Keystone BIOLOGY

Supplemental Materials

Name: _____

Date: _____

Module A, Anchor #1 Basic Biological Principles	
Anchor Descriptor	Eligible Content
Explain the characteristics common to all organisms.	*Describe the characteristics of life shared by all prokaryotic and eukaryotic organisms.*

Review

All living organisms (prokaryotes and eukaryotes) share the following characteristics:

- made up of units called cells
- reproduce
- use a universal genetic code to store hereditary information
- grow and develop
- use energy
- respond to their environment
- as a group, change over time

Prokaryotes are unicellular organisms (e.g., bacteria) that have no nucleus and no membrane-bound organelles, but do have ribosomes and a plasma membrane. Most also have a cell wall.

Eukaryotes are unicellular (e.g., protists) or multicellular organisms (e.g., fungi, plants, animals) that contain a nucleus, membrane-bound organelles and have a plasma membrane.

Practice Questions

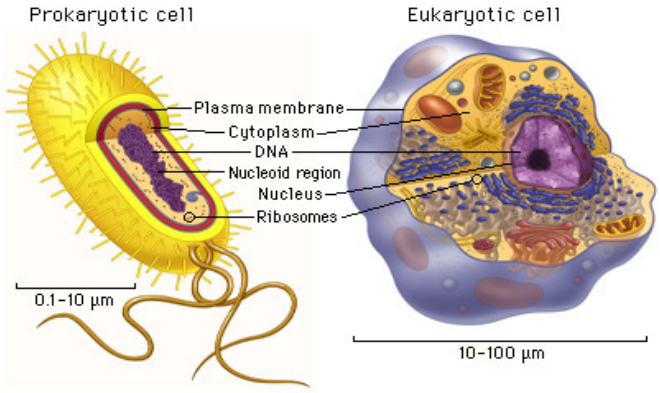
1. Which characteristic is shared by all prokaryotes and eukaryotes?
   a. ability to store hereditary information
   b. use of organelles to control cell processes
   c. use of cellular respiration for energy release
   d. ability to move in response to environmental stimuli

Module A, Anchor #1 Basic Biological Principles (Cont.)	
Anchor Descriptor	Eligible Content
Describe relationships between structure and function at biological levels of organization.	*Compare cellular structures and their functions in prokaryotic and eukaryotic cells.*

Review

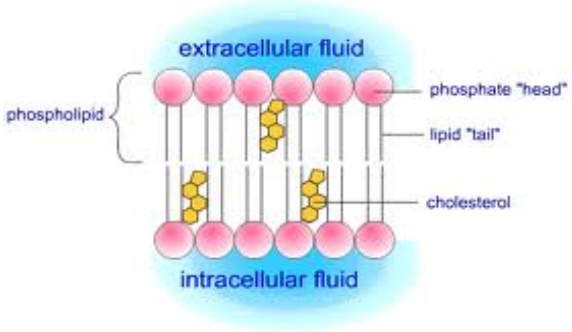
Prokaryotes vs. Eukaryotes Summary

Structure	Nucleus?	Genetic Material?	Cell Wall?	Cell Membrane?	Organelles?	Ribosomes?
Prokaryote	No	DNA	Yes	Yes	No	Yes
Eukaryote	Yes	DNA	Yes/No	Yes	Yes	Yes



Cell Boundaries

Plasma membrane – regulates the passage of materials into/out of the cell; it is selectively permeable. According to the Fluid Mosaic model, the plasma membrane consists of a phospholipid bilayer with phospholipids, cholesterol and proteins as the major components. The hydrophilic heads of the phospholipids face the exterior surfaces of the membrane; the hydrophobic tails of the phospholipids face the interior of the membrane.



Cell wall – found in many organisms including plants, algae, fungi, and many prokaryotes. The cell wall provides support and protection for the cell.

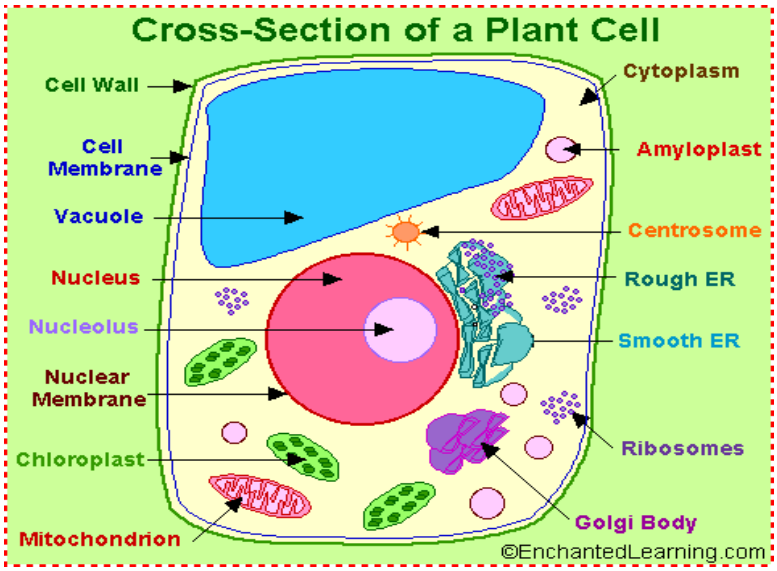
Organelles

Nucleus – contains the cell's DNA

Ribosomes – where proteins are assembled.

Endoplasmic reticulum – site where proteins are assembled that get exported from the cell; it is the transport system for proteins in the cell.

Golgi apparatus – modifies, sorts, and packages proteins from the endoplasmic reticulum for storage in the cell or secretion out of the cell
Lysosomes – small organelles containing enzymes used in the breakdown of lipids, carbohydrates, and proteins; acts as the "clean up" crew in the cell removing old organelles.
Vacuoles – stores materials such as water, salts, proteins, and carbohydrates. In many plant cells, there is a single large vacuole filled with water.
Mitochondria – convert chemical energy stored in food into compounds that the cell can use; it is the "powerhouse" of the cell.
Chloroplasts – capture the energy from sunlight and convert it into chemical energy in the process of photosynthesis. Found in plants and other photosynthetic organisms.
Cytoskeleton – network of protein filaments which help the cell maintain its shape; also involved in movement.
Cytoplasm – material that is inside the cell membrane, but outside of the nucleus.



Practice Questions

2. Living organisms can be classified as prokaryotes or eukaryotes. Which two structures are common to both prokaryotic and eukaryotic cells?

a. cell wall and nucleus
b. cell wall and chloroplast
c. plasma membrane and nucleus
d. plasma membrane and cytoplasm

3. If a cell of an organism contains a nucleus, the organism is a(n):

a. plant
b. eukaryote
c. animal
d. prokaryote

4. Prokaryotic cells are generally much smaller than eukaryotic cells. Identify a structural difference between prokaryotic cells and eukaryotic cells that is directly related to their difference in size.

Module A, Anchor #1 Basic Biological Principles (Cont.)	
Anchor Descriptor	Eligible Content
Describe relationships between structure and function at biological levels of organization.	*Describe & interpret relationships between structure and function at various levels of biological organization (i.e., organelles, cells, tissues, organs, organ systems, and multicellular organisms).*

Review

Levels of biological organization

Organelles → cells → tissues → organs → organ systems → multicellular organisms

Organelle – specialized structure that performs specific functions within eukaryotic cells
Cell – smallest unit of life
Tissue – group of similar cells specialized to perform a specific function
Organ – group of tissues working together to perform closely related functions (e.g., liver, heart, pancreas, lungs)
Organ system – group of organs that work together to perform a vital body function (e.g., nervous system)

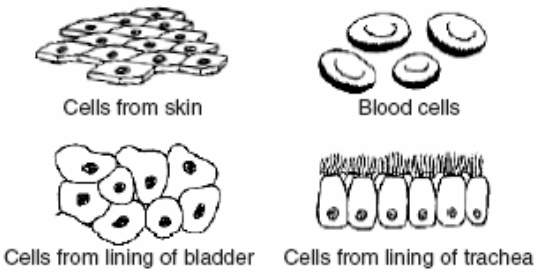
Cell specialization - Cells in an organism can develop in different ways to perform different tasks. Cells in multicellular organisms are specialized to perform particular functions.
Examples:

- Pancreatic cells are specialized to produce proteins needed by an organism; therefore, cells in the pancreas are loaded with ribosomes and rough ER, which are where proteins are produced.
- Skeletal muscles give humans the ability to move. Skeletal muscle cells create this force through a specialized cytoskeleton that is packed with fibers arranged in a specific pattern.

Practice Questions

5. Alveoli are microscopic air sacs in the lungs of mammals. Which statement best describes how the structure of the alveoli allows the lungs to function properly?
    a. They increase the amount of energy transferred from the lungs to the blood.
    b. They increase the flexibility of the lungs as they expand during inhalation.
    c. They increase the volume of the lungs, allowing more oxygen to be inhaled.
    d. They increase the surface area of the lungs, allowing efficient gas exchange.

6. Some human body cells are shown in the diagrams below.



These groups of cells represent different

a. Tissues in which similar cells function together
b. Organs that help to carry out a specific life activity
c. Systems that are responsible for a specific life activity
d. Organelles that carry out different functions

Module A, Anchor #2 The Chemical Basis for Life	
Anchor Descriptor	Eligible Content
Describe how the unique properties of water support life on Earth.	*Describe the unique properties of water and how these properties support life on Earth (e.g., freezing point, high specific heat, cohesion.*

Review

The unique properties of water allow it to support life on Earth:

- Polarity – Water (H_20) is a polar molecule meaning that the opposite ends have opposite charges. The oxygen end is slightly negative; the hydrogen end is slightly positive. The negatively charged oxygen of one water molecule is attracted to the positively charged hydrogen of another water molecule forming a hydrogen bond.
- Cohesion – water molecules are attracted to other water molecules (i.e., water molecules stick together).
- Adhesion – water molecules are attracted other types of molecules (i.e., water molecules stick to other surfaces).
- Capillary action – water can be drawn up a thin tube. Capillary action makes use of both the cohesive and adhesive properties of water (e.g., water going from the roots of a tree to the leaves).
- Density – water molecules in ice are "packed" together less densely than water molecules in liquid form; therefore, ice is less dense than liquid water and will float (e.g., floating ice in lakes insulates the liquid water below, allowing life to survive under the frozen surface).
- High specific heat – The specific heat is the amount of heat per unit mass required to raise the temperature by one degree Celsius. It takes more energy to raise the temperature of water than it does to raise the temperature of other substances. Water has a better ability to resist temperature change than most other substances. (e.g., The temperature of oceans and large lakes does not undergo quick or extreme temperature changes; this causes coastal areas to have less extreme temperatures than inland areas).
- Freezing point – The freezing point of water is 0 degrees Celsius or 32 degrees Fahrenheit.
- Ability to dissolve other substances – Substances (solutes) dissolve in water (solvent). Water is the main solvent in side all cells, in blood, and in plant sap.

Practice Questions

7. Which statement **best** describes an effect of the low density of frozen water in a lake?
    a. When water freezes, it contracts, decreasing the water level in a lake.
    b. Water in a lake freezes from the bottom up, killing most aquatic organisms.
    c. When water in a lake freezes, it floats, providing insulation for organisms below.
    d. Water removes thermal energy from the land around a lake, causing the lake to freeze.

Module A, Anchor #2 The Chemical Basis for Life (Cont.)	
Anchor Descriptor	Eligible Content
Describe and interpret relationships between structure and function at various levels of biochemical organization (i.e., atoms, molecules, and macromolecules).	*Explain how carbon is uniquely suited to form biological macromolecules.*
	Describe how biological macromolecules form from monomers.
	Compare the structure and function of carbohydrates, lipids, proteins, and nucleic acids in organisms.

Review

Properties of carbon that allow it to form biological macromolecules:

- Bond with other atoms - Carbon atoms have four valence electrons. Each electron can form a strong covalent bond with another element. Carbon can bond with many elements, including hydrogen, oxygen, phosphorus, sulfur, and nitrogen.
- Bond with other carbon atoms – Carbon can bond with other carbon atoms forming long chains or rings. Carbon-carbon bonds can be single, double, or triple covalent bonds.

