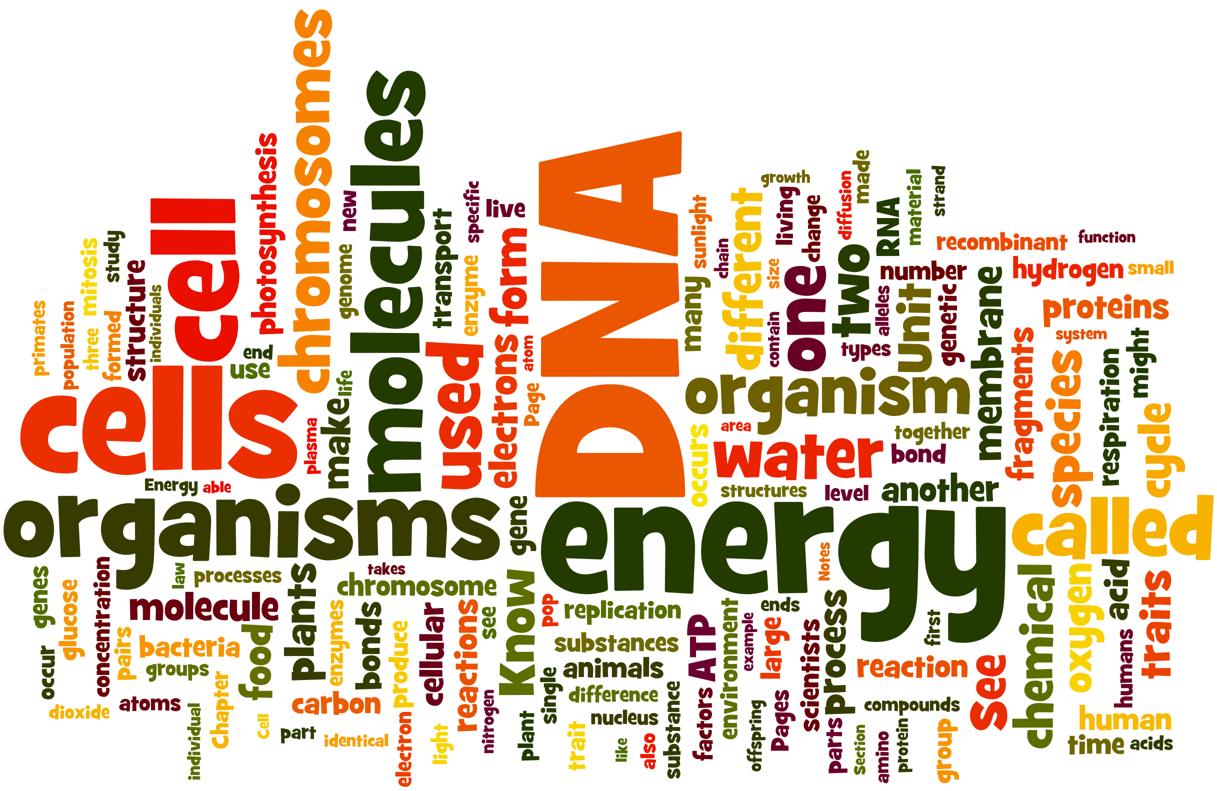
Adv. Biology Final Exam Study Guide



1st Semester

- **Intro. & Ecology Unit**
- **Chemistry of Life Unit**
- **Parts of the Cell/Cell Membrane/Transport into and out of the Cell Unit**
- **Photosynthesis and Cellular Respiration Unit**
- **Mitosis and Meiosis Unit**
- **DNA and RNA Unit**

2nd Semester

- **Genetics Unit**
- **Gene Technology Unit**
- **Evolution Unit**
- **Classification Unit**
- **Primate/Human Evolution Unit**
- **Microbiology Unit**
- **Plants and Body Systems Unit**

Intro. & Ecology Unit

- **Textbook: Chapters 1, 2, 3, and section 4.1**
- Zebra Mussels -
  - An organism that originated in Europe that is clogging up waterways in the U.S.
  - It is cream colored with brown stripes and is headless, hairless, and has no hands.
  - They came on cargo ships from Europe crossing the Atlantic. The ship emptied its ballast, along with the zebra mussels in Lake St. Clair.
  - Their population exploded because they didn't have any predators, the female zebra mussel produced 400 zebra mussels each year, and they are so small.
  - They are a problem because they clog pipes and power lines.
  - They can be called an **invasive species** because their mass reproduction provides issues with overpopulation. They invaded our area.
- Scientific method -
  - Methods used to gather information and to answer questions.
  - Biologists all use similar scientific methods to gather information and answer questions. The biologists observe and infer throughout the entire process.
- Metric System -
  - Uses units with divisions that are powers of ten.
  - The system is called the International System of Units, commonly known as SI. To make communication easier, most scientists use the metric system when collecting data and performing experiments.
  - The SI units most used in biology are meter (length), gram (mass), liter (volume) and second (time).
- Characteristics of Life -
  - Made of one or more cells - The cell is the basic unit of life. It is a basic unit of structure and function in all-living things. All organisms are made up of one or more cell. Humans and plants are multicellular, having many cells.
  - Displays organization - *Organization* - arranged in an orderly way. The levels of organization in biological systems begins with atoms and molecules and increase in complexity. Each organized structure has a specific function.
  - Grows and develops - *Growth* results in an increase of mass to an organism, and, in many, the formation of new cells and new structures. *Development* is the process of natural changes that take place during the life of an organism. It results in different abilities.

- <u>Reproduces</u> - Many living things are the result of ***reproduction***--the production of offspring. Reproduction is not an essential characteristic for individual organisms. ***A species*** is a group of organisms that can breed with one another and produce fertile offspring. If the last individual in a species does not reproduce, the species become extinct.

- <u>Responds to stimuli</u> - Reactions to internal and external stimuli are called ***responses***. Anything that is a part of the environment and causes some reaction by the organism is called a ***stimulus (***plural ***stimuli***. Being able to respond to the environment is critical for an organism's safety and survival; otherwise it won't be able to reproduce.

- <u>Requires energy</u> - Energy is required by living things to fuel their life processes. Living things get their energy from food. Most plants and some unicellular organisms use the energy from sunlight to make their own food and fuel their activities. Other organisms can use the energy in chemical compounds to make their food. Organisms that can't make their own food, such as animals and fungi, get energy by consuming other organisms. Some of the energy that an organism takes in is used for growth, development, and maintaining homeostasis. However, most of the energy is transformed into thermal energy and is radiated to the environment as heat.

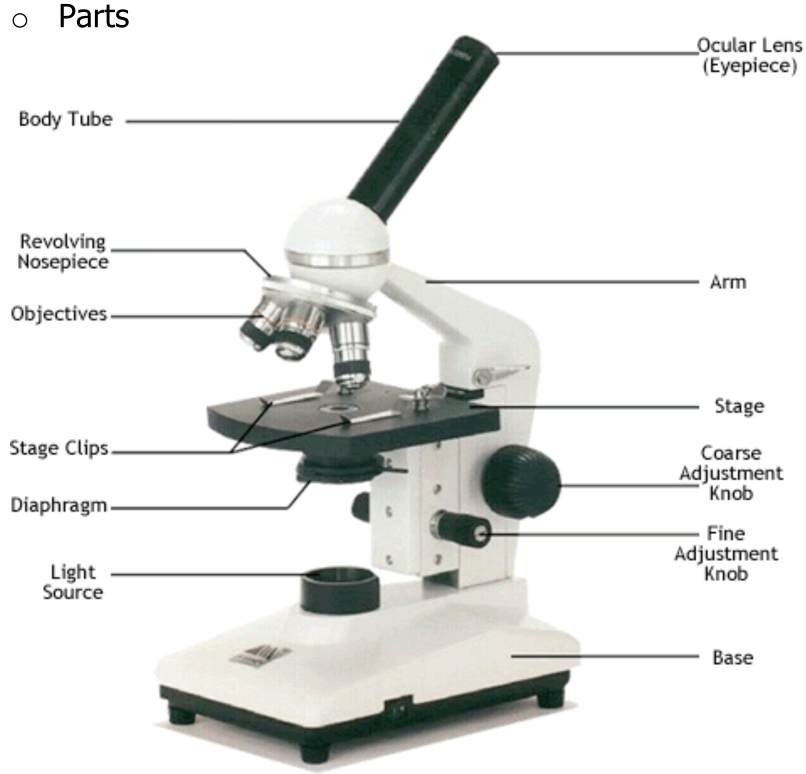
- <u>Maintains homeostasis</u> - All organisms keep internal conditions stable to maintain life by a process called ***homeostasis***. For example, humans perspire to prevent their body temperature from rising too high. If anything happens within an organism that affects it's normal state, processes to restore the normal state begin. If homeostasis is not restored, it can result in death.

- <u>Adaptations evolve over time</u> - *Adaptations* are inherited changes that occur over time that help the species survive.

- Microscope
  - History - Before microscopes were invented, people believed that diseases were causes by curses and supernatural spirits. Microscopes enabled scientists to view and study cells.
  - Types -
    - Simple Light Microscope - the first person to record looking at water under a microscope was Anton van Leeuwenhoek. He uses a simple light microscope.
    - Compound Light Microscope - uses a series of lenses to magnify objects in steps. Objects can be magnified up to 1500 times.

- Electron Microscope - Allowed scientists to see structures inside the cell that they couldn't see before. This microscope uses a beam of electrons, rather than light to magnify structures up to 500,000 times.

- Parts



- What is ecology? - Ecology is the study of interactions that take place between organisms and their environment.
- Biotic Factors - the **living factors** in an organism's environment. For example, in the habitat of a salmon the biotic factors include all of the organism that live in the water, such as other fish, algae, frogs, and microscopic organisms. Organisms that live on the land adjacent to the water might be biotic factors for the salmon.
- Abiotic Factors - the **nonliving factors** in an organism's environment. The abiotic factors for different organism vary across the biosphere, but organisms that live in the same geographic area might share the same abiotic factors. These factors might include temperature, air or water currents, sunlight, soil type, rainfall or available nutrients. For example,

the abiotic factors for salmon might be the temperature range of the water, the pH of the water, and the salt concentration of the water.

- Levels of organization in an ecosystem
  - Organism
  - Population
  - Biological community
  - Ecosystem
  - Biome
  - Biosphere
- Niches - the role or position than an organism has in its environment. It is how it meets its needs for food.
- Habitats - an area where an organism lives.
- Predation - the act of one organism consuming another organism for food. The organism that pursues another organism is the predator, and the organism that is pursued is the prey.
- Prey
- Scavengers - eat animals that have already died.
- Decomposers - break down the complex compounds of dead and decaying plants and animals into smaller molecules that can be more easily absorbed.
- Autotrophs - an organism that collects energy from sunlight or inorganic substances to produce food. Autotrophs are the foundation of all ecosystems because they make energy available for all other organisms in an ecosystem.
- Heterotrophs - an organism that cannot make its own food and feeds on other organisms. They are called consumers.
- Symbiotic relationships
  - Parasitism - a relationship in which one organism benefits at the expense of another organism. Parasites can be external, such as ticks and fleas, or internal, such as bacteria, tapeworms, and roundworms.
  - Commensalism - a relationship in which one organism benefits and the other organism is neither helped nor harmed.
  - Mutualism - the relationship between two or more organisms that live closely together and benefit from each other.
- Food chains - a simple model that shows how energy flows through an ecosystem. For example in a typical grassland food chain, the flower uses energy from the Sun to make its own food. The grasshopper gets its energy from eating the flower. The mouse gets its energy from eating the grasshopper. Finally, the snake gets its energy from eating the mouse. Each organism uses a portion of the energy it obtains from the organism it eats for cellular processes to build new cells and tissues. The remaining energy is released into the surrounding environment and no longer is available to these organisms.

- Food webs - a model representing the many interconnected food chains and pathways in which energy flows through a group of organisms. Feeding relationships usually are more complex than a single food chain because most organisms feed on more than one species. Birds for instance, eat a variety of seeds, fruits, and insects. The model most often used to represent the feeding relationship in an ecosystem is a food web.
- Ecological pyramids

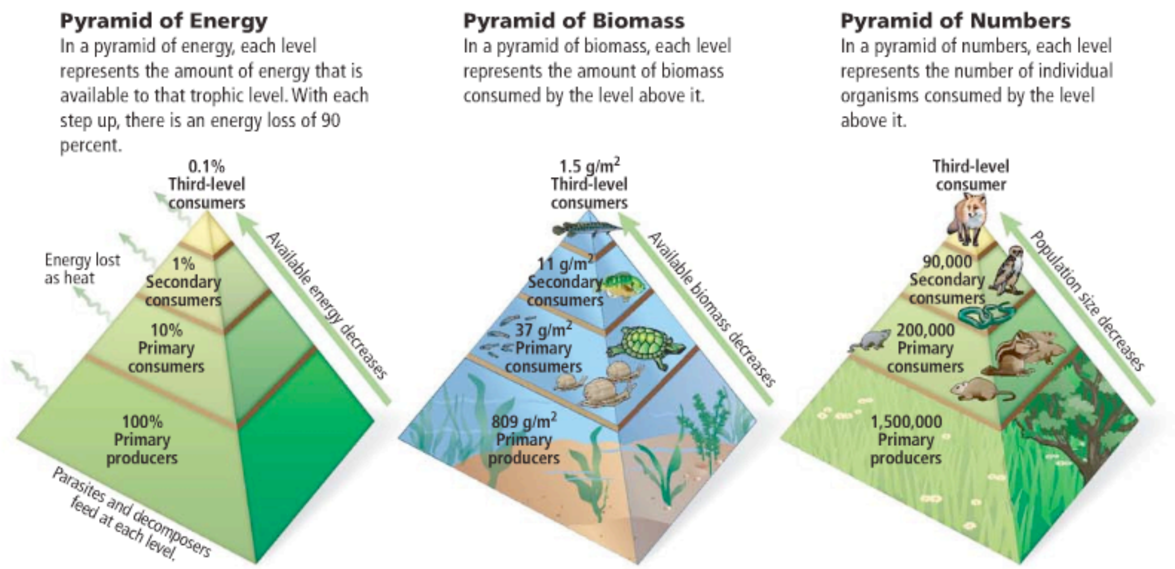
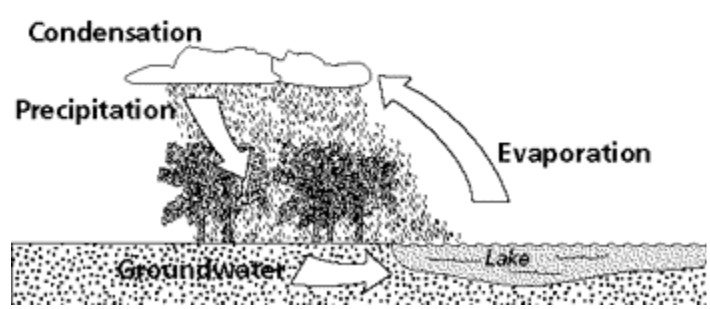


Figure 2.15 Ecological pyramids are models used to represent trophic levels in ecosystems.

Ecological pyramids Another model that ecologists use to show how energy flows through ecosystems is the ecological pyramid. An ecological pyramid is a diagram that can show the relative amounts of energy, biomass, or numbers of organisms at each trophic level in an ecosystem.

  - Energy - illustrates that the amount of available energy decreases at each succeeding trophic level. The total energy transfer from one trophic level to the next is only about 10% b/c organisms fail to capture and eat all the food energy available at the trophic level below them.
  - Biomass - the total weight of living matter at each trophic level. The pyramid represents the total weight of living materials available at each trophic level.
  - Numbers - shows that population size decreases at each higher trophic level.
- Cycles:
  - Water - water moves in a cycle between organisms on land, the land itself, and the atmosphere. All organisms need water. Plants need water because a plant splits water to produce oxygen. The events of the water cycle are evaporation,



condensation, transportation, precipitation, and run off.
  - Nitrogen - the largest concentration of nitrogen is found in the atmosphere, however it can't be readily used by plants and animals. Nitrogen Fixation is the process of capture and conversion of nitrogen into a form that is useable by plants. Consumers get nitrogen by eating plants or animals that contain nitrogen. (Dissolved CO_2 - Decomposers through cellular respiration. **<u>OR</u>** Living thing goes through cellular respiration and dissolves CO_2.) Nitrogen is returned to the soil when: an animal urinates, an organism dies - decomposers transform the nitrogen and into ammonia. Organism in the soil convert ammonia into nitrogen compounds that can be used by plants.
  - Phosphorous - Phosphorus is essential for the growth and development of organisms.
  - There are two cycles - short and long term
    - Short term - phosphates are cycled from the soil to producers and then to consumers. When organisms die, decomposers return the phosphorous to the soil where it can be used again. Phosphorus moves from short to long term though precipitation and sedimentation to form rocks.
    - Long Term - weathering or erosion of rocks that contain phosphorus adds phosphorus to the cycle. Phosphorous in the form of phosphates may only be present in small amounts in soil and water.
  - Carbon - The process of photosynthesis and respiration causes carbon to cycle through the environment. Organisms that respire releases carbon dioxide and water - producers use the carbon dioxide and water for photosynthesis. When decomposers break down dead and decaying organism, they go through cellular respiration and release carbon dioxide. Burning fossil fuels release carbon dioxide back into the environment.
- Succession:
  - Primary - the colonization of barren land by communities of organisms. It takes place on land where there are no living organisms.
  - Secondary - the sequence of changes that takes place after an existing community is severely disrupted in some way. It occurs in areas that previously contained life, and on land that still contains soil. It takes more time than primary succession to reach a climax community.
- Climax communities - a stable mature community that undergoes little or no change in species.
- Pioneer species - the first species to take hold in an area like primary succession.
- Biomes: where they are located, what lives there (primary plants/animals), characteristics and climate (precipitation and temperature)

  - **See Notes Section 3.2**
- Population growth:
  - Linear - populations of organisms do not experience linear growth, rather it starts out slowly and resembles a J-shaped curve.
  - Exponential (J-shaped) - as a population gets larger, it also grows at a faster rate. The graph of a growing population starts out slowly, then begins to resemble a J-shaped curve. The initial increase in the # of organism is slow b/c the # of reproducing individuals is small. Soon the rate of pop. growth increases b/c the total # of individuals that are able to reproduce ahs increased.
  - S-shaped curves - limiting factors such as availability of food, disease, predators, or lack of space will cause population growth to slow. Under these pressures, the population may stabilize in an S-shaped curve.
- Limiting factors - such as availability of food, disease, predators, or lack of space will cause population growth to slow
- Carrying capacity - the # of organisms of one species that an environment can support indefinitely is its carrying capacity. When a pop. overshoots its carrying capacity, then limiting factors may come into effect and deaths begin to exceed births and the pop. falls below carrying capacity.
- Density dependent factors - # of individuals in a given area. They include disease, competition, predators, parasites, and food. (People live close together.)
- Density independent factors - can affect all populations, regardless of their density. Most are abiotic factors such as temperature, storms, floods, drought, and major habitat disruption.
- Competition - a density-dependent factor. When only a few individuals compete for resources, no problem arises. When a population increases to the point at which demand for resources exceeds the supply, the population size decreases.
- Stress - When populations of certain organisms become crowded individuals may exhibit symptoms of stress. Animals can exhibit a variety of stress symptoms that include aggression, decrease in parental care, decreased fertility, and decreased resistance to disease. They become limiting factors for growth and keep populations below carrying capacity.

Chemistry of Life Unit

- **Elements**
  - Pure substance that cannot be broken down into other substances by physical or chemical means.
  - One type of atom
  - 100 known, 92 unknown
  - Each has unique name and symbol
  - Periodic table- organized into rows(periods) and columns(groups)
    - Elements in the same group have similar chemical and physical properties

- **Structure of an atom and energy levels**
  - Building blocks for matter
  - Nucleus- neutrons(particles have no charge) and protons(positively charged particles) are located at the center of an atom
  - Electrons- negatively charged particles that are located outside the nucleus. Move around nucleus in energy levels.
    - 1 energy level - 2
    - 2 energy level - 8
  - Structure of an atom is the result of attraction between protons and electrons.
  - Contain equal number of protons and electrons, so charge is 0.

- **Ions: positive and negative, how are they formed?**
  - An atom that has lost or gained one or more electrons and carries an electric charge

- **Isotopes: what are they**
  - Atoms of the same element that have different number of neutrons
  - Changing the number of neutrons can affect the stability of the nucleus (decay or break apart)
  - Radioactive isotopes- give off radiation when break apart
    - Half life- time it takes for half of carbon-14 to decay

- **Compounds and molecules, mixtures and solutions**
  - <u>Compounds</u>- a substance that is composed of atoms of two or more different elements that are chemically combined ex: table salt (NaCl)
  - Properties of compounds are different from those of their individual elements
    - Hydrogen-gas
      Oxygen-gas
      H2O- water (liquid)
  - <u>Molecules</u>-A group of atoms held together by covalent bonds and they have no overall charge
  - <u>Mixtures-</u> a combination of substances in which the individual components retain their own properties.
  - <u>Solutions-</u> mixture in which one or more substances(solutes) are distributes evenly in another substance (solvent)
    - The more solute that is dissolved in a substance the greater the concentration or strength of the solution

- **Solute and solvent**
  - <u>Solvent</u>- a substance in which another substance is dissolved
  - <u>Solute</u>- the substance that is dissolved in the solvent

- **Covalent bonds and ionic bonds**

- Chemical bonds-Force that hold substances together
  - A partially filled energy level is not as stable as an energy level that is empty or completely filled
  - Become stable by either losing or gaining a electron
  - Store energy and the breaking of chemical bonds that provide energy for processes of growth, development, adaptation, and reproduction in living things
- Covalent bonds- form when electrons are shared
- Ionic Bonds- an electrical attraction between 2 oppositely charged atoms or groups of atoms called ions
  - Ion- an atom that has lost or gained one more electrons and carries and electrical charge
  - Metal donate electrons and nonmetals accept elections
  - Have higher melting points

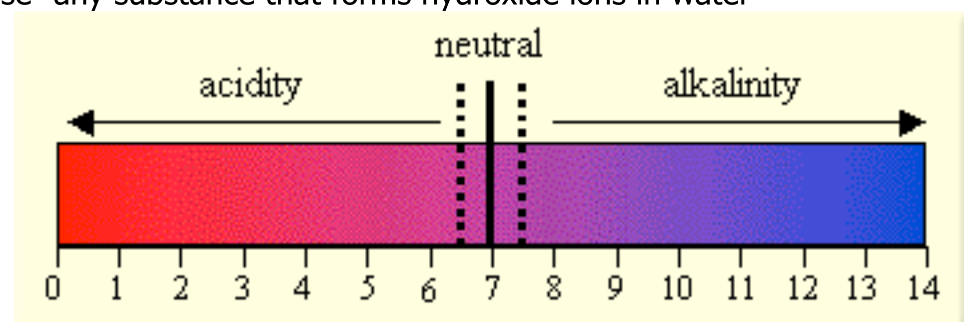
- **Hydrogen bonds**
  - Attraction of opposite charges between hydrogen and oxygen, week bond

- **Chemical reactions: reactant and products, formulas, symbols, subscripts and coefficients, equilibrium, conditions for chemical reactions**
  - Occur when bonds between atoms are formed or broken, causing substances to combine and recombine as different molecules
  - Clues that a chemical reaction has taken place include the production of heat or light, and formation of a new gas, liquid, or solid
    - <u>Metabolism</u>- all the chemical reactions that occur within a organism
  - Written as chemical equations that use symbols and formulas
    - The number of molecules of each substance is indentified by the number that comes before the molecule
    - The subscript tell you how man atoms of each element are there
    - <u>Reactants</u>-starting substances (left side)
    - <u>Products</u>-substances formed during the reaction (right side)
    - Each equation must show a balance of mass which means that the number of atoms of each element on the reactant side must equal the number of atoms on the same element on the product side.
  - A reaction is at <u>equilibrium</u> when reactants and products form at the same rate
  - Bond energy is the amount of energy that breaks a bond
    - Energy is added to break bonds
    - Energy is released when bonds form
  - In every chemical reaction, there is a change in energy due to the making and breaking of chemical bonds as reactants for products

- **Activation energy**
  - The amount of energy that needs to be absorbed to start a chemical reaction

- **Endothermic/exothermic reactions**
  - Exothermic- it releases energy in the form of heat
    - Excess energy is released by the reaction
  - Endothermic- it absorbed heat energy
    - Energy is absorbed by the reaction to make up the difference

- **pH: Acids and bases – scale/ions formed**
  - chemical reactions can occur only when conditions are right
  - A reactions may depend on:
    - Energy availability
    - Temperature
    - Concentration of a substance
    - pH of the surrounding environment
  - pH-is a measure of how acidic or basic a solution is
  - acid- any substance that forms hydrogen ions in water
  - base- any substance that forms hydroxide ions in water



- **Enzymes, substrate, catalyst, active site, lock and key, induced fit model, buffers; how enzymes are named; conditions for enzyme function**
  - Enzyme-type of protein found in all living things that increases the rate of chemical reactions-catalyst
    - Involved in almost all metabolic processes
    - Enables a molecule called substrates to undergo a chemical change and form a product
    - Enzymes and substrates come together (lock and key or educed fit)
    - Act on specific substrates- the reactants that bind to the enzyme
    - Catalyst- lowers activation energy and speeds up chemical reactions
    - Active site- the enzyme fits into an area that fits its shape on the substrate
    - When the substrate fits the active site, it causes the enzyme to alter its shape
    - After the reaction, the enzyme is releases and it goes back to its original shape
    - It can go on to carry out the same reaction again and again
    - The enzyme is not altered after a chemical reaction
    - Disruptions in homeostasis can prevent enzymes from functioning

        - Enzymes function best in a small range of conditions
            - Changes in temperature can break hydrogen bonds
            - Function depend on structure
        - Buffers- mixtures that can react with acids and bases to keep the pH within a particular range

- **Properties of water**
    - Makes up 70-95% of most organisms
    - Serves as a mean of transportation for materials in organisms
    - Water is Polar-a molecule with an unequal distribution of charge; each molecule has a positive end and a negative end
        - This occurs when two atoms form covalent bonds, they do not share electrons equally
    - Shared electrons are attracted by the oxygen atom more strongly than by the hydrogen atoms
        - Therefore the electrons spend more time near the oxygen atom
    - Since water is polar it attracts other polar molecules and other water molecules
    - The positively charged hydrogen atoms of one water molecules are attracted to the negatively charged oxygen atoms
        - Has the ability to creep up tubes because it is polar(plants)
    - Water requires more heat to increase temperature than other substances
    - Water loses a lot of hear when it cools
    - Therefore it is a good insulator and maintains a steady environment when conditions change
    - Water expands when it freezes
        - Because of this property ice is less dense than water and it floats.

- **Carbon: how many bonds it can form, types of bonds**
    - Has 4 electrons available for bonding in its outer energy level
    - In order to become stable, it forms 4 covalent bonds to fill its energy level
    - Carbon can bond with other elements or with other carbon molecules
    - When each atoms shares one pair of electrons a single bong forms
    - When each atom shares two pairs of electrons a double bond forms
    - When each atom shares three pairs of electrons a triple bond forms
    - When they bond to each other they can form:
        - Straight chains
        - Branched chains
        - Rings

- **Isomers: Glucose and fructose**
    - Compounds that have the same simple formula but different three dimensional structures

- **Monomers and polymers**

- Monomers-A molecule that can combine with others to form a polymer.
- Polymers(macromolecules)-large molecules formed when many smaller molecules bond together
  - Organized into four major groups:
    - Carbohydrates
    - Lipids
    - Proteins
    - Nucleic acids

- **Condensation and hydrolysis reactions**
  - Condensation reactions(dehydration synthesis)- chemical reactions that make up polymers
    - Water is removed as a by product
  - Hydrolysis reactions-chemical reactions that break polymers
    - Water is put into the reaction

- **Fatty acids**
  - The building blocks for lipids

- **Amino acid**
  - Building blocks for proteins

- **Monosaccharide, disaccharides, polysaccharides**
  - Monosaccharide- building block for carbohydrates
  - Disaccharides- two monosaccharides that bond together
  - Polysaccharides- the largest carbohydrates; polymers made of many monosaccharides

- **Organic molecules: carbohydrates, lipids, proteins and nucleic acids**
  - Carbohydrates
    - Organic compound composed of carbon, hydrogen and oxygen
    - Used by cells to store and release SHORT TERM energy
    - Ex: glucose and fructose=sucrose
    - Made of monosaccharides
    - Polysaccharides-
      - Starch is used as food storage by plants
      - Mammals store food in their liver in the form of glycogen
      - Cellulose is in the cell wall of plants and gives structural support
  - Lipids
    - Organic compounds that have a large proportion of C-H bonds
    - Commonly called fats
    - Composed of fatty acids, glycerol, and other components
    - Insoluble in water because they are non polar

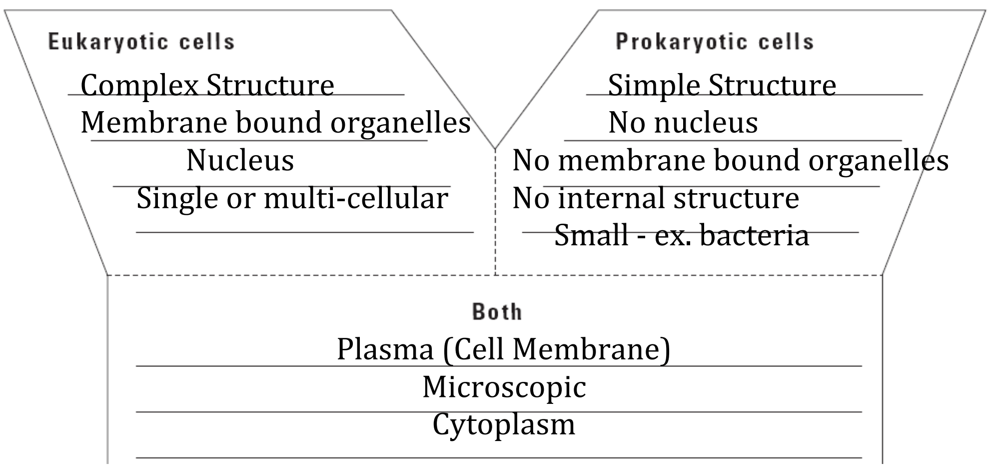
      - No net charge therefore, they are nor attracted to water
    - Cells use lipids:
      - Energy storage
      - Isolation
      - Protective coatings
      - Major component of cell membrane(plasma membrane)
    - Most common lipid: 3 fatty acids attached to a glycerol
    - Saturated fats have only single bonds
    - Unsaturated fats have at least one double bond.
    - Polysaturated- fats with more than one double bond
  - <u>Proteins</u>
    - Large complex polymer made of carbon, hydrogen, oxygen, nitrogen, and usually sulfur.
    - Provide structure for tissues and organs, carry out cell metabolism, aid in the transport of oxygen

    in the blood and carry out chemical reaction.
    - Enzymes are a type of protein
    - Basic building blocks are <u>amino acids</u> - there are 20 amino acids
    - Amino acids link together to form proteins through peptide bonds.
  - <u>Nucleotides</u>
    - Complex, macromolecule that stores cellular information in the form of a code
    - Nucleotide- polymers made of small subunits
    - Consist of carbon, hydrogen, oxygen, nitrogen, and phosphorus
    - Arranged in three groups:
      - Nitrogen base
      - Sugar
      - Phosphate group
    - Ex: DNA (deoxyribonucleic acid)
      - Info in DNA contains all the instructions for making proteins
      - Determines how an organism looks and acts
      - Passed on from generation to generation
    - Ex: RNA(ribonucleic acid)
      - Forms a copy of DNA for use in making proteins
- **Be able to identify the organic structures of organic molecules**
  - Wksht
- **Know what elements make up each organic molecule**
  - **Carbohydrates - Carbon, hydrogen, and oxygen**
  - **Lipids - Carbon and Hydrogen**
  - **Proteins - Carbon, oxygen, nitrogen, and usually sulfur**
  - **Nucleic Acids - carbon, hydrogen, oxygen, nitrogen, and phosphorus**

Parts of the Cell/Cell Membrane/Transport into and out of the Cell Unit

Chapter 7

- Vocabulary - See notes/ vocab sheet
- Notes, HW, Labs, Textbook
- Scientists who helped develop the cell theory
    - Hooke - coined the term cells - looks like a room that monks live in
    - Leeuenhoek - first person to use the microscope (looked at water)
    - Schleiden - said that all plants are composed of cells
    - Schwann - conclusion that all animals were made of cells. All living things are made of cells.
    - Virchow - cells have to come from pre-existing cells
- Cell theory: 3 parts
    1. All living organisms are composed of one or more cells.
    2. Cells are the basic unit of structure and organization of all living organisms.
    3. Cells arise only from previously existing cells, with cells passing copies of their genetic material on to their daughter cells.
- Differences between prokaryotic and eukaryotic cells.



