Understand the characteristics of the four major macromolecules

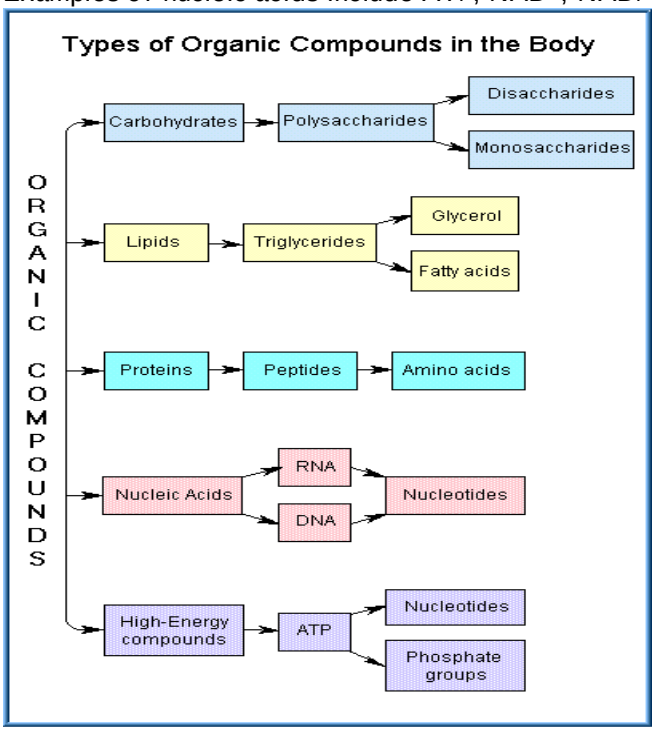
Carbohydrates, lipids, proteins, and nucleic acids are the foundations for the structure and function of every living cell in every organism. They are the building materials of the body and the storehouse for energy for every activity.

Carbohydrates - A carbohydrate is a simple sugar or a molecule composed of two or more simple sugars. In general, the ratio of carbon, hydrogen, and oxygen atoms is 1:2:1 in a carbohydrate molecule. There are three classes of carbohydrates: *monosaccharides, disaccharides,* and *polysaccharides.* Glucose, sucrose, starch, and cellulose are examples of carbohydrates. In all living organisms, carbohydrates, such as glucose, are broken down to provide usable chemical energy for cells. In plants, the carbohydrate cellulose is used for structural support in making cell walls. **"Saccharide"** means sugar. **"Mono"** means one. "**Di**" means two. **"Poly"** means many. A polysaccharide is a straight or branched chain of sugar units in which there may be hundreds or thousands of the same or different kinds of sugars bonded to one another.

Lipids - Lipids are organic compounds that have more carbon-hydrogen (C-H) bonds and fewer oxygen atoms than carbohydrates. They are extremely important for the proper functioning of organisms. Lipids are commonly called *fats* and *oils*. They are insoluble in water due to the nonpolarity of the molecules. Lipids are used by cells for long-term energy storage. Lipids are also a major component of cell membranes. *Waxes* are long-chain fatty acids attached to an alcohol. An example is *cutin* in plants. It helps the plants retain water.

Proteins - Proteins belong to the most diverse group. They are large, complex polymers essential to all life. They are composed of chains of amino acids made of carbon, hydrogen, oxygen, nitrogen, and sometimes sulfur. Proteins are important in muscle contraction, transporting oxygen in the blood, and the immune system. Proteins, like lipids, are an important component of cell membranes. Collagen, enzymes, hemoglobin, insulin, and antibodies are examples of proteins.

Nucleic Acids - Nucleic acids are complex macromolecules that store and transmit genetic information in cells in the form of a code. To form nucleic acids, four different kinds of *nucleotides* are strung together. A nucleotide is a small organic compound that consists of a five-carbon sugar, a nitrogen-containing base, and a phosphate group. Examples of nucleic acids include ATP, NAD+, NADP+, DNA, and RNA.



Functions:
1. Carbohydrates

2. Lipids

3. Proteins

4. Nucleic Acids

Understand the characteristics of enzymes

All cells maintain, increase, and decrease the concentration of substances by developing metabolic pathways. A metabolic pathway is an orderly sequence of reactions with specific **enzymes** that act at each step along the way. Enzymes are catalytic molecules. That is, they speed up specific reactions without being used up in the reaction. Enzymes are proteins.

All enzymes have three special features in common:

1. Enzymes **do** not create processes that would not take place on their own. They just make it take place faster!
2. Enzymes are not permanently altered or used up in reactions.
3. Each enzyme catalyzes only one specific type of reaction, but can catalyze over again and again.