Because of the two properties above, carbon has the unique ability to form millions of different large and complex structures.

Monomer – a small unit that can join together with other small units to form polymers.

Polymer – long chain of monomers bonded together

Polymerization (a.k.a dehydration reaction or condensation) – the process in which monomers bond together to form polymers.

Hydrolysis – the process in which polymers are broken down

Organic compounds are made up of molecules containing carbon. Organic compounds include carbohydrates, lipids, proteins, and nucleic acids.

Carbohydrates:

- Function - used by cells as a quick energy source
- Monomer = Monosaccharides (glucose)
- Polymer = Disaccharides (sucrose) or polysaccharides (starch, glycogen, cellulose)
- Starch is used by plants to store sugar
- Glycogen is used by animals to store sugar in the liver
- Cellulose is found in the cell walls of plant cells; protects cell and give the plant support

Lipids (fats):

- Functions
    - Long-term energy storage
    - Insulation
    - Part of plasma membrane
- Triglycerides – how animals store fat
    - Monomers = molecules in fatty acid chains, glycerol

    - Polymer = triglycerides (which consists of the 3 fatty acids chains and glycerol bonded together)
- Phospholipids – make up the plasma membrane (see Anchor #1 for diagram)
    - Monomers = hydrophilic head, molecules in hydrophobic tails
    - Polymer = phospholipid
- Steroids – circulate in body as chemical signals (e.g., estrogen, testosterone, cholesterol)
    - Monomers = 4 carbon rings
    - Polymers = rings bonded together into steroid

Proteins:

- Functions:
    - Structural - hair, skin, nails
    - Transport – carry things through an organism or into/out of cell
    - Enzymes – catalysts that speed up chemical reactions in cells
- Monomers = amino acids
- Polymers = proteins

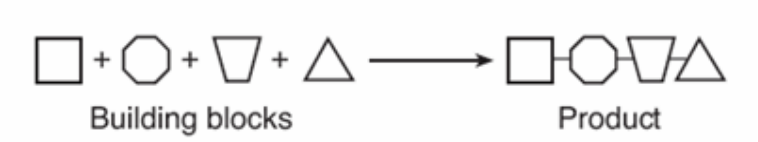
Nucleic Acids:

- Function: store genetic information in the form of a code
- Monomers = nucleotides
- Polymers = DNA or RNA

Practice Questions

8. Which statement correctly describes how carbon's ability to form four bonds makes it uniquely suited to form macromolecules?
    a. It forms short, simple carbon chains.
    b. It forms large, complex, diverse molecules.
    c. It forms covalent bonds with other carbon atoms.
    d. It forms covalent bonds that can exist in a single plan.

9. The diagram below represents the synthesis of a portion of a complex molecule in an organism.



Which row in the chart could be used to identify the building blocks and product in the diagram?

Row	**Building Blocks**	**Product**
A	Starch molecules	glucose
B	Amino acid molecules	Part of protein
C	Sugar molecules	ATP
D	DNA molecules	Part of starch

10. Carbohydrates and proteins are two types of macromolecules. Which functional characteristic of proteins distinguishes them from carbohydrates?

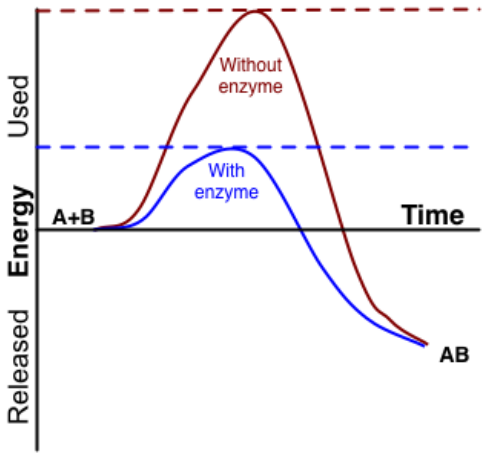
a. Large amount of stored information
b. Ability to catalyze biochemical reactions
c. Efficient storage of usable chemical energy
d. Tendency to make cell membranes hydrophobic

Module A, Anchor #2 The Chemical Basis for Life (Cont.)	
Anchor Descriptor	Eligible Content
Explain how enzymes regulate biochemical reactions within a cell.	*Describe the role of an enzyme as a catalyst in regulating a specific biochemical reaction.*
	Explain how factors such as pH, temperature, and concentration levels can affect enzyme function.

Review
Chemical reactions involve changes in the chemical bonds that join atoms in compounds. Chemical reactions that release energy often occur spontaneously (but not always). Chemical reactions that absorb energy will not occur without a source of energy.

Reactants – the elements or compounds that enter into a chemical reaction.
Products – the elements or compounds produced by a chemical reaction.

Activation energy – the energy needed to get a reaction started



Enzymes – proteins that act as biological catalysts, i.e., they speed up chemical reactions that take place in cells, without being consumed. Enzymes provide a site (the active site) where reactants (called substrates) can be brought together to react. Enzymes are specific to the substrates they bind with. The active site and the substrate have complementary shapes; they fit together like a lock and key.

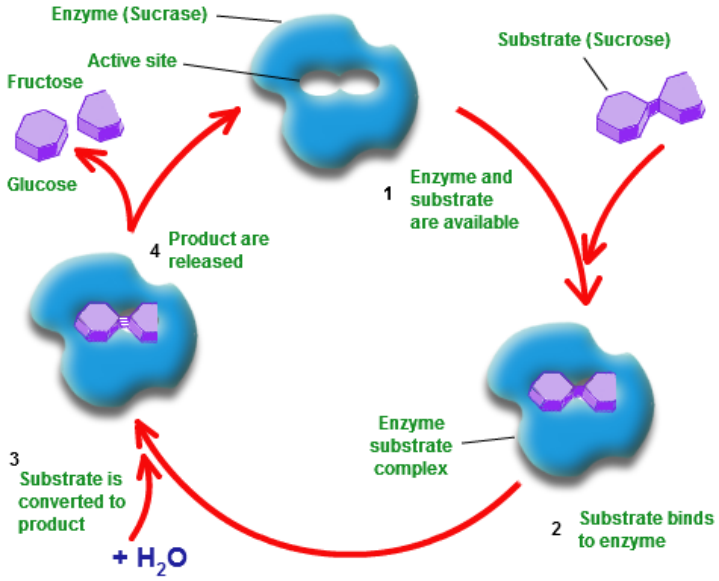
Enzyme activity is regulated by:

pH values – different enzymes work best a certain pH values. Changes in pH can change the shape of the enzyme preventing it from binding with the substrate.

Temperature – enzymes are affected by temperature. Changes in temperature can change the shape of the enzyme. Most enzymes in the body work best at 37 degrees Celsius, the normal temperature of the body.

Concentration levels – If the enzyme level stays constant, adding more substrates will not increase the rate of reaction because of the enzyme active sites will be saturated with substrates. If the substrate level is constant, adding more enzymes will increase the rate of reactions because there will be more active sites for the substrates to bind to.

Example of the Hydrolysis of Sucrose using the Enzyme Sucrase



Practice Questions

11. Substance A is converted to substance B in a metabolic reaction. Which statement **best** describes the role of an enzyme during this reaction?
    a. It adjusts the pH of the reaction medium.
    b. It provides energy to carry out the reaction.
    c. It dissolves substance A in the reaction medium.
    d. It speeds up the reaction without being consumed.

12. A scientist observes that, when the pH of the environment surrounding an enzyme is changed, the rate the enzyme catalyzes a reaction greatly decreases. Which statement **best** describes how a change in pH can affect an enzyme?
    a. A pH change can cause the enzyme to change its shape.
    b. A pH change can remove energy necessary to activate an enzyme.
    c. A pH change can add new molecules to the structure of the enzyme.
    d. A pH change can cause an enzyme to react with a different substrate.

Module A, Anchor #3 Bioenergetics	
Anchor Descriptor	Eligible Content
Identify and describe the cell structures involved in processing energy.	*Describe the fundamental roles of plastids (e.g., chloroplasts) and mitochondria in energy transformations.*
Identify and describe how organisms obtain and transform energy for their life processes.	*Compare the basic transformation of energy during photosynthesis and cellular respiration.*
	Describe the role of ATP in biochemical reactions.

Review

Chloroplast – Organelle found in the cells of plants and some other organisms that captures the energy from sunlight and converts it into chemical energy (photosynthesis). Chlorophyll (a light absorbing pigment) in chloroplasts gives plants their green color.

Photosynthesis – Process in which plants (and some other organisms) use light energy to convert water (H_20) and carbon dioxide (CO_2) into oxygen and high-energy carbohydrates such as sugars and starches. Occurs in the chloroplast.

Equation: $\mathbf{6CO_2 + 6H_2O + light\ energy \rightarrow C_6H_{12}O_6 + 6O_2}$

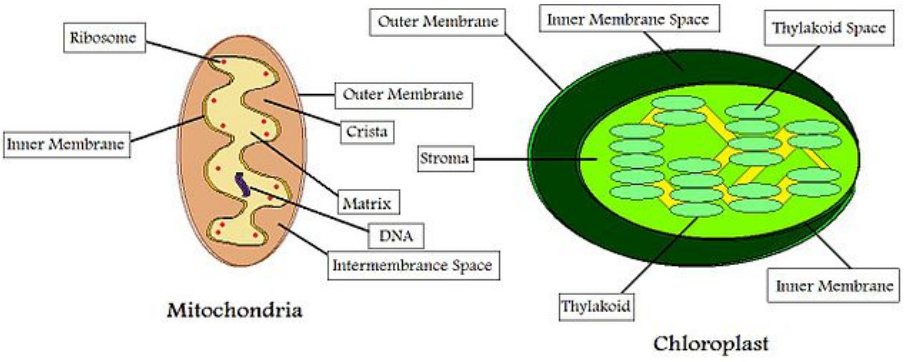
In other words: Carbon dioxide + water + light energy → sugars + oxygen

Mitochondria – Organelle that converts the chemical energy stored in food into compounds that are more convenient for the cell to use (cellular respiration).

Cellular Respiration – Process that releases energy by breaking down glucose and other food molecules in the presence of oxygen. One glucose molecule yields 36 ATP. Occurs in the mitochondrian.

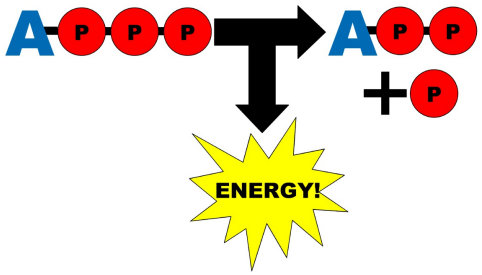
Equation: $\mathbf{6O_2 + C_6H_{12}O_6 \rightarrow 6CO_2 + 6H_2O + energy}$

In other words: oxygen + glucose → carbon dioxide + water + energy (ATP)



ATP (adenosine triphosphate)

- Chemical compound that cells use to store energy
- Consists of adenine, a 5-carbon sugar called ribose, and three phosphate groups
- When a cell **stores energy**, it stores it as ATP
- When a cell needs to **use energy**, it breaks the bond between the 2nd and 3rd phosphate groups to release energy.
- ATP is used in active transport, in the synthesis of proteins and nucleic acids, in response to chemical signals at the cell surface, etc.



Practice Questions

13. Using a microscope, a student observes a small, green organelle in a plant cell. Which energy transformation **most likely** occurs first within the observed organelle?
    a. ATP to light
    b. Light to chemical
    c. Heat to electrical
    d. Chemical to chemical

14. Photosynthesis and cellular respiration are two major processes of carbon cycling in living organisms. Which statement correctly describes one similarity between photosynthesis and cellular respiration?
    a. Both occur in animal and plant cells.
    b. Both include reactions that transform energy.
    c. Both convert light energy into chemical energy.
    d. Both synthesize organic molecules as end products.