- Organelles (their functions, what they look like, what kinds of cells they are in, etc..): mitochondria, chloroplast, nucleus, nucleolus, ribosomes, smooth and rough endoplasmic reticulum, golgi apparatus, flagella, cilia, cytoplasm, centrioles, centrosomes, cell wall, vesicles, vacuoles, lysosomes, cytoskeleton, nuclear pore
- **P. 193 text**

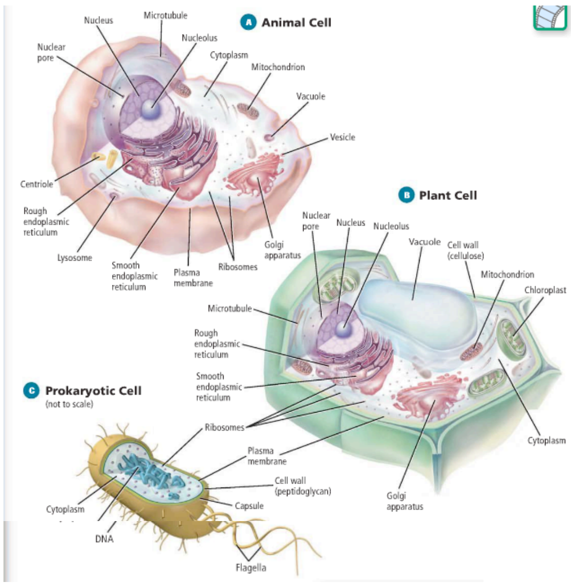
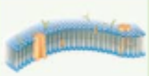
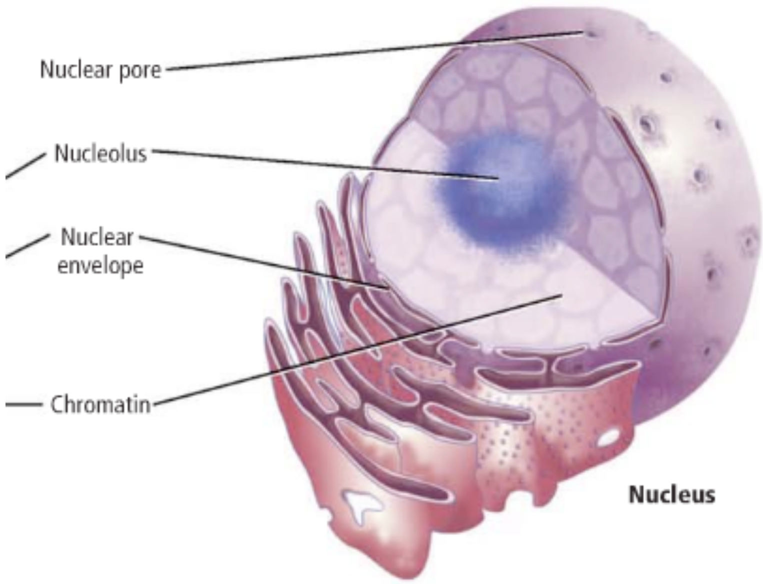

A Animal Cell
Nucleus
Microtubule
Nucleolus
Nuclear pore
Cytoplasm
Mitochondrion
Vacuole
Vesicle
Centriole
Rough endoplasmic reticulum
Lysosome
Smooth endoplasmic reticulum
Plasma membrane
Ribosomes
Golgi apparatus
B Plant Cell
Nuclear pore
Nucleus
Nucleolus
Vacuole
Cell wall (cellulose)
Mitochondrion
Chloroplast
Microtubule
Rough endoplasmic reticulum
Smooth endoplasmic reticulum
Ribosomes
Plasma membrane
Cytoplasm
Golgi apparatus
C Prokaryotic Cell
(not to scale)
Cell wall (peptidoglycan)
Capsule
Cytoplasm
DNA
Flagella

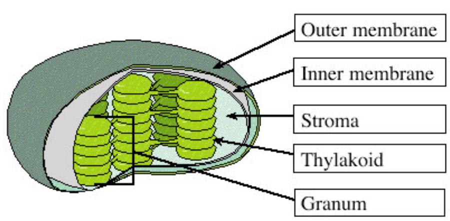
Table 7.1 Summary of Cell Structures

Cell Structure	Example	Function	Cell Type
Cell wall		An inflexible barrier that provides support and protects the plant cell	Plant cells, fungi cells, and some prokaryotes
Centrioles		Organelles that occur in pairs and are important for cell division	Animal cells and most protist cells
Chloroplast		A double-membrane organelle with thylakoids containing chlorophyll where photosynthesis takes place	Plant cells only
Cilia		Projections from cell surfaces that aid in locomotion and feeding; also used to sweep substances along surfaces	Some animal cells, protist cells, and prokaryotes
Cytoskeleton		A framework for the cell within the cytoplasm	All eukaryotic cells
Endoplasmic reticulum		A highly folded membrane that is the site of protein synthesis	All eukaryotic cells
Flagella		Projections that aid in locomotion and feeding	Some animal cells, prokaryotes, and some plant cells
Golgi apparatus		A flattened stack of tubular membranes that modifies proteins and packages them for distribution outside the cell	All eukaryotic cells
Lysosome		A vesicle that contains digestive enzymes for the breakdown of excess or worn-out cellular substances	Animal cells only
Mitochondrion		A membrane-bound organelle that makes energy available to the rest of the cell	All eukaryotic cells
Nucleus		Control center of the cell that contains coded directions for the production of proteins and cell division	All eukaryotic cells
Plasma membrane		A flexible boundary that controls the movement of substances into and out of the cell	All eukaryotic cells
Ribosome		Organelle that is the site of protein synthesis	All cells
Vacuole		A membrane-bound vesicle for the temporary storage of materials	Plant cells–one large; animal cells–a few small



Within the nucleus is the site of ribosome production called the nucleolus. - Found in all cells
Nuclear Pores - allow the movement of substances through it, it allows RNA to leave the nucleus - Found in all cells
Centrosomes - produce microtubules - found in plant and animal cells near the nucleus (round shape)
Vesicles - build lysosomes, pack in large molecules from golgi, transport large objects throughout the cell - Found in all Eukaryotic cells (Small blister like structures)

- Parts of the chloroplast:



  - Stroma - liquid in cholorplast
  - Grana - stack of disks
  - Thylakoid - disk-shaped compartments, where energy from sun is trapped by chlorophyll
- Mitochondria:
  - highly folded inner membrane – why is it there? - provides larger surface area and energy that is stored (through cellular respiration)
- Where cellular respiration occurs? - Mitochondria
- Where photosynthesis occurs? - Chloroplasts
- Differences between plant and animal cells. - Both have a nucleus

- Plant cells have a rectangular/ square shape, a cell wall, and chloroplasts
- Animal cells have a circular shape and no cell wall

Structure/Organelle	Animal Cells	Plants Cells
Cell Wall		✔
Centrioles	✔	
Chloroplast		✔
Cilia	✔	
Cytoskeleton	✔	✔
Endoplasmic Reticulum	✔	✔
Flagella	✔	✔
Golgi Apparatus	✔	✔
Lysosome	✔	
Mitochondrion	✔	✔
Nucleus	✔	✔
Plasma Membrane	✔	✔
Ribosome	✔	✔
Vacuole	✔ (Small)	✔ (Large)

- Describe the structure of the cell/plasma membrane. (helps control what enters and leaves the cell)
  - 2 layers of phosolipids (bilayer) that mirror each other
  - Cholesterol - keeps it stable, prevents fatty acids from sticking together
  - Transport Proteins - move needed substances or waste materials through the plasma membrane, contributing to the selective permeability of the plasma membrane.
    - Why do some molecules pass through a membrane protein? (See above)
- Carbohydrate Chains - send signals in and out of cell Phospholipids:
  - polar head - facing watery environments that are inside and outside of the cell
  - non-polar tail - inside
  - hydrophilic head - water loving
  - hydrophobic tails - Repelling, tending not to combine with, or incapable of dissolving in water.
- Why are phospholipids arranged as mirror images of each other in the cell membrane? - So that the polar heads can be closest to the water molecules and the nonpolar tails can be farthest away from the water molecules
- Summarize how chemical signals are transmitted across the cell membrane.- **Carbohydrate chains**
- Fluid mosaic model (plasma membrane model) - the phospholipids create a "sea" in which other molecules can float. This "Sea" concept is the basis for the model.
- Selective permeability - a key property of the plasma membrane by which a membrane allow some substances to pass through while keeping others out.
- How many layers are there in the plasma/cell membrane? - **2**

- Concentration gradient - difference in concentration across a space

- Active transport: against the concentration gradient (low to high); requires energy (ATP)
- Passive transport: with the concentration gradient (high to low), not using energy
- Describe passive transport. - movement of particles across the cell membrane **without using energy.**
    - Distinguish between three types of passive transport: simple diffusion, facilitated diffusion and osmosis.
        - Simple diffusion - the net movement of particles from an area of higher concentration to an area of lower concentration. (Controlled by temp, press., and concentration)
            - Dynamic equilibrium is reached when the diffusion of material into the cell equals the diffusion of material out of the cell
        - Facilitated diffusion - movement of materials across the membrane using proteins
    - Osmosis - diffusion of water across a selectively-permeable membrane
    - Solutions:
        - **Isotonic -** water and dissolved substances diffuse into and out of the cell at the same rate

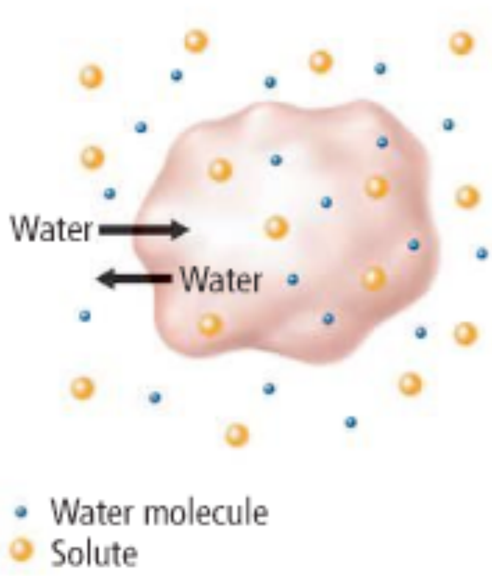


Figure 7.23 In an isotonic solution, water molecules move into and out of the cell at the same rate, and cells retain their normal shape. The animal cell and the plant cell have their normal shape in an isotonic solution.

- **Hypotonic -** solute concentration is higher inside the cell, water diffuses into the cell

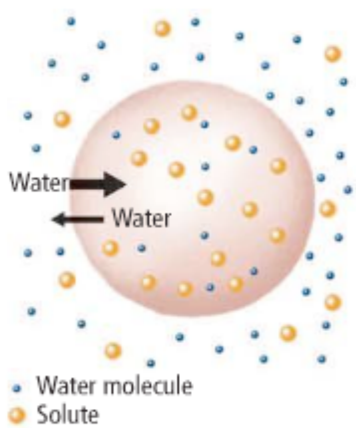


Figure 7.24 In a hypotonic solution, water enters a cell by osmosis, causing the cell to swell. Animal cells may continue to swell until they burst. Plant cells swell beyond their normal size as internal pressure increases.

- **Hypertonic -** solute concentration is higher outside the cell, water diffuses out of the cell

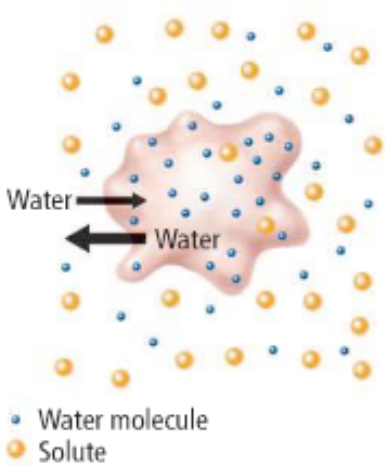


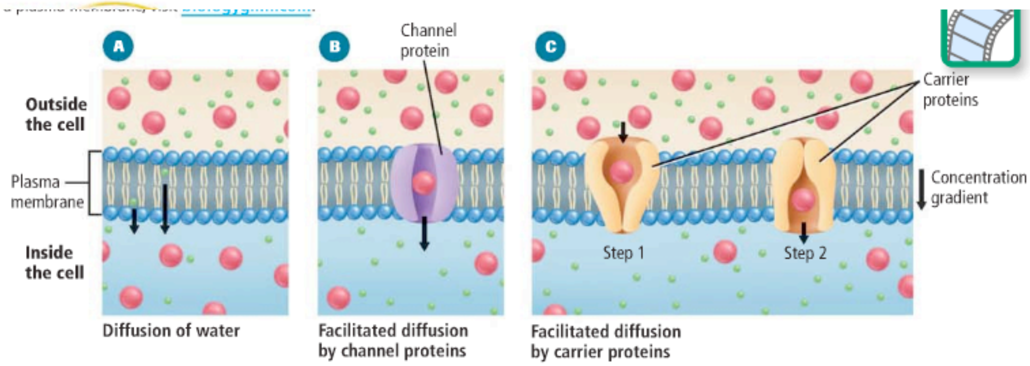
Figure 7.25 In a hypertonic solution, water leaves a cell by osmosis, causing the cell to shrink. Animal cells shrivel up as they lose water. As plant cells lose internal pressure, the plasma membrane shrinks away from the cell wall.

- What happens to a cell (animal and plant) in each of those solutions?
    - Isotonic - normal shape
    - Hypotonic - animal: may swell until it bursts plant: swell beyond normal size as press. increases.

- Hypertonic - animal: shrivel up as they lose water plant: as lose int. press., the plasma membrane shrinks away from the cell wall

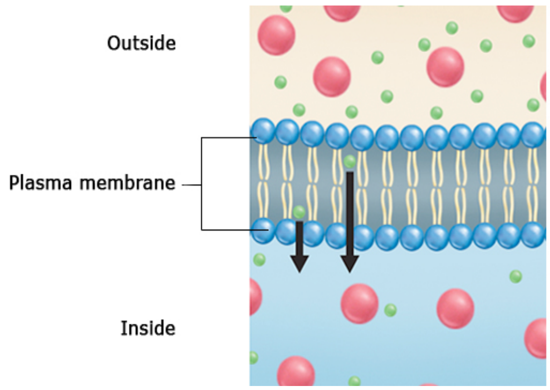
- Describe active transport. - the movement of particles from low concentration to high concentration, which is against the concentration gradient, using transport proteins
  - Distinguish between endocytosis and exocytosis.
    - Endocytosis - process by which the cell surrounds and takes particles **<u>into</u>** the cell
    - Exocytosis - secretion of material **<u>out</u>** of the plasma membrane
- Different types of endocytosis:
  - Phagocytosis - engulfing of large or small molecules by sudopods (fake feet)
  - Pinocytosis - cell drinking: uptake of large molecules (some type of liquid)
  - Receptor mediated endocytosis - takes up large quantities of specific substances - takes extracelluar substance into cell.
- How are endocytosis and exocytosis different than regular active transport? How are they different from diffusion? - Used when the substances are too large to move by diffusion or transport proteins
- Transport proteins:

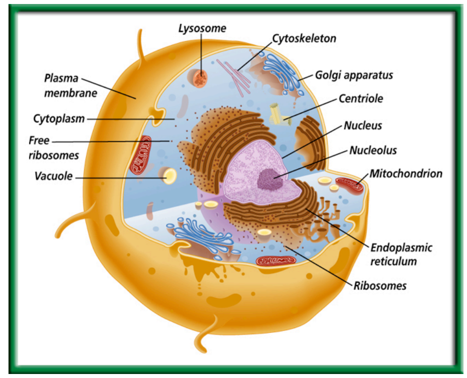
Figure 7.21 Although water moves freely through the plasma membrane, other substances cannot pass through the phospholipid bilayer on their own. Such substances enter the cell by facilitated transport.

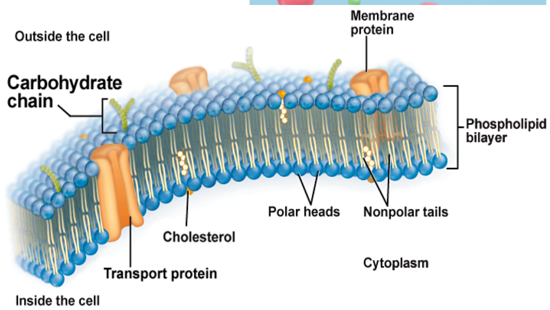


- carrier - change shape as the diffusion process continues to help move the particle through the membrane
- channel - opens and closes to allow the substance to diffuse through the plasma membrane

- How are pumps different from channels? - Pumps are enzymes that catalyze the breakdown of an energy-storing molecule. The Na^+/K^+ ATPase pump (sodium potassium) moves three Na out of the cells and two K into the cell. The high level of sodium creates a concentration gradient.







Photosynthesis and Cellular Respiration Unit

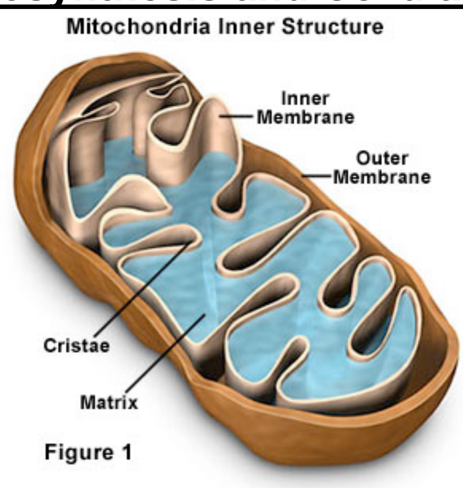


Figure 1

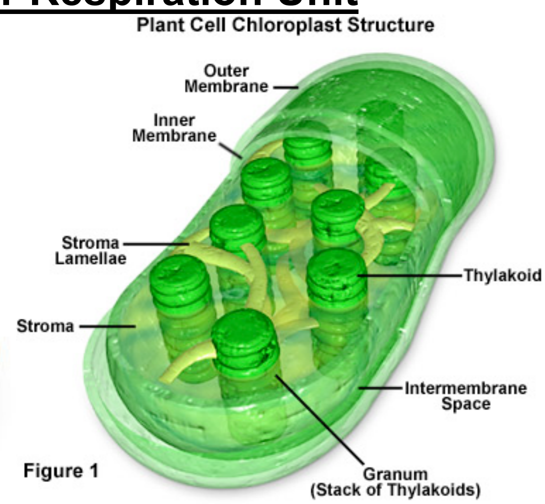
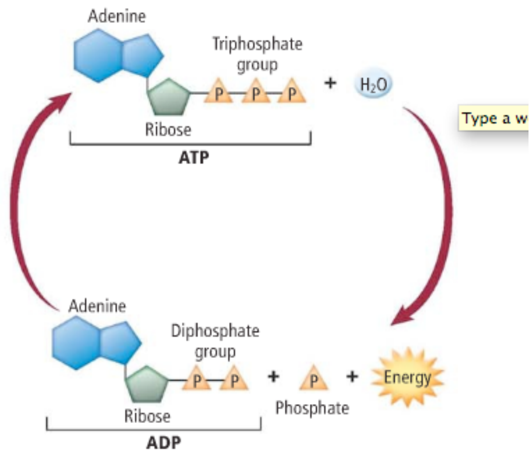


Figure 1

- Chapter 8
- All vocabulary – See Notes
- Energy: ATP, ADP, AMP; ATP cycle



■ **Figure 8.4** The breakdown of ATP releases energy for powering cellular activities in organisms.

- **ATP: Adenosine Triposphate** - the most important biological molecule that provides chemical energy.
- **ADP: Adenosine Diphosphate** – a molecule formed when, ATP releases energy when the bond between the second and third phosphate groups is broken forming a molecule (ADP) and a free phosphate group. **Energy is stored in the phosphate bond formed when ADP receives a phosphate group and becomes ATP.** ATP and ADP can be interchanged by the addition or removal of a phosphate group.
  - Sometimes ADP becomes Adenosine Monophosphate (AMP) by losing an additional phosphate group.
- **AMP: Adenosine Monophosphate** – sometimes ADP becomes this by losing an additional phosphate group. **There is less energy released in this reaction, so most of the energy reactions in the cell involve ATP and ADP.**

- *Describe how ATP works
  - ATP releases energy when the bond between the second and third phosphate groups is broken, forming a molecule called adenosine diphosphate (**ADP**) and a free phosphate group
- Thermodynamics: the two laws
  - **Thermodynamics** - the study of the flow and transformation of energy in the universe.
    - **The first law of thermodynamics** is the law of conservation energy, which states that energy can be converted from one form to another, but it cannot be created nor destroyed.
      - For example, the stored energy in food is converted to chemical energy when you eat and to mechanical energy when you run or kick a ball.

- **The second law of thermodynamics** states that energy cannot be converted without the loss of usable energy.
  - The energy that is "lost" is generally converted to thermal energy. Entropy is the measure of disorder, or unusable energy, in a system. Therefore, the second law of thermodynamics can also be stated "entropy increases." One example of the 2nd law is evident in food chains.

- Compare and contrast heterotrophs and autotrophs.
  - **Autotrophs** are organisms that make their own food.
  - **Heterotrophs** are organisms that need to ingest food to obtain energy.
- Metabolism - all of the chemical reactions in a cell.
  - A series of chemical reactions in which the product of one reaction is the substrate for the next reaction is called a metabolic pathway. Metabolic pathways include two broad types: catabolic and anabolic pathways.
- Definition of anabolic and catabolic reactions and ATP synthase
  - **Catabolic pathways** release energy by breaking down larger molecules into smaller molecule.
  - **Anabolic pathways** use the energy released by catabolic pathways to build larger molecules from smaller molecules
- Ultimate source of energy – **Sunlight**

- **Compare and contrast photosynthetic and chemosynthetic organisms**

Photosynthetic	**Chemosynthetic**
Light energy form the sun is converted to chemical energy for use by the cell. Used by plants Uses sunlight as energy via photosynthesis. This energy is made into glucose, which is eventually converted into ATP after many cycles. This ATP is a ready source of energy for the plant.	**Chemical** energy is used to build carbon-based molecules. • Some organisms don't need sunlight and photosynthesis as a source of energy and live in places that never get sunlight.
Both	
Types of Cell Energy - **Together they fuel all life on earth**	

-
- Photosynthesis:
  - Equation

$$6CO_2 + 6H_2O \xrightarrow{\text{light}} C_6H_{12}O_6 + 6O_2$$

- Steps
  - **Phase One: Light Dependent Reactions**
    - **Captures and transfers energy**
    - Takes place in thylakoids
    - Water and sunlight is needed – captures energy from sunlight (carbon dioxide and chloroplasts are also needed)
    - Chlorphyll absorbs energy
    - Energy is transferred along the thylakoid membrane then to light-independent reactions
    - Oxygen is released
    - The light-dependent reactions include groups of molecules called photosystems.
    - **Electron Transport**
      - Light energy excites electrons in photosystem II and also causes a water molecule to split – **photolysis.** This releases an electron into the electron transport system, H+ into the thylakoid space, and O2 as a waste product. **Releases electrons in electron transport chain.**
        - The excited electrons move from **photosystem II to** an electron-acceptor molecule in the thylakoid membrane.
      - The electron-acceptor molecule transfers the electrons along a series of electron-carriers to **photosystem I – another electron trans. chain**
        - Photosystem I transfers the electrons to a protein called ferrodoxin.
        - Ferrodoxin transfers the electrons to the electron carrier NADP+, forming the energy-storing molecule NADPH.

  - **Phase Two: Light Independent Reactions (Calvin Cycle)**
    - **Uses energy from the first stage to make sugar**
    - In Stroma

        - In the second phase of photosynthesis, called the Calvin cycle, energy is stored in organic molecules such as glucose.
        - Six CO2 molecules combine with six 5-carbon compounds to form twelve 3-carbon molecules called 3-PGA.
        - The chemical energy stored in ATP and NADPH is transferred to the 3-PGA molecules to form high-energy molecules called G3P.
        - Two G3P molecules leave the cycle to be used for the production of glucose and other organic compounds.
        - An enzyme called <u>**rubisco**</u> converts the remaining ten G3P molecules into 5-carbon molecules called RuBP.
  - Why is it important?
    - **Purpose of Photosynthesis = to convert sunlight energy to chemical energy.**
    - Life is powered by sunlight. The energy used by most living cells comes ultimately from the sun. Plants, algae, and some bacteria use energy from sunlight, particularly blue and red wavelengths, to build molecules which later can be split through cellular respiration to retrieve some of that energy. Storing energy in molecules and then oxidizing those molecules to retrieve the stored energy maintains all life on Earth. Plants are often called 'producers' because they produce energy-storing molecules used by almost all other organisms on Earth. By eating plants, herbivores 'steal' these energy-storing molecules to maintain their own life processes. By eating animals, carnivores 'plunder' the molecules that store the energy oringinally captured by plants. By feeding on dead tissue, decomposers exploit whatever molecules remain in the dead the plants, herbivores, and carnivores. Ultimately, the process of photosynthesis is the most important chemical reaction on Earth. As biologists are well aware, "Roses are red, violets are blue. If the green plants go, then so do you!"
- **Summarize the two phases of photosynthesis:**
  - light dependent - **light energy is absorbed and then converted into chemical energy in the form of ATP an NADPH.**
  - light independent (Calvin Cycle) -**energy is stored in molecules such as glucose – makes sugar.** the ATP, and NADPH that were formed in phase one are used to make glucose. Once glucose is produced, it can be joined to other simple sugars to form larger molecules. These molecules are complex carbohydrates, such as

starch. The end products of photosynthesis also can be used to make other organic molecules such as proteins, lipids and nucleic acids.

- Calvin cycle:

structural support for the plant.

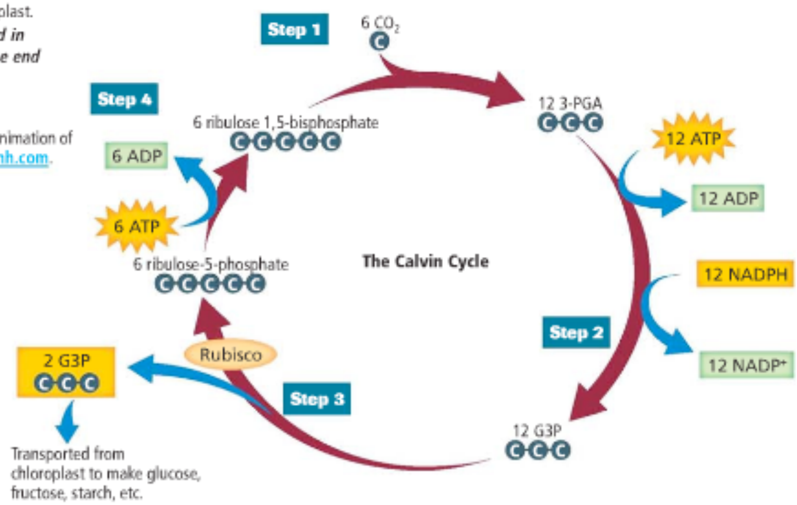


Figure 8.9 The Calvin cycle joins carbon dioxide with organic molecules inside the stroma of the chloroplast.
Determine *the compound in which energy is stored at the end of the Calvin cycle.*

Concepts In Motion
Interactive Figure To see an animation of the Calvin cycle, visit biologygmh.com.

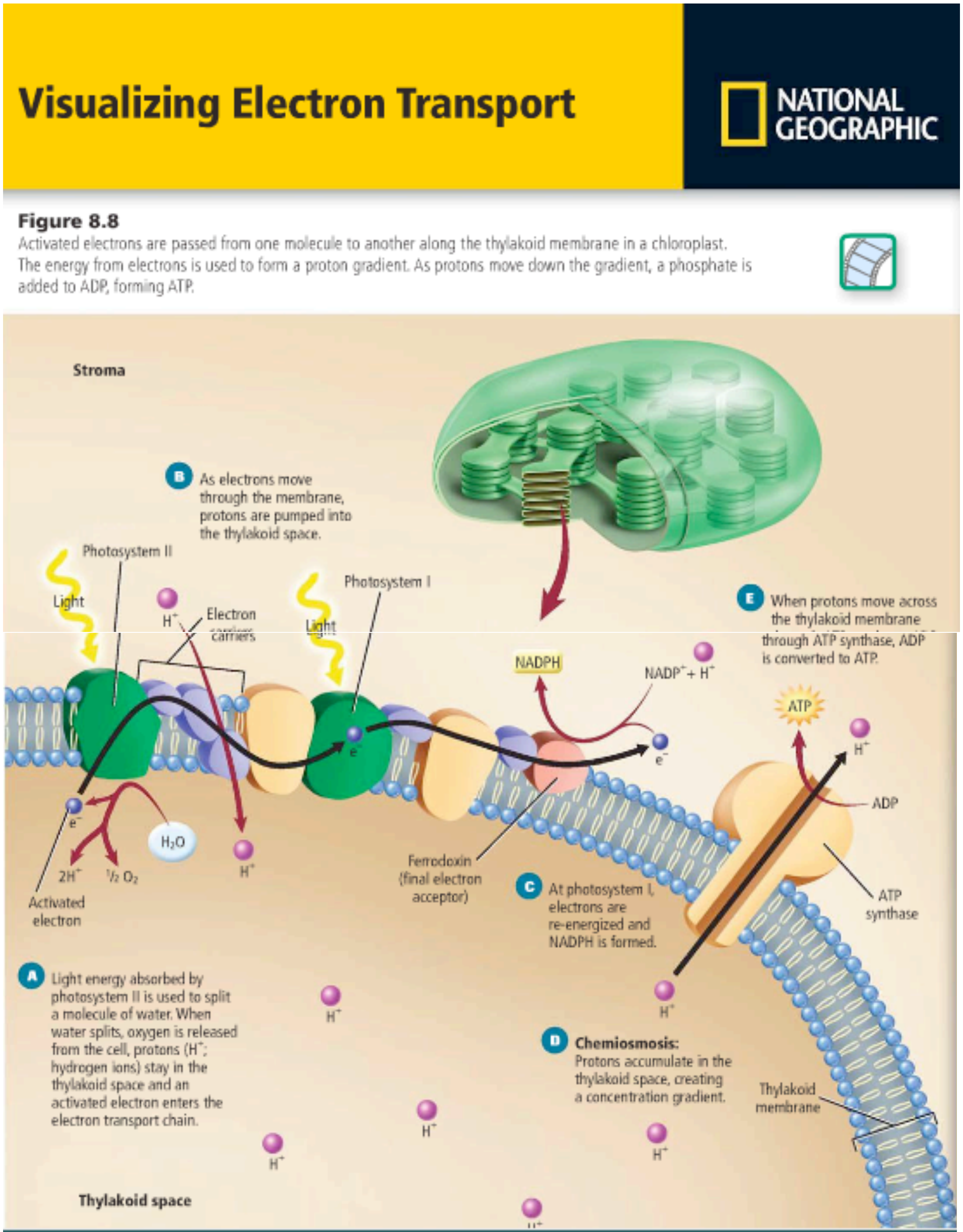
  - where does it take place? - **Stroma**
  - what is another name for the Calvin cycle? - **light independent reactions**
  - what are the main steps?
    - **In the second phase of photosynthesis, called the Calvin cycle, energy is stored in organic molecules such as glucose.**
    - **Six CO2 molecules combine with six 5-carbon compounds to form twelve 3-carbon molecules called 3-PGA.**
    - **The chemical energy stored in ATP and NADPH is transferred to the 3-PGA molecules to form high-energy molecules called G3P.**
    - **Two G3P molecules leave the cycle to be used for the production of glucose and other organic compounds.**
    -

- When is glucose formed in photosynthesis? – **After/ end of calvin cycle w/ oxygen**
- Photolysis – **The splitting of water with hydrogen and oxygen ions – during phase 1.**
- Rubisco and its role in the Calvin cycle - **an enzyme that converts** the remaining ten G3P molecules into 5- carbon molecules called ribulose 1, 5-biphosphates (RuBP). These molecules combine with new carbon dioxide molecules to continue the cycle. The final step of the Calvin cycle

- Where does each phase of photosynthesis occur?
  - Phase 1 – Chloroplasts – **Thylakoids (Chlorophyll)**
  - Phase 2 - **Stroma**

- Structure of Chloroplast:
  - **Thylakoid** - flattened saclike membranes that are arranged in stacks. One of the main compartments essential to photosynthesis. (**Phase 1)**
  - **Grana** - the stacks of thylakoids
  - **Stroma** - the fluid compartment that is outside the grana. This is the location of the light-independent reactions in **phase two** of photosynthesis. One of the main compartments essential to photosynthesis.
  - **Chlorophyll** – the major pigments in plants. It absorbs most wavelengths of light except green.
- The role of glucose in photosynthesis and cellular respiration – **product of photosynthesis and reactant for cellular respiration**
- Explain the function of the chloroplast during the light reactions – **capture light energy in photosynthetic organisms.**

- *****Diagram and explain the electron transport chain**



-
  - **Photosystem II - When water molecules split, two electrons are released as a waste product (photolysis) , releases electrons in electron transport chain**
  - **Photosytem I – another electron transport chain (bucket brigade)**
- Pigments:
  - **absorption spectrum**

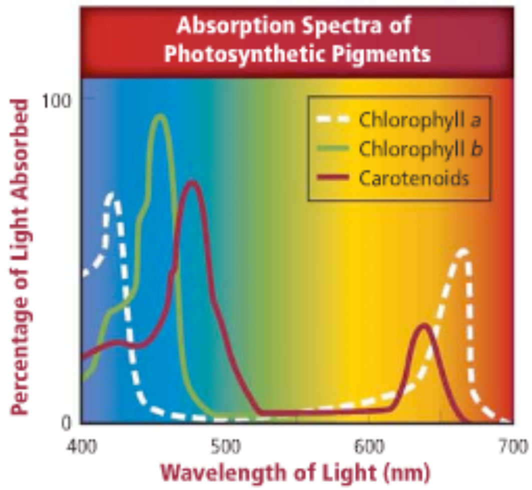


Figure 8.6 Colorful pigments found in the leaves of trees differ in their ability to absorb specific wavelengths of light.

- reflection – **green region of spectrum, why plant pars that have chlorophyll appear green to the human eye.**
- ROYGBIV – **Visible light spectrum**
- chlorophyll a and b – **there are two types of chlorophyll. A absorbs darker colors. B absorbs lighter colors.**

* What are some of the alternatives to photosynthesis? - **C4 and CAM**
* What do C4 and CAM plants do?
  - C4 – **fix carbon dioxide in to 4-carbon compound instead of 3 carbons compounds like the cycle. Minimizes water loss, keep stomata (Pores) closes. Ex – sugar cane, corn.**
  - CAM – **CO_2 enters the leaves only at night when it is cooler and more humid during the day CO_2, enters the Calvin Cycle. Occurs in water conserving plants. Ex – cactus, orchids, pineapple.**
* Cellular Respiration:
  - Equation

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{Energy}$$

  - why is it necessary? - **The function of cellular respiration is to harvest electrons from carbon compounds, such as glucose and use that energy to make ATP. ATP is used to provide energy for cells to do work.**

- Cellular respiration steps:

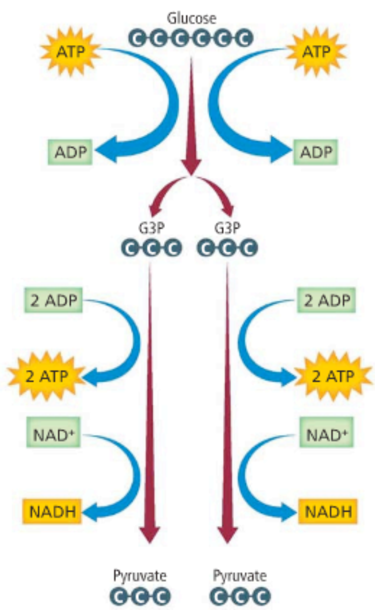


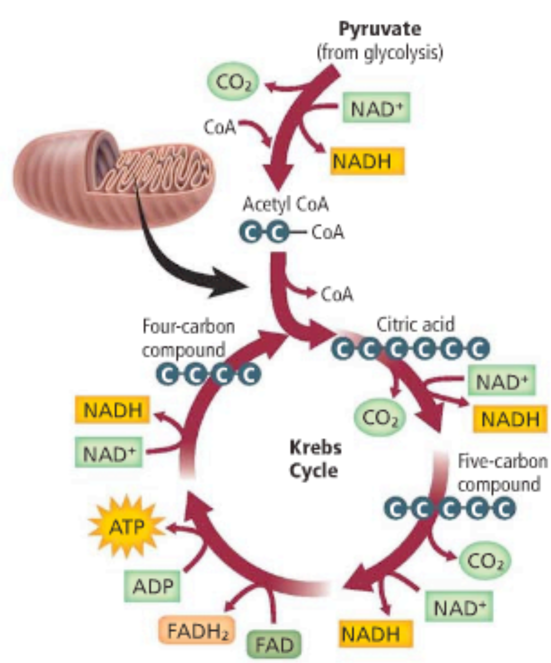
Figure 8.12 Glucose is broken down during glycolysis inside the cytoplasm of cells. **Summarize** *the reactants and products of glycolysis.*

  - Glycolysis - **the process when glucose is broken down in the cytoplasm**

Figure 8.13 Pyruvate is broken down into carbon dioxide during the Krebs cycle inside the mitochondria of cells. **Trace** *Follow the path of carbon molecules that enter and leave the Krebs cycle.*

Concepts In Motion

Interactive Figure To see an animation of the Krebs cycle, visit biologygmh.com.



  - Krebs cycle (citric acid cycle) - **(or tricarboxylic acid (TCA) cycle) series of reactions in which pyruvate is broken down into carbon dioxide.**

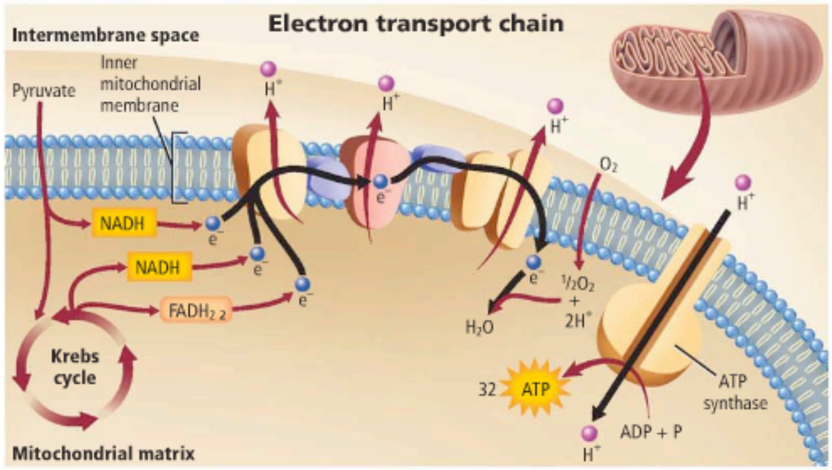


Figure 8.14 Electron transport occurs along the mitochondrial membrane.