Substrates are molecules that a specific enzyme can chemically recognize and to which it can bind. Substrates undergo chemical changes to form new substances called **products**.

Each substrate fits into an area of the enzyme called the *active site*. It is like a **lock-and-key mechanism**. Once the enzyme-substrate complex is together, the enzyme holds the substrate in a position where the reaction can occur. Once the reaction is complete, the enzyme *unlocks* the product & the enzyme is free to facilitate another reaction. The rate of a reaction depends in part on the concentration of the enzyme. If the enzyme is diluted, its concentration is lowered, which slows the reaction rate.

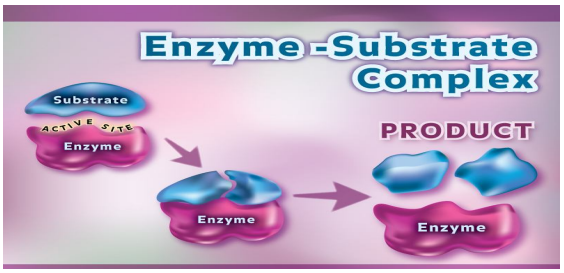
Once substrates have reached the transition state, they react spontaneously. Substrate molecules must collide with a minimum amount of energy to reach the transition state.

This amount of energy is called the **activation energy**. It is like traveling over a hill. The lower the hill, the less energy it takes to get to the top and the faster you can go over it. The higher the hill, the more energy it takes to get to the top and the longer it will take you to go over it.

It takes less energy to boost reactants to the transition state of a lower energy hill. The reaction will proceed more rapidly.

Enzymes are critical to life processes. Carbonic anhydrase is an enzyme that speeds up the process by which carbon dioxide leaves cells and enters the bloodstream so it can be removed from the body. The enzyme lipase is produced by the pancreas and functions in the digestion of lipids. RNA polymerase is an enzyme that facilitates the process of transcription. Some diseases, such as Tay-Sachs and phenylketonuria, occur when the body fails to make a critical enzyme. The human genetic disease Tay-Sachs can cause seizures, blindness, and eventual death because a critical enzyme that breaks down lipids in brain cells does not function properly. In another human genetic disease, PKU (or phenylketonuria), an enzyme is either lacking or totally deficient that is needed to break down one amino acid (phenylalanine) to form a second essential amino acid (tyrosine). Without this enzyme, phenylalanine and other chemicals accumulate in the blood and body tissues and cause eventual death.

Explain how enzymes and substrates react in this diagram. What changes, etc…?



1. List 3 characteristics of enzymes.

2. What do enzymes do to the rate of reaction?

3. What do enzymes do the activation energy?

Differentiate between prokaryotic and eukaryotic cells

Biologists once looked for clues to aging and diseases by studying organs, tissues, and cultures of cells. With the development of the microscope, biologists focused their attention upon smaller elements of living things: the organelles within the cell. With advancements in the microscope, biologists discovered two types of cells: **prokaryotic** and **eukaryotic cells.**

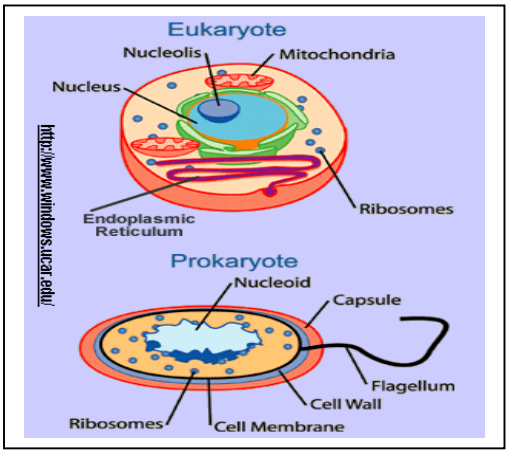
PROKARYOTES:
Single-celled organisms that lack internal structures surrounded by membranes.
They lack a true nucleus.
Examples: bacteria

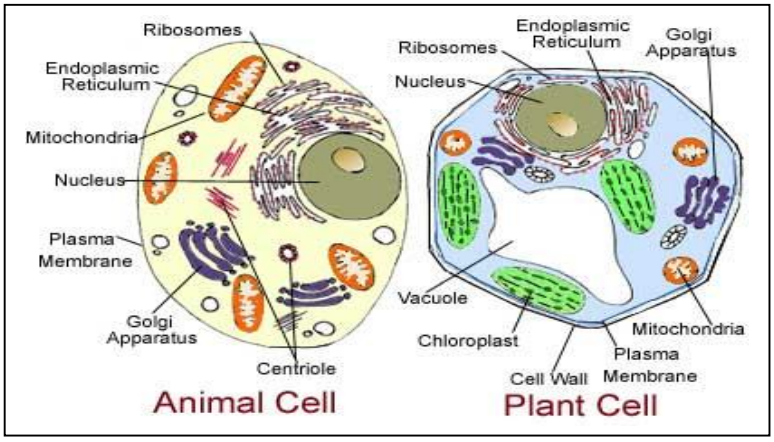
EUKARYOTES:
Single-celled and multi-cellular organisms that have cells containing internal, membrane-bound structures.
They have a true nucleus containing the cell's DNA.
Examples: plants, animals, fungi, protists