15. A protein in a cell membrane changes its shape to move sodium and potassium ions against their concentration gradients. Which molecule was **most likely** used by the protein as an energy source?
    a. ATP
    b. ADP
    c. Catalase
    d. Amylase

Module A, Anchor #4 Homeostasis and Transport	
Anchor Descriptor	Eligible Content
Identify and describe the cell structures involved in transport of materials into, out of, and throughout a cell.	*Describe how the structure of the plasma membrane allows it to function as a regulatory structure and/or protective barrier for a cell.*
	Compare the mechanisms that transport materials across the plasma membrane (i.e., passive transport – diffusion, osmosis, facilitated diffusion; and active transport, - pumps, endocytosis, exocytosis).
	Describe how membrane-bound cellular organelles (e.g., endoplasmic reticulum, Golgi apparatus) facilitate the transport of materials within a cell.

Review

Plasma membrane – A flexible structure that regulates what enters and leaves the cell and provides protection and support. The plasma membrane is a phospholipid bilayer embedded with protein molecules that form channels and pumps to help move material across the membrane.

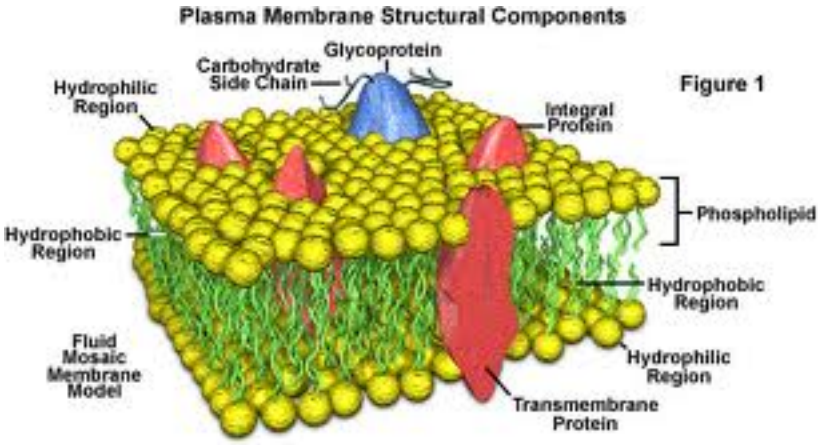


Figure 1

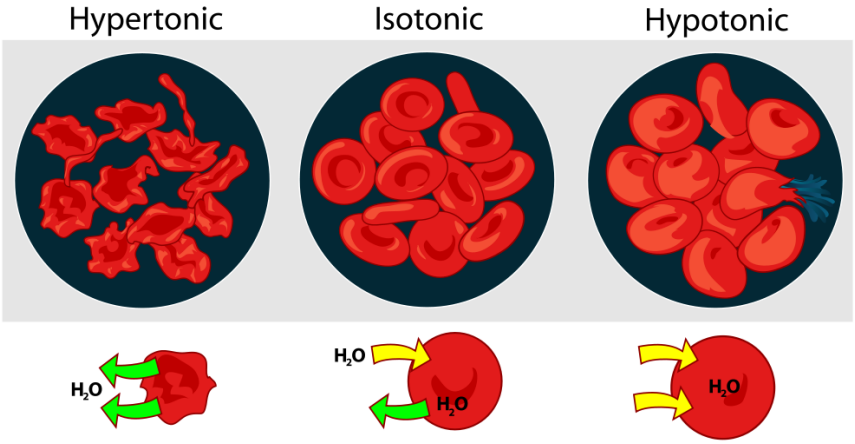
Selective Permeability – The plasma membrane is selectively permeable meaning that it allows some substances to cross the membrane more easily than others and blocks the passage of some substances altogether.

Transport Across the Plasma Membrane

Passive Transport (does not need energy)

- Diffusion – substances move from areas of high concentration to areas of low concentration. Small, nonpolar molecules such as oxygen and carbon dioxide diffuse freely through the plasma membrane.
- Osmosis – the diffusion of water through a selectively permeable membrane
    - Isotonic solution – the concentration of water and solute is the same on both sides of the membrane
    - Hypertonic solution – a solution has more solute compared to another solution. In the picture below, the solution is hypertonic to the red blood cells (there is more solute outside of the cells) so water will move out of the cells.

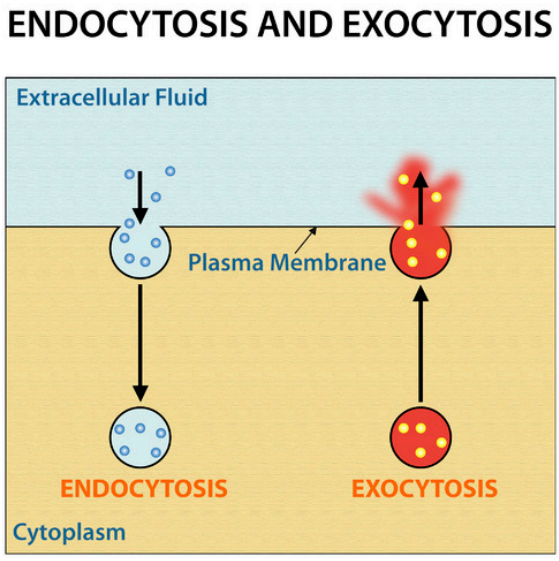
- Hypotonic solution – a solution has less solute compared to another solution. In the picture below, the solution is hypotonic to the red blood cells (there is more solute inside the cells) so water move into the red blood cells.



- Facilitated diffusion – Transport proteins in the plasma membrane provide a pathway for larger molecules or small polar molecules (e.g., water, sugars) to diffuse through the membrane from areas of high concentration to low concentration.

Active Transport (requires energy)

- Active transport – Uses a specific transport protein pump which requires energy to move substances against their concentration gradient (from areas of low concentration to high concentration)
- Exocytosis – process of exporting proteins or large waste products from a cell by a vesicle fusing with the plasma membrane
- Endocytosis – Process of taking material into a cell with vesicles that bud inward from the plasma membrane



Membrane-bound organelles produce products that get moved out of the cell by active transport.

- *Exocytosis Examples*

- Rough Endoplasmic Reticulum – Gets its name from the ribosomes attached to the outside of its membrane. The rough ER produces proteins that are packaged in vesicles by the ER and exported from the cell.
- Smooth Endoplasmic Reticulum – Is considered "smooth" because it does not have ribosomes attached to its membrane. The smooth ER produces lipids (such as the sex hormones) that get packaged by the ER and secreted from the cell.
- Golgi Apparatus – Some products made by the ER get sent to the Golgi apparatus, which modifies, stores, and routes proteins and other chemical products to other destinations within the organism.

- *Endocytosis/Exocytosis Examples*
  - Lysosomes – membrane-bound organelles containing digestive enzymes. Lysosomes bind with incoming food vacuoles (another membrane bound organelle) and digest the food. Lysosomes also release enzymes into vacuoles that contain trapped bacteria or engulf damaged organelles, digest them, and release them from the cell.

Practice Questions

16. Carbon dioxide and oxygen are molecules that can move freely across a plasma membrane. What determines the direction that carbon dioxide and oxygen molecules move?
    a. Orientation of cholesterol in the plasma membrane
    b. Concentration gradient across the plasma membrane
    c. Configuration of phospholipids in the plasma membrane
    d. Location of receptors on the surface of the plasma membrane

17. A sodium-potassium pump within a cell membrane requires energy to move sodium and potassium ions into or out of a cell. The movement of glucose into or out of a cell does not require energy. Which statement best describes the movement of these materials across a cell membrane?
    a. Sodium and potassium ions move by active transport, and glucose moves by osmosis.
    b. Sodium and potassium ions move by active transport, and glucose moves by facilitated diffusion.
    c. Sodium and potassium ions move by facilitated diffusion, and glucose moves by osmosis.
    d. Sodium and potassium ions move by facilitated diffusion, and glucose moves by active transport.

18. The rough endoplasmic reticulum and Golgi apparatus work together in eukaryotic cells. What is one way that the rough endoplasmic reticulum assists the Golgi apparatus?
    a. It assembles nucleic acids from monomers.
    b. It breaks down old, damaged macromolecules.
    c. It packages new protein molecules into vesicles.
    d. It determines which protein molecules to synthesize.

Module A, Anchor #4 Homeostasis and Transport (Cont.)	
Anchor Descriptor	Eligible Content
Explain mechanisms that permit organisms to maintain biological balance between their internal and external environments.	*Explain how organisms maintain homeostasis (e.g., thermoregulation, water regulation, oxygen regulation).*

Review

Homeostasis – the process by which organisms keep internal conditions relatively constant despite changes in external environments. Maintenance of homeostasis requires communication among all organ systems.

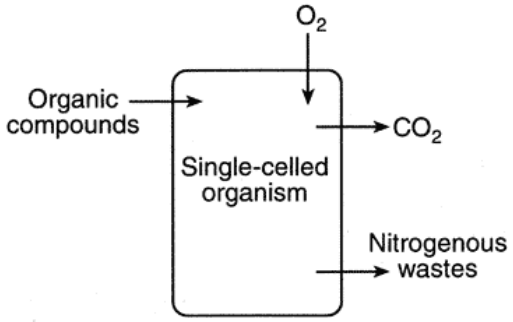
Organismal homeostasis examples:

- Thermoregulation – If nerve cells sense that the core body temperature drops below 37 degrees Celsius, the hypothalamus produces chemicals that signal cells throughout the body to speed up their activities. This increase in activity produces heat. Once body temperature is restored, nerve cells trigger the hypothalamus to inhibit further production of chemicals. If body temperature rises too far above 37 degrees Celsius, the hypothalamus slows down cellular activities to minimize the production of heat.
- Water regulation – Every cell in the body needs water because many of the body's processes, including chemical reactions, take place in water. For instance, hydrolysis of all polymers requires addition of water molecules to break the bonds. In addition, water makes up most of blood and other bodily fluids. Therefore, as water is lost through sweat, urine, etc. it is necessary to drink water to replace what is lost in order to maintain homeostasis.
- Oxygen regulation – All your cells require oxygen to obtain energy from organic molecules during cellular respiration. Oxygen in the air you breath dissolves into tiny air sacs in the lungs (alveoli), diffuses into capillaries, and then binds to hemoglobin in red blood cells. Carbon dioxide, the waste product of respiration, diffuses the other way. Regulation of breathing is actually controlled by the amount of CO_2 in the blood. More CO_2 dissolves in the blood, forming carbonic acid, which lowers blood pH slightly. Receptors in the brain sense the drop in pH and send nerve signals to increase breathing rate. Increased breathing rate removes CO_2 from the blood and blood pH rises to normal, thereby maintaining homeostasis.

Practice Questions

19. Which example is an activity that a fish most likely uses to maintain homeostasis with its body?
    a. Using camouflage to avoid predators
    b. Feeding at night to regulate body temperature
    c. Moving to deeper water to regulate metabolic wastes
    d. Exchanging gases through its gills to regulate oxygen levels

20. The arrows in the diagram below indicate the movement of materials into and out of a single-celled organism.



The movements indicated by all the arrows are directly involved in

a. The maintenance of homeostasis
b. Photosynthesis, only
c. Excretion, only
d. The digestion of minerals

Module B, Anchor #1 Cell Growth and Reproduction	
Anchor Descriptor	Eligible Content
Describe the three stages of the cell cycle: interphase, nuclear division, cytokinesis.	*Describe the events that occur during the cell cycle: interphase, nuclear division (i.e., mitosis or meiosis), cytokinesis.*
	Compare the processes and outcomes of mitotic and meiotic nuclear divisions.

Review

Cell cycle – The growth and division of cells to make new cells.