  - electron transport chain
- Where does each step in cellular respiration occur?
  - Glycolysis – **in cytoplasm** **<u>ANAEROBIC</u>**
  - krebs cycle (citric acid cycle) – **in mitochondria - <u>AEROBIC</u>**
  - electron transport chain – **along mitochondrial membrane <u>AEROBIC</u>**
- What is the final electron acceptor in the electron transport chain of cellular respiration? **- Oxygen**
- NADP+/NADPH – what is the role of these electron carriers?
- *****Compare and contrast photosynthesis and cellular respiration.**

○ **Photosynthesis**	○ **Cellular Respiration**
• Produces glucose and oxygen • Only plant cells • Requires sunlight • Requires chloroplasts and chlorophyll • Requires Carbon Dioxide and water • Carbon dioxide taken in, (oxygen out)	• Produces CO_2 and Water • Animal and plant cells • Requires mitochondria, oxygen and glucose • Breaks down glucose – energy released • Doesn't require sunlight • Oxygen taken in, (Carbon Dioxide out) The process by which mitochondria break down food molecules to produce ATP organisms
Both	
Important processes that cells use to obtain energy	

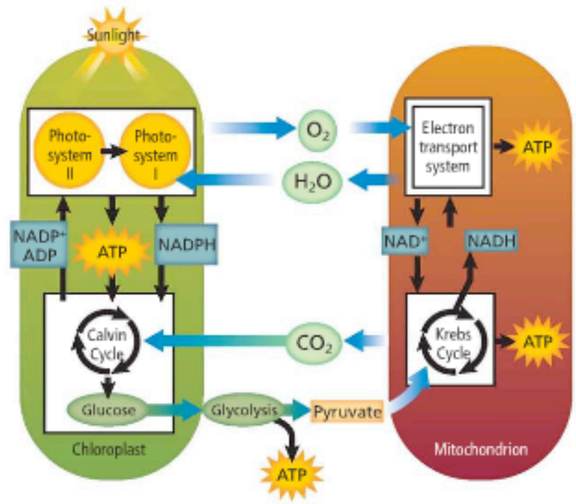
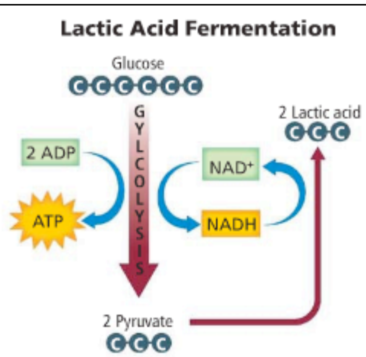
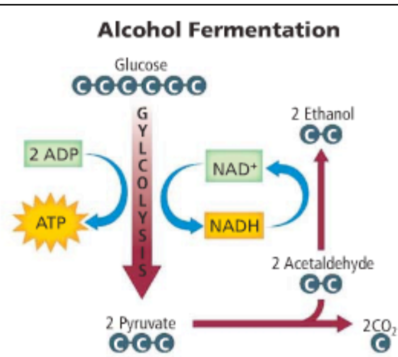


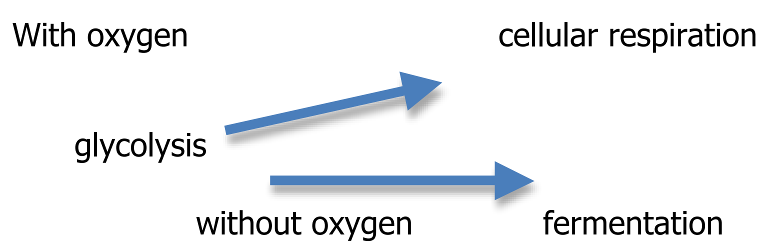
Figure 8.16 Photosynthesis and cellular respiration form a cycle in which the products of one metabolic pathway form the reactants of the other metabolic pathway.

Photosynthesis and Cellular Respiration

As you have learned, photosynthesis and cellular respiration are two important processes that cells use to obtain energy. They are metabolic pathways that produce and break down simple carbohydrates. **Figure 8.16** shows how these two processes are related. Recall that the products of photosynthesis are oxygen and glucose—the reactants needed for cellular respiration. The products of cellular respiration—carbon dioxide and water—are the reactants for photosynthesis.

- How many ATPs are formed in cellular respiration? **36**
- What about fermentation? **2 ATP**
- What does net gain mean? **- overall gain including what left cell**
- Anaerobic/aerobic processes
  - Anaerobic – **no oxygen is required**
  - Aerobic – **require oxygen**
- **Fermentation: lactic acid/alcoholic – compare and contrast**

○ **Lactic Acid**	○ **Alcoholic**
	
Enzymes convert the pyruvate made during glycolysis to lactic acid. This involves the transfer of high-energy	occurs in yeast and some bacteria. The picture above show the chemical reaction that occurs during alcohol fermentation

<table>
<tr><td>electrons and protons from NADH. Skeletal muscle produces lactic acid when the body cannot supply enough oxygen, such as during periods of strenuous exercise. When lactic acid builds up in muscle cells, muscles become fatigued and might feel sore. Lactic acid also is produced by several microorganism that often are used to produce many foods, including cheese, yogurt, and sour cream.</td><td>when pyruvate is converted to ethyl alcohol and carbon dioxide. Similar to lactic acid fermentation, NADH donates electrons during this reaction and NAD+ is regenerated.</td></tr>
<tr><td colspan="2">Both</td></tr>
<tr><td colspan="2">Types of Fermentation – an anaerobic process - occurs when oxygen is not available
for cellular respiration

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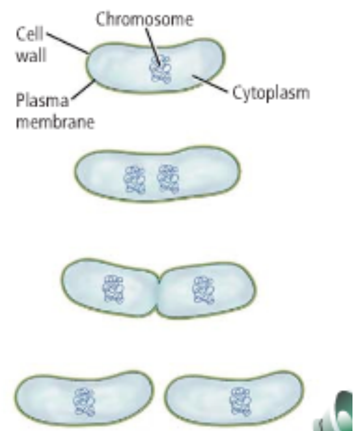
- **Compare and contrast cellular respiration and fermentation**

<table>
<tr><th>○ Cellular Respiration</th><th>○ Fermentation</th></tr>
<tr><td>Oxygen – 36 ATP
The process by which mitochondria break down food molecules to produce ATP organisms</td><td>2 ATP – Not enough Oxygen</td></tr>
<tr><td colspan="2">Both</td></tr>
<tr><td colspan="2">Both Cell Processes</td></tr>
</table>

Mitosis and Meiosis Unit

- Sections in the textbook: Chapter 9 and 10.1
- All vocabulary words – See Notes
- Binary fission and asexual reproduction

- o What is binary fission? – the asexual reproduction of a prokaryotic cell by division into two roughly equal parts (two daughter cells) genetically identical to the parent cell; uses less energy than mitosis.
- o Be able to diagram and explain binary fission.



Binary fission

Figure 18.6 Binary fission is an asexual form of reproduction used by some prokaryotes. Conjugation is a method of exchanging genetic material used by some prokaryotes.

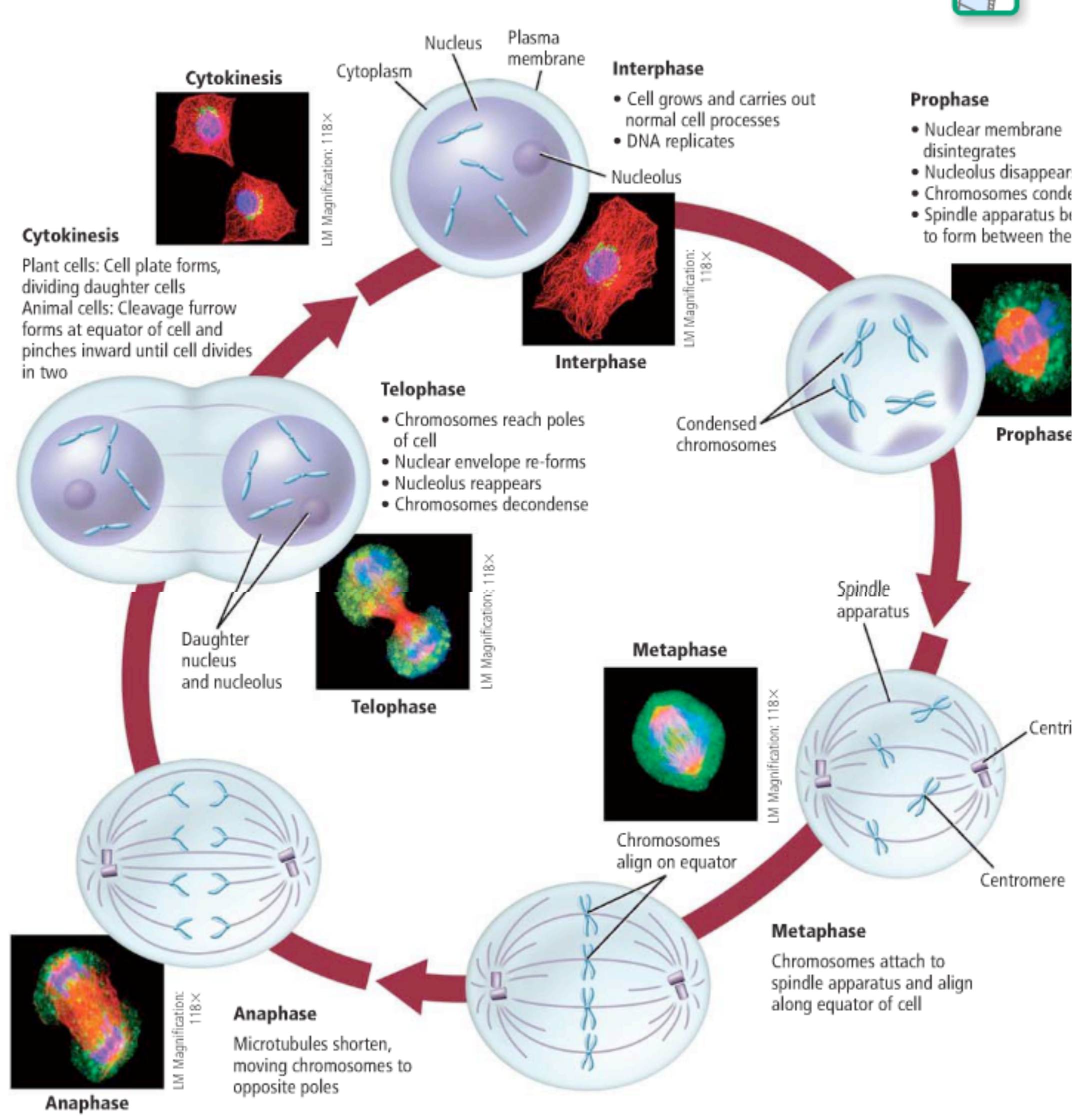
- o What is the difference between asexual and sexual reproduction?
  - ▪ Asexual – the organism inherits all of its chromosomes from a single parent. Therefore, the new individual is genetically identical to its parent and any other offspring produced, barring any mutations. Bacteria reproduce asexually.
  - ▪ Sexual – the organism inherits half of its chromosomes from its father, and the other half from its mother.
  - ▪ Bacteria reproduce asexually, whereas most protists reproduce both asexually and sexually. Many plants and many of the more simple animals can reproduce both asexually and sexually, compared to more advanced animals that reproduce only sexually.
- o What kind of cells go through binary fission? - Prokaryotes
- o Binary fission and mitosis are both asexual – both produce daughter cells genetically identical to the parent cell. They are both asexual reproduction. Binary fission occurs in prokaryotes, while mitosis occurs in eukaryotes. Mitosis splits by binary fission. Binary fission uses less energy than mitosis.

- Why does a cell need to divide? – As a cell grows, it's volume increases faster than it's surface area – therefore cells might have a hard time moving nutrients into and out of the cell.
  - o Surface Area to Volume Ratio – diffusion over large distances is slow; smaller cells function better
  - o Reasons – communication is better in a small cell
- Identify the phases of mitosis and be able to describe the phases:
  - o Prophase - the first stage of mitosis and the longest phase. In this stage, the cell's chromatin tightens, or condenses into chromosomes. In

prophase, the chromosomes are shaped like an X as shown in the picture above. At this point, each chromosome is a single structure that contains the genetic material that was replicated in interphase.

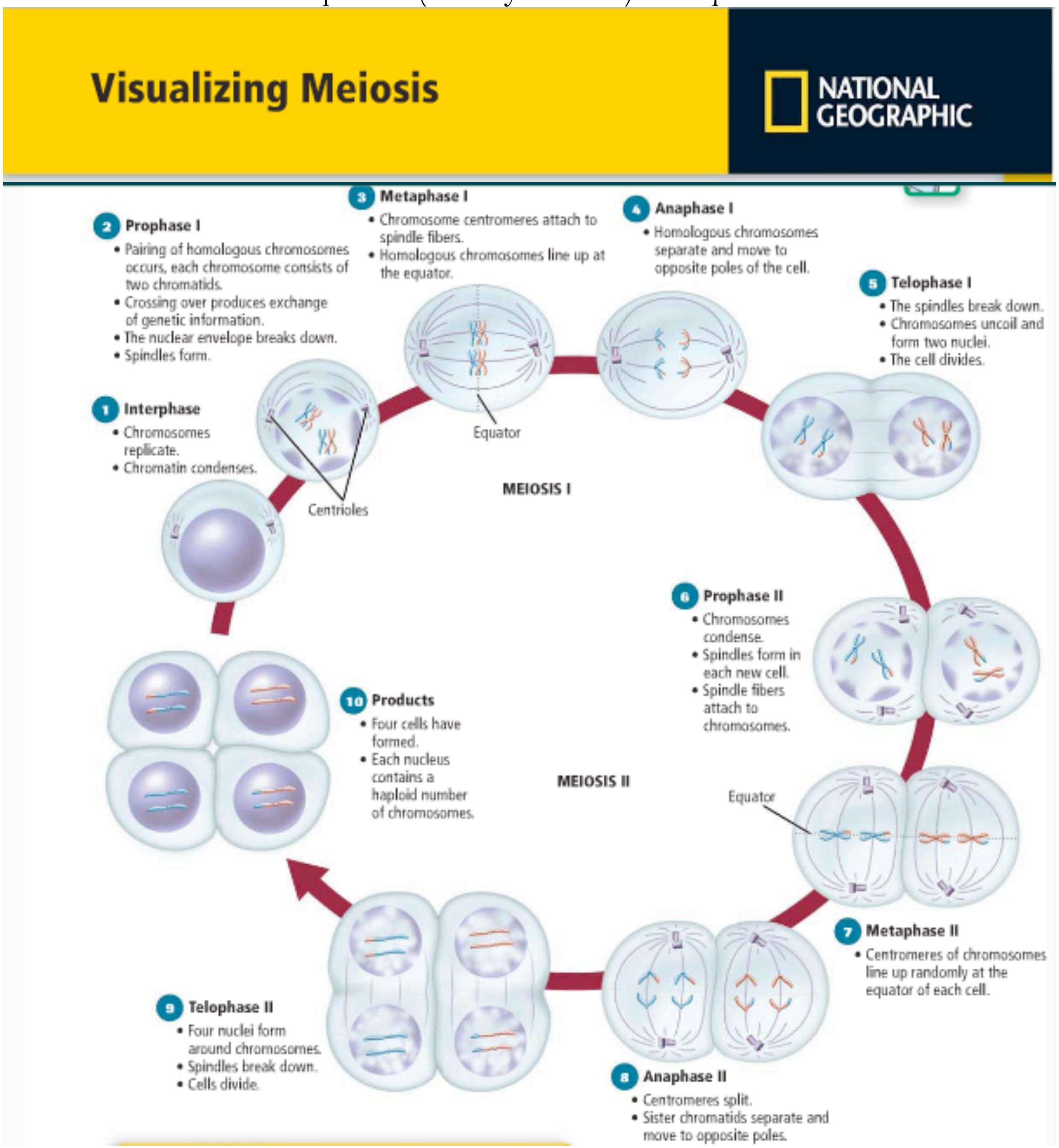
- Metaphase - the sister chromatids are pulled by motor proteins along the spindle apparatus toward the center of cell and line up in the middle, or equator of the cells. Mitosis is one of the shortest stages of mitosis, but when completed successfully, it ensures that the new cells have accurate copies of the chromosomes.
- Anaphase - the chromatids are pulled apart during the 3rd stage of mitosis. In anaphase, the microtubules of the spindle apparatus begin to shorten. This shortening pulls at the centromere of each sister chromatid, causing the sister chromatids to separate into two identical chromosomes. All of the sister chromatids separate simultaneously, although the exact mechanist that controls this is unknown. At the end of anaphase, the microtubules, with the help of motor proteins, move the chromosomes toward the poles of the cells.
- Telophase - the last stage of mitosis during which the chromosomes arrive at the poles of the cell and begin to relax or decondense. Two new nuclear membranes begin to form and the nucleoli reappear. The spindle apparatus disassembles and some of the microtubules are recycled by the cell to build various parts of the cytoskeleton. Although the four stages of mitosis are now complete and the nuclear material is divided, the process of cell division is not yet complete.

Figure 9.6
The cell cycle begins with interphase. Mitosis follows, occurring in four stages—prophase, metaphase, anaphase, and telophase. Mitosis is followed by cytokinesis, then the cell cycle repeats with each new cell.



- Identify the phases of meiosis and be able to describe the phases:
  - Meiosis 1
    - Prophase 1 – (**Diploid cell**) chromosomes pair with their homologous chromosomes and form a tetrad. Crossing over also occurs.
    - Metaphase 1 - Homologous chromosomes line up in the middle of the cell. Spindle fibers attach to the chromosomes.
    - Anaphase 1 – Spindle fibers pull homologous chromosomes toward opposite ends of the cell.
    - Telophase 1(And Cytokinesis) – Nuclear membrane starting to reform. One cell begins to separate into 2 cells. Produces **two haploid cells.**
  - Meiosis 2 (II)

- Prophase 2 – (**2 haploid cells**.) Half of the number of chromosomes from the original cell.
- Metaphase 2 – chromosomes line up in the center of the cell (similar to how they line up in mitosis).
- Anaphase 2 – Sister chromatids separate. Move to opposite ends of the cell.
- Telophase 2 (And Cytokinesis) – 4 haploid cells formed



- What is the difference between mitosis and meiosis?
  - Which one occurs in somatic cells? - Mitosis
  - Which one occurs to produce gametes? What are gametes? – Meiosis. Gametes are sex cells that have half the number of chromosomes. Although the number of chromosomes varies form one species to

another, in humans each gamete contains 23 chromosomes. The symbol *n* can be used to represent the number of chromosomes in a gamete.

- Know the difference between sperm and egg – spermatogenesis/oogenesis
    - Spermatogenesis: The formation of male gametes, they are haploid gametes called sperm, which are produced by meiosis.
    - Oogenesis: The formation of female gametes, mature eggs or ova. The cell divisions at the end of meiosis I and I are uneven – this happens that way the one cell that becomes the egg receives most of the cytoplasm. The other three cells that are produced during oogensis are called **polar bodies** and they do not have a role in reproduction.

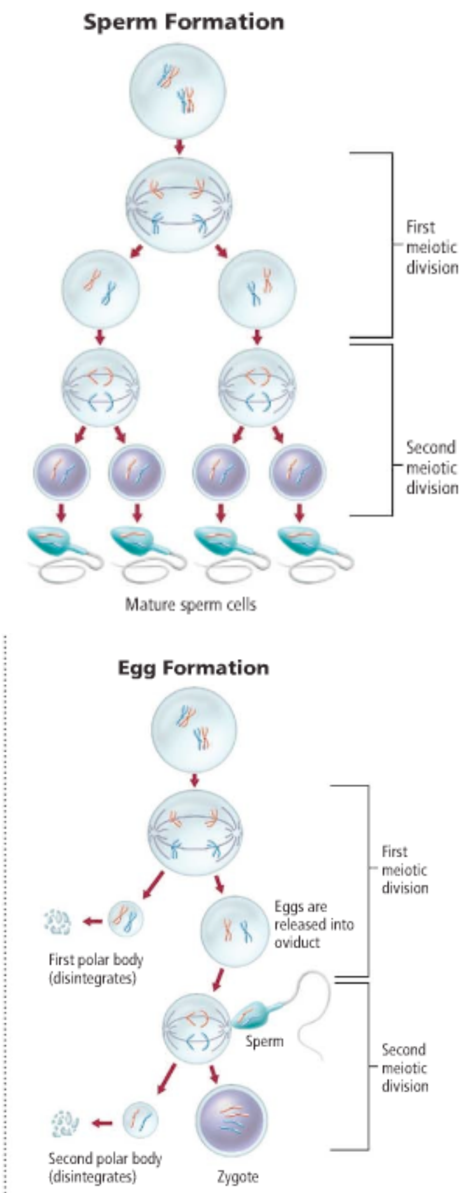
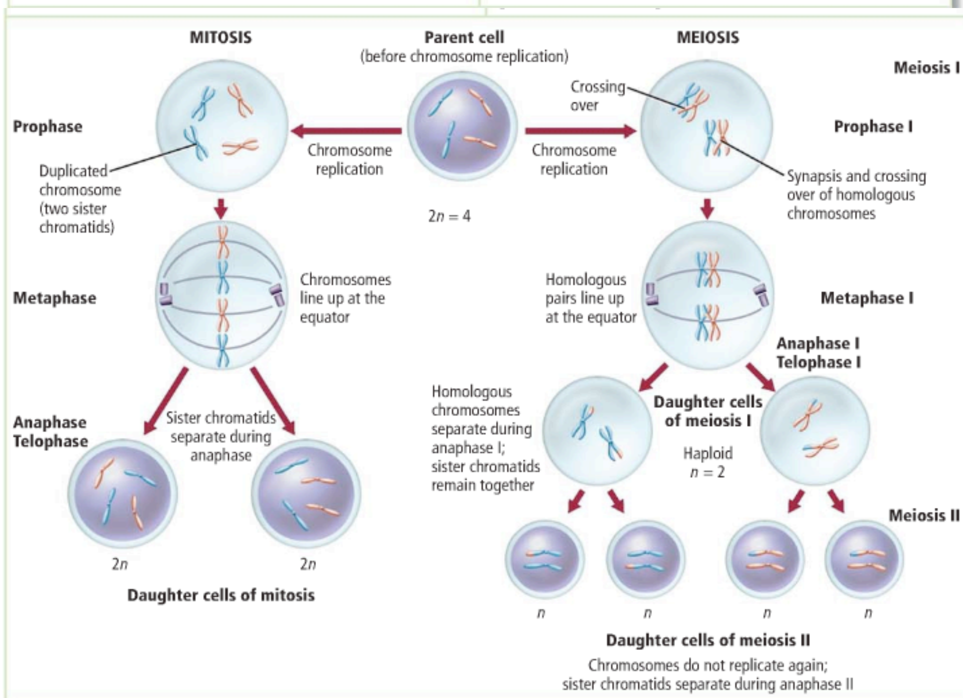


Figure 36.5
Top: The human male sex cell production follows the general pattern of meiosis and results in many sperms.
Bottom: Meiosis in the human female results in one egg. The second division in meiosis will not be completed in a human female unless the egg is fertilized.

Table 10.1 Mitosis and Meiosis

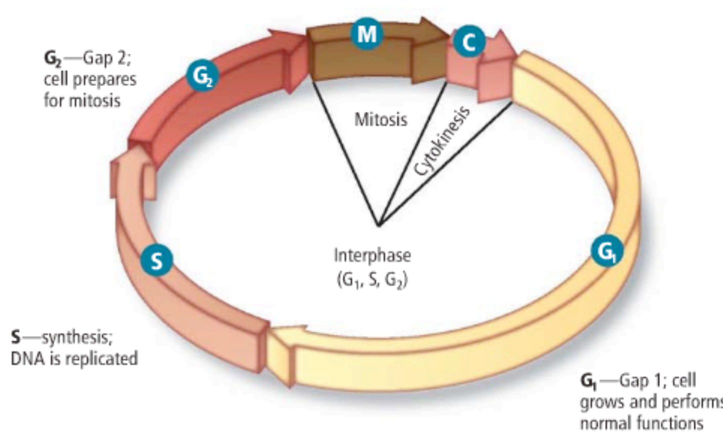
Interactive Table To explore more about mitosis and meiosis, visit biologygmh.com.

Mitosis	Meiosis
One division occurs during mitosis.	Two sets of divisions occur during meiosis: meiosis I and meiosis II.
DNA replication occurs during interphase.	DNA replication occurs once before meiosis I.
Synapsis of homologous chromosomes does not occur.	Synapsis of homologous chromosomes occurs during prophase I.
Two identical cells are formed per cell cycle.	Four haploid cells (*n*) are formed per cell cycle.
The daughter cells are genetically identical.	The daughter cells are not genetically identical because of crossing over.
Mitosis occurs only in body cells.	Meiosis occurs in reproductive cells.
Mitosis is involved in growth and repair.	Meiosis is involved in the production of gametes and providing genetic variation in organisms.

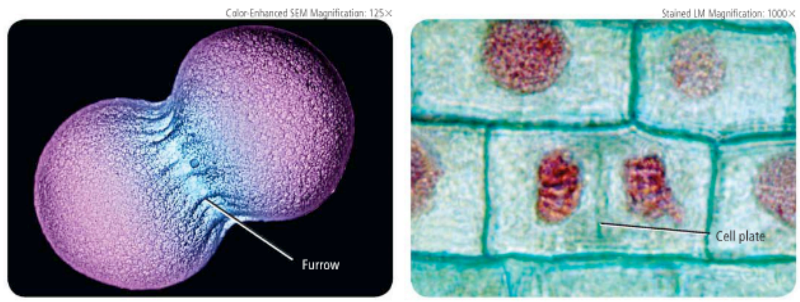


- What is a zygote? When does it form? – A fertilized egg formed in meiosis.

Figure 9.3 The cell cycle involves three stages—interphase, mitosis, and cytokinesis. Interphase is divided into three substages.
Hypothesize ***Why does cytokinesis represent the smallest amount of time a cell spends in the cell cycle?***



- Cell Cycle:
  - Interphase – made up of three parts; the stage during which the cell grows, carries out cellular functions, and replicates.
    - G1: Gap 1 – Cell spends a lot of time in this phase, growing occurs and cell caries out its functions
    - S: Synthesis – DNA replication (copy)
    - G2: Gap 2 – More replication
  - Mitosis – Division of nucleus and nuclear material Has 4 stages – prophase, metaphase, anaphase, and telophase.
  - Cytokinesis – cytoplasm divides, producing two new cells.



Animal cell   Plant cells

    - What is the difference between plant and animal cell cytokinesis
      - Animal cells – the cell membrane punches inward until there is a division of the cytoplasm of almost 2 equal parts.
      - Plant cells – a cell plate forms and it gradually develops into a separating membrane and the cell wall start to be seen in the cell plate.
    - What is G0? – Some cells that don't divide. They cannot be replaced (and you are born with them). Example – Brain cells
    - Do all cells go through the cell cycle at the same pace? – No

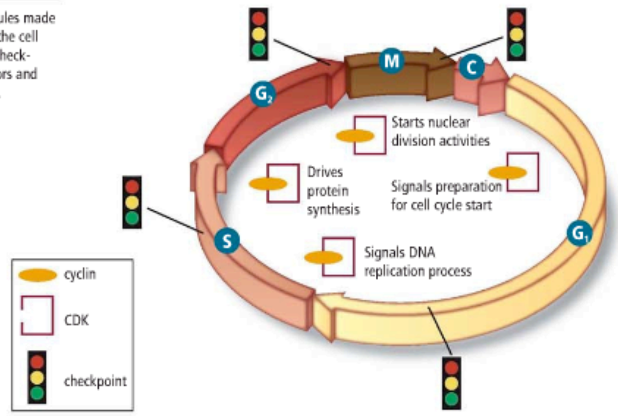
FIGURE 5.2 CELL DIVISION

CELL TYPE	APPROXIMATE LIFE SPAN
Skin cell	2 weeks
Red blood cell	4 months
Liver cell	300–500 days
Intestine—internal lining	4–5 days
Intestine—muscle and other tissues	16 years

Figure 9.11 Signaling molecules made of a cyclin bound to a CDK kick off the cell cycle and drive it through mitosis. Checkpoints monitor the cell cycle for errors and can stop the cycle if an error occurs.

Personal Tutor

To learn about the cell cycle, visit biologygmh.com.

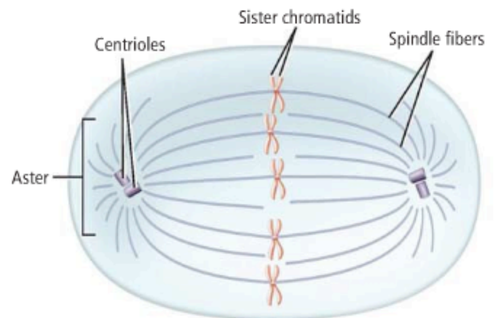


- Cell Cycle checkpoints: - has built in checkpoints that monitor the cycle and can stop it if something goes wrong.

Quality control checkpoints Recall the process of starting a car. Many manufacturers use a unique microchip in the key to ensure that only a specific key will start each car. This is a checkpoint against theft. The cell cycle also has built-in checkpoints that monitor the cycle and can stop it if something goes wrong. For example, a checkpoint near the end of the G_1 stage monitors for DNA damage and can stop the cycle before entering the S stage of interphase. There are other quality control checkpoints during the S stage and after DNA replication in the G_2 stage. Spindle checkpoints also have been identified in mitosis. If a failure of the spindle fibers is detected, the cycle can be stopped before cytokinesis. **Figure 9.11** shows the location of key checkpoints in the cell cycle.

  - When do they occur? –
    - near the end of G1 – stage monitors for DNA damage and can stop the cycle before entering the S stage of interphase
    - During S
    - After DNA replication in the G2 stage
    - Mitosis
  - Why do they occur? – to stop it if something goes wrong
  - What happens during them? – see above
- What are telomeres? – at the end of chromosomes. They contain DNA that does not code for a gene.
- What are autosomes and sex chromosomes?
  - Autosomes: 44 autosomes, 22 pairs – Chromosomes numbers 1 to 22. **Aren't sex chromosomes.**
  - Sex Chromosomes: humans bond 2 sex chromosomes, x or y. Female- xx, Male - xy
- Centrioles: Two small structures in the cytoplasm that are bear the nuclear envelope, they separate and go to opposite pole or ends of the nucleus.
  - What types of cells do they occur in? – **Animal** and most protist cells
  - What is their association with asters? What are asters? – Centrioles migrate to the ends, or poles, of the cells. Coming out of the centrioles

are yet another type of microtubule called aster fibers, which have a star like appearance. Spindle Apparatus – the whole structure, including the spindle fivers, centrioles, and aster fibers.



- What are spindles? Where do they originate in plants and animals? – microtubule structure that helps to pull the chromosome apart. Spindle fibers form during prophase.

- Centromeres:
  - What are centromeres? - the structure at the center of the chromosome where the sister chromatids are attached. Where are they found? - center of the chromosome
  - What are they used for? - This structure is important because it ensures that a complete copy of the replicated DNA will become part of the daughter cells at the end of the cell cycle.
- Chromatin and Chromosomes:

Chromatin and Condensed Chromosome Structure

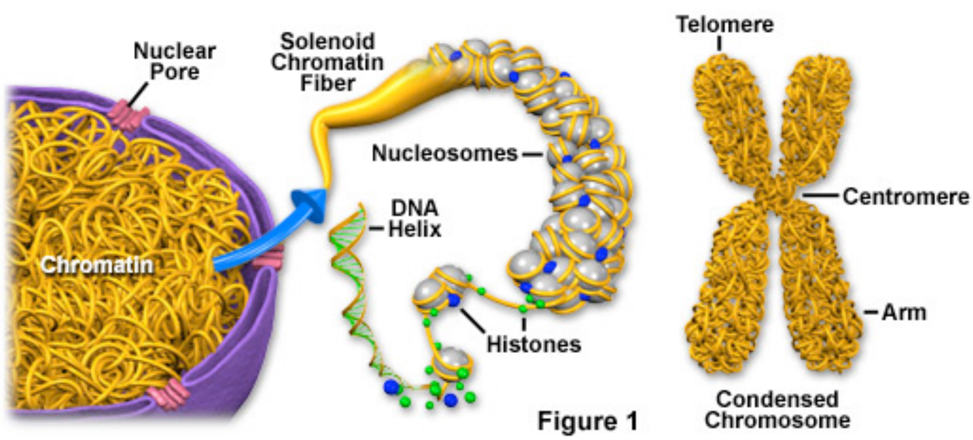


Figure 1

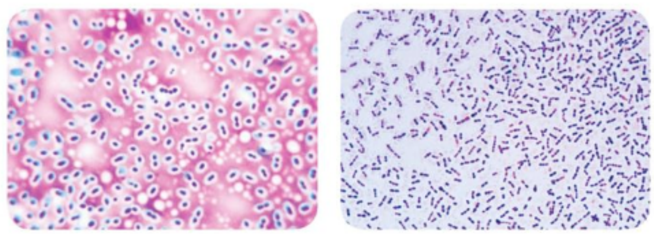
  - What is the difference between the two?
    - Chromatin is the relaxed form of DNA in the cells nucleus (DNA plus protein (histones))
    - Chromosomes – Structures that contain the genetic material that is passed from generation to generation. (Condense at the beginning of mitosis. DNA wraps around proteins histones that condense it)
  - When is chromatin present? - Interphase
  - When are chromosomes present? – Mitosis

  - What is the difference between an unreplicated chromosome and a replicated chromosome? – Single chromosome, double chromosome
  - What are sister chromatids? – held together by a centomere
- Levels of Biological Organization: cells, tissues, organs, organ systems, organisms
- Cancer:
  - What are the causes of cancer? - the uncontrolled growth and division of cells – a failure in the regulation of the cell cycle. When unchecked, cancer cells can kill an organism by crowding out normal cells, resulting in the loss of tissue function.
  - How can you prevent cancer? –
    - Stay out of sun, don't smoke or be around people that do, stay away from asbestos
    - the tumors could be removed if it hasn't spread but if it has spread, you should leave the primary tumor in.
  - What are carcinogens? - substances and agents that are known to cause cancer
  - What does metastasize mean? – spread of cancer from the primary site to other parts of the body
  - What is a tumor? – masses of cells
  - What are the two types of tumors?
    - Benign (ben-good): are noncancerous tumors and does not spread to healthy tissue or other parts of the body.
    - Malignant (mal-bad): are cancerous tumors that invade and destroy surrounding tissue.
  - What is cyclin? - proteins that bind to enzymes called cyclin-dependent kinases
    - Cyclin-dependent kinase (CDKs) – enzymes that cyclin binds to in the stages of interphase and mitosis to start the various activities that take place in the cell cycle. Different cyclin/CDK combination control different activities at different stages in the cell cycle. The picture above illustrates where some of the important combinations are active.
- What is the difference between haploid and diploid?
  - Haploid – a cell with n number of chromosomes. Haploid comes from the Greek word haploos, meaning single.
  - Diploid – a cell that contains 2n number of chromosomes
- What are homologous chromosomes? - the chromosomes that make up a pair, one chromosome from each parent.
  - Why do somatic (body) cells have homologous chromosomes? – same size/length, same centromere position, usually contain genes for the same trait
- How many chromosomes does a human have? How many pairs of chromosomes? – 46, 23 pairs
- What is crossing over? - a process during which chromosomal segments are exchanged between a pair of homologous chromosomes. Genetic variation increases because of it.
  - When does it happen? – Prophase I

- Compare mitosis and meiosis. – See chart above

DNA and RNA Unit

- Chapter 12
- Vocabulary -Notes
- What experiments led up to the discovery of DNA being the hereditary material?
    - The discovery that DNA is the genetic code involved many experiments.
        - Experiments by Griffith, Avery, Hershey and Chase, Watson and Crick.
    - Proteins thought to be genetic material before discovery.
- Know what the following scientists did: Griffith, Avery, Hershey and Chase, Watson and Crick, and Rosalind Franklin



Smooth strain—*S. pneumoniae* **Rough strain—*S. pneumoniae***

Figure 12.1 The smooth (S) strain of *S. pneumoniae* can cause pneumonia, though the rough (R) strain is not disease causing. The strains can be identified by the appearance of the colonies.

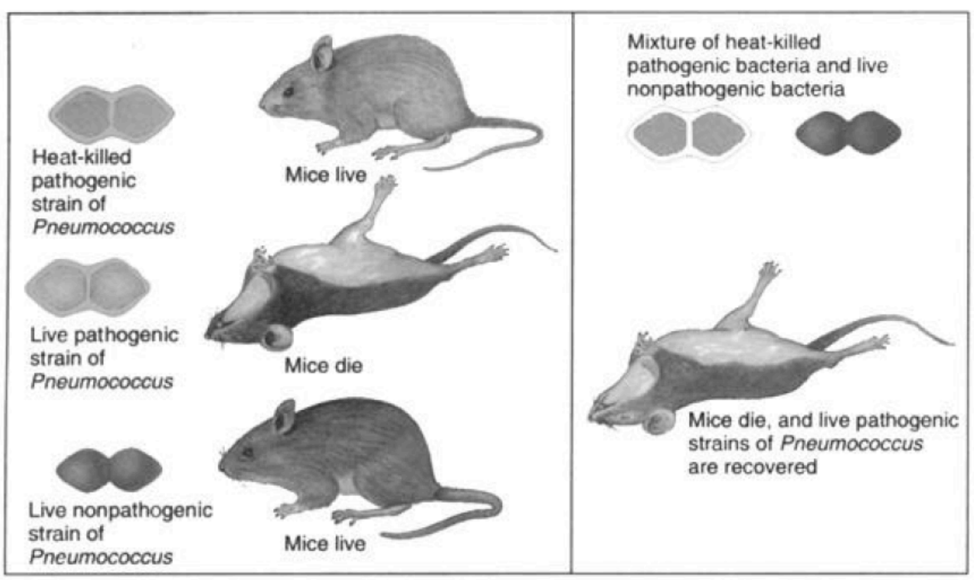
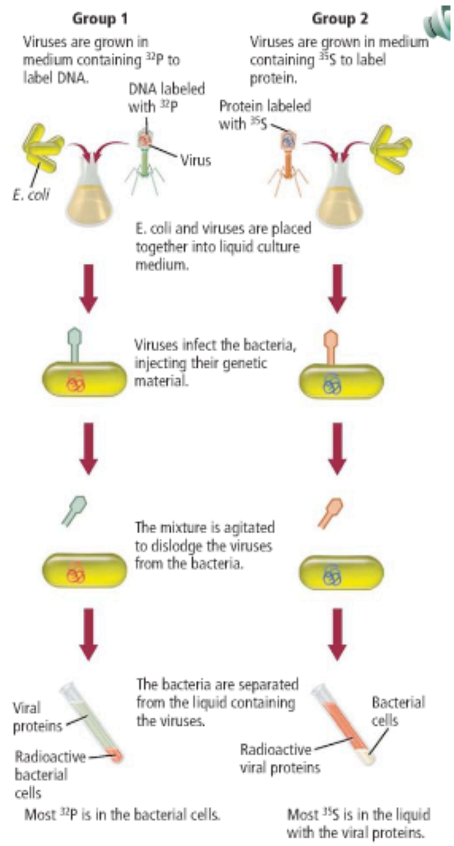


Figure 6.1
Griffith's discovery of the "transforming principle."

