseudocoelomate bodies with a complete digestive tract. Many nematodes are free-living soil dwellers that help decompose and recycle nutrients. One species of roundworms, ingested from incompletely cooked meat, causes trichinosis in humans.
5. **Rotifera** are rotifers. Although many are microscopic, they are multicellular, with specialized organs enclosed in a pseudocoelom, and have a complete digestive tract. They are filter-feeders, drawing water and food into the mouth by the beating action of cilia.
6. **Mollusca** include snails, bivalves, octopuses, and squids. Most mollusks have shells. Bivalves, such as clams and mussels, have a shell that has two parts. In squids, the shell is reduced and internal, and in octopuses, the shell is absent entirely. Mollusks have coelomate bodies, a complete digestive tract, and an open circulatory system with an internal cavity called a hemocoel. Octopuses have a highly developed nervous system with a large and complex brain.
7. **Annelida** are segmented worms. They include the leeches, earthworms, and polychaete worms. Leeches are either predators of small animals or blood-sucking parasites. They have two suckers at opposite ends of their bodies that are used for attachment and movement. Polychaete worms are mostly marine and, as a group, exhibit a variety of lifestyles, including tube building, crawling, burrowing, and swimming.
8. **Arthropoda** include spiders, insects, crustaceans, and various related organisms. They have jointed appendages, a well-developed nervous system, specialization of body segments, and an exoskeleton made of chitin. There are two kinds of life cycles among the arthropods. Some arthropods are born as **nymphs,** or small versions of the adult, and change shape gradually as they grow to adult size and proportions. Other arthropods are born as **larvae,** maggots specialized for eating. When they reach a certain size, they enclose themselves within a **pupa** (cocoon) and undergo a dramatic change in body form, a process called **metamorphosis.** They emerge from their pupae as adults, specialized for dispersal and reproduction.
9. **Echinodermata** include sea stars, sea urchins, and sand dollars. They are coelomate deuterostomes and usually have a complete digestive tract. Although adult echinoderms have bodies with radial symmetry, some features are bilateral, as are the body shapes of their larvae. Ancestors of echinoderms are believed to have been bilateral.
10. **Chordata** consist of animals that exhibit the following four main features. In many cases, these features are temporary, appearing only during embryonic development.
    - A **notochord** provides a dorsal, flexible rod that functions as a support. In most chordates, the notochord is replaced by bone during development.
    - A **dorsal hollow nerve cord** forms the basis of the nervous system. In some chordates, the nerve cord becomes the brain and spinal cord.
    - **Pharyngeal gill slits** provide channels across the pharynx (a muscular structure at the beginning of the digestive tract) to the outside of the body. In some chordates, the slits become gills for oxygen exchange or filter feeding, while in others, the slits disappear during embryonic development.
    - A **muscular tail** extends beyond the digestive tract. In many chordates, such as humans, the tail is lost during embryonic development.

There are two groups of chordates, the **invertebrate** chordates, which include the lancelets and the tunicates, and the **vertebrate** chordates, which include sharks, fish, amphibians, reptiles, birds, and mammals. Vertebrate chordates are characterized by a series of bones, the **vertebrae,** that enclose the spinal cord.

Table 10-3							
Phylum	***Common Names***	***Tissue Complexity***	***Germ Layers***	***Body Symmetry***	***Gut Openings***	***Coelom***	***Embryonic Development***
Porifera	sponges	parazoa	–	none	0*	–	–
Cnidaria	jellyfish, corals	eumetazoa	2	radial	1	–	–
Platyhelminthes	flatworms	eumetazoa	3	bilateral	1	acoelomate	–
Nematoda	roundworms	eumetazoa	3	bilateral	2	pseudo-coelomate	–
Rotifera	rotifers	eumetazoa	3	bilateral	2	pseudo-coelomate	–
Mollusca	clams, snails, octopuses	eumetazoa	3	bilateral	2	coelomate	protostome
Annelida	segmented worms	eumetazoa	3	bilateral	2	coelomate	protostome
Arthropoda	insects, spiders, crustaceans	eumetazoa	3	bilateral	2	coelomate	protostome
Echinodermata	sea stars, sea urchins	eumetazoa	3	radial	2	coelomate	deuterostome
Chordata	vertebrates	eumetazoa	3	bilateral	2	coelomate	deuterostome

** Amoebocytes carry out digestion.*
– Characteristic does not apply to this phylum.