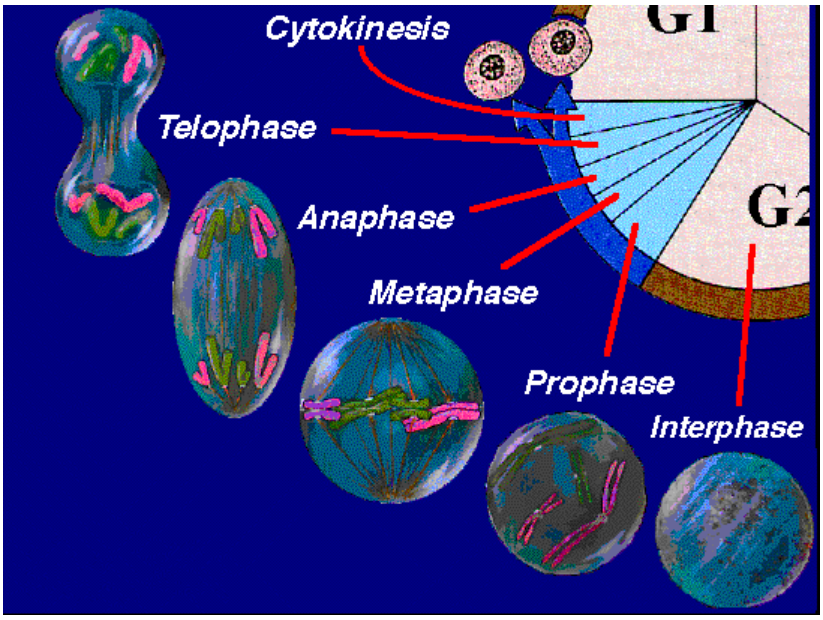
Mitosis - Eukaryotic cells use mitosis to divide into two new identical daughter cells. Human body cells undergo mitosis to form new body cells. Single-celled organisms use mitosis to reproduce through *asexual reproduction*.

Stages of the Cell Cycle (Mitosis)

There are four stages – G_1, S, G_2 and Mitosis. G_1, S, and G_2 are the *Interphase* stages. The fourth stage, mitosis, is when actual division occurs.

- Interphase – the longest stage of the cell cycle
  - *Stage G_1* – Stage of normal cell activity and growth. The cell doubles in size, and new organelles such as mitochondria, ribosomes, and centrioles are produced.
  - *Stage S* – Stage during which DNA synthesis occurs. Each chromosome is replicated. After DNA replication, each chromosome consists of two identical sister *chromatids* held together by a central region called the *centromere*.
  - *Stage G_2* – The cell prepares for mitosis by making anything still needed for cell division (mitosis).
- Mitosis (study tip – remember PMAT)
  - *Prophase*
    - Chromosomes condense so they are visible under a microscope.
    - *Centrioles* (organelles which form microtubules) separate and start moving to opposite poles with the spindle spanning between them.
    - The nuclear membrane dissolves and nucleoli disappears.
    - Spindle fibers attach themselves to each chromosome with a structure called the *kinetochore* that attaches in the middle of each chromosome.
  - *Metaphase*
    - The two centrioles are at opposite poles of the cell with the spindle spanning between them.
    - The kinetochore fibers attached to each chromosome's centromere cause the chromosomes to line up in the middle of the cell at the metaphase plate.
  - *Anaphase*
    - The sister chromatids in each chromosome are pulled apart by the kinetochore and spindle fibers and begin to move toward opposite poles.
  - *Telophase*
    - The sister chromatids have been pulled apart so that one copy of each chromosome is at one end of the cell and another copy is at the other end.
    - The spindle apparatus disappears.
    - The nuclear membrane reforms around each set of chromosomes and the nucleoli reappear.

        - Chromosomes uncoil.
- Cytokinesis
    - The cytoplasm and all the organelles of the cell are divided as the plasma membrane pinches inward and the two newly formed daughter cells separate from each other.

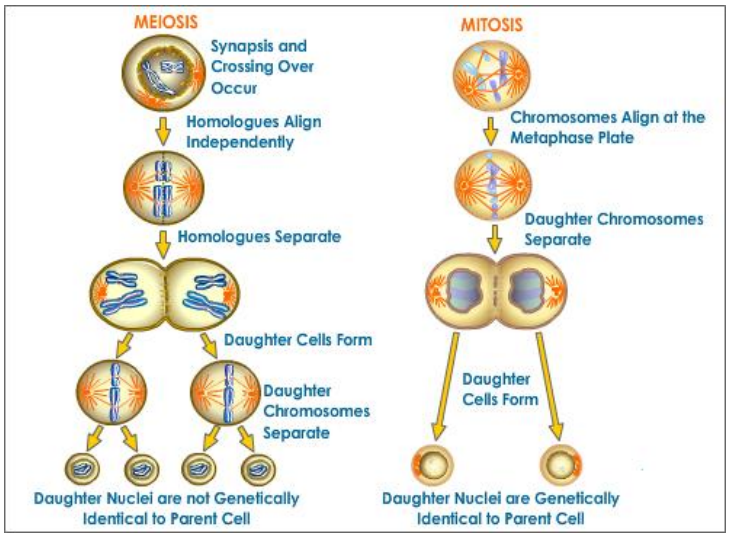


Meiosis – Cell division that produces four cells, each with half as many chromosomes as the parent cell. Meiosis occurs in sex cells (*gametes*) of organisms that reproduce *sexually*.

Haploid Cells – cells that have one copy of each chromosome. Gametes (sperm and egg) are haploid. The human haploid number is 23 chromosomes.
Diploid Cells – cells that have two copies of each chromosome. Somatic cells (body cells) are diploid. When a sperm (haploid) fertilizes an egg (haploid), the resulting zygote is diploid. The human diploid number is 46 chromosomes.

Stages of Meiosis – Like mitosis, meiosis includes interphase during which the chromosomes replicate. The cell then goes through two divisions as follows:

- *Meiosis I*
    - *Prophase I* – The replicated chromosomes condense and homologues pair up in a process called synopsis. Crossing over occurs. *Crossing over* is the exchange of genetic material between homologous chromosomes.
    - *Metaphase I* – Homologous pairs line up in the middle of the cell.
    - *Anaphase I* – Homologous pairs separate and move to the poles.
    - *Telophase I* – Each pole now has a haploid chromosome set. Telophase I occurs simultaneously with cytokinesis and two cells are formed.
- *Meiosis II* (similar to Mitosis)
    - *Prophase II* – A spindle apparatus forms and the chromosomes condense.
    - *Metaphase II* – Sister chromatids line up in the center of the cell
    - *Anaphase II* – The sister chromatids separate and move to opposite poles.
    - *Telophase II* – The nuclear membrane reforms and cytokinesis occurs resulting in 4 genetically different haploid cells.

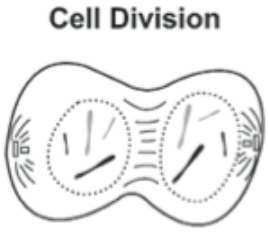


Meiosis	**Mitosis**
Only occurs in sex cells	Occurs in all body (somatic) cells
Chromosome number is reduced to half, i.e. haploid (*n*)	Chromosome number stays the same, i.e. diploid (*2n*)
Four genetically different daughter cells produced – genetic variability	Two genetically identical daughter cells produced
Two cell sub-divisions: Meiosis I and Meiosis II each with 4 phases	One cell division with 4 phases
Crossing over occurs	No crossing over

Nondisjunction – The process in which homologous chromosomes or sister chromatids fail to separate during meiosis. Nondisjunction can occur in anaphase of meiosis I or II, resulting in gametes with abnormal numbers of chromosomes. Ex: Down Syndrome – people with Down Syndrome have an extra copy of chromosome 21.

Practice Questions

21. Use the illustration below to answer the question.



Which statement **best** describes the phase of the cell cycle shown?

a. The cell is in prophase of mitosis because the number of chromosomes has doubled.
b. The cell is in prophase I of meiosis because the number of chromosomes has doubled.
c. The cell is in telophase of mitosis because the cell is separating and contains two copies of each chromosome.
d. The cell is in telophase of meiosis because the cell is separating and contains two copies of each chromosome.

22. Mitosis and meiosis are processes by which animal and plant cells divide. Which statement **best** describes a difference between mitosis and meiosis?

a. Meiosis is a multi-step process.
b. Mitosis occurs only in eukaryotic cells.
c. Meiosis is used in the repair of an organism.
d. Mitosis produces genetically identical daughter cells.

23. Patau syndrome can be a lethal genetic disorder in mammals, resulting from chromosomes failing to separate during meiosis. Identify the step during the process of meiosis when chromosomes would **most likely** fail to separate.

Module B, Anchor #1 Cell Growth and Reproduction (Cont.)	
Anchor Descriptor	Eligible Content
Explain how genetic information is inherited.	*Describe how the process of DNA replication results in the transmission and/or conservation of genetic information.*
	Explain the functional relationships between DNA, genes, alleles, and chromosomes and their roles in inheritance.

Review
DNA replication is the molecular mechanism of inheritance. DNA replication occurs during the S phase of mitosis or meiosis.

DNA Structure

- DNA is a polymer made from building blocks called nucleotides strung together.
- Each nucleotide consists of a phosphate group, a 5-carbon sugar and a nitrogenous base
- There are 4 nitrogenous bases: adenine (A), guanine (G), thymine (T), and cytosine (C)
- DNA is a *double-helix* – It contains 2 strands of DNA bonded together that run in opposite directions. The DNA double-helix has the sugar-phosphate backbones on the outside of the double helix and the nitrogenous bases on the inside.
- *Complementary Base Pairing* – The two strands of DNA are bound together by hydrogen bonds between the bases of the nucleotides. Due to their molecular structure, A allows pair with T, C allows pairs with G.

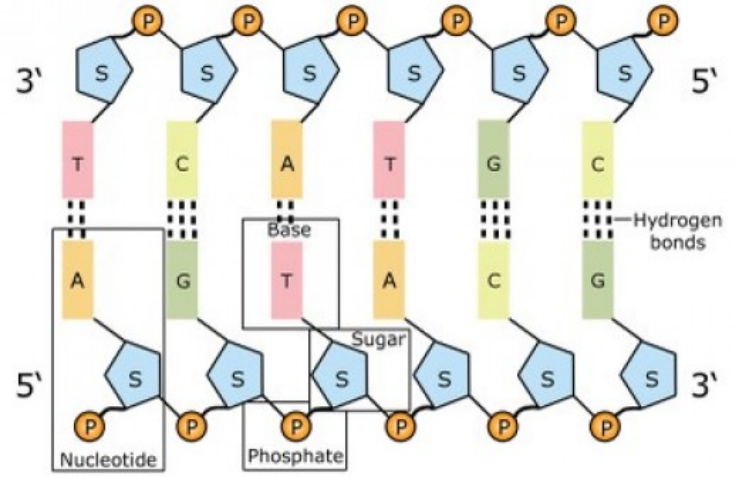
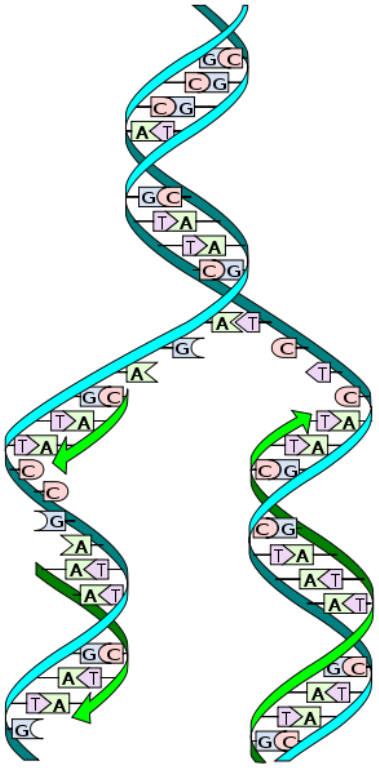


Image adapted from: National Human Genome Research Institute.