■ **Figure 12.6** Rosalind Franklin's Photo 51 and X-ray diffraction data helped Watson and Crick solve the structure of DNA. When analyzed and measured carefully, the pattern shows the characteristics of helix structure.



■ **Figure 12.3** Hershey and Chase used radioactive labeling

Concepts In Motion
Interactive Table To explore more about Hershey and Chase, visit biologygmh.com.

Table 12.1 Summary of Hershey-Chase Results

Group 1 (Viruses labeled with ^{32}P)		Group 2 (Viruses labeled with ^{35}S)	
Infected Bacteria	**Liquid with Viruses**	**Infected Bacteria**	**Liquid with Viruses**
• Labeled viral DNA (^{32}P) found in the bacteria • Viral replication occurred • New viruses contained ^{32}P	• No labeled DNA • No viral replication	• No labeled viral proteins (^{35}S) • Viral replication occurred • New viruses did not have a label	• Labeled proteins found • No viral replication

Figure 12.5 Chargaff's data showed that though base composition varies from species to species, within a species C = G and A = T.

Chargaff's Data

	Base Composition (Mole Percent)			
Organism	A	T	G	C
Escherichia coli	26.0	23.9	24.9	25.2
Yeast	31.3	32.9	18.7	17.1
Herring	27.8	27.5	22.2	22.6
Rat	28.6	28.4	21.4	21.5
Human	30.9	29.4	19.9	19.8

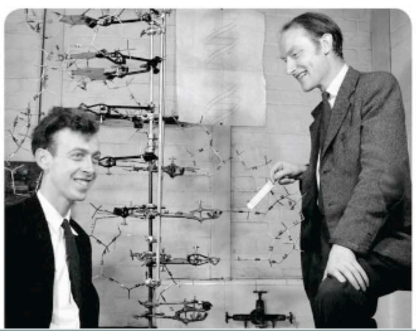
- **Know the scientists and what they did to determine that DNA was the heredity molecule and the scientists that discovered the structure of DNA.**

■ **Figure 12.6** Rosalind Franklin's Photo 51 and X-ray diffraction data helped Watson and Crick solve the structure of DNA. When analyzed and measured carefully, the pattern shows the characteristics of helix structure.

X-ray diffraction Wilkins was working at King's College in London, England, with a technique called X-ray diffraction, a technique that involved aiming X rays at the DNA molecule. In 1951, Franklin joined the staff at King's College. There she took the now famous Photo 51 and collected data eventually used by Watson and Crick. Photo 51, shown in **Figure 12.6,** indicated that DNA was a **double helix,** or twisted ladder shape, formed by two strands of nucleotides twisted around each other. The specific structure of the DNA double helix was determined later by Watson and Crick when they used Franklin's data and other mathematical data. DNA is the genetic material of all organisms, composed of two complementary, precisely paired strands of nucleotides wound in a double helix.

Watson and Crick Watson and Crick were working at Cambridge University in Cambridge, England, when they saw Franklin's X-ray diffraction picture. Using Chargaff's data and Franklin's data, Watson and Crick measured the width of the helix and the spacing of the bases. Together, they built a model of the double helix that conformed to the others' research. The model they built is shown in **Figure 12.7.** Some important features of their proposed molecule include the following:

1. two outside strands consist of alternating deoxyribose and phosphate
2. cytosine and guanine bases pair to each other by three hydrogen bonds
3. thymine and adenine bases pair to each other by two hydrogen bonds

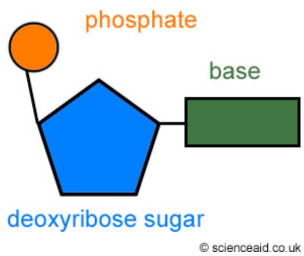


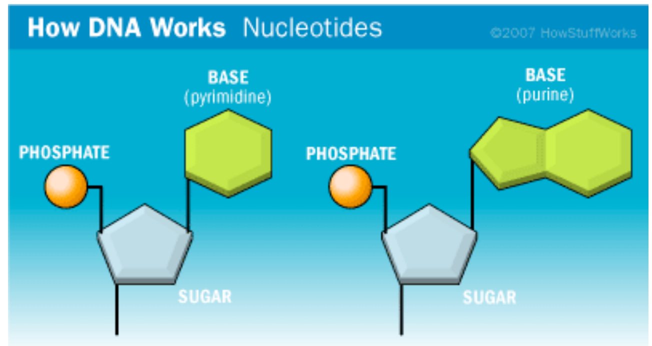
■ **Figure 12.7** Using Chargaff's and Franklin's data, Watson and Crick solved the puzzle of the structure of DNA.

DNA structure DNA often is compared to a twisted ladder, with the rails of the ladder represented by the alternating deoxyribose and phosphate. The pairs of bases (cytosine–guanine or thymine–adenine) form the steps, or rungs, of the ladder. A purine base always binds to a pyrimidine base, ensuring a consistent distance between the two rails of the ladder. This proposed bonding of the bases also explains Chargaff's data, which suggested that the number of purine bases equaled the number of pyrimidine bases in a sample of DNA. Remember, cytosine and thymine are pyrimidine bases, adenine and guanine are purines, and C = G and A = T. Therefore, C + T = G + A, or purine bases equal pyrimidine bases. Complementary base pairing is used to describe the precise pairing of purine and pyrimidine bases between strands of nucleic acids. It is the characteristic of DNA replication through which the parent strand can determine the sequence of a new strand.

- Bacteriophage – used by Hershey and Chase, a type of virus that attacks bacteria. In their experiment the bacteriophage was made of DNA and protein.
- Nucleotides: the different kinds for DNA and RNA
    - **There are 4 different kinds of nucleotides – the only difference is the type of nitrogenous base: thymine, adenine, cytosine, and guanine. In RNA there is Uracil instead of thymine.**
- What are the base-pairing rules?
    - DNA
        - Adenine pairs with Thymine
        - Guanine pairs with Cytosine
    - RNA – no Thymine, but Uracil

        - Adenine pairs with Uracil
        - Guanine pairs with Cytosine
- Hydrogen bonding: double and triple bonds
    - Adenine pairs with Thymine forming a **double hydrogen bond**
    - Cytosine pairs with Guanine forming a **triple hydrogen bond**
    - What is the structure of DNA?





    - DNA – 3 parts
        - Phosphate group
        - Sugar (dexoyribose)
        - Nitrogenous bases (A,T, G, and C)
- How does the structure of DNA enable it to reproduce itself accurately?
    - Each strand acts as a template for building a new identical strand of DNA with the help of many enzymes.
- Semi-conservative – only half of the original DNA molecule is conserved in each new strand. In DNA replication there are two identical copies (strands) of DNA, Each new molecule consists of a new and original strand.
- **How does replication occur? What are the steps?**
    - Main Idea – DNA replicated by making a strand that is complementary to each original strand.

Semiconservative Replication

When Watson and Crick presented their model of DNA to the science community, they also suggested a possible method of replication—semiconservative replication. During **semiconservative replication,** parental strands of DNA separate, serve as templates, and produce DNA molecules that have one strand of parental DNA and one strand of new DNA. Recall from Chapters 9 and 10 that DNA replication occurs during interphase of mitosis and meiosis. An overview of semiconservative replication is in **Figure 12.10.** The process of semiconservative replication occurs in three main stages: unwinding, base pairing, and joining.

Unwinding DNA helicase, an enzyme, is responsible for unwinding and unzipping the double helix. When the double helix is unzipped, the hydrogen bonds between the bases are broken, leaving single strands of DNA. Then, proteins called single-stranded binding proteins associate with the DNA to keep the strands separate during replication. As the helix unwinds, another enzyme, RNA primase, adds a short segment of RNA, called an RNA primer, on each DNA strand.

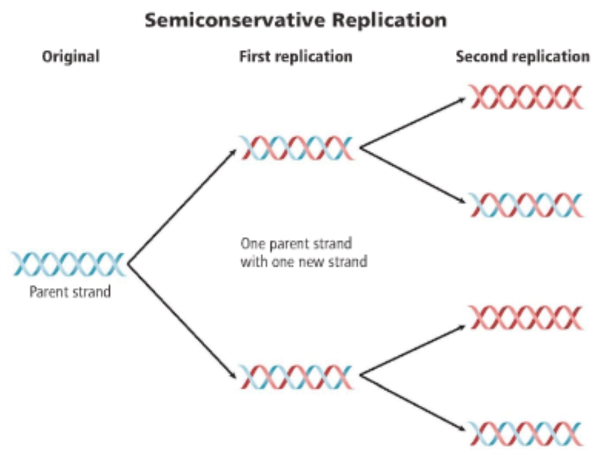


Figure 12.10 In semiconservative replication, the parental DNA separates and serves as templates to produce two daughter DNA, which then can separate to produce four DNA.

Base pairing The enzyme **DNA polymerase** catalyzes the addition of appropriate nucleotides to the new DNA strand. The nucleotides are added to the 3' end of the new strand, as illustrated in **Figure 12.11.** DNA polymerase continues adding new DNA nucleotides to the chain by adding to the 3' end of the new DNA strand. Recall that each base binds only to its complement—A binds to T and C binds to G. In this way, the templates allow identical copies of the original double-stranded DNA to be produced.

Notice in **Figure 12.11** that the two strands are made in a slightly different manner. One strand is called the leading strand and is elongated as the DNA unwinds. This strand is built continuously by the addition of nucleotides to the 3' end.

The other strand of DNA, called the lagging strand, elongates away from the replication fork. It is synthesized discontinuously into small segments, called **Okazaki fragments,** by the DNA polymerase in the 3' to 5' direction. These fragments are later connected by the enzyme DNA ligase. Each Okazaki fragment is about 100–200 nucleotides long in eukaryotes. Because one strand is synthesized continuously and the other is synthesized discontinuously, DNA replication is said to be semidiscontinuous as well as semiconservative.

Concepts In Motion
Interactive Figure To see an animation of DNA replication, visit biologygmh.com.

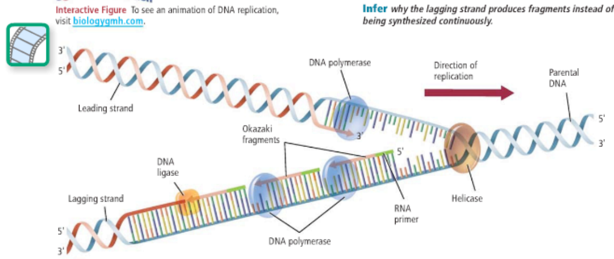


Figure 12.11 The DNA strands are separated during replication as each parent strand serves as a template for new strands.
Infer *why the lagging strand produces fragments instead of being synthesized continuously.*

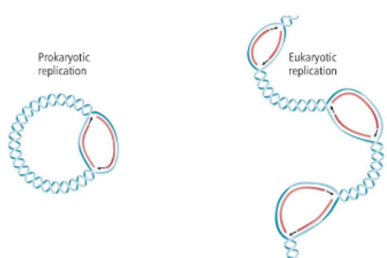


Figure 12.12 Eukaryotes have many origins of replication. Bacteria have one origin of replication, with the DNA replicating in both directions when it unzips.

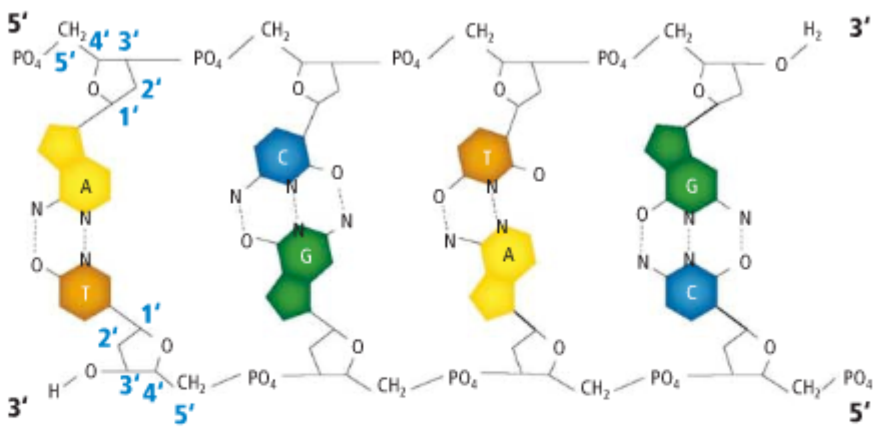
Joining Even though the leading strand is synthesized continuously, in eukaryotic DNA replication there often are many areas along the chromosome where replication begins. When the DNA polymerase comes to an RNA primer on the DNA, it removes the primer and fills in the place with DNA nucleotides. When the RNA primer has been replaced, DNA ligase links the two sections.

Comparing DNA Replication in Eukaryotes and Prokaryotes

Eukaryotic DNA unwinds in multiple areas as DNA is replicated. Each individual area of a chromosome replicates as a section, which can vary in length from 10,000 to one million base pairs. As a result, multiple areas of replication are occurring along the large eukaryotic chromosome at the same time. Multiple replication origins look like bubbles in the DNA strand, as shown in **Figure 12.12.**

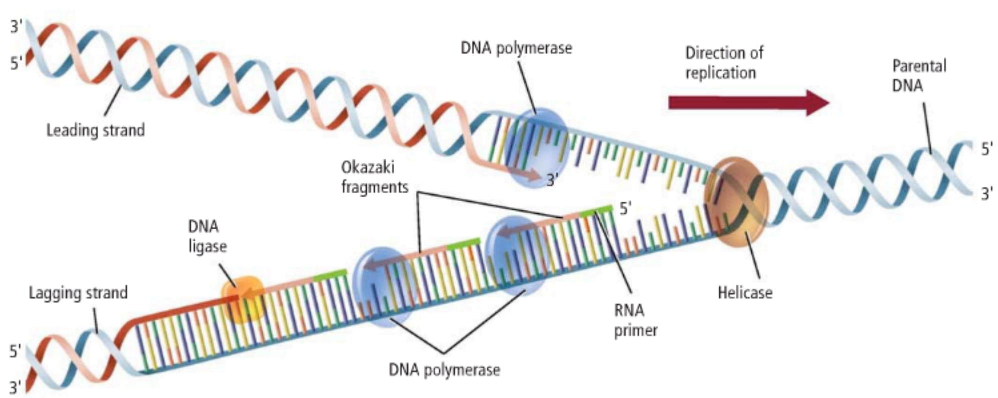
In prokaryotes, the circular DNA strand is opened at one origin of replication, as shown in **Figure 12.12.** Notice in the figure that DNA replication occurs in two directions, just as it does in eukaryotes. Recall from Chapter 7 that prokaryotic DNA typically is shorter than eukaryotic DNA and remains in the cytoplasm—not packaged in a nucleus.

- Helicase and ligase
  - Helicase – unwinds the DNA Double Helix and breaks the hydrogen bonds between each nitrogenous base this splitting the molecule into two. The splitting region is called the replication fork (origin of replication). Since DNA is so big, multiple origins of replication (helicase) are formed to speed up replication.
  - Ligase – an enzyme that bonds or glues segments (Okazaki fragments) together
- Okazaki fragments – In DNA replication, one strand, the leading strand, is made continuously, the other is built in fragments called Okazaki fragments, which are bonded by ligase.
- DNA orientation (5' and 3') – **DNA polymerase always moves along the original DNA in the 3' to 5' direction.**



- **DNA replication**

■ **Figure 12.11** The DNA strands are separated during replication as each parent strand serves as a template for new strands.
Infer *why the lagging strand produces fragments instead of being synthesized continuously.*



- DNA polymerase – In DNA replication, 2 enzymes of DNA polymerase attach to each strand and move along the molecule, base by base, adding the appropriate nitrogenous bases each time (A w/T and C w/ G).
- **Prokaryotic replication** -
- RNA polymerase – transcription requires this enzyme, which is similar to DNA polymerase. During transcription, RNA polymerase binds to DNA and separates the DNA strands. RNA polymerase then uses one strand of DNA as a template from which nucleotides are assembled into a strand of RNA.
- Central Dogma

  Transcription Translation
  - DNA ➔ RNA ➔ Protein

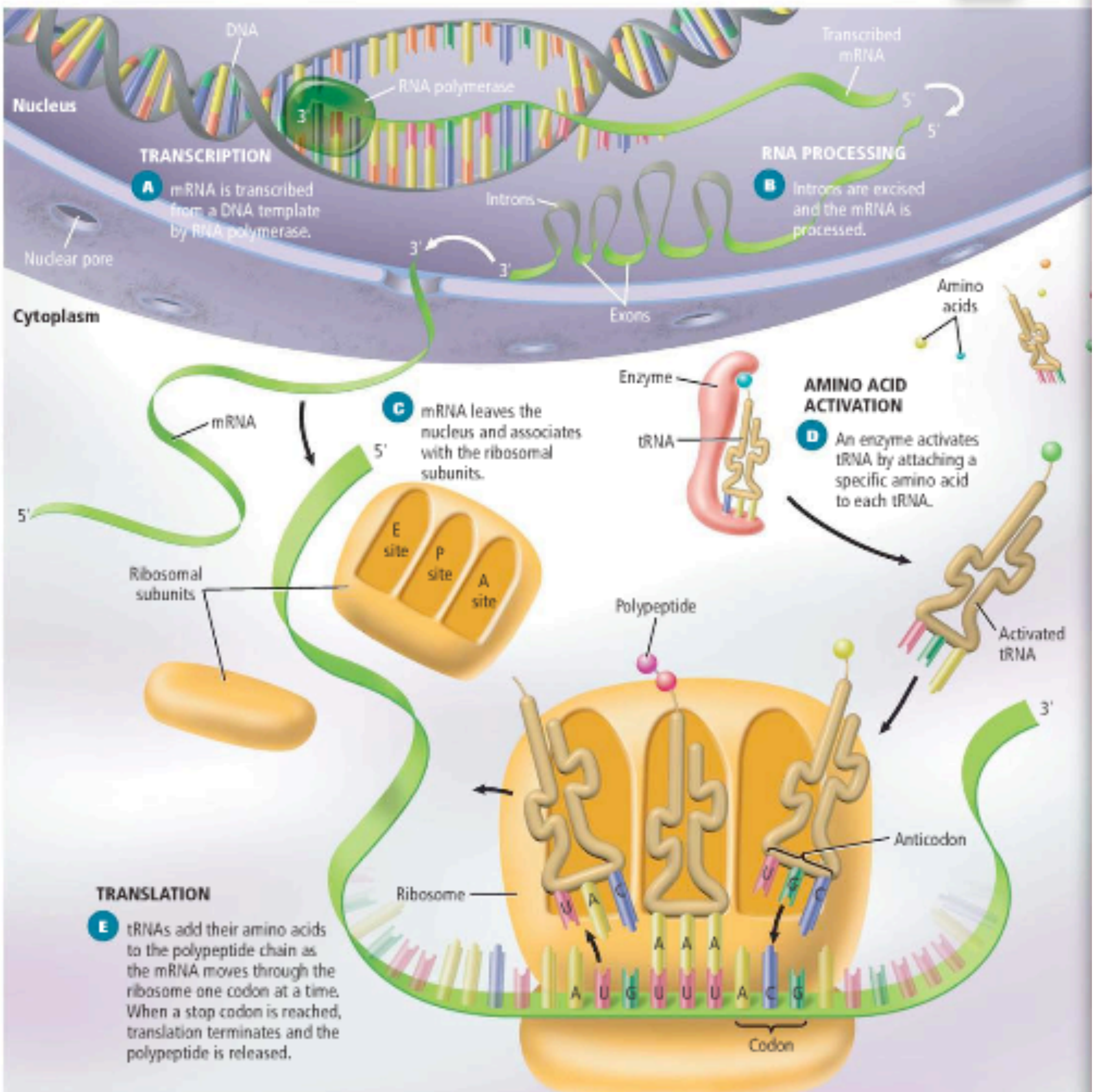
  Replication
- Introns and exons
  - Introns – the DNA of eukaryotic cells contain these gene sequences of nucleotides, which **are not involved in the coding for proteins.**
  - Exons – the DNA sequence that **code for proteins**, because they are **expressed in proteins.**
- What are the differences between DNA and RNA?

1. RNA has ribose, while DNA has Dexoyribose.
2. RNA has Uracil, while DNA has Thymine.
3. RNA is a single stranded nucleic acid, while DNA DNA is double stranded.

What are the steps involved in protein synthesis? (See Below)

Visualizing Transcription and Translation

Figure 12.15
Transcription takes place in the nucleus. Translation occurs in the cytoplasm and results in the formation of polypeptides.



- What are the different kinds of mutations?
  - Gene mutations – changes in single genes:

        - Point mutations – changes that involve one or few nucleotides because they occur at a single point in the DNA.
            - Substitutions – one base changed to another bases in the DNA sequences
        - Frameshift mutations – shift the reading frame of the DNA. They can then change every amino acid that follows the point of the mutation and change the protein that is produced.
            - Insertions – base inserted in the DNA sequence.
            - Deletions - base removed from the DNA sequence.
    - Chromosomal – in whole chromosomes:
        - Translocation – part of chromosome breaks off and attaches to another chromosome.
        - Duplications – produces an extra copy of part of a chromosome.
        - Deletion – loss of a part of a chromosome.
        - Inversion – reverses the direction of part of a chromosome.
- What are the effect of different kinds of mutations on cells and organisms?
    - Substitutions usually affect one amino acid, while insertions and deletions have much more drastic effects b/c
        - They could affect more than one amino acid.
        - Stop codon is still correct in substitution.
        - Maybe the same amino acid might result

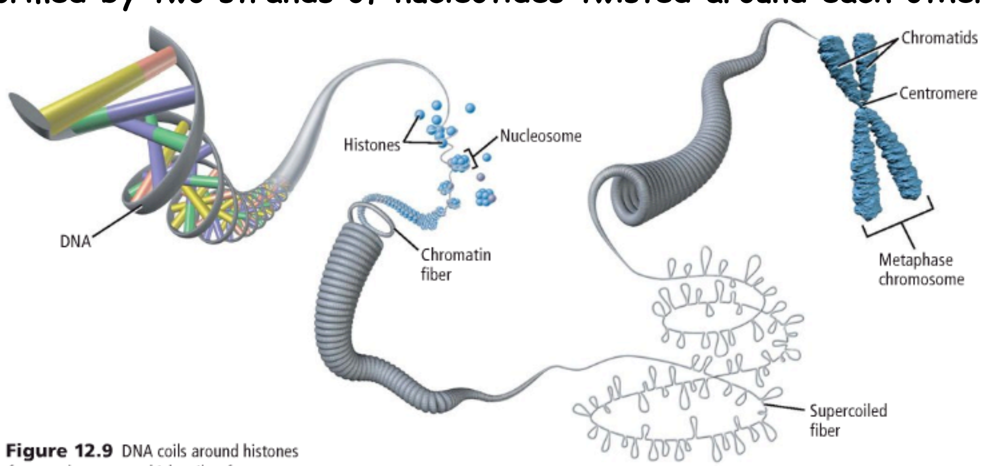
Concepts In Motion

Table 12.3 Mutations

Interactive Table To explore more about types of mutations, visit biologygmh.com.

Mutation Type	Analogy Sentence	Example of Associated Disease
Normal	THE BIG FAT CAT ATE THE WET RAT	
Missense (substitution)	THE BIZ FAT CAT ATE THE WET RAT	Achondroplasia: improper development of cartilage on the ends of the long bones of arms and legs resulting in a form of dwarfism
Nonsense (substitution)	THE BIG RAT	Muscular dystrophy: progressive muscle disorder characterized by the progressive weakening of many muscles in the body
Deletion (causing frameshift)	THB IGF ATC ATA TET HEW ETR AT	Cystic fibrosis: characterized by abnormally thick mucus in the lungs, intestines, and pancreas
Insertion (causing frameshift)	THE BIG ZFA TCA TAT ETH EWE TRA	Crohn's disease: chronic inflammation of the intestinal tract, producing frequent diarrhea, abdominal pain, nausea, fever, and weight loss
Duplication	THE BIG FAT FAT CAT ATE THE WET RAT	Charcot-Marie-Tooth disease (type 1A): damage to peripheral nerves leading to weakness and atrophy of muscles in hands and lower legs
Expanding mutation (tandem repeats) Generation 1 Generation 2 Generation 3	THE BIG FAT CAT ATE THE WET RAT THE BIG FAT CAT CAT CAT ATE THE WET RAT THE BIG FAT CAT CAT CAT CAT CAT CAT ATE THE WET RAT	Huntington's disease: a progressive disease in which brain cells waste away, producing uncontrolled movements, emotional disturbances, and mental deterioration

- Double helix – the structure of DNA, **a twisted ladder shape, formed by two strands of nucleotides twisted around each other.**



■ **Figure 12.9** DNA coils around histones to form nucleosomes, which coil to form chromatin fibers. The chromatin fibers supercoil to form chromosomes that are visible in the metaphase stage of mitosis.

- Purines and Pyrimidines – **Because a pyrimidine (Single ring) pairs with a purine (double ring), the helix has a uniform width. (T w/ A and C w/ G)**

- Purine – double ring
- Pyrimide – sing ring

- Structure of a nucleotide –

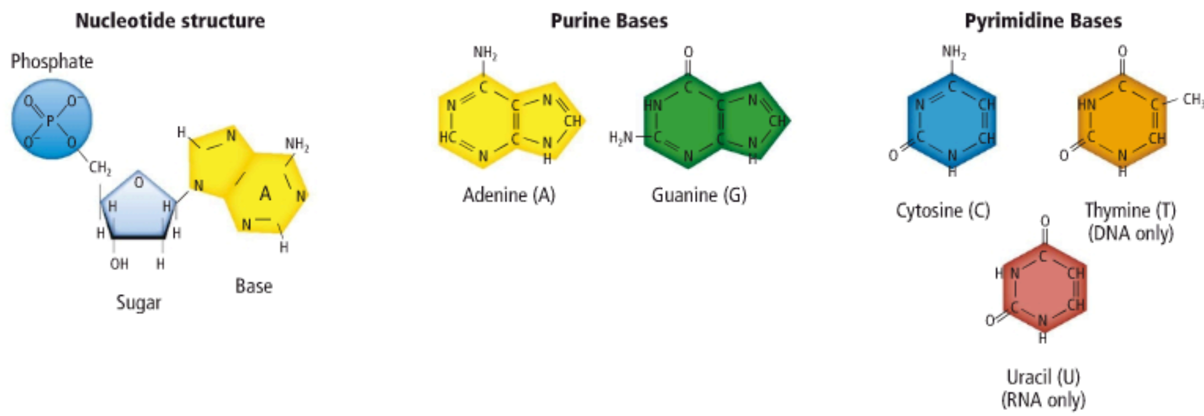


Figure 12.4 Nucleotides are made of a phosphate, sugar, and a base. There are five different bases found in nucleotide subunits that make up DNA and RNA.
Identify *What is the structural difference between purine and pyrimidine bases?*

- RNA:

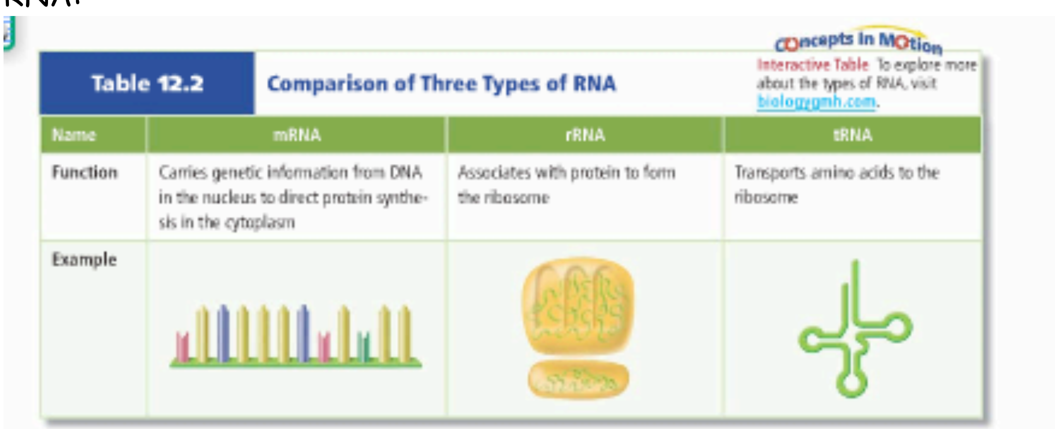


Table 12.2 Comparison of Three Types of RNA

Concepts in Motion — Interactive Table To explore more about the types of RNA, visit biologygmh.com.

Name	mRNA	rRNA	tRNA
Function	Carries genetic information from DNA in the nucleus to direct protein synthesis in the cytoplasm	Associates with protein to form the ribosome	Transports amino acids to the ribosome
Example			

- Messenger (mRNA) – contains the instructions for assembling amino acids into proteins. It is the copy of DNA that goes to the ribosome.

  - Ribosomal (rRNA) – makes up ribosomes.
  - Transfer (tRNA) – transfers each amino acid to the ribosomes during the construction of a protein.
- Transcription and translation
  - Transcription – the process by which RNA is made from DNA. It occurs in the nucleus. It requires RNA polymerase. **Example TAC becomes TUG.**
  - Translation – the decoding of an mRNA message into a polypeptide/protein. It takes place in the ribosome. mRNA has to attach to the ribosome, which is located in the cytoplasm of the cell. Translation happens when the mRNA molecule attached to the ribosome, as each of the codons is read the proper amino acid is brought to the ribosome by tRNA. **Example AUG: Amino Acid Sequence – Met, tRNA anticodon – UAC.**
- Codons and anticodons
  - Codon – the genetic code is read three letters at a time. Each three-letter combination called a codon. Each codon specifies a single amino acid that is to be added to the polypeptide.
  - Anticodon – tRNA has **three unpaired bases** called anticodons in addition to one amino acid. Anticodons are complementary to one mRNA codon. **Ex. Codon: AUG – Anticodon: UAC**
- Mutagens – substances, which cause mutations such as chemicals and radiation mutations.
- DNA → RNA → Protein – **Central Dogma**

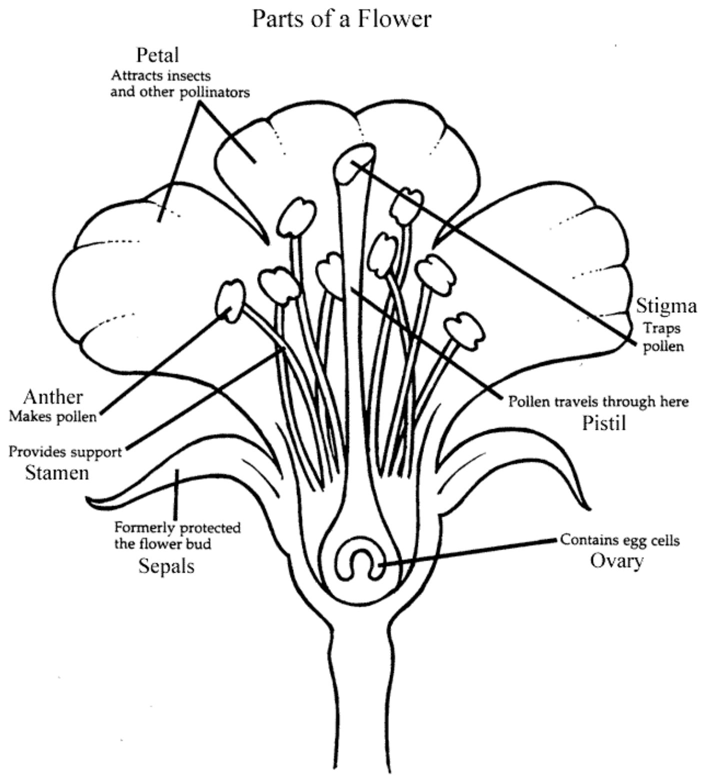
Final Exam Study Guide: 2nd Semester

- **Genetics Unit**
- **Gene Technology Unit**
- **Evolution Unit**
- **Classification Unit**
- **Primate/Human Evolution Unit**

Genetics Unit

This is a general list of the material that will be covered on the test. Please make sure that you study all the notes from class (the ones I gave you and the ones that you took yourself); study the labs and you read the textbook and are able to do the questions in the textbook.