DIFFERENCES

Prokaryote

Eukaryote





Cells must have boundaries.
Cells have **cell membranes** that serve as a boundary between the cell and its external environment. The cell membrane is flexible and allows the cell to vary its shape if necessary. It controls the movement of materials entering and exiting the cell. The cell membrane also helps maintain a chemical balance within the cell. An additional boundary outside of the cell membrane is the **cell wall**. The cell wall is thicker than the cell membrane and is inflexible. It protects the cell and gives the cell its shape. Plants, fungi, most bacteria, and a few protists have cell walls. Animal cells ***do not*** have cell walls.

ORGANELLE	FUNCTION(S)
Chloroplast	
Golgi	
Mitochondria	
Nucleus	
Ribosomes	
Vacuole	
Cell wall	
Endoplasmic reticulum	

ORGANELLE	FUNCTION(S)
Cell Membrane	
Cytoplasm	
Lysosomes	
Nucleolus	
Lysosomes	
Centrioles	
Cytoskeleton	
Cilia & Flagella	

Comprehend the importance of homeostasis

Organisms maintain their internal equilibrium by responding and adjusting to environmental stressors. For example, aquatic organisms must respond to changes in water temperature, sunlight, chemicals, and other organisms. All organisms must adjust and respond to changes in their environment. Failure to **do** so may result in death. Living cells maintain a balance between materials entering and exiting the cell. Their ability to maintain this balance is called **homeostasis**. It is important for a cell to control internal concentrations of water, glucose, and other nutrients, while eliminating cellular wastes.

Cell Membrane - The cell membrane is to control what comes into and goes out of a cell. In this way, the cell membrane helps to maintain the proper concentrations of substances inside the cell. MAINTAIN HOMEOSTASIS!! **Selective permeability** is the property of the membrane that allows certain materials to pass through the cell while keeping others out. It also allows different cells to perform different activities within the same organism.

Passive Transport

Passive transport is the movement of materials across the cell membrane without the use of the cell's energy.

Diffusion: the movement of dissolved molecules from an area of high to an area of lower concentration

Osmosis: the diffusion of water molecules from an area of high to an area of lower water concentration

Facilitated diffusion: occurs when a carrier molecule embedded in the cell membrane transports a substance across the membrane by means of diffusion

Active Transport

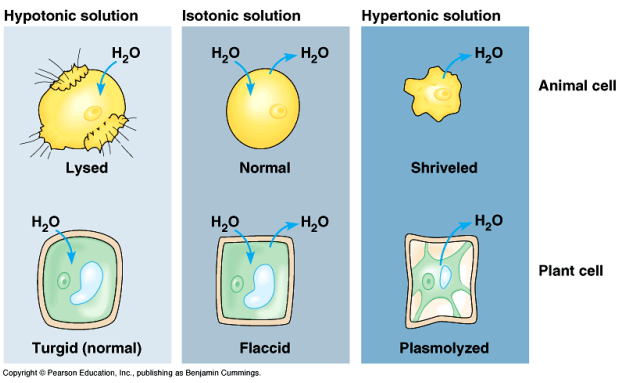
Active Transport is the process by which materials are transported through the cell membrane against a concentration gradient, as in the sodium-potassium pump. Active transport moves large molecules from lower concentration to higher concentration.

Endocytosis: a process in which a cell surrounds and takes in material from its environment

Exocytosis: a process by which a cell surrounds and removes materials from inside the cell

Comprehend the importance of water on life processes

Water is essential for life on Earth. All living cells contain mostly water. The transport of important materials for life's processes depends on the properties of diffusion and osmosis. Carbon dioxide, oxygen and small lipids diffuse easily across the cell membrane. Osmosis through cell membranes happens in two ways—water diffuses directly through the cell membrane and through water channels in the cell membrane called aquaporins.



How is the water moving and what happens to a cell placed in these solutions?