DNA Replication

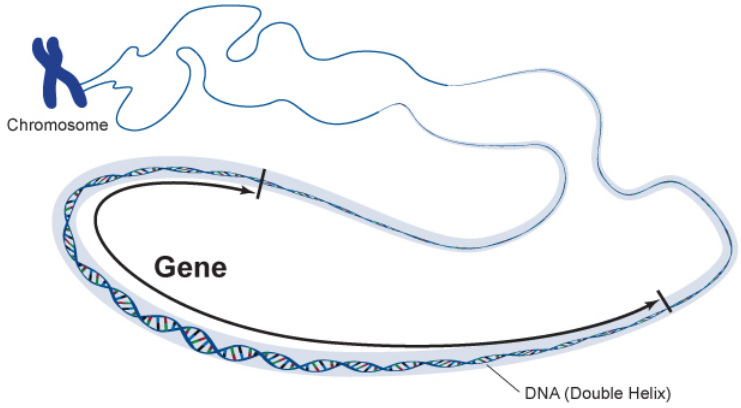
- DNA replication is *semi-conservative* because one old strand if DNA is maintained (conserved) while a new strand is made from the template of the old strand.
- During replication, the double helix separates and each DNA strand serves as a template for a new DNA strand. The new strand is built by adding the complementary nucleotide (using base pairing rules) to the existing template strand.
- Genetic information is conserved during replication because the base pairing rules ensure that the new DNA is an exact copy of the original DNA.



The genetic code is contained in the specific order of the four base pairs in DNA.

Basic rules of gene transmission and expression:

- *Genes* are elements of DNA that are responsible for observed traits.
- In eukaryotes, genes are found in large linear *chromosomes*.
- A chromosome is very long continuous DNA double-helix.
- Humans have 23 pairs of chromosomes in somatic (body) cells. Each pair of chromosome represent *homologous chromosomes* (one from mom and one from dad). Diploid organisms (like humans) have two copies of each chromosome and, therefore, 2 copies of each gene.
- Each gene has a specific location on a chromosome.
- The two copies of each gene can have a different nucleotide sequence in an organism. These different versions of a gene are called *alleles*. Ex. – Attached (f) and free earlobes (F) are different alleles of a gene.
    - *Homozygous individual* – has two copies (two alleles) of a gene that are identical. Ex. – FF
    - *Heterozygous individual* – has two different alleles for a gene. Ex - Ff
- An organism's *genotype* is the type of alleles is has (its genetic composition).
- An organism's *phenotype* is the appearance and physical expression of its genes.



Practice Questions

24. Which process helps to preserve the genetic information stored in DNA during DNA replication?
    a. The replacement of nitrogen base thymine with uracil
    b. Enzymes quickly linking nitrogen bases with hydrogen bases
    c. The synthesis of unique sugar and phosphate molecules for each nucleotide
    d. Nucleotides lining up along the template strand according to base pairing rules

25. In a flowering plant species, red flower color is dominant over white flower color. What is the genotype of any red-flowering plant resulting from this species?
    a. Red and while alleles present on one chromosome
    b. Red and white alleles present on two chromosomes
    c. A red allele present on both homologous chromosomes
    d. A red allele present on at least one of two homologous chromosomes

Module B, Anchor #2 Genetics	
Anchor Descriptor	Eligible Content
Compare Mendelian and non-Mendelian patterns of inheritance.	*Describe and/or predict observed patterns of inheritance (i.e., dominant, recessive, co-dominance, incomplete dominance, sex-linked, polygenic, and multiple alleles).*

Review

Genetics – the scientific study of heredity

Patterns of Inheritance

- *Dominant* – A dominant allele is expressed in an organism regardless of the second allele (remember: eukaryotic organisms have 2 copies of each gene).
    - Ex. - Free earlobes (F) are dominant to attached earlobes (F)
        - An individual whose genotype is Ff has a phenotype of free earlobes.
- *Recessive* – A recessive allele is only expressed if an organism has 2 recessive alleles for the gene.
    - Ex. – From the example above, a person can only have the phenotype of attached earlobes if they have the genotype ff.
- *Co-dominance* – Both alleles are fully expressed without one allele dominant over another.
    - Ex. – For blood types, the A allele and B allele are codominant. This produces the AB blood group. (However, note that A and B are both dominant over O).
- *Incomplete dominance* – Both alleles are partially expressed; the resulting phenotype is in between the individual allele phenotypes.
    - Ex. – A red snapdragon (R) crossed with a white snapdragon (W) produces pink (RW) offspring.
- *Sex-linked* – Genes for some traits are located on the X chromosome and have no corresponding allele on the Y chromosome. Since males are XY and only have 1 X chromosome, recessive sex-linked traits are more often observed in males.
    - Ex. – color blindness, hemophilia
- *Polygenic* – multiple genes affect the expression of a trait; allows for more variation in phenotypes.
    - Ex. – skin color, height
- *Multiple alleles* – several alleles (i.e., more than two) exist in a population and increases the number of possible genotypes and phenotypes
    - Ex. – Three alleles exist for blood type – I^A, I^B and i. The different combination of these alleles produces the four blood types A, B, AB and O.

Punnett Square – diagram showing the probabilities of the possible outcomes of a genetic cross

- A woman homozygous for attached earlobes marries a man heterozygous for free earlobes. What are the possible genotypic and phenotypic ratios for their children for this trait?

	f	**f**
F	Ff	Ff
f	ff	ff

Genotypic ratio – 1 Ff: 1 ff
Phenotypic ratio – 1 Free: 1 attached

Practice Questions

26. Use the table below to answer the question.

Blood Types	
Genotype(s)	**Phenotype**
ii	O
I^AI^A, I^Ai	A
I^BI^B, I^Bi	B
I^AI^B	AB

Blood type is inherited through multiple alleles, including I^A, I^B, and i. A child has type A blood. If the father has type AB blood, what are all the possible phenotypes of the mother?

a. Phenotypes O or A
b. Phenotypes A or AB
c. Phenotypes A, B, AB
d. Phenotypes O, A, B, AB

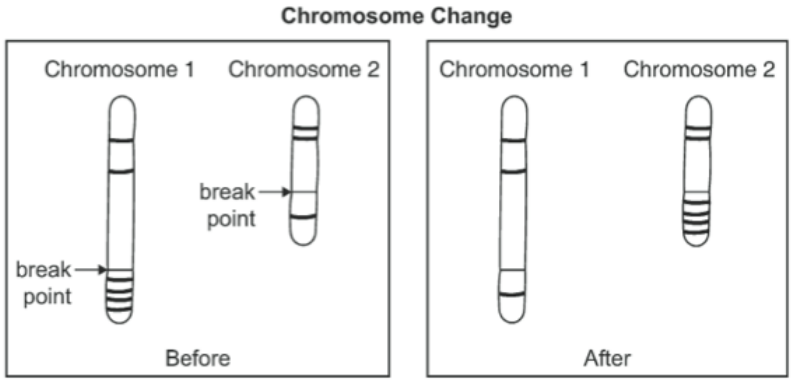
27. A cattle farmer genetically crosses a cow (female) with a white coat with a bull (male) with a red coat. The resulting calf (offspring) is roan, which means there are red and white hairs intermixed in the coat of the calf. The genes for coat color in cattle are co-dominant.

Part A: Although a farm has cattle in all three colors, the farmer prefers roan cattle over white or red cattle. Use a Punnett square to show a cross that would produce only roan offspring.

Part B: Explain how a roan calf results from one white- and one red-coated parent. In your explanation, use letters to represent genes. Be sure to indicate what colors the letters represent.

Part C: Predict the possible genotypes and phenotypes of the offspring produced from two roan cattle.

28. Use the diagram below to answer the question.



Which type of change in chromosome composition is illustrated in the diagram?

a. Deletion
b. Insertion
c. Inversion
d. Translocation

Module B, Anchor #2 Genetics (Cont.)	
Anchor Descriptor	Eligible Content
Explain the process of protein synthesis (i.e., transcription, translation, and protein modification).	*Describe how the processes of transcription and translation are similar in all organisms.*
	Describe the role of ribosomes, endoplasmic reticulum, Golgi apparatus, and the nucleus in the production of specific types of proteins.

Review

Central Dogma of Biology

- DNA → mRNA → Proteins
- In order words, there are two main steps in *protein synthesis*:
  - The process of *transcription* takes DNA to RNA
  - The process of *translation* takes RNA to protein

DNA	RNA
Double-stranded	Single-stranded
Deoxyribose sugar in nucleotides	Ribose sugar in nucleotides
Bases = G, C, A, T	Bases = G, C, A, U (uracil instead of thymine)
One type of DNA per organism	Three types of RNA (mRNA, tRNA, rRNA)

mRNA (messenger RNA) – RNA molecule transcribed from the DNA template; carries the code from the nucleus out to the cytoplasm. mRNA is "read" in units of 3 nucleotides called *codons*. Each codon codes for a specific amino acid.

rRNA (ribosomal RNA) – makes up the ribosome where translation occurs

tRNA (transfer RNA) – carries amino acids to the ribosomes to make proteins

Protein Synthesis Overview

1. Transcription
   - Occurs in the nucleus
   - Single stranded mRNA is transcribed from a DNA template using the base pairing rules. Recall that in mRNA uracil (U) replaces thymine (T).
   - An enzyme called *RNA polymerase* links the RNA nucleotides together.
   - mRNA is modified. *Intron*s (noncoding regions of mRNA) are removed and the *exon*s (coding regions) are spliced together.
   - mRNA leaves the nucleus and goes out to the cytoplasm.
2. Translation
   - Occurs at the ribosomes in the cytoplasm
   - mRNA, the first tRNA with its attached amino acid, and the two subunits of the ribosome come together. The *start codon AUG* dictates where translation begins.

- Each three-base pair codon codes for a specific amino acid that will be included in the amino acid chain. Ribosomes match each codon with the correct amino acid using a "middle man" called tRNA. tRNA has an three-base pair *anticodon* that matches each codon on mRNA. Each tRNA carries a specific amino acid.
- Ribosomes continue down the mRNA adding amino acids to the growing polypeptide chain until a *stop codon* (UAA, UAG, or UGA) is reached and the protein polypeptide is released.

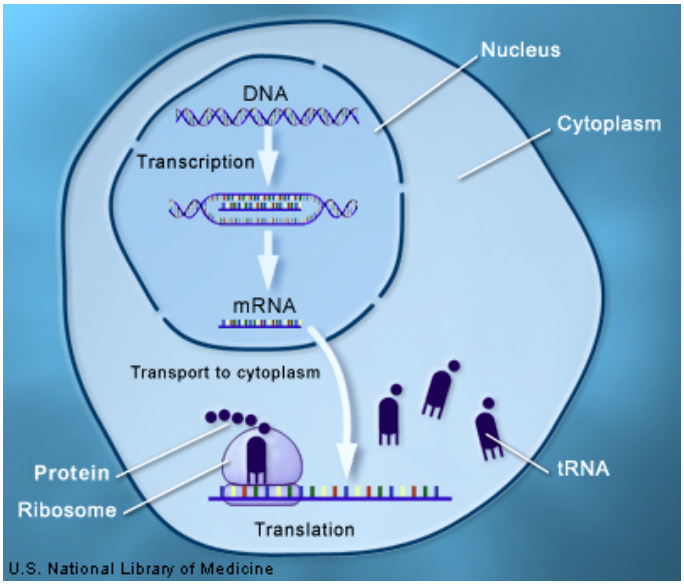
<u>What happens to the proteins?</u>

- Proteins that will remain in the cytoplasm are translated by ribosomes in the cytoplasm.
- Proteins that are destined for the ER, Golgi apparatus, or the plasma membrane or that will be secreted by the cell are synthesized by ribosomes on the rough ER.
  - The protein is synthesized and inserted into the ER through the ER membrane.
  - The protein sequence tells the ER where to send it.
  - The protein is then packaged into vesicles.
  - The vesicles move from the ER to the Golgi apparatus where they are modified.
  - The proteins move to the plasma membrane where they are secreted or remain as membrane proteins.

One gene encodes one polypeptide. One or more polypeptides combine to form a protein. Proteins determine the appearance and functioning of the cell and of the whole organism.

There are 64 different codons (i.e. 64 different three basepair combinations). 61 code for amino acids; 3 code for stop codons. These 61 codons code for the 20 different amino acids. *This genetic code is universal to almost all organisms*.

Transcription and translation are similar in all organisms; however, since prokaryotes do not have a nucleus, both transcription and translation both occur in the cytoplasm.