- Chapters 10.2-10.3 and Chapter 11
- Know the Vocabulary
- Know about Mendel and his experiments
    - Explained how a dominant allele can mask the presence of a recessive allele
    - Mendel began the study of genetics – his experiments with garden pea plants gave insight into the inheritance of traits.
    - Mendel developed the law of segregation and the law of independent assortment
- P generations, F1 and F2 generations
    - What does the P and F stand for?
        - P – Parent Generation: Green-seed plant and yellow-seed plant
        - F – Filial (1st and 2nd):
            - F1 – All yellow seeds
            - F2 – 3:1 ratio of yellow to green seeds
- Know the parts of the flower

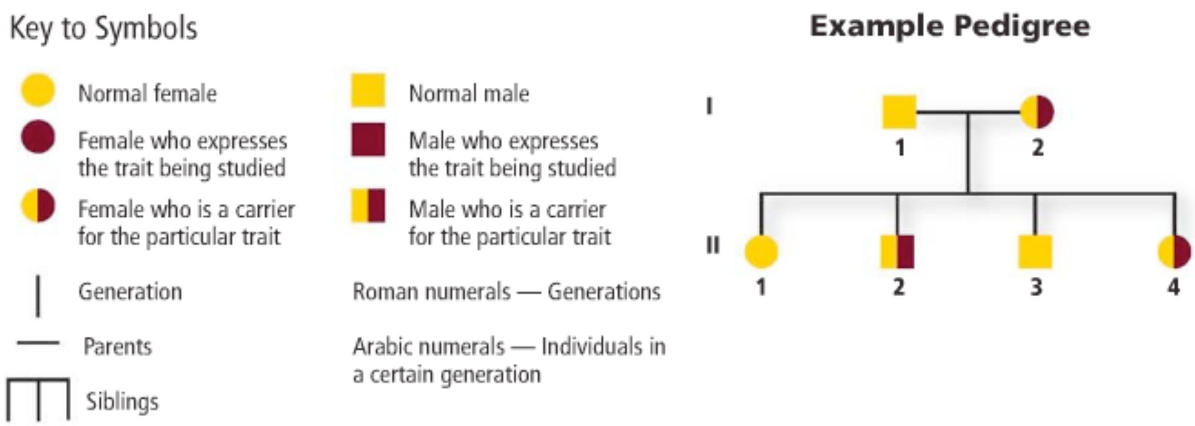


- Know how to do monohybrid and dihybrid crosses and how they are different
  - **Monohybrid** – a cross that involves hybrids for a single trait
  - **Dihybrid** – heterozygous for both traits (two or more traits in the same plant)
  - Phenotypic and genotypic ratios
    - **Larger number is first for phenotypic, for genotypic it is homozygous dom., heterozygous dom, and homozygous recessive.**
  - Law of independent assortment is best seen through a dihybrid cross
- Know the law of segregation and the law of independent assortment and how they are different
  - Law of segregation – states that the two alleles for each trait separate during meiosis. During fertilization, two alleles for that trait unite.
  - Law of independent assortment – states that a random distribution of alleles occurs during gamete formation. **Genes on separate chromosomes sort independently during meisosis.**
- Know the difference between a phenotype and genotype
  - **Genotype** – the organisms allele pairs (Yellow seeds YY or Yy)

- **Phenotype** – the outward expression of an allele pair (Genotype yy will have phenotype of green seeds)

- Know how to do punnett squares and probability questions: testcross (between unknown and recessive), dihybrid, monohybrid, etc…

- Know how to read and interpret a pedigree – <u>**Male square, female circle**</u>



    - Dominant- nothing
    - Carrier – half and half
    - Recessive - shaded
    - Sex-linked – circle in center
    - (Blood types -)
- **Incomplete dominance** – what is it? Know how to figure out problems
    - **Heterozygous phenotypes is an intermediate phenotype between two homozygous phenotypes**
    - Problems have three things such as Red, pink, and white
- **Codominance** – sickle cell is an example
    - **Both alleles are expressed in the heterozygous condition.**
    - Why is being heterozygous for <u>sickle cell</u> a benefit? - Having sickle-cell disease would be advantageous to a person living in central Africa. Scientists have discovered that those who are heterozygous for the sickle-cell trait also have a <u>**higher resistance to malaria**</u>. **The death rate due to malaria is lower where the sickle-cell trait is higher. Because less malaria exists in those areas, more people live to pass on the sickle-cell to offspring. Consequently, sickle-cell disease continues to increase in Africa.**
- Multiple alleles – blood types is an example
    - Forms of inheritance determined by more than 2 alleles
- Sex-linked traits and how to determine sex

  - Sex chrom. – X and y – XX is fem. AND XY male.
  - Sex-linked traits – traits controlled by genes located on the X chromosome
  - Corlor blindess- x chrom
- Polygenic inheritance – eye color, hair color and skin color are examples
  - Polygenic traits – he interaction of multiple pairs of genes
- Know about environmental influences on gene expression and epistasis
  - Epistasis – 1 allele hiding effect of another allele
  - Twin studies help to differentiate the effect of genetic and environmental influences. Identical twins are genetically the same. If a trait is inherited, both identical twins will have the same trait. Scientists conclude that traits that appear frequently in identical twins are at least partially controlled by heredity. Also, scientists presume that traits expressed differently in identical twins are strongly influenced by the environment. The percentage of twins who both express a given trait is called a concordance rate. A large difference between fraternal twins and identical twins shows a strong genetic influence.
- Know about human blood types and how to do blood typing problems and pedigrees
- Know how to read a karyotype: determine the sex of a person and if they have a chromosomal disorder
  - A micrograph with homologous chromosomes arranged in decreasing size
  - Sex – if says XX=female, XY=male.
  - Chromosmal disorder – extra copies of chromosomes or missing parts
- Know what nondisjunction is, how it can occur and how you can tell that it has occurred
  - Cell division during which sister chromatids fail to sep. properly.
  - It can occur in both autosomes and sex chroms.
  - It can occur in Meiosis I and II
  - You can tell b/c the resulting gametes will not have the correct # of chromosomes.
- Know the difference between homozygous and heterozygous
  - Homozygous – an organism w/ 2 of the same alleles for a particular trait. (Yellow seed plans are YY and green seed plants are yy)
  - Heterozygous – an organism w/ 2 different alleles for a particular trait (Yy) When alleles are present in the heterozygous state, the dominant trait will be observed.
- Know what a carrier is – an individual who is heterozygous for a recessive disorder.
- What are autosomes? – 22 pairs of chromosomes not X and Y, not sex chromosomes

- Define: alleles, dominant/recessive, fertilization, gamete, genetics, heredity, hybrid, pollination, trait, egg, sperm and zygote
- Gene linkage and polyploidy – the linkage of genes on a chromosome results in an exception to Medel's law of independent assortment b/c linked genes usually do not segregate independently. **Linked genes can separate during crossing over.**
    - **Polyploidy** – occurrence of 1 or more extra sets of all chromosomes in an organism
- Fetal testing

Table 11.5	**Fetal Tests**	Interactive Table To explore more about fetal testing, visit biologygmh.com.
Test	**Benefit**	**Risk**
Amniocentesis	• Diagnosis of chromosome abnormalities • Diagnosis of other defects	• Discomfort for expectant mother • Slight risk of infection • Risk of miscarriage
Chorionic villus sampling	• Diagnosis of chromosome abnormality • Diagnosis of certain genetic defects	• Risk of miscarriage • Risk of infection • Risk of newborn limb defects
Fetal blood sampling	• Diagnosis of genetic or chromosome abnormality • Checks for fetal blood problems and oxygen levels • Medications can be given to the fetus before birth	• Risk of bleeding from sample site • Risk of infection • Amniotic fluid might leak • Risk of fetal death

The **benefits** of fetal testing might be that the parents find out whether they are carriers of a genetic disorder. Also, they could find out the chromosomal status of their developing baby, known as the fetus, and whether there are chromosome or genetic abnormalities. There could be a diagnosis of certain genetic defects or other defects. Also, it checks for fetal blood problems and oxygen levels, and medications can be given to the fetus before birth. The **risks** might be that there is discomfort for the expectant mother, a risk of infection, a risk of miscarriage, a risk of newborn limb defects, a risk of bleeding from the sample site, amniotic fluid might leak, and a risk of fetal death.

Connection to Health Many fetal tests can provide important information to the parents and the physician. **Table 11.5** describes the risks and benefits of some of the fetal tests that are available. Physicians must consider many factors when advising such examinations. At least a small degree of risk usually is possible in any test or procedure. The physician would not want to advise tests that would endanger the mother or the fetus; therefore, when considering whether to recommend fetal testing, the physician would need to consider previous health problems of the mother and also the health of the fetus. If the physician and parents determine that any fetal test is needed, the health of both the mother and the fetus need to be closely monitored throughout the testing.

Gene Technology Unit

- Chapter 13
- All vocabulary – Textbook Printouts
- **Selective breeding** – the process by which desired traits of certain plants and animals are selected and passed on to their future generations.
    - Produces organisms with desired traits
    - Increasing the frequency of certain alleles in a population is the essence of genetic technology.
    - Through the processes of hybridization and inbreeding, desired traits can be passed on to future generations.
- Why is selective breeding used? – to have organisms with desired traits
    - Dog breeding – to do certain tasks, be a show dog – nicest coat and teeth
    - Horses – for racing and showing
    - Example: In 1947, cows were producing 4997 pounds of milk on average, but because of selective breeding in 1997 the average went up to 16, 915 pounds of milk in a year
- **Inbreeding** - the process, in which two closely related organism are bred to have the desired traits and to eliminate the undesired ones in future generations.
    - Mating between closely related individuals,
        - Ensures that the organisms are homozygous for most traits.
    - Why would breeders do this?
        - To make sure breeding is pure and the organism has desired traits.
    - Can bring out harmful recessive traits because 2 individuals are closely related and can both carry a harmful allele.
        - Example: Horses and dogs are organisms that breeders have developed as pure breeds through inbreeding.
- Compare inbreeding with hybridization.
    - **Inbreeding** is the process in which two closely related organisms are bred to have the desired traits and to eliminate the undesired ones in future generations. It creates pure breeds. A disadvantage of inbreeding is that harmful recessive traits also can be passed onto future generations. Inbreeding increases the chance of homozygous recessive offspring. If both parents carry the recessive allele, the harmful trait likely will not be eliminated.
    - **Hybridization** produces organism with desired/specific traits from parent organisms with different traits. Traits are selected that will give hybrid organisms a competitive edge such as more disease-resistant, able to produce more offspring, or grow faster. A disadvantage is that it is time consuming and expensive. The advantages sometimes outweigh the disadvantages.
- Genetic Engineering and recombinant DNA

- **Genetic Engineering** – technology that involves manipulating the DNA of one organism in order to insert exogenous DNA (the DNA of another organism.)
    - Example: Researchers have inserted a gene for a bioluminescent protein called green fluorescent protein (GFP) into various organisms. GFP, which is a substance naturally found in jellyfishes that live in the north Pacific Ocean, emits a green light when it its exposed to ultraviolet light.
- **Recombinant DNA** - newly generated DNA molecule, with DNA from different sources / DNA from different sources combined together
    - When DNA fragments have been separated by gel electrophoresis, fragments of a specific size can be removed from the gel and combined with DNA fragments from another source.
    - Recombinant DNA technology has revolutionized the way scientists study DNA because it enables individual genes to be studied.
    - Large quantities of recombinant DNA molecules are needed in order to study them. A carrier, called a vector, transfers the recombinant DNA into a bacterial cell called the host cell. Plasmids and viruses are commonly used vectors.
    - **Enables individual genes in DNA to be studied**
    - **Circular DNA, called plasmids are in bacteria and yeast, they can be used to transfer recombinant DNA.**
    - **If you want to make a large amount of recombinant plasmids, mix bacterial cells with recombinant DNA and some bacterial cells might take up the recombinant plasmid DNA through a process called <u>transformation</u>.**

- How can genetic engineering improve human health?/ How does genetic engineering manipulate DNA?
    - These genetically engineering organisms are used in various processes, such as studying the expression of a particular gene, investing cellular processes, studying the development of a certain disease, and selecting traits that might be beneficial to humans.
    - These genetically engineering organisms are used in various processes, such as studying the expression of a particular gene, investing cellular processes, studying the development of a certain disease, and selecting traits that might be beneficial to humans.
- Compare and contrast selective breeding and genetic engineering
    - You have learned that selective breeding is used to produce plants and animals with desired traits. Genetic engineering can be used to increase or decrease the expression of specific genes in selected organisms. It has many applications from human health to agriculture.

- Genome
  - **An organism's genome is the total DNA present in the nucleus of each cell.** Genomes, such as the human genome, can contain millions and millions of nucleotides. In order to study a specific gene, DNA tools can be used to manipulate DNA and to isolate genes from the rest of the genome.
- Restriction enzymes
  - Some types of bacteria contain powerful defenses against viruses.
  - **These cells contain proteins called restriction enzymes that recognize and bind to specific DNA sequences and cleave the DNA within that sequence.** A restriction enzyme, also called an endonuclease, cuts the viral DNA into fragments after it enters the bacteria. Since their discovery in the late 1960s, scientists have identified and isolated hundreds of restriction enzymes. Restriction enzymes are used as powerful tools for isolating specific genes or regions of the genome. When the restriction enzyme cleaves genomic DNA, it crates fragments of different sizes that are unique to every individual.
  - EcoRI - A restriction enzyme used widely by scientists is EcoRI. As shown in **figure 13.4 below**, EcoRI specifically cuts DNA containing the sequence GAATTC. The ends of the DNA fragments created by EcoRI are called sticky ends because they contain single-stranded DNA that is complementary. The ability of some restriction enzymes to create fragments with sticky ends is important because these sticky ends can be joined together with other DNA fragments that have complementary sticky ends.

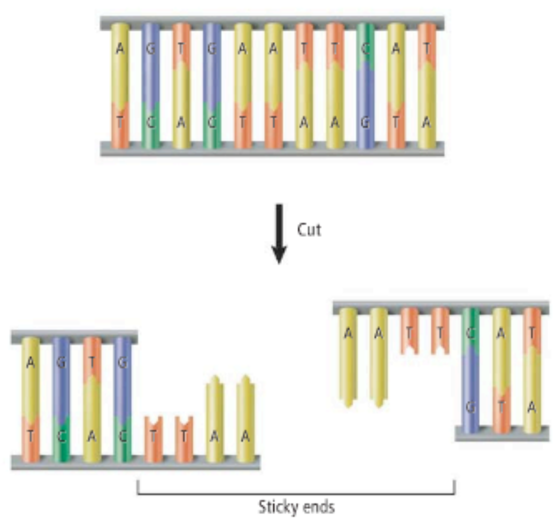


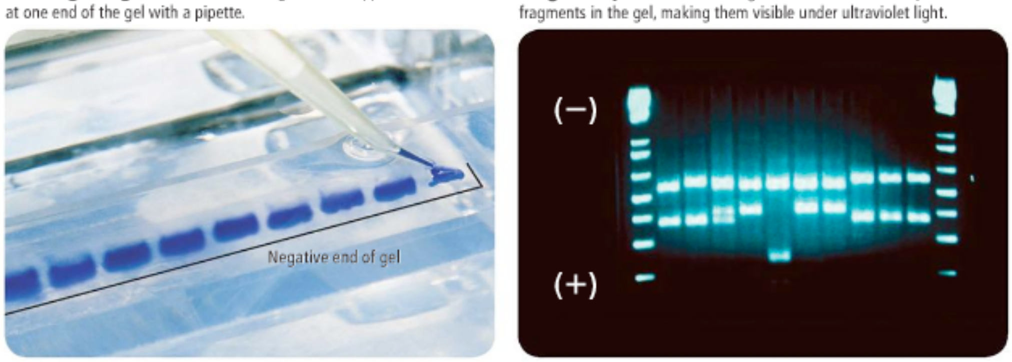
Figure 13.4 DNA containing the sequence GAATTC can be cut by the restriction enzyme *EcoRI* to produce sticky ends.

Concepts In Motion

Interactive Figure To see an animation of restriction enzymes cleaving strands of DNA between specific nucleotides, visit biologygmh.com.

- Gel electrophoresis and DNA Fingerprinting **(See Gel ?s and Fingerprinting Notes)** –
  - Gel electrophoresis – An electric current is used to separate the DNA fragments according to the site of the fragments in a process called gel electrophoresis.

- The **figure 13.5 below** shows how the DNA fragments are loaded on the negatively charged end of a gel. When an electric current is applied, the DNA fragments move toward the positive end of the gel. The smaller fragments move further faster than the larger ones. The unique pattern created based on the size of the DNA fragment can be compared to known DNA fragments for identification. Also, portions of the gel containing each band can be removed for further study.



Loading the gel Solution containing DNA is dropped into holes at one end of the gel with a pipette.

Fragment pattern A staining solution binds to the separated DNA fragments in the gel, making them visible under ultraviolet light.

Figure 13.5 When the loaded gel is placed in an electrophoresis tank and the electric current is turned on, the DNA fragments separate.

However, not all restriction enzymes create sticky ends. Some enzymes produce fragments containing blunt ends—created when the

  - DNA Fingerprinting – involves separating these DNA fragments using gel electrophoresis in order to observe the distinct banding patterns that are unique to every individual.

- How do forensic scientists use DNA Fingerprinting? - Forensic scientists use DNA fingerprinting to identify suspects and victims in criminal cases, to determine paternity, and to identify soldiers killed in war.

Figure 13.13 People can be identified using the genetic information contained in blood, hair, semen, or skin.

Figure 13.13 shows a sample obtained from hair that forensic scientists can use for DNA fingerprinting. PCR is used to copy this small amount of DNA to create a larger sample for analysis. The amplified DNA then is cut using different combinations of restriction enzymes. The fragments are separated by gel electrophoresis and compared to DNA fragments from known sources, such as victims and suspects in a criminal case, to locate similar fragmentation patterns. There is a high probability that the two DNA samples came from the same person if two fragmentation patterns match. Since its development in England in 1985, DNA fingerprinting has been used not only to convict criminals but also to free innocent people who had been wrongfully imprisoned. **Figure 13.14** provides a closer look at the history of genetic technology.

Reading Check Summarize how forensic scientists use DNA fingerprinting.

Identifying Genes

Once the genome has been sequenced, the next step in the process is to identify the genes and determine their functions. The functions of many of the genes in the human genome are still unknown. Researchers use techniques that integrate computer analysis and recombinant DNA technology to determine the function of these genes.

For organisms such as bacteria and yeast, whose genomes do not have large regions of noncoding DNA, researchers have identified genes

- Know how to read a DNA Fingerprint. – See Notes/?s

- Plasmids - small, circular, double-stranded DNA molecules that occur naturally in bacteria and yeast cells – can be used as vectors because they can be cut with restriction enzymes, If a plasmid and a DNA fragment obtained from another genome have been cleaved by the same restriction enzyme, the ends of each DNA fragment will be complementary and can be combined, as shown in Figure 13.6 below.
    - (An enzyme normally used by cells in DNA repair and replication, called **DNA ligase**, joins the two DNA fragments chemically. Ligase joins DNA fragments that have sticky ends as well as those that have blunt ends.)

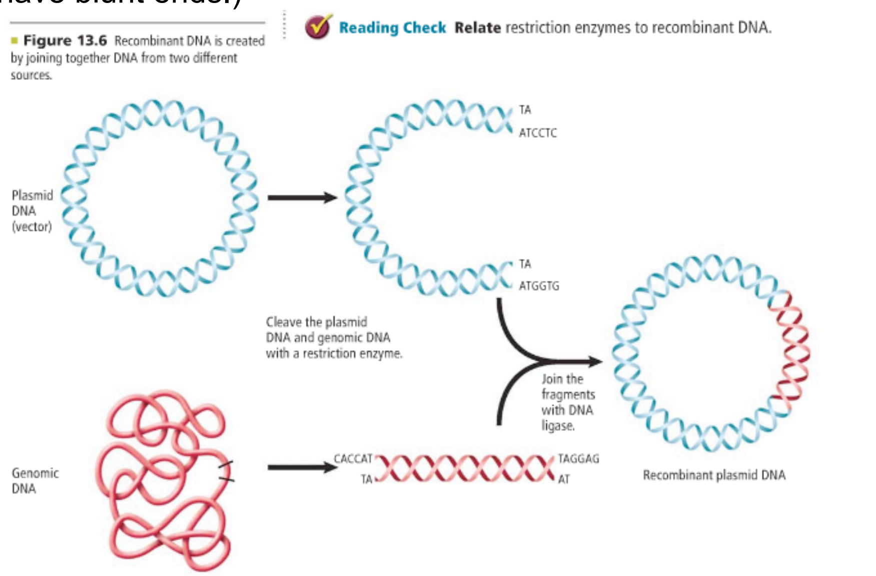


Figure 13.6 Recombinant DNA is created by joining together DNA from two different sources.

- Transformations
    - To make a large quantity of recombinant plasmid DNA, bacterial cells are mixed with recombinant plasmid DNA.
    - **Some of the bacterial cells take up the recombinant plasma DNA through a process called transformation, as shown in Figure 13.7 below**. Bacterial cells can be transformed using electric pulsation or heat Recall that all cells, including bacterial cells, have plasma membranes. A short electric pulse or a brief rise in temperature temporarily creates openings in the plasma membrane of the bacteria. These temporary openings allow small molecules, such as the recombinant plasmid DNA, to enter the bacterial cells. The bacterial cells make copes of the recombinant plasmid DNA during cell replication.

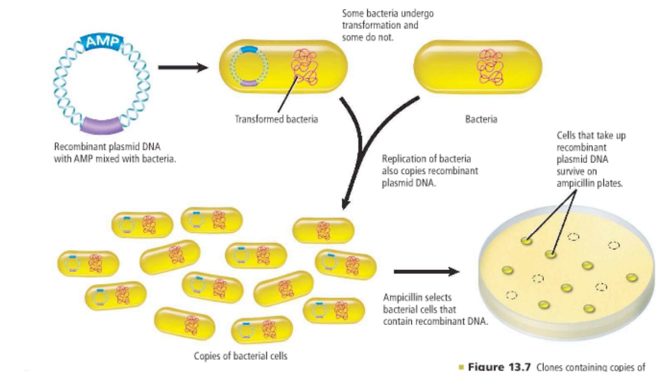
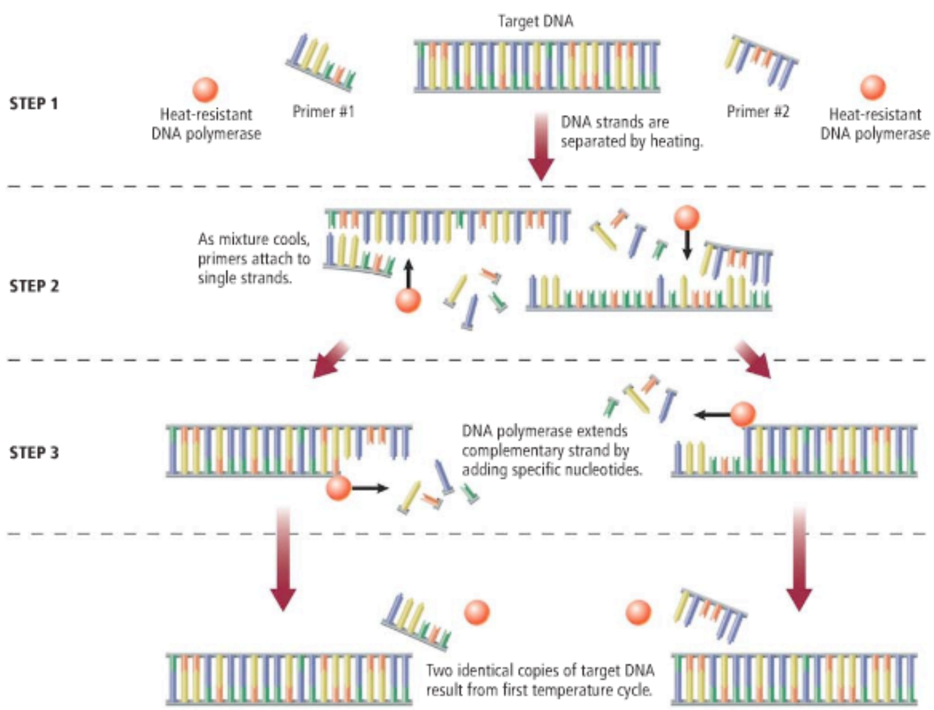


Figure 13.7 Clones containing copies of

Figure 13.7 Clones containing copies of the recombinant DNA can be identified and used for further study when the bacterial cells that do not contain recombinant DNA die.

- Cloning – large numbers of identical bacteria, each containing the inserted DNA molecules, can produce through this process called cloning.
    - Two types of cloning
        - Reproductive – animal or person in cloned
        - Therapeutic – spare parts that help the sick are cloned
    - Dolly cloned sheep, was 1st clone – some
    - Are ethical issues w/ cloning – try to create perfect human, against nature
    - Pigs can be genetically modified to produce organs for humans
    - Environment can affect how clone acts or appears – UV Rays effect this
    - Identical twins = clones
- How does cloning occur? – see above
- PCR **(sheet)**– Once the sequence of the DNA fragment is known, a technique called the polymerase chain reaction that can be used to make millions of copies of a specific region of a DNA fragment. PCR is extremely sensitive and can detect a single DNA molecule in a sample. PCR is useful because this single DNA molecule then can be copied, or amplified, numerous times to be used for DNA analysis. **Below in Figure 13.9** are the steps of PCR.
    - Millions of copies of DNA would be needed at a crime scene – need to do DNA analysis

Figure 13.9 PCR is a biological version of a copy machine. During each PCR cycle, the reaction mixture is heated to separate the DNA strands and then cooled to allow primers to bind to complementary sequences. The DNA polymerase then adds nucleotides to form new DNA molecules.



- Transgenic organisms – organisms, such as the mosquito larvae, genetically engineering by inserting a gene from another organism. Transgenic animals, plants, and bacteria are used not only for research, but also for medical and agricultural purposes.
- The human genome – see Notes Sheet
- What are the parts of the human genome? – **The goal of the HGP was to determine the sequence of the approximately three billion nucleotides that make up human DNA and to identify all the 23,299 human genes.**
    - After sequencing the human genome, scientists observed that less than 2% of all the nucleotides in the human genome code for all the proteins in the body. That is, the genome is filled w/ long stretches of repeated sequences that have no direct function. These regions are called noncoding sequences.
- How can information from the human genome project be used to treat human diseases? – see pgs. 377+378 for important

The Genome and Genetic Disorders

Although more than 99 percent of all nucleotide base sequences are exactly the same in all people, sometimes there are variations that are linked to human diseases. These variations in the DNA sequence that occur when a single nucleotide in the genome is altered are called **single nucleotide polymorphisms** or SNPs (SNIHPS). For a variation to be considered an SNP, it must occur in at least one percent of the population. Many SNPs have no effect on cell function, but scientists hypothesize that SNP maps will help identify many genes associated with many different types of genetic disorders.

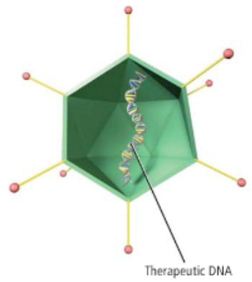
The HapMap project An internationl group of scientists is creating a catalog of common genetic variations that occur in humans. Recall from Chapter 10 that linked genes are inherited together. Similarly, genetic variations located close together also tend to be inherited together. Therefore, regions of linked variations in the human genome, known as **haplotypes,** can be located. The project to create this catalog is called the haplotype map, or HapMap project. Assembling the HapMap involves identifying groups of SNPs in a specific region of DNA.

Figure 13.16 shows how the genome is divided into haplotypes. Once completed, the HapMap will describe what these variations are, where they occur in our DNA, and how they are distributed among people within populations and among populations in different parts of the world. This information will help researchers find genes that cause disease and affect an individual's response to drugs.

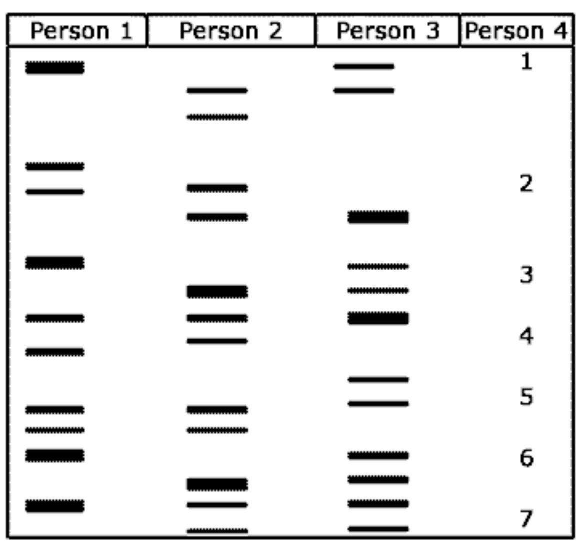
Pharmacogenomics Sequencing the human genome combines the knowledge of genes, proteins, and SNPs with other areas of science. The study of how genetic inheritance affects the body's response to drugs is called **pharmacogenomics** (far muh koh jeh NAW mihks). The benefits of pharmacogenomics include more accurate dosing of drugs that are safer and more specific. Researchers hope that pharmacogenomics will allow for drugs to be custom-made for individuals based on their genetic makeups. Prescribing drugs based on an individual's genetic makeup will increase safety, speed recovery, and reduce side effects. Perhaps one day when you are sick, your doctor will read your genetic code and prescribe medicine tailor-made for you.

- Gene therapy – a technique aimed at correcting mutated genes that cause human diseases.
  - Scientists insert a normal gene into a chromosome to replace a dysfunctional gene. In most gene therapy studies, inserting a normal gene into a viral vector, like the one in **figure 13.17 below,** produces recombinant DNA. Target cells in the patient are infected with the virus and the recombinant DNA material is released into the affected cells. Once deposited into cells, the normal gene inserts itself into the genome and begins functioning.

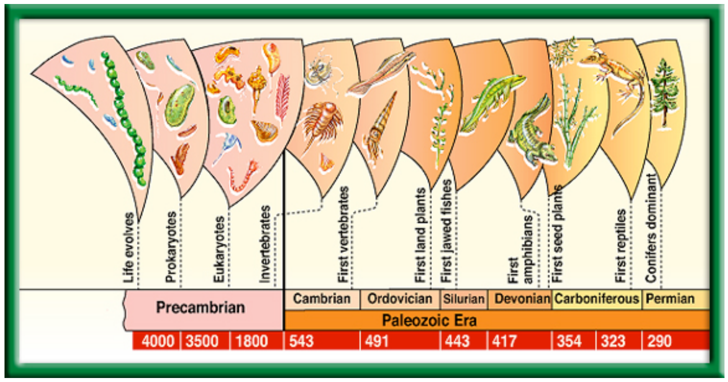
Figure 13.17 DNA can be encapsulated in a virus and delivered into a patient to replace a defective gene. Once the virus enters the cells, the genetic information is released into the nucleus and inserted into the genome.



- Genomics – the study of an organism's genome
    - Sequencing the human genome began what researchers call "the genomic era". Genomics has become one of the most powerful strategies for identifying human genes and interpreting their functions. In addition to the mass of data obtained from sequencing the genomes of humans, rice, mice, fruit flies, and corn, scientists also are investing the proteins produced by these genes.
- Stem cells – **(See notes sheet)** cells that remain undifferentiated during development. They have the ability to become many different types of cells.
    - There are two kinds of stem cells
        - Embryonic Stem Cells
        - Adult Stem Cells
- What are stems cells? What can they be used for? – see above



Evolution Unit



Section 14.2

(Pages 9 – 15)

- Spontaneous generation – the idea that life arises from non-life (nowhere).
- Francesco Redi and his experiment – An Italian scientist that tested the idea of spontaneous generation and disproved it. He put meat in jars, and one had maggots growing, which was uncovered, while the covered one did not.

One of the first recorded investigations of spontaneous generation came in 1668. Francesco Redi, an Italian scientist, tested the idea that flies arose spontaneously from rotting meat. He hypothesized that flies—not meat—produced other flies. In his experiment, illustrated using present-day equipment in **Figure 14.11,** Redi observed that maggots, the larvae of flies, appeared only in flasks that were open to flies. Closed flasks had no flies and no maggots. The results of his experiments failed to convince everyone, however. Although people were beginning to use the microscope during Redi's time and knew that organisms invisible to the naked eye could be found almost everywhere, some thought that these tiny organisms must arise spontaneously, even if flies did not.

Figure 14.11 Francesco Redi showed that flies and maggots did not arise spontaneously from rotting meat.
Infer *the purpose of the covered flask in Redi's experiment.*

failed to convince everyone, however. Although people were beginning to use the microscope during Redi's time and knew that organisms invisible to the naked eye could be found almost everywhere, some thought that these tiny organisms must arise spontaneously, even if flies did not.

- (Theory of) Biogenesis – states that only living organisms can produce other living organisms.

- Louis Pasteur and his experiment – He designed an experiment to show that biogenesis was true even for microorganisms.

The idea of spontaneous generation was not completely rejected until the mid-1800s. It was replaced by the **theory of biogenesis** (bi oh JEN uh sus), which states that only living organisms can produce other living organisms. Louis Pasteur designed an experiment to show that biogenesis was true even for microorganisms. Pasteur's experiment is illustrated in **Figure 14.12.** In one flask, only air was allowed to contact a sterile nutrient broth. Nutrient broth supports the growth of microorganisms. In another flask, both air and microorganisms were allowed to contact the broth. No microorganisms grew in the first container. They did, however, grow in the second container.

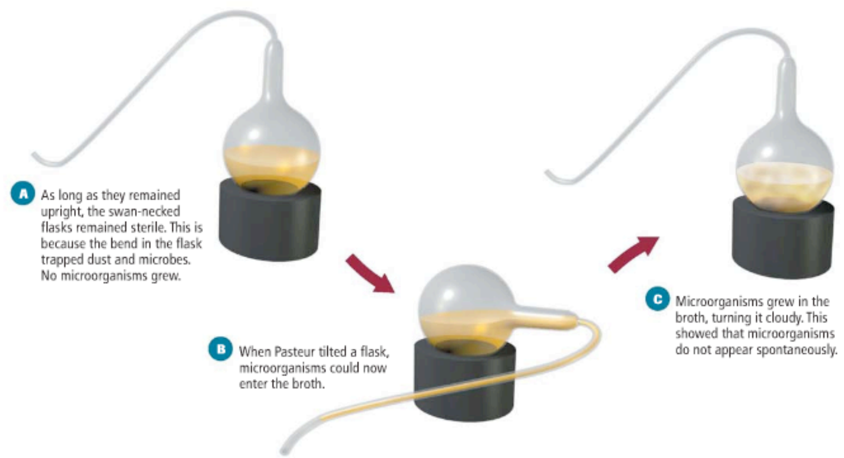


Figure 14.12 Pasteur's experiment showed that sterile broth remained free of microorganisms until exposed to air.

The idea of spontaneous generation was not completely rejected until the mid-1800s. It was replaced by the **theory of biogenesis**

- Primordial soup – an early hypothesis about the origin of life. Scientists

Alexander Oparin and John Haldane suggested this hypothesis in the 1920s. They thought that if Earth's early atmosphere had a mix of certain gases, organic molecules could have been synthesized from simple reactions involving those gases in the early oceans. UV light from the Sun and electric discharge in lightning might have been the primary energy sources. They thought that these organic molecules would have eventually supplied the precursors to life.

- Stanley Miller and Harold Urey and their experiment. – Scientists who were the first to show that simple organic molecules could be made from inorganic compounds. (See Ch. 14 – Page 11)
- Evolution of cells: first cells to evolve – See Ch. 14 – Pages 13-14
- Endosymbiont theory – **according to this theory, the ancestors of eukaryotic cells lived in association with prokaryotic cells.** In some cases, prokaryotes even might have lived inside eukaryotes. Eventually the relationship between the cells became mutually beneficial,

and the prokaryotic symbionts became organelles in eukaryotic cells. **This theory explains the origin of chloroplasts and mitochondria, as show in Figure 14.17 (See Ch. 14 – Page 14)**

•

Section 14.1 (Pages 1-8)

- Early earth– there was not a lot of free oxygen (See Ch.14 - Page 1)
  - Formation – was a molten body, and gravity pulled the densest elemets to the center of the plantet.
  - gases on the early earth – probably what is in volcanoes such as water vapor, carbon dioxide, sulfur dioxide, carbon monoxide, hydrogen sulfide, hydrogen cyanide, nitrogen, and hydrogen.
  - Weather – see above and below
  - atmosphere – because of its gravitational field, Earth is a planet that is able to maintain an atmosphere. The early atmosphere, unlike today's atmosphere had little or no free oxygen.
- Geologic time scale – is a record of Earth's History. All major geological and biological events in Earth's history can be identified within the geologic time scale. It is divided into two distinct segments – Precambrian time and Phanerozoic eon.. (See Ch.14 – Pages 5-8)
  - Eras – unit of geological time consisting of two or more periods that lasts hundreds of millions of years.
  - Major events – mass extinction (meteoroid strike), ice age, dinosaurs, etc.
  - animals that were present – from prokaryotes to humans
- Mass extinctions, meteorite strike – A mass extinction occurred at the end of Paleozoic and Mesozoic era (dinosaurs) – in the Mesozoic one, there is evidence in the K-T boundary of a meteoroid strike b/c of high levels of iridium, which is found in meteorites. (Ch. 14, Page 7)
- Pangea – Name of landmass, 225 million years ago (mya) when all of the continents were joined into one landmass.
  - plate tectonics – describes the movement of several large plates that make up the surface of the Earth. These plates, some of which contain continents, move atop a partially molten layer of rock underneath them.

Section 15.1 (Pages 1-4)

- Lamarck and Darwin's theories (See Notes Copy pg. 1)
  - Lamark – one of the 1st scientists to understand that change occurs over time. He states that changes are adaptations to the environment acquired in an organism's lifetime. He said that acquired changes are passed to offspring. Law of Use and Disuse – if body part is used, it got stronger; if not used, it deteriorated.

  - Darwin – evolution is the slow, gradual change in a pop. of organisms over tune. Natural Selection - Individuals who inherited characteristics most fit for their environment are likely to leave more offspring than less fit individuals. "Survival of the fittest." Artificial selection – proc. Of directed breeding to produce offspring w/ desired traits (selective breeding). (**Chapter 15, pgs. 1-4)**
- Steps in Natural Selection – (Chapter 15, Page 3)
  - Individuals in a pop. show differences, or variations.
  - Variations can be inherited, meaning they are passed from parent to offspring.
  - Organisms have more offspring than can survive on available resources.
  - Variations that increase reproductive success will have a greater chance of being passed on than those that do not increase reproductive success.

Section 14.1 (Pages 1-8) *Continued*

- Fossils and dating fossils – (Chapter 14, Pages 1-4) a fossils is any preserved evidence of an organism. There are 6 categories – trace fossil, molds and casts, replacement, petrified or permineralized, amber, original material. **Dating fossils**: relative dating – method used to determine the age of rocks by comparing them w/ those in other layers. This is based on the law of superposition – younger deposited on top of older layers. Radiometirc dating – used day of radioactive isotopes to measure age of rock. This requires the use of the half-life isotope = amount of time for half of original isotope to decay.