Practice Questions

29. Which statement describes a cell process that is common to both eukaryotic and prokaryotic cells?
    a. Both cell types carry out transcription in the nucleus.
    b. Both cell types use ribosomes to carry out translation.
    c. Both cell types assemble amino acids to carry out transcription.
    d. Both cell types carry out translation in the endoplasmic reticulum.

30. The endoplasmic reticulum is a network of membranes within the cell, and it is often classified as rough or smooth, depending on whether there are ribosomes on its surface. Which statement **best** describes the role of the rough endoplasmic reticulum in the cell?
    a. It stores all proteins for later use.
    b. It provides an attachment site for larger organelles.
    c. It aids in the production of membrane and secretory proteins.
    d. It stores amino acids required for the production of all proteins.

Module B, Anchor #2 Genetics (Cont.)	
Anchor Descriptor	Eligible Content
Explain how genetic information is expressed.	*Describe how genetic mutations alter the DNA sequence and may or may not affect phenotype (e.g., silent, nonsense, frameshift).*

Review

The sequence of nucleotides in a gene determines the sequences of amino acids in the resulting protein. A protein's function depends on its sequence of amino acids. If that sequence changes, then it can change or harm the protein's function. A *mutation* can change the DNA sequence and, therefore, impact the resulting protein. Mutations can be both beneficial or harmful.

Point Mutations – one nucleotide is substituted, inserted or deleted

- Silent Mutation
  - A nucleotide substitution that occurs in a noncoding region and does not affect the protein OR
  - A nucleotide substitution that changes the codon to another codon that happens to code for the same amino acid. The protein is not affected.
- Missense Mutation
  - A nucleotide substitution that results in a different amino acid.
- Nonsense Mutation
  - A substitution that causes a premature stop codon. The protein is then shorter than it should be and is usually not functional.

Frameshift Mutations – a nucleotide is inserted or deleted causing the codon "reading frame" to shift. All codons after the insertion or deletion will read incorrectly.

Mutation Type	**Example of Disease Caused**
Missense (substitution)	Achondroplasia (dwarfism)
Nonsense (substitution)	Muscular dystrophy
Deletion (causing frameshift)	Cystic fibrosis
Insertion (causing frameshift)	Crohn's disease

Practice Questions

31. A genetic mutation resulted in a change in the sequence of amino acids of a protein, but the function of the protein was not changed. Which statement **best** describes the genetic mutation?
    a. It was a silent mutation that caused a change in the DNA of the organism.
    b. It was a silent mutation that caused a change in the phenotype of the organism.
    c. It was a nonsense mutation that caused a change in the DNA of the organism.
    d. It was a nonsense mutation that caused a change in the phenotype of the organism.

Module B, Anchor #2 Genetics (Cont.)	
Anchor Descriptor	Eligible Content
Apply scientific thinking, processes, tools and technologies in the study of genetics.	*Explain how genetic engineering has impacted the fields of medicine, forensics, and agriculture (e.g., selective breeding, gene splicing, cloning, genetically modified organisms, gene therapy).*

Review

Genetic engineering - making changes in the DNA code of a living organism

Genetic engineering has impacted medicine, forensics, and agriculture in the following ways:

- *Selective breeding*
  - Allowing only those organisms with desired characteristics to produce the next generation
  - Most domestic animals (dogs, cats, horses, farm animals) and crop plants have been produced by selective breeding
    - *Hybridization* – crossing dissimilar individuals to bring together the best features of both organisms
    - *Inbreeding* – continued breeding of individuals with similar characteristics (purebred animals are produced this way)
- *Gene splicing (recombinant DNA)*
  - Combining DNA from different sources
- *Cloning*
  - Producing genetically identical organisms
  - Researchers hope that cloning will allow them to makes copies of transgenic organisms and also help save endangered species
- *Transgenic organisms (genetically modified)*
  - Organisms that contain genes from other species
  - Transgenic bacteria
    - Used to produce human proteins such as insulin, growth hormone, and clotting factor to help treat human diseases
  - Transgenic animals
    - Also used to produce human proteins
    - Livestock such as cows have extra copies of growth hormone to make them grow faster and produce leaner meat
  - Transgenic plants
    - Crops are being modified to contain genes for a natural insecticide so that pesticides do not need to be used
- *Gene therapy*
  - An absent or faulty gene is replaced by a normal, working gene
  - Being studied as a way to treat human genetic disorders

Practice Questions

32. Genetic engineering has led to genetically modified plants that resist insect pests and bacterial and fungal infections. Which outcome would **most likely** be a reason why some scientists recommend caution in planting genetically modified plants?
    a. Unplanned ecosystem interactions
    b. Reduced pesticide and herbicide use
    c. Improved agricultural yield and profit
    d. Increased genetic variation and diversity

33. Which of the following can be used to produce organisms with desirable traits?
    I. inbreeding
    II. genetic engineering
    III. inducing mutations

    a. I only
    b. II only
    c. I and II only
    d. II and III only
    e. I, II, and III

Module B, Anchor #3 Theory of Evolution	
Anchor Descriptor	Eligible Content
Explain the mechanisms of evolution.	*Explain how natural selection can impact allele frequencies of a population.*
	Describe the factors that can contribute to the development of new species (e.g., isolating mechanisms, genetic drift, founder effect, migration).
	Explain how genetic mutations may result in genotypic and phenotypic variations within a population.

Review

Evolution – The change in a population of a species over time. The changes are the result of changes in the gene pool of a population of organisms.

Gene pool – the sum total of all alleles in a population

Allele frequency – the frequency of a specific allele in the gene pool

Population – a group of individuals of the same species living in a specific geographical area and reproducing

Species – organisms that can mate and produce fertile offspring

Mechanisms of Evolution

Allele frequencies in a population can change (and thus evolution can occur) as a result of:

- *Nonrandom mating/Sexual Selection* – organisms selecting mating partners that resemble themselves or have a specific trait
- *Immigration or emigration (gene flow)* – new genes introduced as a result of individuals entering the population
- *Mutations* - Some mutations offer a selective advantage. Mutations may produce new alleles that result in a new phenotype that offer an advantage in a population. Mutations introduce genetic diversity.
- *Small populations* – small populations are subject to random events that can statistically alter the gene pool. See *genetic drift* below.
- *Genetic drift* – changes in the gene pool caused by random events in a small population
    - *Bottleneck* – when an event (e.g., a flood) drastically reduces the size of a population. The allele frequencies of the survivors are not the same as the allele frequencies of the original population. As the population grows, the allele frequencies will represent the frequencies from the bottleneck population, not the original population.
    - *Founder effect* – a small number of individual colonize a new habitat. The allele frequencies of the new population will reflect the alleles of the founders, not the original population they came from.
- *Natural selection* – survival and reproduction of individuals based on inherited traits. Those organisms with certain phenotypes may be better adapted to their environment and

will survive and reproduce. The frequency of the alleles for that phenotype will increase in the population.

Speciation – The creation of a new species. Occurs when the gene pool for a group of organisms becomes reproductively isolated (which can occur when any of the evolution mechanisms noted above cause populations to become so genetically different that they can no longer mate).

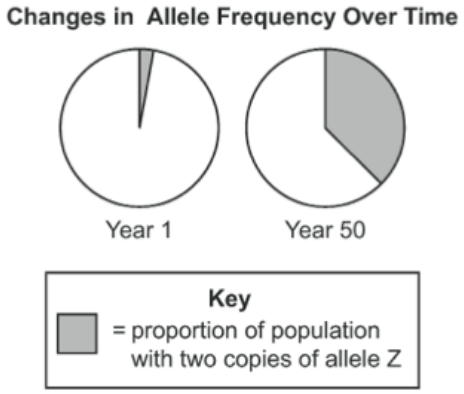
- Types of speciation
  - *Allopatric speciation* – Two populations of a species are separated geographically or by a physical barrier. Each population evolves specific adaptations for their environment. Over time the genetic differences become so great that the populations can no longer interbreed and are two separate species.
  - *Sympatric speciation* – A species evolves into a new species without a physical barrier. Usually happens as a result of a sudden genetic change. Happens fairly frequently in plants through polyploidy, an increase in the chromosome number.
- *Isolating mechanisms (reproductive isolation)* - features or behaviors, morphology, or genetics which prevent mating or breeding between two different species
  - *Temporal Isolation* – individuals are active at different times of the day, seasons, or mating periods
  - *Ecological Isolation* – individuals only mate in their specific habitat
  - *Behavorial Isolation* – there are no sexual cues between representatives of the species
  - *Mechanical Isolation* – when there is no sperm transfer during attempted mating
  - *Gametic incompatibility* – when there is sperm transfer without fertilization occurring

Patterns of Evolution

- *Adaptive radiation* – The production of a number of different species from a single ancestral species.
- *Coevolution* – When the evolution of one species affects the evolution of another species (mutualism is an example of coevolution).
- *Convergent evolution* - unrelated species evolve similar traits even though they live in different parts of the world. Occurs in environments that are geographically far apart but that have similar ecology and climate.
- *Rate of speciation*
  - *Gradualism* – the theory that evolution proceeds in small, gradual steps, i.e., that new species arise from the result of slight modifications (mutations and resulting phenotypic changes) over many generations.
  - *Punctuated equilibrium* – the theory that rapid spurts of genetic change cause species to diverge quickly; these periods punctuate much longer period when the species exhibit little change.

Practice Questions

34. Use the circle graphs below to answer the question.



The graphs illustrate change in a lizard population over time. Which process most likely led to the change in the lizard population?

a. Natural selection acting on a harmful trait
b. Natural selection acting on a beneficial trait
c. Natural selection acting on a dominant trait
d. Natural selection acting on a recessive trait

35. In North America, the eastern spotted skunk mates in late winter, and the western spotted skunk mates in later summer. Even though their geographic ranges overlap, the species do not mate with each other. What **most likely** prevents these two species from interbreeding?

a. Habitat isolation
b. Gametic isolation
c. Geographic isolation
d. Temporal isolation

Module B, Anchor #3 Theory of Evolution (Cont.)	
Anchor Descriptor	Eligible Content
Analyze the sources of evidence for biological evolution.	*Interpret evidence supporting the theory of evolution (i.e., fossil, anatomical, physiological, embryological, biochemical, and universal genetic code).*

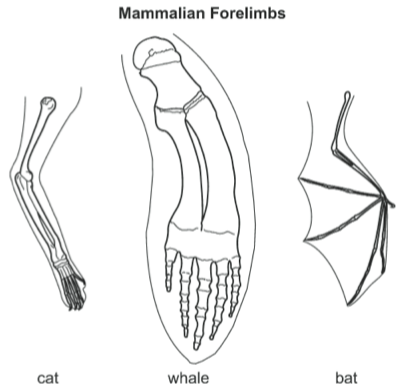
Review

Evidence of Evolution

- *Fossil record* – can compare fossils from older rock layers with fossils from younger layers to show that life on Earth has changed over time.
- *Anatomical evidence*
    - *Homologous structures* – anatomically similar structures inherited from a common ancestor (Ex. – bird wings and reptile limbs are similar in shape and have similar bones)
    - *Analogous structures* - structures that are used for the same purpose, but are NOT inherited from a common ancestor. (Ex. – the wing of an eagle and the wing of a fly).
    - *Vestigial structures* – structures that are the reduced forms of functional structures in other organisms (Ex. – tailbones in humans)
- *Embryological evidence* – Vertebrate embryos display homologous structures during certain phases of development but become totally different structures in the adult forms. The shared features in embryos suggest that vertebrates share a common ancestor.
- *Biochemical evidence* – Different organisms share the same complex metabolic molecules suggesting common ancestry. Evolutionary theory suggests that molecules in species with a recent common ancestor should share certain ancient amino acid sequences. The more closely related the species are, the greater number of sequences that will be shared.
- *Universal genetic code* – The fact that organisms share a genetic code suggests a common ancestor. The more similar the DNA sequence, the more closely related the species.
- *Geographic distribution* – generally, animals living in closer geographical proximity are more closely related. For example, Darwin observed that animals on the South American mainland were more similar to other South American animals than they were to animals living in similar environments in Europe.