Section 15.3 (Pages 13-24)

- Peppered moths – (Chapter 15, Page 18)

Directional selection If an extreme version of a trait makes an organism more fit, **directional selection** might occur. This form of selection increases the expression of the extreme versions of a trait in a population. One example is the evolution of moths in industrial England. The peppered moth has two color forms, or morphs, as shown in **Figure 15.17.** Until the mid 1850s, nearly all peppered moths in England had light-colored bodies and wings. Beginning around 1850, however, dark moths began appearing. By the early 1900s, nearly all peppered moths were dark. Why? Industrial pollution favored the dark colored moths at the expense of the light-colored moths. The darker the moth, the more it matched the sooty background of its tree habitat, and the harder it was for predators to see. Thus, more dark moths survived, adding more genes for dark color to the population. This conclusion wa reinforced in the mid-1900s when the passage of air pollution laws led t the resurgence of light-colored moths. This phenomenon is called indus trial melanism.

Directional selection also can be seen in Galápagos finches. For three decades in the latter part of the twentieth century, Peter and Rosemary Grant studied populations of these finches. The Grants found that during drought years, food supplies dwindled and the birds had to eat the hard seeds they normally ignored. Birds with the largest beaks were more successful in cracking the tough seed coating than were birds with smaller beaks. As a result, over the duration of the drought, birds with larger beaks came to dominate the population. In rainy years, however, the directional trend was reversed, and the population's average beak size decreased.

<u>Section 15.2 (Pages 5-12)</u>

- Evidence of Evolution: **See Packet**
  - Homologous structures – anatomically similar structures inherited from a common ancestor. (Page 6)
  - Analogous structures – can be used for same purpose and similar ins structure, but not inherited from common ancestor. (Page 8)
  - vestigial structures – reduced forms of functional structures in other organisms. (Page 7)
  - embryology – the study of embryos, provided a glimpse into evolutionary relationships.
  - Biochemistry – molecules w/ a recent common ancestor should have more amino acid sequences in common. The more closely related the species are, greater number of sequences will be shared.
- **<u>Section 15.3 (Pages 13-24) *continued*</u>**
- Stabilizing, directional and disruptive selection (**Pages 17-19 and packet**)
  - Stabilizing selection – eliminate extreme expression when avg. expression leads to high fitness.
  - Directional selection – if an extreme version of a trait makes an organism more fit. Increases exp. Of extreme versions of a trait in a pop.

- Disruptive selection – process that splits a pop into two groups, Removes indiv. w/ avg traits.

- Speciation – **See Page 21** - allopatric: barrier divides, sympatric: w/out physical barrier.
- Geographic isolation and reproductive isolation (prezygotic and postzygotic)
  - **See Pages 20 and 21** – Prezygotic – before fertilization, postzyogtic- after fertilization=infertile.
- Allopatric speciation and sympatric speciation – **Page 21 -** allopatric: barrier divides, sympatric: w/out physical barrier.
- Adaptive radiation - a type of speciation – diversication of a species into a number of different species, often over a relatively short time span. (pg 22)
  - divergent evolution – another name for adaptive radiation
  - convergent evolution – when unrelated species evolve similar traits even thought they live in different parts of the world. They have similar ecology and climate. (Pages 22 and 23)
- Coevolution – many species evolve in close relationship w/ other species. This relationship might be so close that the evolution of one species affects the evolution of other species. This is called coevolution (Page 22)
- Rate of speciation: (page 23)
  - gradualism – most scientists think that evolution occurs in small, gradual steps. A great deal of evidence favors this theory, but the fossil record contains instance of abrupt transitions.
  - punctuated equilibrium – attempts to explain abrupt transitions in the fossil record. According to this theory, rapid spurts of genetic change cause species to diverge quickly; these periods **punctuate** much longer periods when the species exhibit little change.
- **<u>Section 15.2 (Pages 5-12) *continued*</u>**
- Adaptations:
  - Mimicry – one species evolves to resembles another species, usually poisonous.
  - Camouflage – some species have evolved morphological adaptations that allow them to blend in with their environments.
  - Antibiotic resistance – (Page 11) – species of bacteria that originally were killed by penicillin and other antibiotics have developed drug resistance.

<u>Section 15.3 (Pages 13-24) *continued*</u>

- Genetic drift, gene pool, nonrandom mating, bottleneck, founder effect, gene flow – See Copied Notes
  - Genetic drift – any change in the allelic frequencies in a population that is due to change (pg. 15)
  - gene pool – there is tremendous variation within any gene pool. Ex. hundreds of breeds of dogs are dif. from each other but belong to

same species. Sources of variation are mutations, genetic drift, and gene flow.
  - nonrandom mating – rarely is mating completely random in a pop. Usually, organisms mate w/ individuals close in proximity. This promotes inbreeding and could lead to change in allelic proportions favoring individual that are homozygous for part. traits. (page 16)
  - bottleneck effect – occurs when a pop. declines to a very low # and then rebounds. Could be nat. disaster like fire, earthquake, flood.
  - founder effect – occurs when a small sample of a pop. settles in a location separated from the rest of the pop. Alleles uncommon in original pop might be common in the new pop.
  - gene flow – movement of alleles into and out of a population. Happens b/c of migration of fertile individuals or gametes between populations.

Classification Unit

- 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.

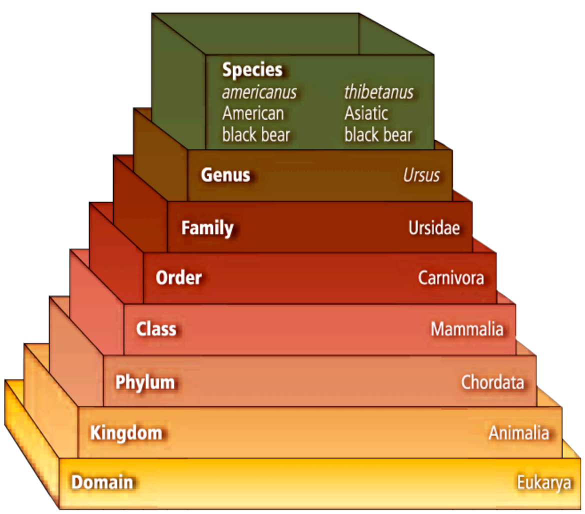
Figure 17.3 All species in the genus *Ursus* have large body size and massive skulls. Sloth bears are classified in the genus *Melursus*.

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.

Table 17.2 Species Concepts

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

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.

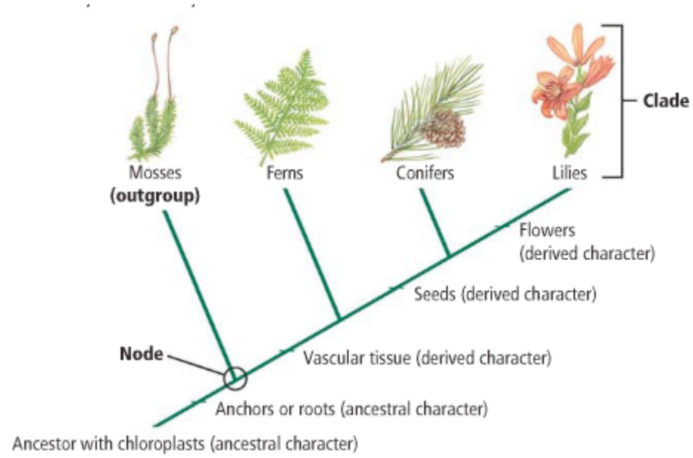


Figure 17.11 This cladogram uses the derived characters of plant taxa to model its phylogeny. Groups that are closer to the lily on the cladogram share a recent common ancestor.
Identify ***which clades have chloroplasts but do not produce seeds.***

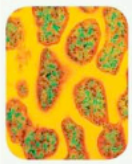
Concepts In Motion

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.

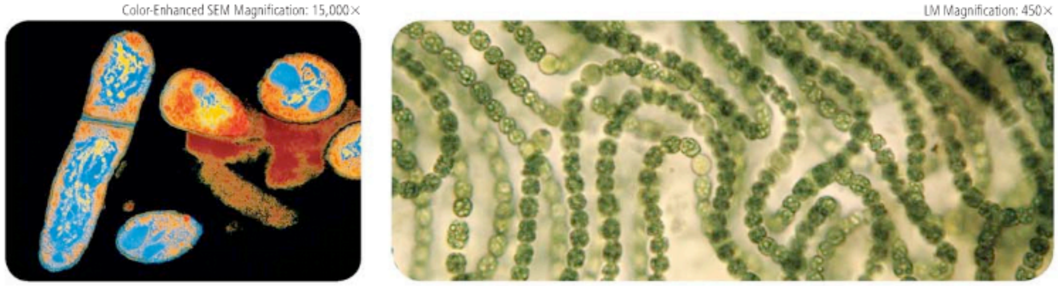
Domain	Bacteria	Archaea	Eukarya			
Kingdom	Bacteria	Archaea	Protista	Fungi	Plantae	Animalia
Example	*Pseudomonas*  SEM Magnification: 5500×	*Methanopyrus*  TEM Magnification: 25,000×	*Paramecium*  LM Magnification: 150×	Mushroom 	Moss 	Earthworm 
Cell type	Prokaryote		Eukaryote			
Cell walls	Cell walls 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× LM Magnification: 450×



Mycobacterium tuberculosis ***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.

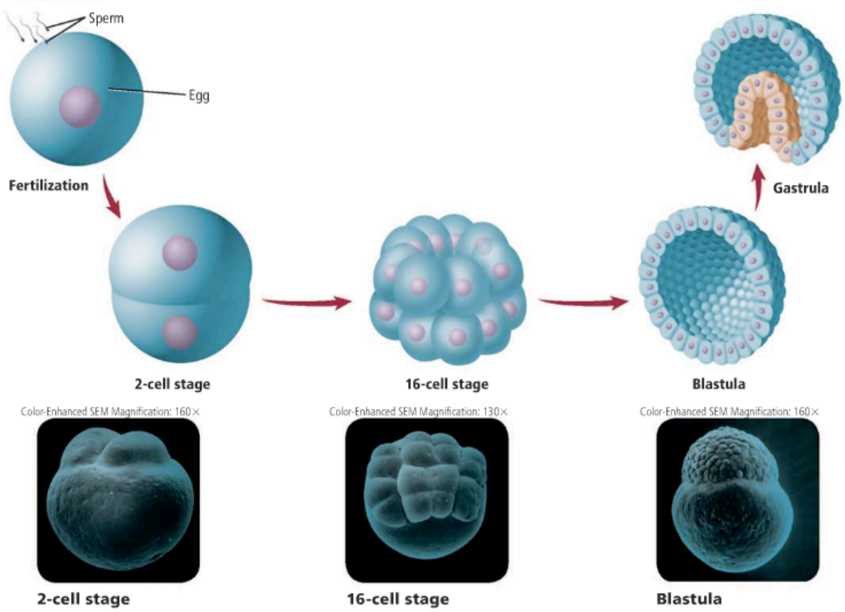
Look again at **Figure 24.5.** Notice how the diagrams of the two-cell Look again at Figure 24.5. Notice how the diagrams of the two-cell stage, the 16-cell stage, and the blastula differ from the photographs of these same stages. The diagrams illustrate early development in embryos that develop inside 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.



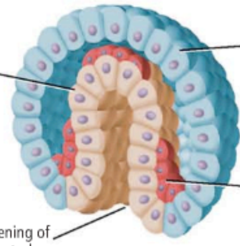


Figure 24.6 As development continues, each cell layer differentiates into specialized tissues.

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 tubelike 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.

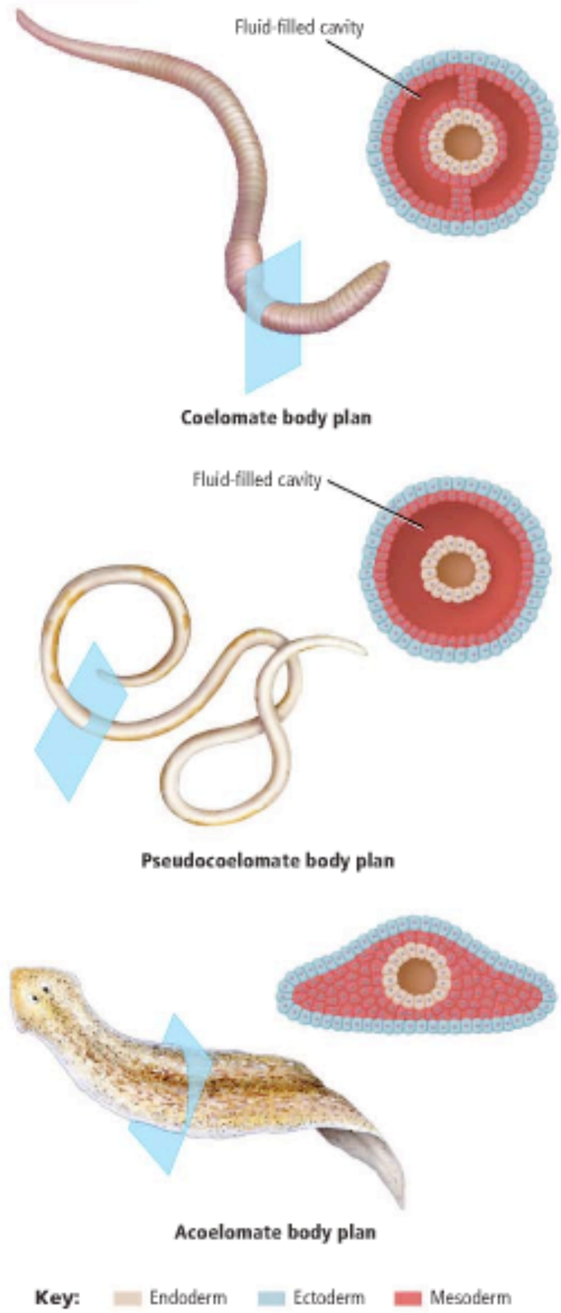
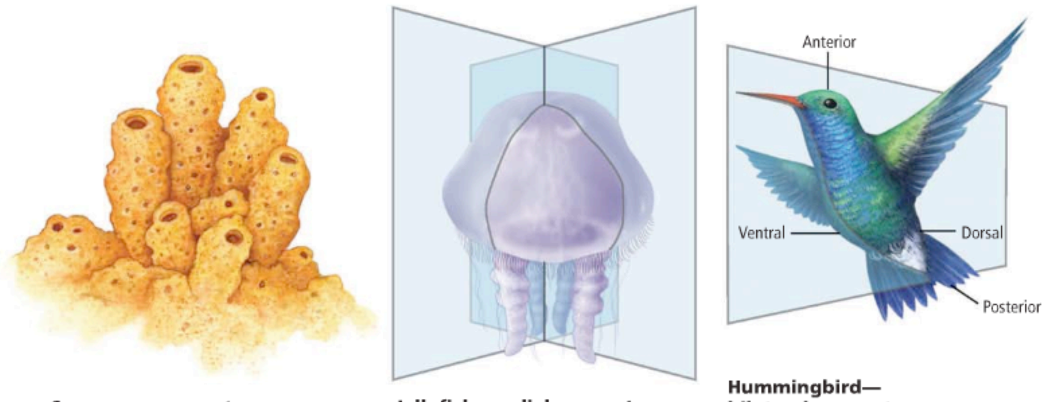


Figure 24.10 An earthworm has a coelom, a fluid-filled body cavity surrounded completely by mesoderm. The pseudocoelom of a roundworm develops between the mesoderm and endoderm. A flatworm has a solid body without a fluid-filled cavity.

- 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.*

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.

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

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.

Human/Primate Evolution Unit

Primates: what they are and some examples

Humans, apes, monkeys, and lemurs belong to a group of mammals known as primates. Though primates are highly diverse, they share some general features. Some primates have a high level of manual dexterity, which is the ability to manipulate or grasp objects with their hands. They usually also have keen eyesight and long, highly movable arms. Compared to other animals, they have large brains. The primates with the largest brains, which includes humans, have the capacity to reason.

Arboreal - the majority of primates are arboreal, meaning that they have live in trees. (tree-dwelling). Arboreal primates live in the world's tropical and subtropical forests. Primates that live on the ground are considered terrestrial primates.

Characteristics of primates

Manual dexterity Primates are distinguished by their flexible hands and feet. All primates typically have five digits on each hand and foot; as you know, humans have fingers and toes. Most have flat nails and sensitive areas on the ends of their digits. The first digits on most primates' hands are opposable, and the first digit on many primates' feet are opposable. An **opposable first digit,** either a thumb or a great toe, is set apart from the other digits. This digit can be brought across the palm or foot so that it touches or nearly touches the other digits. This action allows the primate to grasp an object in a powerful grip. Some primates also have lengthened first digits that provide added dexterity. **Figure 16.1** shows a monkey using its opposable thumbs to grasp its food.

Senses Though there are exceptions, primates rely more on vision and less on their sense of smell than other mammals do. Their eyes, protected by a bony eye socket, are on the front of their face. This creates overlapping fields of vision, often called **binocular vision.** Forward-looking eyes allow for a greater field of depth perception, and enable primates to judge relative distance and movement of an object.

Most primates are **diurnal** (di YUR nul), which means they are active during the day. Because these primates are active in daylight, most also have color vision. Primates that are **nocturnal** (nahk TUR nul) are active at night. They only see in black and white. An increased sense of vision is generally accompanied by a decreased sense of smell. Their snouts are smaller and their faces tend to be flattened, which increases the degree of binocular vision. Their teeth are reduced in size and usually are unspecialized, meaning that they are suitable for many different types of diets.

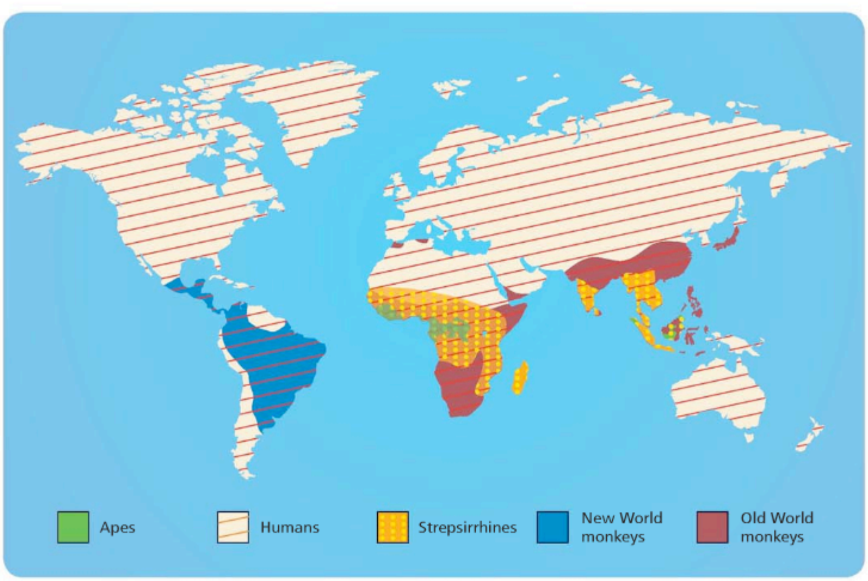
Locomotion Another characteristic of primates is their flexible bodies. Primates have limber shoulders and hips, and primarily rely on hind limbs for locomotion. Most primates live in trees and have developed an extraordinary ability to move easily from branch to branch. When on the ground, all primates except humans walk on all four limbs. Many primates can walk upright for short distances and many have a more upright posture compared to four-legged animals.

Complex brain and behaviors Primates tend to have large brains in relation to their body size. Their brains have fewer areas devoted to smell and more areas devoted to vision. They also tend to have larger areas devoted to memory and coordinating arm and leg movement. Along with larger brains, many primates have problem-solving abilities and well-developed social behaviors, such as grooming and communicating. Most diurnal primates spend a great deal of time socializing by spending time grooming each other. In addition, many primates have complex ways of communicating to each other, which include a wide range of facial expressions.

Reproductive rate Most primates have fewer offspring than other animals. Usually, primates give birth to one offspring at a time. Compared to other mammals, pregnancy is long, and newborns are dependent on their mothers for an extended period of time. For many primates, this time period allows for the increased learning of complex social interactions. A low reproductive rate, the loss of tropical habitats, and human predation has threatened some primate populations. Many are endangered. **Figure 16.2** illustrates the tropical areas of the world, such as Africa and Southeast Asia, where primates live.

primates, this time period allows for the increased learning of complex social interactions. A low reproductive rate, the loss of tropical habitats, and human predation has threatened some primate populations. Many are endangered. **Figure 16.2** illustrates the tropical areas of the world, such as Africa and Southeast Asia, where primates live.

Figure 16.2 Non-human primates live in a broad area spanning most of the world's tropical regions. Use this map as you read about the different primates.



See above for descriptions

Dexterity: five digits; opposable thumbs -

Binocular vision - a characteristic of primates, which results in greater depth perception, and creates overlapping fields of vision
Senses: which do they rely on the most? - They rely mostly on vision
They have binocular vision
Color vision
Decreased sense of smell (in relation to other animals.)
Teeth are reduced in size and usually unspecialized, unlike dogs for example who have specialized teeth.
Flexible bodies
Complex brain and behaviors
Strepsirrhines and Haplorhines:

Primate Groups

Primates are a large, diverse group of more than 200 living species. Examine **Figure 16.3** as you read about this diverse group. Most primates are **arboreal** (ar BOHR ee uhl), or tree-dwelling. Arboreal primates live in the world's tropical and subtropical forests. Primates that live on the ground are considered terrestrial primates.

Primates are classified into two subgroups based on characteristics of their nose, eyes, and teeth. The most basic subgroup is the strepsirrhines (STREP sihr ines), (also called "wet-nosed primates"), such as the lemur. The second subgroup consists of the haplorhines (HAP lohr ines), also called "dry-nosed" primates. The haplorhines include the **anthropoids** (AN thruh poydz), a group of large-brained, diurnal monkeys and hominoids.

Strepsirrhines

Strepsirrhines can be identified by their large eyes and ears. However, they are the only primates that rely predominantly on smell for hunting and social interaction. Some members of this primate group can be found in tropical Africa and Asia. Most are found in Madagascar and nearby islands. Madagascar drifted away from the African mainland as these animals evolved leaving them reproductively isolated. This isolation resulted in their diversification. **Table 16.1** lists characteristics of some strepsirrhine groups.

VOCABULARY

WORD ORIGIN

Lemur

comes from Latin, meaning *spirit of the night.*

Concepts In Motion

Interactive Table To explore more about strepsirrhines, visit biologygmh.com.

Table 16.1 Characteristics of Strepsirrhines

Group	Lemurs	Aye-Ayes	Lorises	Galagos
Example				
Active Period	Large—diurnal Small—nocturnal	Nocturnal	Nocturnal	Mostly nocturnal
Range	Madagascar	Madagascar	Africa and Southeast Asia	Africa
Characteristics	• Vertical leaper • Uses long bushy tail for balance • Herbivores and omnivores	• Taps bark, listens, fishes out grubs with long third finger	• Small and slow climber, solitary • Lack tails • Some have toxic secretions	• Small and fast leaper • No opposable digit • Long tail

Most small lemurs are nocturnal and solitary. Only a few large species, such as the sifaka shown in **Figure 16.4,** are diurnal and social. The indri is unique because it does not have a tail, unlike most lemurs that use their bushy tails for balance as they jump from branch to branch. Lorises are similar to lemurs but are found primarily in India and Southeast Asia. Galagos (ga LAY gohs), also called bushbabies, are found only in Africa.

Haplorhines

The second group of primates is a much larger group. The haplorhines include tarsiers, monkeys, and apes. The apes, in turn, include gibbons, orangutans, gorillas, chimpanzees, and humans.

The tarsier is found only on Borneo and the Philippines. It is a small, nocturnal creature with large eyes. It has the ability to rotate its head 180 degrees like an owl. It lives in trees, where it climbs and leaps among the branches. The tarsier shares characteristics with both lemurs and monkeys. Scientists once classified it with the lemurs, but new evidence suggests that it is more closely related to anthropoids, which makes it part of the haplorhine group.

Anthropoids are generally larger than strepsirrhines, and they have large brains relative to their body size. They are more likely to be diurnal, with eyes adapted to daylight and sometimes to color. Anthropoids also have more complex social interactions. They tend to live longer than lemurs and other strepsirrhines. The anthropoids are split into the New World monkeys and the Old World monkeys. "New World" refers to the Americas; "Old World" refers to Africa, Asia, and Europe. New World monkeys are the only monkeys that live in the Americas.

Anthropoids: See above

what are they? – a group of large-brained diurnal monkeys and hominoids.
Characteristics of them – generally large than stepsirrhines, large brains in relation to body size.

Old world and new world monkeys and their differences

New World monkeys The New World monkeys are a group of about 60 species of arboreal monkeys that inhabit the tropical forests of Mexico, Central America, and South America. New World monkeys include the marmosets and tamarins. These are among the smallest and most unique primates. Neither species has fingernails or opposable digits.

The New World monkeys also include the squirrel monkeys, spider monkeys, and capuchin monkeys. Some of these monkeys have opposable digits and most are diurnal and live together in social bands. Most are also distinguished by their prehensile (pree HEN sul) tails. A **prehensile tail** functions like a fifth limb. It can grasp tree branches or other objects and support a monkey's weight, like that shown in **Figure 16.5.**

Old World monkeys Old World monkeys live in a wide variety of habitats throughout Asia and Africa, from snow-covered mountains in Japan to arid grasslands in Africa. Some Old World monkeys live in Gibraltar, which is located at the southern tip of Spain. There are about 80 species in this group, including macaques and baboons in one subgroup, and colobus and proboscis monkeys in another. Old World monkeys are similar to New World monkeys in many ways. They are diurnal and live in social groups. However, their noses tend to be narrower and their bodies are usually larger. They also spend more time on the ground. None have prehensile tails, and some have no tails. Most Old World monkeys have opposable digits.

Prehensile tails:

What are they? – Functions like a fifth limb that can grasp tree branches or other objects and support a monkey's weight.

What organisms have them? – New World Monkeys

Why are they beneficial? – See above

Hominoids: Text below answers questions

what are they?

How are they classified?

What are their characteristics?

New Vocabulary

hominoid
bipedal
australopithecine

Hominoids

Hominoids (HAH mih noydz) include all nonmonkey anthropoids—the living and extinct gibbons, orangutans, chimpanzees, gorillas, and humans. The fossil transition from early anthropoid to ape is not clear; very few fossils from the late Oligocene exist. The earliest hominoid fossils appear in the fossil record only about 25 mya at the beginning of the Miocene. These hominoids retained some ancestral primate features. For example, most had bodies adapted for brachiation. There is evidence that they had relatively large brains and had shoulders and hips that moved freely, and some might even have had the ability to stand on two legs.

Connection to Chemistry Scientists use fossils to help them determine when ancestral hominoids diverged into the hominoids that exist today. But because the fossil record for hominoids is so sparse, scientists also turn to biochemical data to help them in this task. By comparing the DNA of living hominoid species, researchers conclude that gibbons likely diverged first from an ancestral anthropoid, followed by orangutans, gorillas, chimpanzees and bonobos, and finally, humans. **Figure 16.11** shows the potential divergence of these species. Chimpanzees and bonobos are the closest living relatives to humans. All three share at least 96 percent of their DNA sequences.

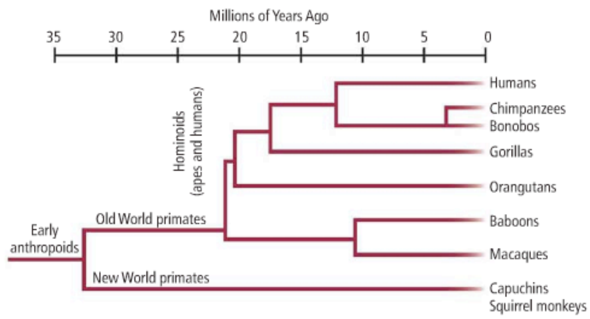


Figure 16.11 Orangutans, gorillas, bonobos, and chimpanzees all diverged from an ancestral anthropoid.

Hominoid characteristics Hominoids are the largest of the primates, and they have the largest brain size in relation to their body size. They tend to have broad pelvises, long fingers, no tail, and flexible arm and shoulder joints. They also have semi-upright or upright posture, and, except for hominins, their arms are longer than their legs. Their teeth are less specialized than those of other animals, and their molars have a distinctive pattern that scientists use to distinguish hominoid fossils from other primate fossils.

Hominoid biogeography During the Miocene (24–5 mya), the world's climate became warmer and drier. As a result, tropical rain forests in Africa began to shrink. Many new animals, including new hominoids, evolved as they adapted to the changing environments. Between about 23 and 14 mya, perhaps as many as 100 hominoid species existed. Early hominoids were more diverse than the modern apes, and they migrated from Africa to Europe and Asia.

Proconsul The best-known hominoid fossils, and some of the oldest, are those from the genus *Proconsul*. **Figure 16.12** shows a fossil skull of one *Proconsul* species discovered by Mary Leakey in Kenya in 1948. This *Proconsul* species generally had the smallest brains of the hominoids. Most had freely moving arms and legs, and while they lived predominantly in trees, some might have had the ability to walk upright. Some scientists think that this *Proconsul* species is a human ancestor, but others suggest that one of the European hominoids—whose fossils are in some ways more humanlike than *Proconsul*—might have returned to Africa at the end of the Miocene and given rise to the human line.

Hominins

The lineage that most likely led to humans split off from the other African apes sometime between 8 and 5 mya. The hominins include humans and all their extinct relatives. These extinct relatives are more closely related to humans than to chimpanzees. The time line in **Figure 16.13** highlights some important hominin discoveries.

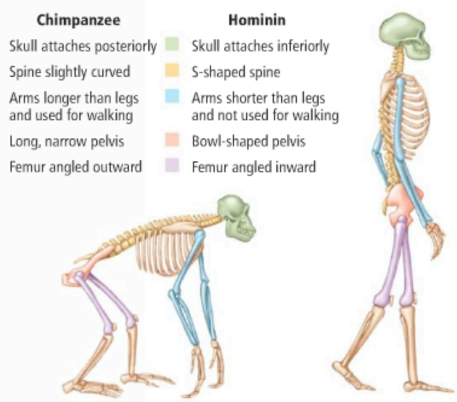
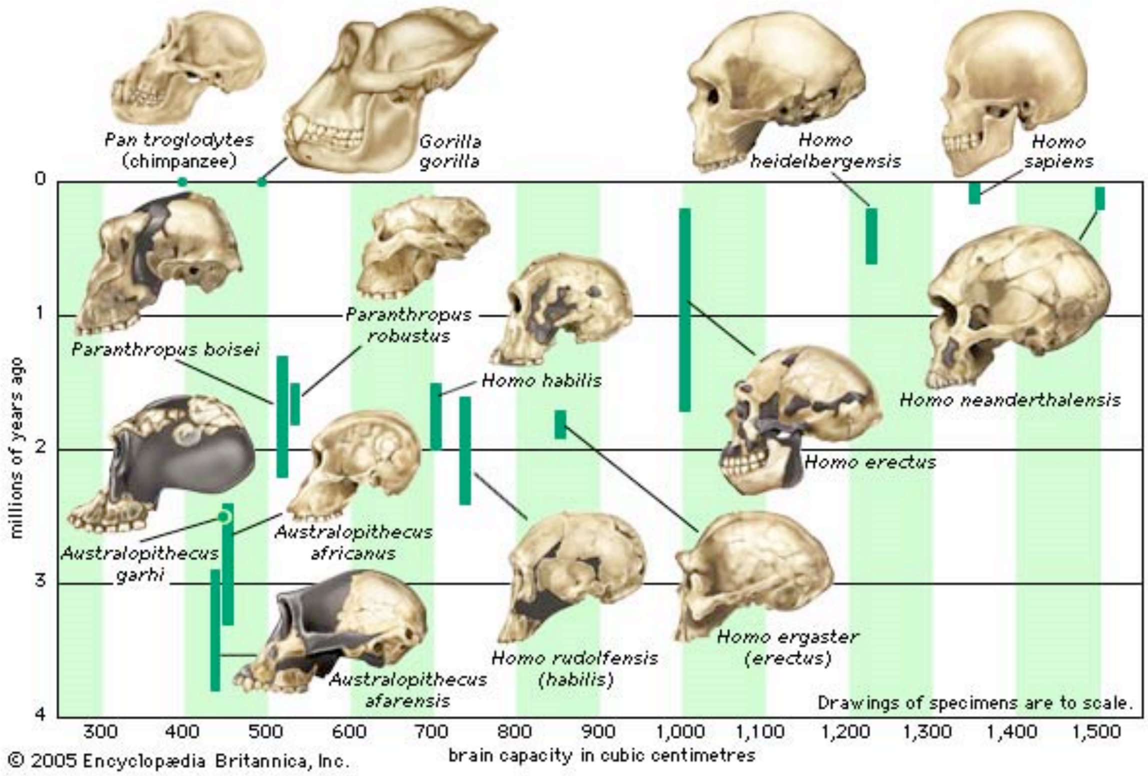


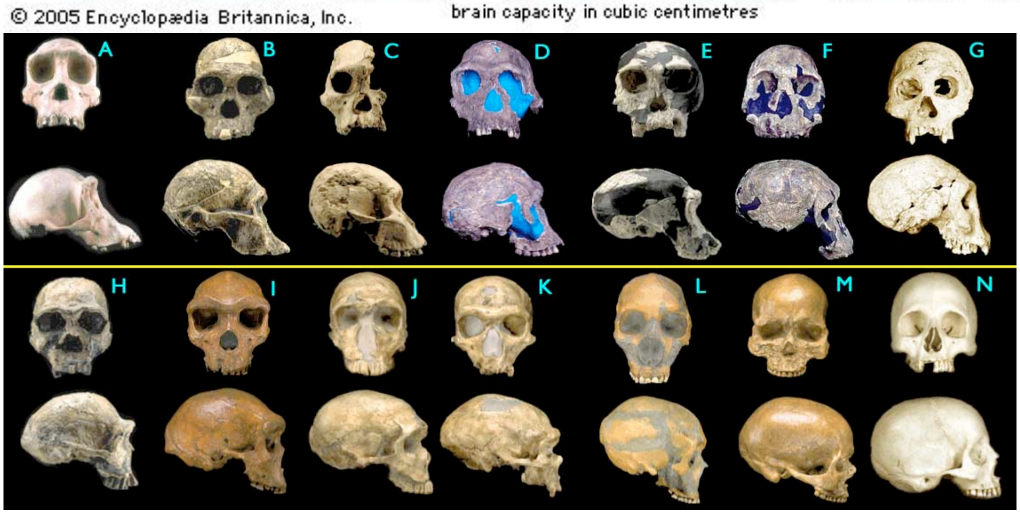
Figure 16.14 A comparison between chimpanzee and hominin skeletons illustrates evolutionary changes leading to bipedalism. **Observe and Infer** *What differences in the lengths of the arms and the legs do you detect?*

Hominin characteristics Hominins have bigger brains than other hominoids, with more complexity in parts of the brain where high-level thought occurs. The hominin face is thinner and flatter than that of other hominoids. Hominin teeth are also smaller. With lengthened thumbs and more flexible wrists, hominins have high manual dexterity. Hominins are also **bipedal,** which means that they can walk upright on two legs.

Examine **Figure 16.14,** which illustrates anatomical differences in a quadruped and a biped. When becoming bipedal, hominins developed a fully upright stance, shortened arms, restructured pelvic bones and foot bones, and a change in the position of the head on the spinal cord. In quadrupedal animals, or those that walk on all four limbs, the foramen magnum—the hole in the skull where the spine extends from the brain—is located at the back of the skull. In hominins, it is positioned at the base of the skull.

Compare the skulls and brain capacities of the different primates - can look at textbook pages here w/pics for answers





Lesser apes and greater apes

Apes Only a handful of ape species exist today. Apes generally have larger brains in proportion to their body size than monkeys. They also have longer arms than legs, barrel-shaped chests, no tails, and flexible wrists. They are often highly social and have complex vocalizations. They are classified into two subcategories: the lesser apes, which include the gibbons and siamangs, and the great apes, which include orangutans, gorillas, chimpanzees, and humans.

Lesser apes The Asian gibbons and their close relatives, the larger siamangs, are the arboreal gymnasts of the ape family. Though they have the ability to walk on either two or four legs like all great apes, they generally move from branch to branch using a hand-over-hand swinging motion called brachiation. This motion, as shown in **Figure 16.6,** enables an adult gibbon to move almost 3 m in one swing.

Great apes Orangutans are the largest arboreal primates and the only great ape species that lives exclusively in Asia. Orangutans are large enough that the males are often more comfortable on the ground, though they are not efficient walkers. Female orangutans give birth once every eight years and nurse their young for up to six years. A male orangutan with prominent cheek pads and female orangutan with her offspring are shown in **Figure 16.7.**

The gorillas are the largest of the primates. Like all great apes, they are predominantly terrestrial animals. They walk on all four limbs, supporting themselves by their front knuckles. Also, like other great apes, they use sticks as simple tools in the wild, and some living in captivity have been taught to recognize characters and numbers.