Practice Questions

36. Use the illustrations below to answer the question.



The skeletons of mammalian forelimbs represent variations of a structure that was present in their common ancestor. What has **most likely** caused the variation in forelimbs?

a. Changes in muscle structure
b. Changes in the genetic codes
c. Trait formation due to behaviors
d. Development of vestigial structures

37. Use the table below to answer the question.

Sequence Differences between COII Genes in Some Animals	
Animal	**# of Base Differences from a Rat**
Mouse	101
Cow	136

The gene COII is in the genome of many organisms. A comparison of the number of base differences between the COII gene in a rat and that of two other animals is shown.

Part A: Based on the data, describe a possible evolutionary relationship between rats, mice, and cows.

Part B: Describe how different organisms having a common gene such as COII supports the theory of evolution.

Module B, Anchor #3 Theory of Evolution (Cont.)	
Anchor Descriptor	Eligible Content
Apply scientific thinking, processes, tools, and technologies in the study of the theory of evolution.	*Distinguish between the scientific terms: hypothesis, inference, law, theory, principle, fact, and observation.*

Review

Hypothesis – A proposed, scientifically testable explanation for an observed phenomenon.

Inference – An assumption based on prior experience.

Law – Generalizes a body of observations. At the time it is made, no exceptions have been found to the law. Serves as the basis for scientific principles. Scientific laws explain things, but they do not describe them.

Theory – An explanation of natural phenomenon based on many observations and investigations over time.

Principle – A concept based on scientific laws and axioms (rules assumed to be present, true, and valid) where general agreement is present.

Fact – indisputable observations

Observation – a direct method of gathering information in an orderly way

Scientists make observations. Scientists will then formulate a hypothesis based on inferences in order to explain their observations. Once the hypothesis is tested and confirmed, it becomes a theory. Only when a theory has withstood every challenge and has been proven to provide reproducible results does it become a recognized scientific law. There is no 'proof' or absolute 'truth' in science. The closest we get are facts.

Practice Questions

38. Use the table below to answer the question.

Student's Observations of a Pond Ecosystem

Quantitative	Qualitative
37 fish and 3 frogs	Leaves lie on the bottom of the pond.
2 types of aquatic grass	Water insects move along the water's surface.
12 small rocks and 1 medium rock	All 3 frogs are sitting on a pond bank.
sand	

A group of students measured a ten-square-meter section of a pond ecosystem and recorded observations. Which statement is a testable hypothesis?

a. The frogs living in the pond represent a population.
b. Water is an abiotic component in the pond ecosystem.
c. If the fish are given more food, they will be happier.
d. If the frogs are startled, then they will jump into the water.

39. A scientific theory is
    a. Another word for hypothesis.
    b. A well-tested explanation that unifies a broad range of observations.
    c. The same as the conclusion of an experiment.
    d. The first step in a controlled experiment.

Module B, Anchor #4 Ecology	
Anchor Descriptor	Eligible Content
Describe ecological levels of organization in the biosphere.	*Describe the levels of ecological organization (i.e., organism, population, community, ecosystem, biome, and biosphere).*
	Describe characteristic biotic and abiotic components of aquatic and terrestrial ecosystems.

Review

Ecology – the study of relationships among living organisms and the interaction the organisms have with their environment

Levels of Ecological Organization

Organism → Population → Community → Ecosystem → Biome → Biosphere

- Population – individual organisms of a single species that share the same geographic location at the same time
- Community – a group of interacting populations that occupy the same geographic area at the same time
- Ecosystem – a biological community and all of the abiotic factors that affect it
- Biome – a large group of ecosystems that share the same climate and have similar types of communities
- Biosphere – all of the biomes on Earth

Biotic factors – the living factors in an organism's environment

Aquatic examples – fish, algae, frogs, microscopic organisms

Terrestrial examples – humans, birds, trees

Abiotic factors – the nonliving factors in an organism's environment

Aquatic examples – water currents, sunlight, nutrients, temperature

Terrestrial examples – air currents, sunlight, nutrients, temperature, soil type

Practice Questions

40. A researcher observing an ecosystem describes the amount of sunlight, precipitation, and type of soil present. Which factors is the researcher most likely describing?
    a. Biotic factors in a forest
    b. Biotic factors in a tundra
    c. Abiotic factors in a prairie
    d. Abiotic factors in an ocean

41. Use the list below to answer the question.

Observations

- Two grey wolves
- Five moose
- Several species of conifer trees
- Large granite rock
- Shallow pond

A student wrote several observations in a field notebook. Which term best classifies all of the student's observations?

a. Population
b. Food chain
c. Ecosystem
d. Community

Module B, Anchor #4 Ecology (Cont.)	
Anchor Descriptor	Eligible Content
Describe interactions and relationships in an ecosystem.	*Describe how energy flows through an ecosystem (e.g., food chains, food webs, energy pyramids).*
	Describe biotic interactions in an ecosystem (e.g., competition, predation, symbiosis).

Review

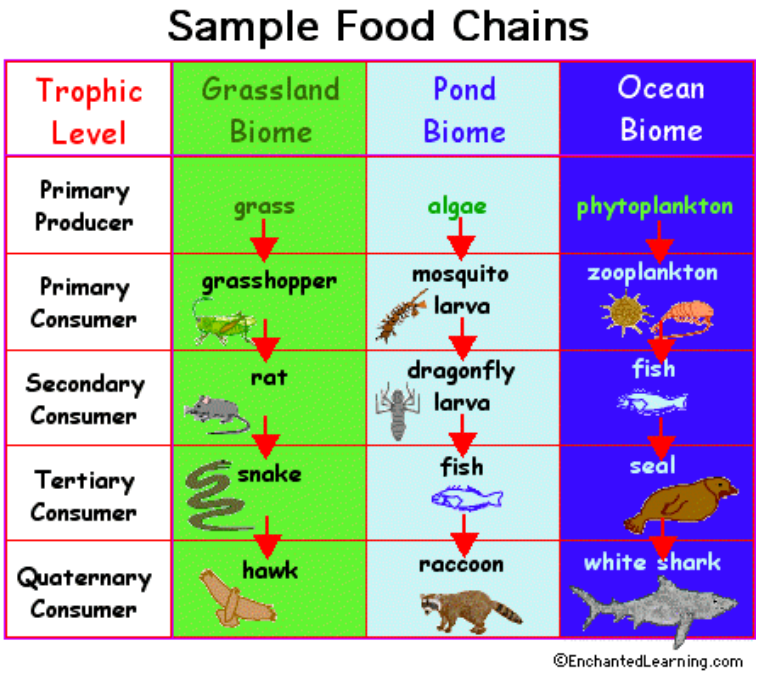
Autotroph – organism that collects energy from sunlight or inorganic substances to produce their own food (e.g., plants). Autotrophs are the primary producers in an ecosystem.

Heterotroph – an organism that gets its energy requirements by consuming other organisms

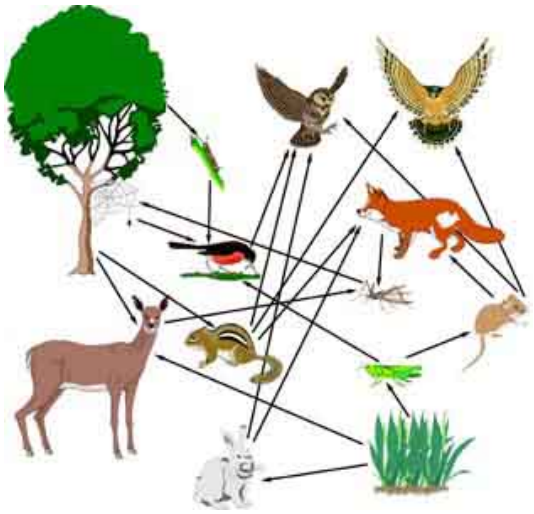
- *Herbivore* – heterotroph that only eats plants
- *Carnivore* – heterotroph that prey on other heterotrophs
- *Omnivore* – organisms that eat both plants and other animals
- *Detritivore* – organism that eats fragments of dead matter in an ecosystem, return nutrients to the soil, air, and water where the nutrients can be reused by organisms

Models of Energy Flow

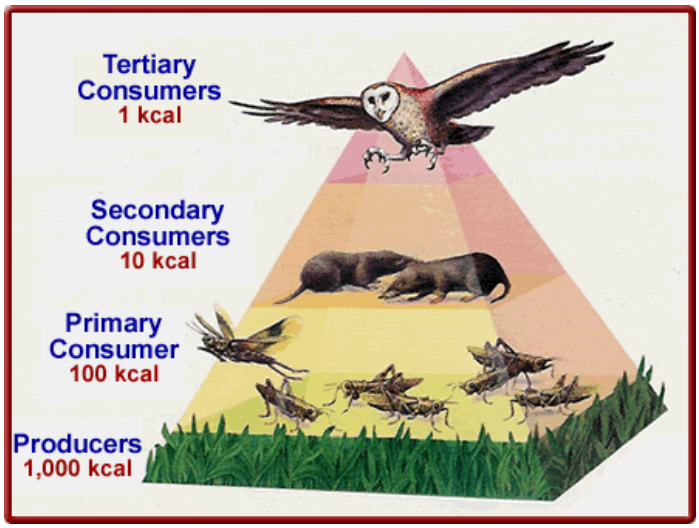
- *Trophic level* – each step in a food chain or food web. Autotrophs make up the first trophic level. Heterotrophs make up the remaining levels. 90% of energy is lost between each trophic level.
- *Food chain* – simple model that shows how energy flows through an ecosystem



Food webs – model representing the many interconnected food chains and pathways in which energy flows through a group of organisms



- *Energy pyramids* – model that shows the relative amounts of energy, biomass, or numbers of organisms at each trophic level in an ecosystem.



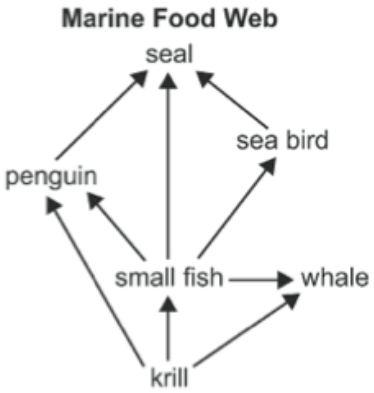
<u>Biotic Interactions in an Ecosystem</u>

- *Competition* – occurs when more than one organism uses a resource (e.g., food, water, space, light) at the same time. Strong organisms directly compete with weak organisms for resources needed for survival. Usually the strong survive.
- *Predation* – when one organism (predator) eats another organism (prey)
- *Symbiosis* – the close relationship that exists when two or more species live together
    - *Mutualism* – relationship between two or more organisms that live closely together and benefit form each other
        - Ex. – Lichens – algae provide food for the fungi and fungi provide a habitat for the algae
    - *Commensalism* – Relationship in which one organism benefits and the other organism is neither helped nor harmed
        - Ex. – Clownfish and sea anemones – the anemone protects the clownfish from predators, the anemone is neither helped nor harmed

- *Parasitism* – relationship in which one organism benefits at the expense of another organism
  - Ex. – ticks on humans

Practice Questions

42. Use the diagram below to answer the question.



Which sequence correctly describes the flow of energy between organisms in the marine food web?

a. From seals to penguins to krill
b. From whales to krill to small fish
c. From sea birds to seals to penguins
d. From small fish to penguins to seals

43. A species of snapping turtles has a tongue that resembles a worm. The tongue is used to attract small fish. Which **best** describes the interaction between the fish and the snapping turtle?

a. Predation
b. Symbiosis
c. Parasitism
d. Competition

Module B, Anchor #4 Ecology (Cont.)	
Anchor Descriptor	Eligible Content
Describe interactions and relationships in an ecosystem.	*Describe how matter recycles through an ecosystem (i.e., water cycle, carbon cycle, oxygen cycle, and nitrogen cycle).*

Review
Essential nutrients are cycled through an ecosystem in biogeochemical processes. The movement of these nutrients between the biotic and abiotic elements in an ecosystem form cycles that are critical to all life on Earth.

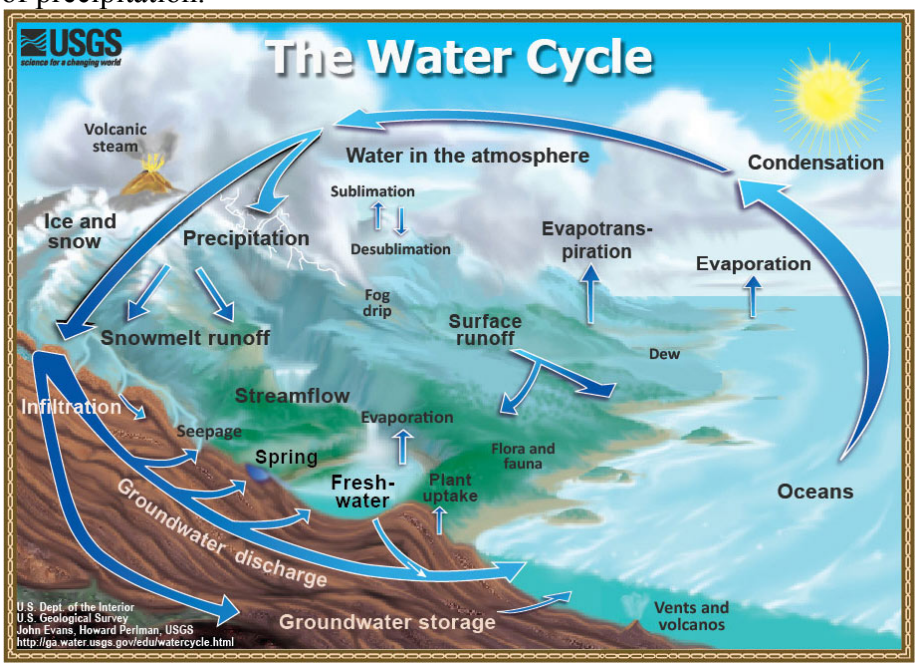
Biogeochemical cycle – the exchange of matter through the biosphere.

Matter – anything that take up space and has mass.

Nutrient – a chemical substance that an organism must obtain from its environment to sustain life and to undergo life processes.

Water Cycle

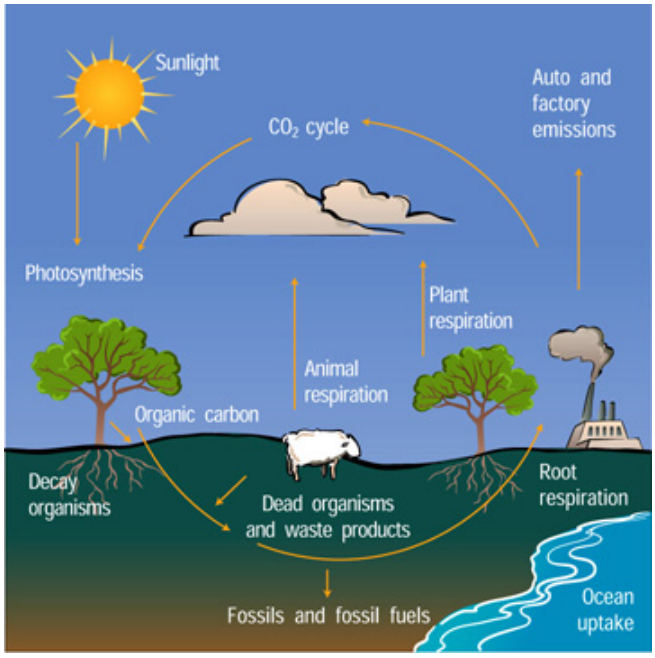
- Water is found underground, in the atmosphere, and on Earth's surface in lakes, streams, rivers, glaciers, ice caps and oceans
- Water is constantly evaporating from bodies of water as the sun heats Earth's surface and from plants in the process of transpiration.
- As water vapor rises, it cools in the atmosphere, condenses, and falls back to Earth in the form of precipitation.



Carbon Cycle

- Carbon is taken out of the atmosphere when plants take in CO_2 during photosynthesis and produce glucose ($C_6H_{12}O_6$).
- Animals eat plants and use the nutrients to make carbohydrates, fats, and proteins.

- Organisms release organic carbon compounds through their wastes and into the atmosphere as CO_2 during respiration. The rest of the organic carbon compounds remained lock in the organism until they die. Organisms' bodies decay releasing carbon in CO_2 back to the air. Human activities such as burning fossil fuels also release carbon into the atmosphere.



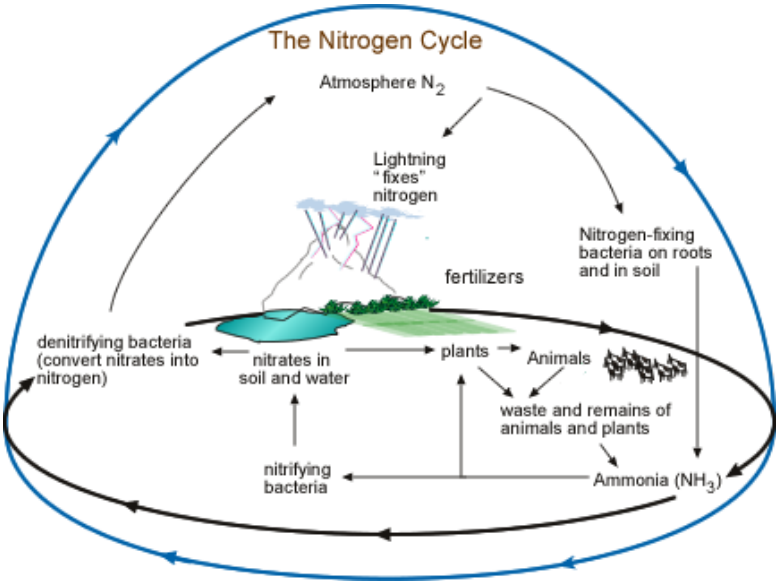
Oxygen Cycle

- Plants produce oxygen as a by-product during photosynthesis
- Humans and other organisms utilize oxygen during cellular respiration and exhale carbon dioxide
- Plants take up the carbon dioxide in photosynthesis and release oxygen back into the oxygen

Nitrogen Cycle

- Nitrogen an essential element of amino acids and nucleic acids (DNA and RNA).
- 80% of the Earth's atmosphere is nitrogen gas (N_2), but producers can only use nitrogen in the form of ammonium (NH_4^+) or nitrate (NO_3^-).
- Nitrogen-fixing bacteria in the soil and in the nodules on the roots of certain plants convert nitrogen gas to ammonia (NH_3) in a process called *nitrogen fixation*.
- In the soil, ammonia (NH_3) picks up another hydrogen from water and becomes ammonium (NH_4^+).
- Other bacteria in the soil convert ammonium to nitrates (NO_3^-) in a process called *nitrification*.
- Producers absorb ammonium and nitrates from the soil and use them to build amino acids, proteins, and nucleic acids.
- Animals eat plants and make animal proteins from plant proteins. Both animals and plants give off wastes and eventually die.

- Nitrogen in wastes and dead matter gets converted into ammonium (NH_4^+) by decomposers.
- Denitrifying bacteria in the soil convert nitrates back to nitrogen gas and release it into the atmosphere.



Practice Questions

44. Which statement correctly describes how nitrogen in the soil returns to the atmosphere?
    a. Soil bacteria convert nitrates into nitrogen gas.
    b. Decomposers directly convert ammonium into nitrogen gas.
    c. Plants assimilate nitrites and convert them into nitrogen gas.
    d. Nitrogen-fixing bacteria in plant roots convert nitrates into nitrogen gas.

45. Human activities, such as the burning of fossil fuels, cycle carbon through the carbon cycle. Which other processes also participate in the carbon cycle?
    i. Biological processes, such as photosynthesis
    ii. Geochemical processes, such as the release of gas from volcanoes
    iii. Mixed biogeochemical processes, such as the formation of fossil rules
    a. I only
    b. II only
    c. I and II only
    d. II and III only
    e. I, II, and III

Module B, Anchor #4 Ecology (Cont.)	
Anchor Descriptor	Eligible Content
Describe interactions and relationships in an ecosystem.	*Describe how ecosystems change in response to natural and human disturbances (e.g., climate changes, introduction of nonnative species, pollution, fires).*
	Describe the effects of limiting factors on population dynamics and potential species extinction.

Review

Natural and human disturbances destroy biodiversity in ecosystems. Biodiversity increases the stability of an ecosystem and contributes to the health of the biosphere. Threats to biodiversity upset the balance (homeostasis) of an ecosystem.

Examples of disturbances include:

- Overexploitation – excessive use of species that have an economic value. Overexploiting species can lead to their extinction.
    - Ex. – American bison were hunted to the brink of extinction.
- Habitat loss – if a habitat is destroyed or disrupted, native species must relocate or they could die
    - Ex. – clearing areas of tropical rainforests displaces native species
- Fragmentation of habitat – separation of an ecosystem into small pieces of land. Smaller areas of land support fewer species and introduce barriers for individuals in a species to reproduce. Thus, genetic diversity may occur in the separated populations.
    - Ex. – Constructing roads through a forest divides the forest into smaller areas.
- Pollution – pollution changes the composition of air, soil, and water, which can harm species.
    - *Biomagnification* – as toxins make their way through each trophic level of the food web, their concentration increases
        - Ex. – DDT was a pesticide used from the 1940s through the 1970s that washed into the water supply. DDT made its way through the food chain from producers to zooplankton to small fish to large fish to bald eagles. DDT was so concentrated in the tissues of bald eagles that it almost led to their extinction.
    - *Acid precipitation* – caused by burning fossil fuels and automobile emissions, among other things, which release compounds such as sulfur dioxide and nitrogen oxides into the air. Acid rain removes nutrients from the soil, which deprives plants of nutrients. Acid concentration can also accumulate in lakes, rivers, and streams.
    - *Eutrophication* – occurs when fertilizers, animal waste, sewage, or other substances rich in nitrogen and phosphorus flow into waterways causing algal growth. Algae use up oxygen causing other organisms in the water to suffocate.
- Nonnative species – species that are either intentionally or unintentionally transported to a new habitat. Introduced species may reproduce in large numbers because they have no natural predators in their new habitat. They may outcompete native species.

    - Ex. – Zebra mussels accidentally introduced to the Great Lakes from ships that came from Europe. They have exploded in population driving some native species to extinction.
- Climate Change – All life on Earth depends on climate conditions such as temperature and rainfall. Evidence show that the average temperature of the biosphere is increasing (*global warming*). Long-term changes in climate will affect ecosystems. Some organisms will be able to live in places where they once could not; other organisms may be threatened or become extinct.

Limiting Factors and Population Dynamics

Limiting factor – biotic or abiotic factor that restricts the number, distribution, or reproduction of a population. Drastic decreases in a species' limiting factors could lead to extinction.

- Abiotic limiting factors include sunlight, climate, temperature, water, nutrients, fire, soil chemistry, and space.
- Biotic limiting factors include other plant and animals species.
- Two types of limiting factors:
    - Density Independent – do not depend on population density to affect population size
        - Usually abiotic factors (drought, flooding, extreme hot or cold, tornadoes, hurricanes)
    - Density Dependent – depend on population density to affect population size
        - Usually biotic factors (predation, disease, parasites, competition)

Practice Questions

46. Agricultural runoff can carry fertilizers into lakes and streams. This runoff can cause algae populations to greatly increase. Which effect does this change in the algae population sizes **most likely** have on affected lakes and streams?
    a. An increase in water level
    b. An increase in water clarity
    c. A reduction in dissolved oxygen needed by fish and shellfish
    d. A reduction in temperature variations near the water's surface

47. A farmer observed that an increase in a field's soil nitrogen content was followed by an increase in producer productivity. What does this observation **most likely** indicate about the relationship between nitrogen and the producers in the field?
    a. Nitrogen is a biotic factor.
    b. Nitrogen is a limiting factor.
    c. Nitrogen became a surplus resource.
    d. Nitrogen became a selection pressure.