Hominids: what are they? -

Chimpanzees and their close relatives, the bonobos, are also knuckle-walkers. They have well-developed communication systems, such as body positions and gestures, and social behavior, and they live in a wide variety of habitats. They are more like humans in their physical structure and behavior than any other primate. The bonobo, shown in **Figure 16.8,** is slightly smaller than the chimpanzee. It was once called the "pygmy chimpanzee," but it now is considered a separate species.

Humans are included in the great ape family. They are then classified in a separate subcategory of hominids called hominins. **Hominins** are humanlike primates that appear to be more closely related to present-day humans than they are to present-day chimpanzees and bonobos. Though many species of hominins have existed on Earth, only one species—the group to which you belong—survives today. The diagram in **Figure 16.9** illustrates evolutionary relationships among primates.

Primate Evolution

Most primates today are arboreal. Prehensile tails, long limbs, binocular vision, brachiation, and opposable digits are traits that help them take full advantage of their forest environments.

Arboreal adaptation Some scientists suggest that primates evolved from ground-dwelling animals that searched for food in the top branches of forest shrubbery. They then evolved into additional food-gathering niches in trees. For example, the flexible hand with its opposable digits evolved not to grasp tree branches but to catch insects. Other scientists suggest that the rise of flowering plants provided new niche opportunities, and that arboreal adaptations allowed primates to take advantage of the fruits and flowers of trees.

take advantage of the fruits and flowers of trees.

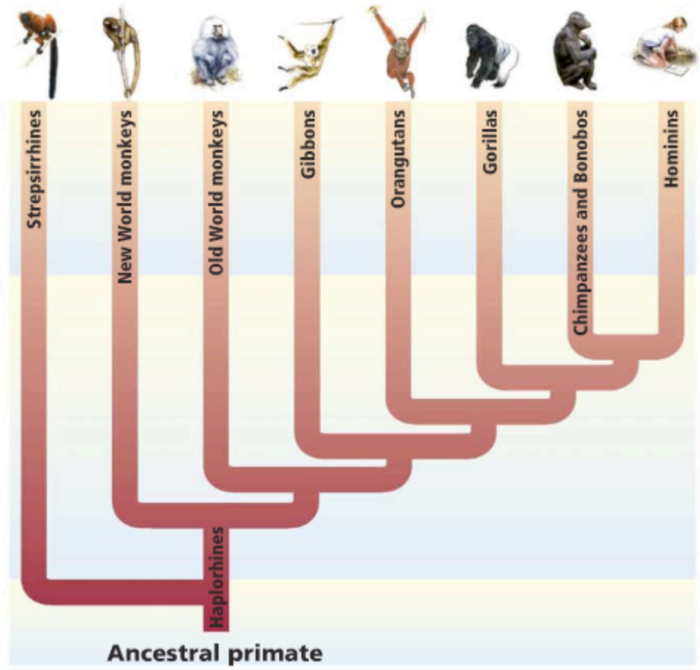


Figure 16.9 This branching diagram illustrates the diverging pattern of primate evolution.
Trace ***Which primate was the earliest to diverge?***

Bipedal - The ability to walk upright on two legs, which primates can do, specifically Hominins.

Hominin fossils Bipedalism evolved before many other hominin traits, and it is often used to identify hominin fossils. The earliest fossils of species that show some degree of bipedalism are 6–7 million years old. The first hominins that were truly bipedal, however, were the australopithecines (aw stray loh PIH thuh seens).

Australopithecines lived in the east-central and southern part of Africa between 4.2 and 1 mya. They were small—the males were only about 1.5 m tall—and they had apelike brains and jaws. However, their teeth and limb joints were humanlike.

Taung baby The anthropologist Raymond Dart (1893-1988) identified the first australopithecine fossil, the "Taung baby," in Africa in 1926. He called the species *Australopithecus africanus,* meaning "southern ape from Africa." *A. africanus* likely lived between 3.3 and 2.3 mya. The placement of the foramen magnum in the skull of the Taung baby, shown in **Figure 16.15,** convinced Dart that *A. africanus* was bipedal. Not everyone agreed because *A. africanus* had a small brain. Some scientists thought that larger brains evolved before bipedalism. The question continued to be debated for many years, even after the discovery of other African australopithecine fossils such as *A. bosei* and *A. robustus* that indicated bipedalism and small brains.

Lucy In 1974 in Kenya, the anthropologist Donald Johanson discovered an australopithecine skeleton that helped resolve the debate. Lucy is one of the most complete australopithecine fossils ever found. She was a member of the species *A. afarensis,* which lived between 4 and 2.9 mya.

Lucy was about the size of a chimpanzee. She had the typical australopithecine skull and small brain, and her arms were still somewhat long in proportion to her legs. She also had finger bones that were more curved than those of modern humans, which indicates that she was capable of arboreal activity. But her hip and knee joints were humanlike, and it was clear that she walked upright. A few years later, Mary Leakey uncovered further evidence that australopithecines were bipedal when she discovered fossilized australopithecine footprints. Lucy's skeleton and the footprints of her relatives are illustrated in **Figure 16.16.**

Mosaic pattern Like other hominin fossils, Lucy and her relatives show a patchwork of human and apelike traits. In this way, they follow a mosaic pattern of evolution. Mosaic evolution occurs when different body parts or behaviors evolve at different rates. For example, hominins developed the ability to walk upright nearly two million years before they developed modern flat faces and larger brains.

Raymond Dart's discovery – **See Hominin Fossils page for answers**
what the interesting about the skull he found?
What was it called?
Australopithecine – **See Hominin Fossils page for answers**
what are they?
Characteristics
"Lucy" – **See Hominin Fossils page for answers**
Forum magnum, brow ridge, sagittal crest

In quadrupedal animals, or those that walk on all four limbs, the foramen magnum—the hole in the skull where the spine extends from the brain—is located at the back of the skull. In hominins, it is positioned at the base of the skull.

from Africa." *A. africanus* likely lived between 3.3 and 2.3 mya. The placement of the foramen magnum in the skull of the Taung baby, shown in **Figure 16.15,** convinced Dart that *A. africanus* was bipedal. Not

H. habilis possessed a brain averaging 650 cm^3, about 20 percent larger than that of the australopithecines. It also had other *Homo* species traits, including a smaller brow, reduced jaw, flatter face, and more humanlike teeth. Like australopithecines, it was small, long-armed, and

Foramen Magnum – the hole in the skull where the spine extends from the brain
Brow ridge - refer to a bony ridge located above the eye sockets of all primates. In *Homo sapiens sapiens* (modern humans) the eyebrows are located on their lower margin.
Sagittal Crest - (in many mammals) a bony ridge on the top of the skull to which the jaw muscles are attached.

Homo habilis, Homo ergaster, Homo erectus: characteristics of them, relative brain size to each other and modern humans – **Use Text below for answers**
Characteristics
Relative brain size to each other and modern humans
Tools, fire, caves - used these

The Genus *Homo*

The African environment became considerably cooler between 3 and 2.5 mya. Forests became smaller in size, and the range of grasslands was extended. The genus ***Homo,*** which includes living and extinct humans, first appeared during these years and although the fossil record is lacking fossils, many scientists infer that they evolved from an ancestor of the australopithecines.

Homo species had bigger brains, lighter skeletons, flatter faces, and smaller teeth than their australopithecine ancestors. They are also the first species known to control fire and to modify stones for tool use. As they evolved, they developed language and culture.

***Homo habilis* used stone tools** The earliest known species that is generally accepted as a member of the genus *Homo* is *Homo habilis,* called "handy man" because of its association with primitive stone tools. This species lived in Africa between about 2.4 and 1.4 mya. **Figure 16.17** shows a scientific illustrator's idea of what *H. habilis* might have looked like.

H. habilis possessed a brain averaging 650 cm^3, about 20 percent larger than that of the australopithecines. It also had other *Homo* species traits, including a smaller brow, reduced jaw, flatter face, and more humanlike teeth. Like australopithecines, it was small, long-armed, and it seems to have retained the ability to climb trees. Other *Homo* species might have coexisted with *H. habilis*, among them a species called *Homo rudolfensis*. Because few fossils of *H. rudolfensis* have been found, its exact relationship to the rest of the *Homo* line is uncertain.

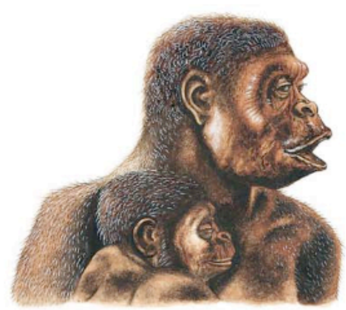
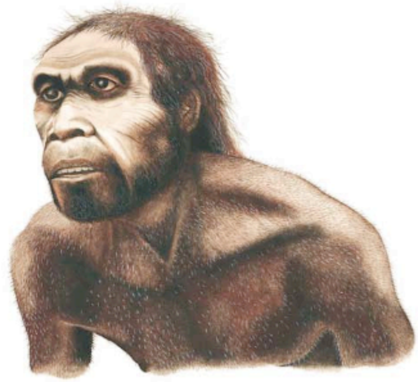


Figure 16.17 Scientific illustrators use fossils and their knowledge of anatomy to create drawings of what *H. habilis* might have looked like.

Figure 16.18 Models of nonliving species also can be created from fossil remains. *H. ergaster* appeared in the fossil record about 1.8–1.3 mya.



Homo ergaster migrated Within about 500,000 years of the appearance of *H. habilis,* another *Homo* species, *Homo ergaster,* emerged with an even larger brain. *H. ergaster,* illustrated in **Figure 16.18,** appeared only briefly in the fossil record, from about 1.8 to 1.3 mya. *H. ergaster* was taller and lighter than *H. habilis,* and had longer legs and shorter arms. Its brain averaged 1000 cm^3, and it had a rounded skull, reduced teeth, and what many scientists think is the first human nose (with the nostrils facing downward).

Tools Carefully made hand axes and other tools associated with *H. ergaster* fossils suggest to some scientists that *H. ergaster* was a hunter, but others think that *H. ergaster* was primarily a scavenger and used the tools to scrape the meat off of scavenged bones.

Figure 16.19 *H. erectus* might have lived in caves, made tools, and used fire.
Explain *some of the advantages* H. erectus *would have over* H. ergaster.

Migration Both scavenging and hunting are associated with a migratory lifestyle, and *H. ergaster* appears to have been the first African *Homo* species to migrate in large numbers to Asia and possibly Europe, perhaps following the trail of migrating animals. The later Eurasian forms of *H. ergaster* are called *Homo erectus.* Because *H. ergaster* shares features with modern humans, scientists hypothesize that *H. ergaster* is an ancestor of modern humans.

Homo erectus used fire *H. erectus,* illustrated in **Figure 16.19,** lived between 1.8 million and 400,000 years ago and appears to have evolved from *H. ergaster* as it migrated out of Africa. While some scientists consider *H. ergaster* and *H. erectus* a single species, *H. erectus* appears to have evolved traits that the early African *H. ergaster* species did not have. Members of this species seem to have been more versatile than their predecessors, and they adapted successfully to a variety of environments. *H. erectus* includes "Java Man," discovered in Indonesia in the 1890s, and "Peking Man," discovered in China in the 1920s.

In general, *H. erectus* was larger than *H. habilis* and had a bigger brain. It also had teeth that were more humanlike. Brain capacity ranged from about 900 cm^3 in early specimens to about 1100 cm^3 in later ones. It was as tall as *H. sapiens* but it had a longer skull, lower forehead, and thicker facial bones than either *H. ergaster* or *H. sapiens.* It also had a more prominent browridge. Evidence indicates that *H. erectus* made sophisticated tools, used fire, and sometimes lived in caves.

Figure 16.20 Scientists are debating whether *H. floresiensis* is a new species. The *H. floresiensis* skull on the left is smaller than

Neanderthals – what they are, characteristics – **See below for answers**

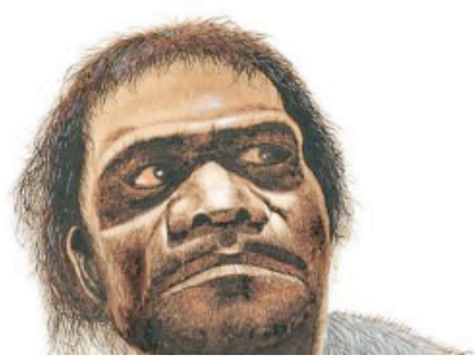
What they are

Characteristics

***Homo neanderthalensis* built shelter** A distinct human species called *Homo neanderthalensis*, or the **Neanderthals,** evolved exclusively in Europe and Asia about 200,000 years ago, likely from *H. erectus* or a *Homo* intermediary. Neanderthals were shorter but had more muscle mass than most modern humans. Their brains were sometimes even larger than the brains of modern humans, though the brains might have been organized in different ways. Neanderthals had thick skulls, bony browridges, and large noses. They also had a heavily muscled, robust stature, as illustrated in **Figure 16.21.** Evidence of heavy musculature appears in the extremely large muscle attachments and the bowing of the long bones.

Neanderthals lived near the end of the Pleistocene ice age, a time of bitter cold. Their skeletons reflect lives of hardship; bone fractures and arthritis seem to have been common. There is evidence that they used fire and constructed complex shelters. They hunted and skinned animals, and it is possible that they had basic language. There is also some evidence that they cared for their sick and buried their dead.

Are Neanderthals our ancestors? In some areas of their range, particularly in the Middle East and southern Europe, Neanderthals and modern humans overlapped for as long as 10,000 years. Some scientists suggest that the two species interbred. However, DNA tests on fossil bones suggest that Neanderthals were a distinct species that did not contribute to the modern human gene pool. Neanderthals went extinct about 30,000 years ago.

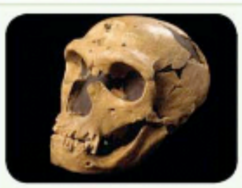


Emergence of Modern Humans

The species that displaced the Neanderthals, *Homo sapiens*, is characterized by a more slender appearance than all other *Homo* species. They have thinner skeletons, rounder skulls, and smaller faces with prominent chins. Their brain capacity averages 1350 cm^3. *H. sapiens* first appeared in the fossil record, in what is now Ethiopia, about 195,000 years ago. These early *H. sapiens* made chipped hand axes and other sophisticated stone tools. They appear to have had the ability to use a range of resources and environments, and at some point they began migrating out of Africa. **Table 16.2** compares modern humans with other *Homo* species.

Concepts In Motion
Interactive Table To explore more about the *Homo* species, visit biologygmh.com.

Table 16.2 **Characteristics of the *Homo* species**

Species	Skull	Time in fossil record	Characteristics
Homo habilis		2.4–1.4 million years ago	• Average brain had a capacity of 650 cm^3 • Used tools
Homo ergaster		1.8–1.2 million years ago	• Average brain had a capacity of 1000 cm^3 • Had thinner skull bones • Had humanlike nose
Homo erectus		1.8 million–400,000 years ago	• Average brain had a capacity of 1000 cm^3 • Had thinner skull bones • Used fire
Homo neanderthalensis		300,000–200,000 years ago	• Average brain had a capacity of 1500 cm^3 • Buried their dead • Possibly had a language
Homo sapiens		195,000 years ago to present	• Average brain has a capacity of 1350 cm^3 • Does not have browridge • Has a small chin • Has language and culture

Cro-Magnons – what they are, characteristics – **See text below**

What they are

Characterisitcs

The beginning of culture The first evidence of complex human culture appeared in Europe only about 40,000 years ago, shortly before the Neanderthals disappeared. Unlike the Neanderthals, early modern humans expressed themselves symbolically and artistically in decorative artifacts and cave drawings, as illustrated in **Figure 16.23.** They developed sophisticated tools and weapons, including spears and bows and arrows. They were the first to fish, the first to tailor clothing, and the first to domesticate animals. These and many other cultural expressions marked the appearance of fully modern humans, the subspecies *Homo sapiens*. Some people call them **Cro-Magnons.** They represent the beginning of historic hunter-gatherer societies.

Connection to History Humans continued their migration throughout Europe and Asia. They probably reached Australia by boat and traveled to North America via a land bridge from Asia. From North America, they spread to South America. They adapted to new challenges along the way, leaving behind a trail of artifacts that we study today.

Figure 16.23 Cro-Magnons were known for their sophisticated cave paintings, tools, and weapons. This painting was found in Lascaux Cave in France.

Out of Africa hypothesis - The hypothesis that all humans originated in Africa.

Mitochondrial Eve - The idea that all modern human beings can trace their ancestry back to a single woman who lived 200,000 years ago in Africa. This one woman was nicknamed “Eve” (a.k.a., “mitochondrial

Eve").

Out-of-Africa hypothesis The world's population 200,000 years ago looked significantly different than it does today. It was inhabited by a morphologically diverse genus of hominins, including primitive humans, Neanderthals, and modern humans, as illustrated in **Figure 16.22.** By 30,000 years ago, however, only modern humans remained. Some scientists propose that these modern humans evolved from several dispersed populations of early *Homo* species at the same time in different areas of the world. According to this multiregional evolution model, modern races of humans arose in isolated populations by convergent evolution.

Most scientists explain the global dominance of modern humans with the African Replacement model or, more commonly, the Out-of-Africa hypothesis. According to this hypothesis, which was first proposed by Christopher Stringer and Peter Andrews of the British Museum of Natural History in 1988, modern humans evolved only once, in Africa, and then migrated to all parts of the world, eventually displacing other hominins.

"Mitochondrial Eve" The Out-of-Africa hypothesis was supported by mitochondrial DNA analysis of contemporary humans in the early 1990s. Mitochondrial DNA changes very little over time, and humans living today have nearly identical mitochondrial DNA. Researchers Allan Wilson and Rebecca Cann of the University of California, Berkeley, reasoned that the population with the most variation should be the population that has had the longest time to accumulate diversity. This was exactly what they found in the mitochondrial DNA of Africans. Because mitochondrial DNA is inherited only from the mother, this analysis suggested that *H. sapiens* emerged in Africa about 200,000 years ago from a hypothetical "Mitochondrial Eve."

Later, work by other scientists studying DNA sequences in the male Y chromosome yielded similar results. While some scientists think that a single movement of only a few hundred modern humans ultimately gave rise to the world's current population, others think the process occurred in phases, with some interbreeding among the species that humans displaced.

Microbiology Unit

- Chapters: 18, 19 and 20
- All vocabulary

Chapter 18

- Difference between archaea and bacteria

Differences between bacteria and archaea Bacteria and archaea have many differences that have led them to be classified in different domains. Recall from Chapter 17 that there are three domains. Based on their classification, we understand that bacteria and archaea are as different from each other as they are from eukaryotic cells. Some differences include: bacterial cell walls contain peptidoglycan, but archaea do not; different lipids in their plasma membranes; and different ribosomal proteins and RNA. The ribosomal proteins in archaea are similar to those of eukaryotic cells.

- Know how bacteria survive in harsh conditions

Bacteria Bacteria are the most-studied organisms and are found almost everywhere except in extreme environments where mostly archaea are found. Bacteria have strong cell walls that contain peptidoglycan. Some bacteria have a second cell wall, a property which can be used to classify them. Additionally, some bacteria, such as the cyanobacteria in **Figure 18.1,** are photosynthetic.

- Know how bacteria is beneficial to humans and other organisms

nutritional quality, and safety of our food. They test for amounts of nutrients and presence of harmful organisms such as bacteria. For more information on biology careers, visit biologygmh.com.

Ecology of Bacteria

When many people think of bacteria, they immediately think of germs or disease. Most bacteria do not cause disease, and many are beneficial. In fact, it has been said that humans owe their lives to bacteria because they help fertilize fields, recycle nutrients, protect the body, and produce foods and medicines.

Nutrient cycling and nitrogen fixation In Chapter 2, you learned how nutrients are cycled in an ecosystem. Some organisms get their energy from the cells and tissues of dead organisms and are called decomposers or detrivores. Bacteria are decomposers, returning vital nutrients to the environment. Without nutrient recycling, all raw materials necessary for life would be used up. Without nitrogen fixation, far more fertilizer would be needed for growing plants.

Connection to Chemistry All forms of life require nitrogen. Nitrogen is a key component of amino acids, the building blocks of proteins. Nitrogen also is needed to make DNA and RNA. Most of Earth's nitrogen is found in the atmosphere in the form of nitrogen gas (N_2). Certain types of bacteria can use nitrogen gas directly. These bacteria have enzymes that can convert nitrogen gas into nitrogen compounds by a process called nitrogen fixation. Some of these bacteria live in the soil.

Figure 18.9 Nitrogen-fixing bacteria on a plant root nodule are able to remove nitrogen from the air and convert it into a form the plant can use.

Some nitrogen-fixing bacteria live in a symbiotic relationship in the root nodules of plants such as soybeans, clover, and alfalfa. The bacteria use the nitrogen in the atmosphere to produce forms of nitrogen the plant can use. The plants then are able to take up ammonia (NH_3) and other forms of nitrogen from the soil. These plants are at the base of a food chain and the nitrogen is passed along to organisms that eat them. **Figure 18.9** shows where nitrogen-fixing bacteria live on root nodules.

Normal flora Your body is covered with bacteria inside and out. Most of the bacteria that live in or on you are harmless. These are called normal flora. Normal flora are of great importance to the body. By living and replicating on the body, they compete with harmful bacteria and prevent them from taking hold and causing disease.

A certain type of bacteria called *Escherichia coli (E. coli)* lives inside your intestines, and is illustrated in **Figure 18.10.** Some *E. coli* strains can cause food poisoning. The type that lives in the digestive tracts of humans and other mammals is harmless and important for survival. The *E. coli* that live in humans make vitamin K, which humans absorb and use in blood clotting. In this symbiotic relationship, *E. coli* are provided with a warm place with food to live. In return, the bacteria provide the body with an essential nutrient.

Foods and medicines Think about what you have eaten in the last few days. Have you had pizza? How about a cheeseburger? Cheese, yogurt, buttermilk, and pickles, as well as other foods, are made with the aid of bacteria.

Bacteria are even used in the production of chocolate. Although bacteria are not found in the chocolate products you eat, bacteria are used to break down the covering of cocoa beans during the production of cocoa. Bacteria also are responsible for commercial production of vitamins, such as vitamin B12 and riboflavin.

Bacteria also are important in the fields of medicine and research. Although some bacteria cause disease, others are useful in fighting disease. Streptomycin, bacitracin, tetracycline, and vancomycin are commonly prescribed antibiotics that were originally made by bacteria.

- Know the different shapes of bacteria

Shape There are three general shapes of prokaryotes, as shown in **Figure 18.5.** Spherical or round prokaryotes are called cocci (KAHK ki) (singular, coccus), rod-shaped prokaryotes are called bacilli (buh SIH li) (singular, bacillus), and spiral-shaped prokaryotes, or spirilli (spi RIH li) (singular, spirillium), are called spirochetes (SPI ruh keets).

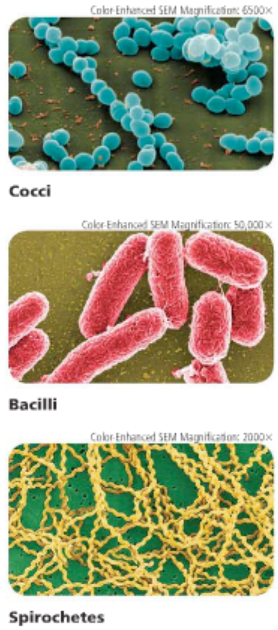
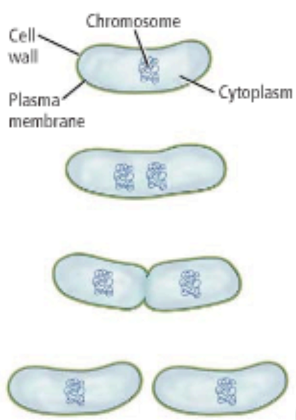
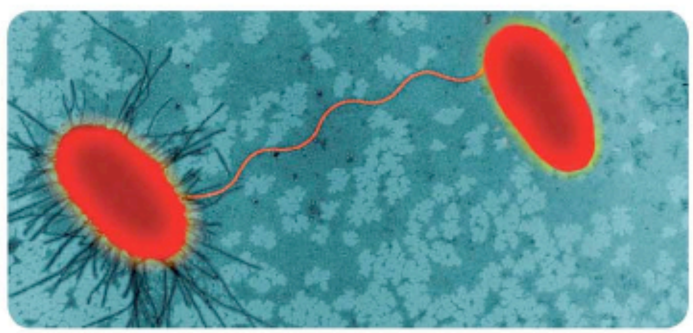


Figure 18.5 There are three shapes of prokaryotes: cocci, bacilli, and spirochetes.

- Know binary fission



Binary fission



Conjugation

Figure 18.6 Binary fission is an asexual form of reproduction used by some prokaryotes. Conjugation is a method of exchanging genetic material used by some prokaryotes.

Analyze ***Which means of reproducing shown here exchanges genetic information?***

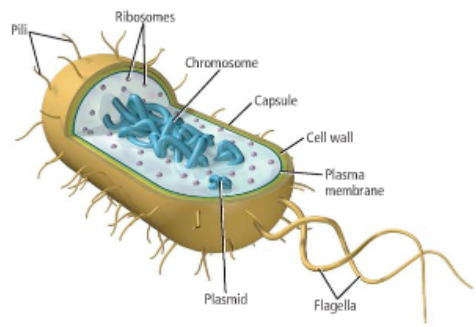
Reproduction of Prokaryotes

Most prokaryotes reproduce by an asexual process called binary fission, illustrated in **Figure 18.6. Binary fission** is the division of a cell into two genetically identical cells. In this process, the prokaryotic chromosome replicates, and the original chromosome and the new copy separate. As this occurs, the cell gets larger by elongating. A new piece of plasma membrane and cell wall forms and separates the cell into two identical cells. Under ideal environmental conditions, this can occur quickly—as often as every 20 minutes. If conditions are just right, one bacterium could become one billion bacteria through binary fission in just ten hours.

Some prokaryotes exhibit a form of reproduction called **conjugation,** in which two prokaryotes attach to each other and exchange genetic information. As shown in **Figure 18.6,** the pilus is important for the attachment of the two cells so that there can be a transfer of genetic material from one cell to the other. In this way, new gene combinations are created and diversity of prokaryote populations is increased.

- Capsule, conjugation, transformation, endospore, nucleoid, and pilus
    - Transformation – the process when some of the bacteria cells take up the recombinant plasmid DNA.

Figure 18.3 Prokaryotic cells have structures that are necessary for carrying out life processes.
Compare and Contrast ***How does a bacterial cell differ structurally from a eukaryotic cell?***



Prokaryote Structure

Prokaryotes are microscopic, unicellular organisms. They have some characteristics of all cells, such as DNA and ribosomes, but they lack a nuclear membrane and other membrane-bound organelles, such as mitochondria and chloroplasts. Although a prokaryotic cell is very small and doesn't have membrane-bound organelles, it has all it needs to carry out life functions. Examine **Figure 18.3** as you read about the structure of prokaryotic cells.

Chromosomes The chromosomes in prokaryotes are arranged differently than the chromosomes found in eukaryotic cells. Their genes are found on a large, circular chromosome in an area of the cell called the **nucleoid.** Many prokaryotes also have at least one smaller piece of DNA, called a *plasmid,* which also has a circular arrangement.

Capsule Some prokaryotes secrete a layer of polysaccharides around the cell wall, forming a **capsule,** illustrated in **Figure 18.3.** The capsule has several important functions, including preventing the cell from drying out and helping the cell attach to surfaces in its environment. The capsule also helps prevent the bacteria from being engulfed by white blood cells and shelters the cell from the effects of antibiotics.

Pili Structures called pili are found on the outer surface of some bacteria. **Pili** (singular, pilus) are submicroscopic, hairlike structures that are made of protein. Pili help bacterial cells attach to surfaces. Pili also can serve as a bridge between cells. Copies of plasmids can be sent across the bridge, thus providing some prokaryotes with new genetic characteristics. This is one way of transferring the resistance to antibiotics.

Size Even when using a typical light microscope, prokaryotes are small when magnified 400 times. Prokaryotes are typically only 1 to 10 micrometers long and 0.7 to 1.5 micrometers wide. Study **Figure 18.4,** which shows a bacterial cell and a human cell. Notice the relative size of bacterial cells found adjacent to a cheek cell.

Recall from Chapter 9 that small cells have a larger, more favorable surface area-to-volume ratio than large cells. Because prokaryotes are so small, nutrients and other substances the cells need can diffuse to all parts of the cell easily.

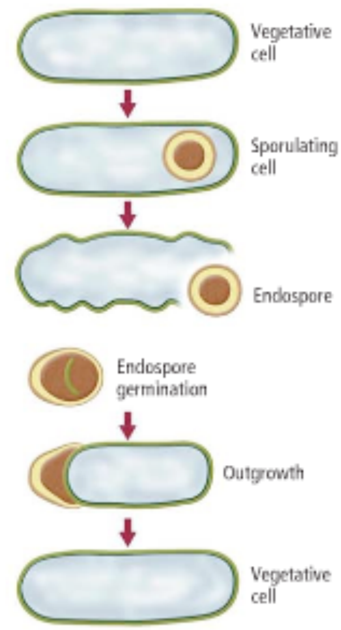
Survival of Bacteria

How can bacteria survive if their environment becomes unfavorable? They have several mechanisms that help them survive such environmental challenges as lack of water, extreme temperature change, and lack of nutrients.

Endospores When environmental conditions are harsh, some types of bacteria produce a structure called an **endospore.** The bacteria that cause anthrax, botulism, and tetanus are examples of endospore producers. An endospore can be thought of as a dormant cell. Endospores are resistant to harsh environments and might be able to survive extreme heat, extreme cold, dehydration, and large amounts of ultraviolet radiation. Any of these conditions would kill a typical bacterial cell.

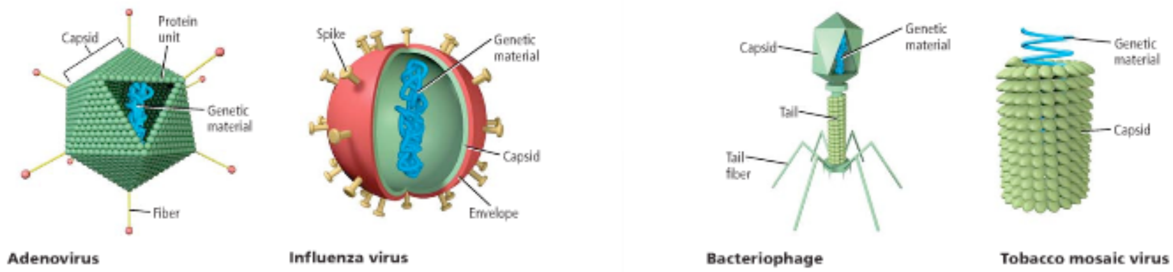
As illustrated in **Figure 18.8,** when a bacterium is exposed to harsh environments, a spore coat surrounds a copy of the bacterial cell's chromosome and a small part of the cytoplasm. The bacterium itself might die, but the endospore remains. When environmental conditions become favorable again, the endospore grows, or germinates, into a new bacterial cell. Endospores are able to survive for long periods of time. Because a bacterial cell usually only produces one endospore, this is considered a survival mechanism rather than a type of reproduction.

Figure 18.8 Endospores can survive extreme environmental conditions.



- Know the different shapes of viruses – **See Packet –** Polyhedral , Spherical, rod shaped, and bacteria phage.

Figure 18.11 Viruses have several different types of arrangements, but all viruses have at least two parts: an outer capsid portion made of proteins, and genetic material.



Virus structure **Figure 18.11** shows the structures of adenovirus, influenza virus, bacteriophage, and tobacco mosaic virus. Adenovirus infection causes the common cold, and influenza virus is responsible for causing the flu. A virus that infects bacteria is called a bacteriophage (bak TIHR ee uh fayj). Tobacco mosaic virus causes disease in tobacco leaves. The outer layer of all viruses is made of proteins and is called a **capsid.** Inside the capsid is the genetic material, which could be DNA or RNA, never both. Viruses generally are classified by the type of nucleic acid they contain.

Connection to History The virus that causes smallpox is a DNA virus. Outbreaks of smallpox have occurred in the human population for thousands of years. A successful program of worldwide vaccination eliminated the disease and routine vaccination was stopped. For a closer look at the history of the discovery of the virus that causes smallpox and smallpox vaccination, examine **Figure 18.12.**

Viral Infection

- Know the events of the lytic and lysogenic cycle, how are they different? The same?

Lytic cycle In the **lytic cycle,** illustrated in **Figure 18.13,** the host cell makes many copies of the viral RNA or DNA. The viral genes instruct the host cell to make more viral protein capsids and enzymes needed for viral replication. The protein coat forms around the nucleic acid of new viruses. These new viruses leave the cell by exocytosis or by causing the cell to burst, or lyse, releasing new viruses that are free to infect other cells. Viruses that replicate by the lytic cycle often produce active infections. Active infections usually are immediate, meaning symptoms of the illness caused by the virus start to appear one to four days after exposure. The common cold and influenza are two examples of widespread viral diseases that are active infections.

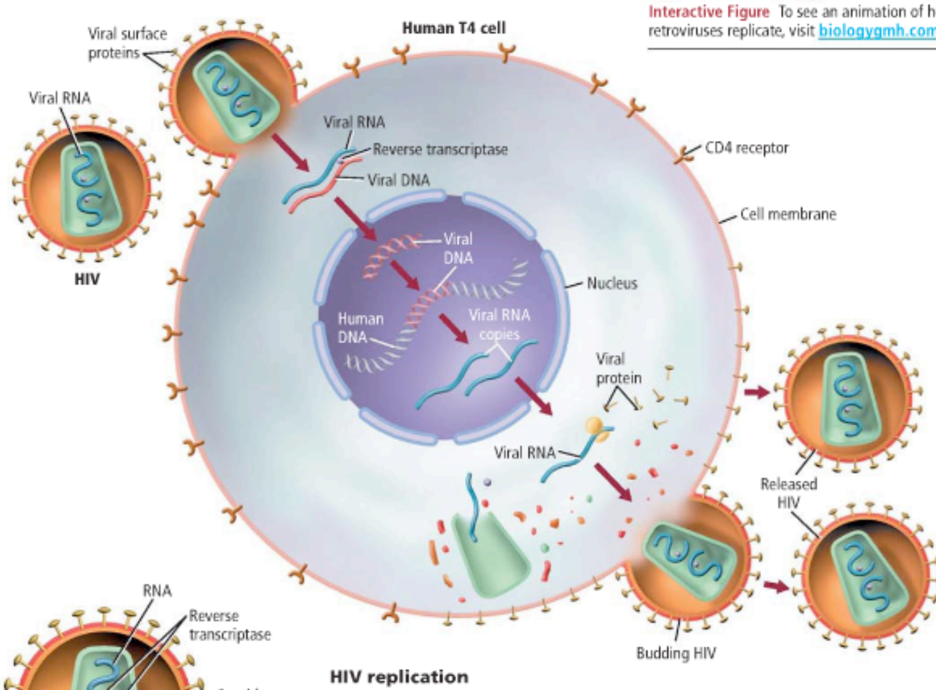
Lysogenic cycle In some cases, the viral DNA might enter the nucleus of the host cell. In the **lysogenic cycle,** also illustrated in **Figure 18.13,** the viral DNA inserts, or integrates into a chromosome in a host cell. Once integrated, the infected cell will have the viral genes permanently. The viral genes might remain dormant for months or years. Then at some future time, the viral genes might be activated by many different factors. Activation results in the lytic cycle. The viral genes instruct the host cell to manufacture more viruses. The new viruses will leave the cell by exocytosis or by causing the cell to lyse.

Many disease-causing viruses have lysogenic cycles. Herpes simplex I is an example of a virus that causes a latent infection. This virus is transmitted orally, and a symptom of this infection is cold sores. When the viral DNA enters the nucleus, it is inactive. It is thought that during times of stress, whether physical, emotional, or environmental, the herpes genes become activated and the production of viruses occurs.

- What is a retrovirus? How do they replicate?

Concepts in Motion

Interactive Figure To see an animation of how retroviruses replicate, visit biologygmh.com.



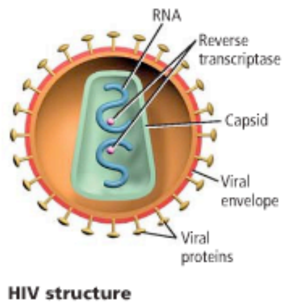


Figure 18.14 The genetic material and replication cycle of a retrovirus, such as HIV, is different from that of DNA viruses.

Infer *What is unique about the function of reverse transcriptase?*

Retroviruses

Some viruses have RNA instead of DNA for their genetic material. This type of virus is called a **retrovirus** and has a complex replication cycle. The best-known retrovirus is the human immunodeficiency virus (HIV). Some cancer-causing viruses also belong to this group.

Figure 18.14 shows the structure of HIV. Like all viruses, retroviruses have a protein capsid. Surrounding the capsid is a lipid envelope, which was obtained from the plasma membrane of a host cell. RNA and an enzyme called reverse transcriptase are in the core of the virus. Reverse transcriptase is the enzyme that transcribes DNA from the viral RNA.

Refer to **Figure 18.14** as you learn about the replication cycle of HIV. When HIV attaches to a cell, the virus moves into the cytoplasm of the host cell and the viral RNA is released. Reverse transcriptase synthesizes DNA using the viral RNA as a template. Then, the DNA moves into the nucleus of the host cell and integrates into a chromosome. The viral DNA might lie inactive for a period of years before it is activated. Once it is activated, RNA is transcribed from the viral DNA, and the host cell manufactures and assembles new HIV particles.

- What is the structure, replication and activities of prions

Prions

A protein that can cause infection or disease is called a proteinaceous (pro te NAY shuhs) infectious particle, or a **prion** (PREE ahn). Although diseases now believed to be caused by prions have been studied for decades, they were not well understood until 1982, when Stanley B. Prusiner first identified that the infectious particle was a protein.

Prions normally exist in cells, although their function is not well understood. Normal prions are shaped like a coil. Mutations in the genes that code for these proteins occur, causing the proteins to be misfolded. Mutated prions are shaped like a piece of paper folded many times. Mutated prions are associated with diseases known as transmissible spongiform encephalopathies (SPUN gee form • in SEH fuh la pah thees) (TSE). Examples of diseases caused by prions include mad cow disease in cattle, Creutzfeldt-Jakob disease (CJD) in humans, scrapie (SKRAY pee) in sheep, and chronic wasting disease in deer and elk.

Prion infection **Figure 18.15** shows a normal brain compared with a brain infected with prions. What scientists find fascinating about these misfolded proteins is that these prions can cause normal proteins to mutate. These prions infect nerve cells in the brain, causing them to burst. This results in spaces in the brain, hence the description of spongiform (spongelike) encephalopathy (brain disease).

In the mid-1980s, a new variant of CJD, or nvCJD, was discovered in England. Scientists do not fully agree on the origin of nvCJD, but a leading hypothesis is that the prions are transmitted from cattle. Abnormal prions can be found in the brains and spinal cords of cattle. The hypothesis is that if the spinal cord is cut in the butchering process, the prions might contaminate the beef and then be transmitted to humans that eat the beef. Although this mode of transmission is not agreed upon, the United States government has strict regulations concerning the importation of cattle and beef from other countries.

- Know: capsid – outer layer of all viruses and made of proteins. See above under virus parts for more.

Chapter 19

- How are protists classified?

Protists

Protists are classified more easily by what they are not than by what they are. Protists are not animals, plants, or fungi because they do not have all of the characteristics necessary to place them in any of these kingdoms. The Kingdom Protista was created to include this diverse group of more than 200,000 organisms.

All protists share one important trait—they are eukaryotes. You learned in Chapter 7 that eukaryotic cells contain membrane-bound organelles. Like all eukaryotes, the DNA of protists is found within the membrane-bound nucleus. Although protists have a cellular structure similar to other eukaryotes, there are remarkable differences in their reproductive methods. Some reproduce asexually by mitosis while others exchange genetic material during meiosis.

Classifying protists Because they are such a diverse group of organisms, some scientists classify protists by their method of obtaining nutrition. Protists are divided into three groups using this method: animal-like protists, plantlike protists, and funguslike protists. The **protozoan** (proh tuh ZOH un) (plural, protozoa or protozoans), shown in **Figure 19.1,** is an example of an animal-like protist because it is a heterotroph—it ingests food. Additional examples of protists and a summary of characteristics are shown in **Table 19.1.**

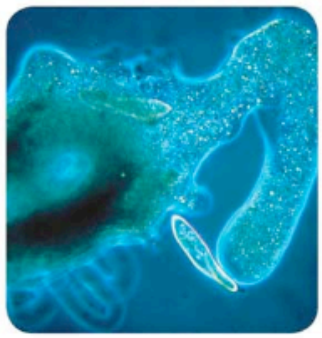
Animal-like protists The amoeba is an example of a unicellular, animal-like protist or protozoan. Protozoans are heterotrophs and usually ingest bacteria, algae, or other protozoans. The amoeba shown in **Table 19.1** is in the process of capturing and ingesting another unicellular protozoan—a paramecium.

Plantlike protists The giant kelp, shown in **Table 19.1,** is an example of a plantlike protist that makes its own food through photosynthesis. Plantlike protists commonly are referred to as algae (AL jee) (singular, alga). Some algae are microscopic. The unicellular algae *Micromonas* are about 10^{-6} m in diameter. Other forms of algae are multicellular and are quite large. The giant kelp, *Macrocystis pyrifera,* can grow up to 65 m long.

Funguslike protists The water mold in **Table 19.1** is an example of a funguslike protist that is absorbing nutrients from a dead salamander. Funguslike protists are similar to fungi because they absorb their nutrients from other organisms. These organisms are not classified as fungi because funguslike protists contain centrioles—small, cylindrical organelles that are involved in mitosis and usually are not found in the cells of fungi. Fungus and funguslike protists also differ in the composition of their cell walls.

Table 19.1 **The Protists**

Interactive Table To explore more about protists, visit biologygmh.com.

	Animal-like protists (Protozoans)	Plantlike protists (Algae)	Funguslike protists
Group	Ciliates, amoebas, apicomplexans, and zooflagellates	Euglenoids, diatoms, dinoflagellates, green algae, red algae, brown algae, yellow-green algae, and golden-brown algae	Slime molds, water molds, and downy mildews
Example	 **Amoeba**	 **Giant kelp**	 **Water mold**
Distinguishing Characteristics	• Considered animal-like because they consume other organisms for food • Some are parasites.	• Considered plantlike because they make their own food through photosynthesis • Some consume other organisms or are parasites when light is unavailable for photosynthesis.	• Considered funguslike because they feed on decaying organic matter and absorb nutrients through their cell walls • Some slime molds consume other organisms and a few slime molds are parasites.

Habitats Protists typically are found in damp or aquatic environments such as decaying leaves, damp soil, ponds, streams, and oceans. Protists also live in symbiotic relationships. **Microsporidia** (MI kroh spo rih dee uh) are microscopic protozoans that cause disease in insects. Some species of microsporidia can be used as insecticides. New technology might allow these microsporidia to be used to control insects that destroy crops.

One beneficial protist lives in the hair of a sloth, shown in **Figure 19.2.** A sloth is a large, slow-moving mammal that lives in the uppermost branches of trees in tropical rain forests. The sloth spends most of its life hanging upside down. Green algae help the brown sloth blend into the leaves on the tree, providing camouflage for the sloth.

- What are the characteristics of protozoans? – See above table
- **Know the life cycles of protozoans** – asexually and sexually, takes 2 generations
- Know: pellicle, contractile vacuole, pseudopod

Paramecia Some of the most commonly studied ciliates are found in the genus *Paramecium* (per uh MEE see um) (plural, paramecia). The paramecium in **Figure 19.5** lives symbiotically with green algae. The green algae undergoes photosynthesis, providing nutrients to the paramecium.

A paramecium is a unicellular protozoan. It is enclosed by a layer of membrane called a **pellicle.** Directly beneath the pellicle is a layer of cytoplasm called ectoplasm. Embedded in the ectoplasm are the **trichocysts** (TRIH kuh sihsts), which are elongated, cylindrical bodies that can discharge a spinelike structure. The function of trichocysts is not completely understood, but they might be used for defense, as a reaction to injury, as an anchoring device, or to capture prey.

Cilia Notice the cilia on the paramecium in **Figure 19.5,** which are used for movement and feeding. Cilia completely cover the organism—including the oral groove. Locate the oral groove on the paramecium in **Figure 19.6.** The cilia covering the wall of the oral groove are used to guide food, primarily bacteria, into the gullet. Once the food reaches the end of the gullet, it is enclosed in a food vacuole. Enzymes within the food vacuole break down the food into nutrients that can diffuse into the cytoplasm of the paramecium. Waste products from the paramecium are excreted through the anal pore.

Contractile vacuoles Because freshwater paramecia live in a hypotonic environment, water constantly enters the cell by osmosis. Recall from Chapter 7 that a hypotonic solution is one in which the concentration of dissolved substances is lower in the solution outside the cell than the concentration inside the cell. The **contractile vacuoles,** shown in **Figure 19.6,** collect the excess water from the cytoplasm and expel it from the cell. The expelled water might contain waste products, which is another way paramecia can excrete waste. Paramecia often have two or three contractile vacuoles that help to maintain homeostasis in the cell.

Members of the phylum Sarcodina (sar kuh DI nuh), also called sarcodines (SAR kuh dinez), are animal-like protists that use pseudopods for feeding and locomotion. A **pseudopod** (SEW duh pahd) is a temporary extension of cytoplasm and is shown in **Figure 19.7.** These extensions surround and envelop a smaller organism, forming a food vacuole. Digestive enzymes are secreted and break down the captured organism.

Some of the most commonly studied sarcodines are found in the genus *Amoeba*. Most amoebas are found in saltwater, although some freshwater species live in streams, in the muddy bottoms of ponds, and in damp patches of moss and leaves. Some amoebas are parasites that live inside an animal host.

- Ciliophora, Sarcodina, Apicomplexa, Zoomastigina

Ciliophora

One of the characteristics that biologists use to further classify protozoans into different phyla is their method of movement. Members of the phylum Ciliophora (sih lee AH fuh ruh), also known as ciliates (SIH lee ayts), are animal-like protists that have numerous short, hairlike projections. Recall from Chapter 7 that some unicellular organisms use cilia (singular, cilium) to propel themselves through water and to move food particles into the cell. Some ciliates have cilia covering their entire plasma membrane, while others have groups of cilia covering parts of their membrane, as shown in **Figure 19.4.** Note that the *Stentor's* cilia are located on the anterior end; they help propel food into the cell. The ciliate *Trichodina pediculus* has two visible sets of cilia. The outer ring is used for movement and the inner ring is used for feeding.

There are more than 7000 species of ciliates. They are abundant in most aquatic environments—ocean waters, lakes, and rivers. They also are found in mud, and it is estimated that as many as 20 million ciliates can inhabit one square meter in some mud flats.

Sarcodina

Members of the phylum Sarcodina (sar kuh DI nuh), also called sarcodines (SAR kuh dinez), are animal-like protists that use pseudopods for feeding and locomotion. A **pseudopod** (SEW duh pahd) is a temporary extension of cytoplasm and is shown in **Figure 19.7.** These extensions surround and envelop a smaller organism, forming a food vacuole. Digestive enzymes are secreted and break down the captured organism.

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Amoeba structure The structure of an amoeba is simple, as shown in **Figure 19.7.** Amoebas are enveloped in an outer cell membrane and an inner thickened cytoplasm called ectoplasm. Inside the ectoplasm, the cytoplasm contains a nucleus, food vacuoles, and occasionally a contractile vacuole. Notice that an amoeba does not have an anal pore like the paramecium. Waste products and undigested food particles are excreted by diffusion through the outer membrane into the surrounding water. The oxygen needed for cellular processes also diffuses into the cell from the surrounding water.

Foraminiferans (fuh rah muh NIH fur unz) and radiolarians (ray dee oh LER ee unz) are types of amoebas that have tests. A **test** is a hard, porous covering similar to a shell, which surrounds the cell membrane. Most of these amoebas live in marine environments, although there are some freshwater species.

Connection to Earth Science Foraminiferans have tests made of calcium carbonate ($CaCO_3$), grains of sand, and other particles cemented together. Geologists use the fossilized remains of foraminiferans to determine the age of some rocks and sediments, and to identify possible sites for oil drilling. Radiolarians, another amoeba with tests shown in **Figure 19.8,** have tests made mostly of silica (SiO_2).

Amoeba reproduction Amoebas reproduce by asexual reproduction during which a parent cell divides into two identical offspring. During harsh environmental conditions, some amoebas become cysts that help them survive until environmental conditions improve and survival is more likely.

Apicomplexa

Animal-like protists that belong to the phylum Apicomplexa (ay puh KOM pleks uh) are also known as sporozoans (spo ruh ZOH unz). They are called sporozoans because they produce spores at some point in their life cycle. Spores are reproductive cells that form without fertilization. Sporozoans lack contractile vacuoles and methods for locomotion. Respiration and excretion occur by diffusion through the plasma membrane.

All sporozoans are parasitic. Recall from Chapter 2 that parasites get their nutritional requirements from a host organism. Sporozoans infect vertebrates and invertebrates by living as internal parasites. Organelles at one end of the organism are specialized for penetrating host cells and tissues, allowing them to get their nutrients from their host.

The life cycle of sporozoans has both sexual and asexual stages. Often two or more hosts are required for an organism to complete a life cycle. The life cycle of *Plasmodium,* which causes malaria, is shown in **Figure 19.9.**

Sporozoans cause a variety of illnesses in humans, some of which are fatal. The sporozoans responsible for the greatest number of human deaths are found in the genus *Plasmodium.* These parasites cause malaria in humans and are transmitted to humans by female *Anopheles* mosquitoes. Malaria causes fever, chills, and other flu-like symptoms. Its greatest impact is in tropical and subtropical regions where factors such as high temperature, humidity, and rainfall favor the growth of mosquitoes and sporozoans, and preventative measures are too costly.

Zoomastigina

Protozoans in the phylum Zoomastigina (zoh oh mast tuh JI nuh) are called zooflagellates. Zooflagellates (zoh oh FLA juh layts) are animal-like protozoans that use flagella for movement. Flagella are long whip-like projections that protrude from the cell and are used for movement. Some zooflagellates are free living, but many are parasites.

At least three species of zooflagellates from the genus *Trypanosoma* (TRY pan uh zohm uh) cause infectious diseases in humans that often are fatal because of limited treatment options. One species found in Central and South America causes Chagas disease, sometimes called American sleeping sickness. The second species causes East African sleeping sickness. The third species causes West African sleeping sickness.

American sleeping sickness The zooflagellates that cause Chagas' disease are similar to the sporozoans that cause malaria because they have two hosts in their life cycle and insects spread the diseases through the human population. The reduviid bug (rih DEW vee id) bug, shown in **Figure 19.10,** serves as one host for the protist in Central and South America. The parasitic zooflagellates reproduce in the gut of this insect. The reduviid bug gets its nutrients by sucking blood from a human host. During the feeding process, the zooflagellates pass out of the reduviid body through its feces. The zooflagellates enter the human body through the wound site or mucus membranes. Once the zooflagellate enters the body, it multiplies in the bloodstream and can damage the heart, liver, and spleen.

African sleeping sickness The life cycles of the zooflagellates that cause both African sleeping sicknesses are similar to the one that causes American sleeping sickness. The insect host is the tsetse (SEET see) fly, shown in **Figure 19.10.** The blood-sucking tsetse fly becomes infected when it feeds on an infected human or other mammal. The zooflagellate reproduces in the gut of the fly and then migrates to its salivary glands. When the fly bites the human, the zooflagellate is transferred to the human host. The zooflagellates reproduce in the human host and cause fever, inflammation of the lymph nodes, and damage to the nervous system.

- Characteristics of algae

Characteristics of Algae

The group of protists called algae (singular, alga) is considered plant-like because the members contain photosynthetic pigments. Recall from Chapter 8 that photosynthetic pigments enable organisms to produce their own food using energy from the Sun in a process called photosynthesis. Algae differ from plants because they do not have roots, leaves, or other structures typical of plants.

The light-absorbing pigments of algae are found in chloroplasts. In many algae, the primary pigment is chlorophyll—the same pigment that gives plants their characteristic green color. Many algae also have secondary pigments that allow them to absorb light energy in deep water. As water depth increases, much of the sunlight's energy is absorbed by the water. These secondary pigments allow algae to absorb light energy from wavelengths that are not absorbed by water. Because these secondary pigments reflect light at different wavelengths, algae are found in a variety of colors, as shown in **Figure 19.11.**

Know: alternation of generations

Alternation of generations The life cycles of many algae exhibit a pattern called alternation of generations, illustrated in **Figure 19.21** for the sea lettuce *Ulva*. **Alternation of generations** is a life cycle of algae that takes two generations—one that reproduces sexually and one that reproduces asexually—to complete a life cycle. Organisms alternate between a diploid *(2n)* form and a haploid *(n)* form in which each is considered a generation.

- Know: Diatoms, Dinoflagellates, Euglenoids, Chryophytes

Diatoms The unicellular algae, shown in **Figure 19.12,** are members of the phylum Bacillariophyta (BAH sih LAYR ee oh FI tuh). These intricately shaped organisms are called diatoms. Look at **Figure 19.13** and notice that the diatom consists of two unequal halves—one fits neatly inside the other, forming a small box with a lid.

Connection to Physics Diatoms are photosynthetic autotrophs. They produce food by photosynthesis using chlorophyll and secondary pigments called carotenoids, which give diatoms their golden-yellow color. Diatoms store their food as oil instead of as a carbohydrate. The oil not only makes diatoms a nutritious food source for many marine animals, but it also provides buoyancy. Oil is less dense than water, so diatoms float closer to the surface of the water, where they can absorb energy from the Sun for photosynthesis.

Diatoms reproduce both sexually and asexually, as illustrated in **Figure 19.14.** Asexual reproduction occurs when the two separated halves each create a new half that can fit inside the old one. This process produces increasingly smaller diatoms. When a diatom is about one-quarter of the original size, sexual reproduction is triggered and gametes are produced. The gametes fuse to form a zygote that develops into a full-sized diatom. The reproduction cycle then repeats.

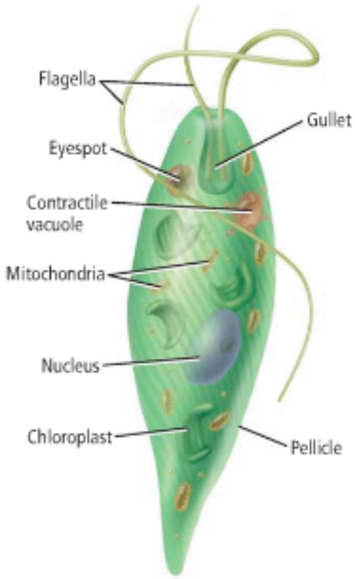
The hard silica walls of the diatom last long after the diatom has died. The silica walls accumulate on the ocean floor to form sediment known as diatomaceous earth. This sediment is collected and used as an abrasive and a filtering agent. The gritty texture of many tooth polishes and metal polishes is due to the presence of diatom shells.

Dinoflagellates Plantlike protists that are members of the phylum Pyrrophyta (puh RAH fuh tuh) are called dinoflagellates (di nuh FLA juh layts). Most members of the phylum are unicellular and have two flagella at right angles to one another. As these flagella beat, a spinning motion is created, so dinoflagellates spin as they move through the water. Some members in this group have cell walls made of thick cellulose plates that resemble helmets or suits of armor. Other members of this group are **bioluminescent,** which means they emit light. Although there are a few freshwater dinoflagellates, most are found in saltwater. Like diatoms, photosynthetic dinoflagellates are a major component of phytoplankton.

Dinoflagellates vary in how they get their nutritional requirements. Some dinoflagellates are photosynthetic autotrophs, and other species are heterotrophs. The heterotrophic dinoflagellates can be carnivorous, parasitic, or mutualistic. Mutualistic dinoflagellates have relationships with organisms such as jellyfishes, mollusks, and coral.

Algal blooms When food is plentiful and environmental conditions are favorable, dinoflagellates reproduce in great numbers. These population explosions are called blooms. Algal blooms can be harmful when they deplete the nutrients in the water. When the food supply diminishes, the dinoflagellates die in large numbers. As the dead algae decompose, the oxygen supply in the water is depleted, suffocating fish and other marine organisms. Additional fish suffocate when their gills become clogged with the dinoflagellates.

■ **Figure 19.16** *Euglena gracilis* are unicellular, plantlike algae that have characteristics of both plants and animals.



being developed that can constantly measure the concentration of red tide algae. If the concentration becomes too high, scientists can issue a warning to stop shellfish harvesting.

Euglenoids Members of the phylum Euglenophyta are unicellular, plantlike protists called euglenoids (yoo GLEE noydz). Most euglenoids are found in shallow freshwater, although some live in saltwater. Euglenoids are challenging to classify because they have characteristics of both plants and animals. Most euglenoids contain chloroplasts and photosynthesize, which is characteristic of plants, yet they lack a cell wall. Euglenoids also can be heterotrophs. When light is not available for photosynthesis, some can absorb dissolved nutrients from their environment. Others can ingest other organisms such as smaller euglenoids, which is a characteristic of animals. There even are a few species of euglenoids that are animal parasites.

The structure of a typical euglenoid is shown in **Figure 19.16.** Notice that instead of a cell wall, a flexible, tough outer membrane, called a pellicle, surrounds the cell membrane, which is similar to a paramecium. The pellicle allows euglenoids to crawl through mud when the water level is too low to swim. Note the flagella that are used to propel the euglenoid toward food or light. The eyespot is a light-sensitive receptor that helps orient the euglenoid toward light for photosynthesis. The contractile vacuole serves the same purpose in the euglenoid as it does in paramecia. It expels excess water from the cell to maintain homeostasis inside the cell.

Chrysophytes Yellow-green algae and golden-brown algae are in the phylum Chrysophyta (KRIS oh fyt uh) and are called chrysophytes (KRIS oh fytz). Like diatoms, these algae have yellow and brown carotenoids that give them their golden brown color. The algae in **Figure 19.17** are two examples of organisms from this phylum. Most members of this phylum are unicellular, but some species form colonies. A **colony** is a group of cells that join together to form a close association. The cells of chrysophytes usually contain two flagella attached at one end of the cell. All chrysophytes are photosynthetic, but some species also can absorb dissolved organic compounds through their cell walls or ingest food particles and prokaryotes. They reproduce both asexually and sexually, although sexual reproduction is rare. Chrysophytes are components of both freshwater and marine plankton.

- Know: uses of alage

Uses for Algae

Algae are used as a source of food for animals and people worldwide. In coastal areas of North America and Europe, algae are fed to farm animals as a food supplement. Algae are found in many dishes and processed foods, as described in **Table 19.2.** Algae are nutritious because of their high protein content and because they contain minerals, trace elements, and vitamins. Some of the substances found in algae also are used to stabilize or improve the texture of processed foods.

Concepts In Motion

Interactive Table To explore more about the uses for algae, visit biologygmh.com.

Table 19.2 Some Uses for Algae

Type of Algae	Uses
Red algae	A species of red alga, *Porphyra,* is called nori, which is dried, pressed into sheets, and used in soups, sauces, sushi, and condiments. Some species of red algae provide agar and carrageenan, which are used in the preparation of scientific gels and cultures. Agar also is used in pie fillings and to preserve canned meat and fish. Carrageenan is used to thicken and stabilize puddings, syrups, and shampoos.
Brown algae	Brown algae are used to stabilize products, such as syrups, ice creams, and paints. The genus *Laminaria* is harvested and eaten with meat or fish and in soups.
Green algae	Species from the genera *Monostroma* and *Ulva,* also called sea lettuce, are eaten in salads, soups, relishes, and in meat or fish dishes.
Diatoms	Diatoms are used as a filtering material for processes such as the production of beverages, chemicals, industrial oils, cooking oils, sugars, water supplies, and the separation of wastes. They also are used as abrasives.

- Slime molds, water molds, downy molds

Slime Molds

As you can imagine, funguslike protists are protists that have some characteristics of fungi. Fungi and slime molds use spores to reproduce. Like fungi, slime molds feed on decaying organic matter and absorb nutrients through their cell walls. However, fungi and slime mold differ in the composition of their cell walls. Fungi cell walls are composed of a substance called chitin (KI tun). Chitin is a complex carbohydrate that is found in the cell walls of fungi, and in the external skeletons of insects, crabs, and centipedes. The cell walls of funguslike protists do not contain chitin as a true fungus does. The cell walls of these protists contain cellulose or celluloselike compounds.

Slime molds are found in a variety of colors, ranging from yellows and oranges to blue, black, and red as shown in **Figure 19.22.** They usually are found in damp, shady places where decaying organic matter is located, such as on a pile of decaying leaves or on rotting logs. Slime molds are divided into two groups—acellular slime molds and cellular slime molds.

Water Molds and Downy Mildew

There are more than 500 species of water molds and downy mildews in the phylum Oomycota (oo oh my COH tuh). Most members of this group of funguslike protists live in water or damp places. Some absorb their nutrients from the surrounding water or soil, while others obtain their nutrients from other organisms, as shown in **Figure 19.26.**

Originally, water molds were considered fungi because of their method of obtaining nutrients. Like fungi, water molds envelope their food source with a mass of threads; they break down the tissue, and absorb the nutrients through their cell walls. Although this is characteristic of fungi, water molds differ from fungi in the composition of their cell walls and they produce flagellated reproductive cells. Recall that the cell walls of funguslike protists are composed of cellulose and celluloselike compounds.

Chapter 20

- Characteristics of fungi and structure

Characteristics of Fungi

Some of the largest and oldest organisms on Earth belong to the Kingdom Fungi. When you see the word *fungi* (FUN ji) (singular, fungus), you might envision the mushrooms found in grocery stores or ones that grow in your backyard. In eastern Oregon, there is a honey mushroom that is so big that it is called the "Humongous Fungus." The honey mushroom, similar to the one shown in **Figure 20.1,** is estimated to be at least 2400 years old. All fungi are eukaryotic heterotrophs. More than 100,000 species of fungi have been identified.

Multicellular fungi Most members of the Kingdom Fungi, such as the honey mushroom, are multicellular. At first glance, you might think these multicellular fungi look like plants. Although they do not contains chloroplasts, at one time fungi were classified as plants because they appeared to have some characteristics similar to plants. However, after careful study, scientists decided that fungi are different enough to be placed in their own kingdom.

Unicellular fungi Yeasts are unicellular fungi. They are found throughout the world in soils, on plant surfaces, and even in the human body. While there are hundreds of different kinds of yeasts, the most familiar yeasts are used commercially to produce breads, beer, and wine. The yeast *Candida albicans,* shown in **Figure 20.1,** can cause a yeast infection in humans.

Major Features in Fungi

Some features in fungi that distinguish them from plants include their cell walls, their hyphae, and their cross-walls.

Cell walls One significant difference between plants and fungi is the composition of their cell walls. Plants have a cell wall composed of cellulose, while fungi have a cell wall composed of chitin. **Chitin** (KI tun)is a strong, flexible polysaccharide that is found in the cell walls of all fungi and in the exoskeletons of insects and crustaceans. Recall from Chapter 6 that polysaccharides are carbohydrate polymers that are composed of many simple sugar subunits. Chitin is one of the most abundant organic compounds on Earth.

Hyphae The physical structure of fungi also differs from plants. Look at the magnified image of the fungus in **Figure 20.2** and notice that it is composed of long chains of cells. Without a microscope, hyphae appear to be threadlike filaments. These filaments are the basic structural units that make up the body of a multicellular fungus and are called **hyphae** (HI fee) (singular, hypha). Hyphae grow at their tips and branch repeatedly to form a netlike mass called a **mycelium** (mi SEE lee um) (plural, mycelia). While the mycelium is visible in some fungi, it is packed so tightly in mushrooms that it is almost impossible to distinguish the individual hyphae. The fungus that you see above ground, illustrated in **Figure 20.2,** is a reproductive structure called the **fruiting body.** The hyphae form all parts of the mushroom, including the fruiting body above ground and the mycelium below ground. The extensive hyphae of fungi give them an advantage in obtaining nutrients by providing a large surface area for nutrient absorption.

Reading Check **Describe** the structural unit of a mushroom.

Connection to History Fungal hyphae are found in the work of many medieval painters. Victorian illustrators often link fairies and toadstools (another name for mushrooms). Today, the colorful spotted cap of a *Fly Agaric* mushroom often is associated with a gnome or sprite in children's stories.

Cross-walls In many fungi, hyphae are divided into cells by cross-walls called **septa** (singular, septum), as shown in **Figure 20.3.** The septa have large pores that allow nutrients, cytoplasm, organelles, and, in some cases, nuclei to flow between cells.

Some fungi are aseptate, meaning they have no septa. The cytoplasm, containing hundreds or thousands of nuclei, flows freely through the hyphae. This condition is a result of repeated mitosis without cytokinesis. Nutrients and other materials flow very quickly through aseptate hyphae.

- How do fungi get their nutrients?

Nutrition in Fungi

Unlike humans who ingest their food and then digest it, fungi digest their food before they ingest it. Many fungi produce enzymes that break down organic material, allowing the nutrients to be absorbed through their thin cell walls. All fungi are heterotrophs, but there are three types of fungi that differ in how they obtain their nutrients.

Saprophytic fungi A saprobe is an organism that feeds on dead organisms or organic wastes. Saprophytic fungi, such as the bracket fungus shown in **Figure 20.4,** are decomposers and recycle nutrients from dead organisms back into food webs. The fungus in **Figure 20.5** also is a saprobe.

Parasitic fungi Parasitic fungi absorb nutrients from the living cells of another organism, called a host. Many parasitic fungi produce specialized hyphae called **haustoria** (haws TOH ree ah), which grow into the host's tissues and absorb their nutrients. *Arthrobotrys* is a group of parasitic soil fungi that trap prey with rings of hyphae.

Mutualistic fungi Some fungi live in a mutualistic relationship with another organism, such as a plant or an alga. The mycelia of a particular fungus cover the root of a soybean plant. The fungus receives sugar from the host plant. The mycelia increase water uptake and mineral absorption for the host plant.

- Classification of fungi

Classification of Fungi

Biologists use fungal structure and methods of reproduction to divide fungi into four major phyla—Chytridiomycota, Zygomycota, Ascomycota, and Basidiomycota. The cladogram shown in **Figure 20.8** shows the evolutionary relationships between the phyla of fungi as they currently are understood.

Fungi are likely to have colonized the land with plants more than 450 million years ago, possibly due to mutualistic associations with plants. Yet, molecular evidence supports the view that fungi are more closely related to animals than plants. Evidence suggests that fungi and animals diverged from a common protist ancestor.

- Characteristics of each type of fungi – see sheet
- Symbiotic relationships of fungi

Fungi and Photosynthesizers

Lichens and mycorrhizae are two examples of mutualistic relationships between fungi and other organisms. As you learned in Chapter 2, mutualism is a type of symbiosis in which both organisms benefit from the relationship.

Lichens A symbiotic relationship between a fungus and an alga or a photosynthetic partner is called a **lichen** (LI ken). The fungus usually is an ascomycete, but lichens also may contain basidiomycetes. The photosynthetic partner is either a green alga or cyanobacterium which provides food for both organisms. The fungus provides a dense web of hyphae in which the alga or cyanobacterium can grow. Examine **Figure 20.12** to see the structure of a lichen. Notice that fungal tissues account for most of the mass of a lichen.

- Lichens – see directly above
- Mycorrhizae – see below
- Uses of fungi – see below

Mycorrhizae Another mutalistic relationship involving a fungus is **mycorrhiza** (my kuh RHY zuh) (plural, mycorrhizae)—a symbiotic relationship between a specialized fungus and plant roots. Plants with mycorrhizae are healthier and more vigorous than similar plants lacking mycorrhizae. Other plant species, such as orchids, cannot survive without mutualistic partners. Orchid seeds will not germinate unless they are infected by a fungal partner or provided with the fungal carbohydrate trehalose.

Figure 20.14 shows a mycorrhizal relationship between a *Schleroderma geaster* fungus and a *Eucalyptus* tree. The fungus absorbs and concentrates various minerals for the plant. The hyphae of the fungus also increase the plant's root surface area for water and mineral absorption. In return, the fungus receives carbohydrates and amino acids from the plant.

Between 80 and 90 percent of plants, including primitive plants, have mycorrhizae. Mycorrhizae are extremely important in natural habitats and for agricultural crops. Crops associated with mycorrhizae include corn, carrots, potatoes, tomatoes, and strawberries.

Fungi and Humans

For the most part, fungi have a positive effect on the lives of humans. Their most important role is as decomposers, assisting with the recycling of nutrients found in dead organisms. Decomposing organic matter makes nutrients available for other organisms and prevents dead organisms and their wastes from littering the surface of Earth.

Beneficial fungi Fungi have many medical uses. The ascomycete, *Penicillium notatum*, can be used as a source of penicillin. This antibiotic has saved countless lives. Chemical compounds found in the fungus *Claviceps purpurea* are used to reduce high blood pressure, to control excessive bleeding, to treat migraine headaches, and to promote contractions during childbirth. The Norwegian deuteromycete *Tolypocladium inflatum* is the source for cyclosporine. Cyclosporine is an immune suppressant drug given to organ transplant patients to keep their bodies from rejecting the new organ.

Foods Many of the foods we eat are made from fungi or fungal products. The most obvious are the many different mushrooms we eat. Yeast makes bread rise by releasing carbon dioxide gas during fermentation, as discussed in Chapter 8. Another product of fermentation is the alcohol found in beer and wine. Truffles are fungi and are one of the most expensive food items. Many other fungi are enjoyed similarly as delicacies. The flavors of some cheeses such as Brie, Camembert, and Roquefort are the result of fungi. The citrus flavor found in colas is created by the fungus *Aspergillus*. This fungus also is used to make soy sauce.

Bioremediation Fungi also can be used for cleaning the environment of pollutants that are threatening some ecosystems. The fungi are mixed with water or soil where they decompose organic materials in the pollutants. During this process, called bioremediation, the pollutants are broken down into harmless substances. The rate at which microorganisms, such as fungi and bacteria, remove environmental pollutants can be increased if additional nutrients are added to the water or soil. Bioremediation is a relatively new scientific field, and new discoveries and processes are being developed to be used in environmental clean-up projects.

Connection to Chemistry Researchers are using white-rot fungi to break down top priority pollutants, such as dyes and polycyclic aromatic hydrocarbons (PAHs). PAHs are carcinogenic (cancer-causing) molecules. Researchers also are taking advantage of the fact that these fungi contain enzymes that degrade lignin, a molecule found in wood fiber that hardens and strengthens the cell walls of plants, enabling them to recycle wood. These enzymes also can attach to structurally similar chemicals, including many man-made pollutants.

- Harmful fungi

Harmful fungi Some fungi can be harmful to other organisms. For example, American elm trees are killed by the fungus *Ceratocystis ulmi* and American chestnut trees are killed by the fungus *Endothia parasitica*. The fungi quickly spread from tree to tree, and they have killed many trees in North America. Agricultural crops are also damaged by fungi. The fungal parasite *Leptoterochila medicaginis* causes leaf blotch in alfalfa plants and can diminish crop production by as much as 80 percent. The ripe grapes shown in **Figure 20.15** have been infected with a parasitic fungus *Botrytis cinerea*, causing what is known as noble rot. The fungus attacks the grapes and causes an increase in their sugar content. Certain wines are produced from such grapes in France.

Fungi can also parasitize humans and other animals. The parasitic fungus *Cordyceps militaris* can infect larvae and pupae of butterflies and moths, as shown in **Figure 20.15.** Athlete's foot, ringworm, yeast infections, and oral thrush are infections in humans that are caused by fungi. **Figure 20.15** shows skin infected with ringworm, which can be caused by several species of fungi.

Plants and Body Systems Unit

- Xylem/phloem
- Tracheids/vessels
- Sieve tube members/ companion cells
- Sieve plates
- Roots: taproots/fibrous roots
- Root hair
- Cortex
- Endodermis
- Apical meristem/vascular cambium/nodes
- Woody stems
- Parenchyma tissue
- Difference in vascular bundles in moncots and dicots
- Structure and function of the leaf
- Palisade mesophyll/spongy mesophyll
- Stomata and guard cells
- Transpiration
- Arteries, capillaries and veins
- Arterioles
- Venules
- Valves
- Blood pressure
- The heart: atriums and ventricles
- Superior and inferior venae cava

- Oxygen rich/poor blood
- Aorta
- Heart beat/pulse
- Sequence the digestive system
- Mechanical/ chemical digestion
- Salivary amylase
- Pepsin/pepsinogen
- Bolus/ chyme
- Esophagus/ epiglottis
- Liver, gallbladder and pancreas
- Small and large intestine/colon
- Bile and pancreatic enzymes
- Peristalsis
- Stomach churning
- Feces
- Villi
- Rectum/anus

GOOD LUCK!