DIFFERENCES

Passive	Active

Explain the flow of energy needed by all organisms to carry out life processes

Energy in a Cell

All life on Earth depends on the flow of energy. The primary source of this energy is the Sun. Plants and other photosynthetic organisms (for example, cyanobacteria, or blue-green algae) are the entry point for this flow of energy. The process of photosynthesis supports almost all life on Earth directly or indirectly. Photosynthesis is the process that converts solar energy to chemical energy in the form of carbohydrates. Carbohydrates are then broken down by the metabolism of the cells of these photosynthetic organisms or by the cells of other organisms, such as animals, fungi, or microbes that consume plant materials. In all cells, the processes of life are constantly moving and rearranging atoms, ions, and molecules. All this biological work requires energy.

Understanding ATP

ATP, **adenosine triphosphate**, is a special molecule that stores and releases the energy in its bonds in response to the energy need of the cell. Cells work constantly to maintain a vast supply of this energy storage molecule. The stored energy is released when ATP is split into ADP, **adenosine diphosphate**, and an inorganic phosphate. Remember that ATP and ADP are nucleotides. When the appropriate enzyme is present, the terminal phosphate group of an ATP molecule can be transferred to a variety of other compounds. This process is known as **phosphorylation**. The energy released when ATP is split is stored in other energy-intermediate molecules and is used to power other biological processes. Most of these processes are energy-requiring biological reactions in cells.

Consider the following cycle:
By removing a phosphate group, energy is released for chemical reactions to occur in the cell, and ATP becomes ADP. When the cell has an excess of energy, the energy is stored in the bond when the phosphate group is added to the ADP. ATP is the major energy link between energy-using and energy-releasing reactions. The amount of energy released when the phosphate group bond breaks is suitable for use in most cellular reactions.

Examples of Ways That Cells Use Energy

Cells use energy to make new molecules, including enzymes, and to build cell organelles and membranes. Cells also use energy to maintain homeostasis. Some cells, such as muscle cells, use energy from ATP in order to move. Nerve cells are able to transmit impulses by using ATP to power the active transport of certain ions. Lightning bugs, certain caterpillars, and some deep-sea organisms produce light by a process known as **bioluminescence**. The light that is produced is a result of a chemical reaction that is powered by the breakdown of ATP.

Trapping Energy--Photosynthesis

Many of the carbon atoms and oxygen molecules that you breathe once cycled through the tissues of a plant. Plants, algae, and other photosynthetic organisms are important to the maintenance and balance of life on Earth. They convert solar energy to chemical energy in the form of carbohydrates. Photosynthetic organisms must also break down carbohydrates to form ATP. These carbohydrates are usually in the form of simple sugars, mainly glucose. The process of breaking down carbohydrates for ATP is called **cellular respiration**. **Autotrophs** are organisms that can manufacture their own energy-providing food molecules. Most autotrophic organisms trap energy from the Sun and use this energy to build carbohydrates in a process known as **photosynthesis**. This trapped energy is used to convert the inorganic raw materials CO_2 and H_2O to carbohydrates and O_2. The key to this process is the pigment **chlorophyll**, which is the molecule in the chloroplasts of plants that absorbs energy from sunlight.

The general equation for photosynthesis is as follows:

$$6CO_2 + 6H_2O + \text{energy (sunlight)} \longrightarrow C_6H_{12}O_6 + 6O_2$$

Two Main Reactions of Photosynthesis:

1. Light reactions – these reactions split water molecules, providing hydrogen and an energy source for the Calvin cycle. Oxygen is given off.
2. Calvin cycle – the series of reactions that form simple sugars using carbon dioxide and hydrogen from water.

The Light Reaction - Light reactions take place in chloroplasts. Chloroplasts contain chlorophyll and other light-absorbing molecules which absorb energy from sunlight. Inside the chloroplast is a gel-like matrix called the stroma, which contains the ribosomes, DNA, and material for carbohydrate synthesis. The most prominent structures in the chloroplasts are stacks of flattened sacs called grana. Each of these grana contains **thylakoids**, which are interconnected. It is in the thylakoids that the light reaction of photosynthesis takes place. The energy from sunlight causes electrons in chlorophyll to gain energy and pass the energy to other molecules which are used to make ATP. Electrons, along with hydrogen ions from water, are added to NADP+ to produce NADPH. NADP+ is the oxidized form (the form that lacks electrons) of NADPH. NADPH is the reduced form (the form that has electrons) of the same molecule. NADPH carries the energy to the Calvin cycle.

The Calvin Cycle - The Calvin cycle reaction takes place in the stroma of the chloroplasts. Carbon dioxide from the air combines with hydrogen from the light reaction to form simple sugars. These sugars are used to make other carbohydrates such as complex sugars, starches, and cellulose. An enzyme adds the C atom of CO_2 to a 5-C molecule. The carbon is now fixed in place in an organic molecule. This process is known as **carbon fixation**. When the carbon combines with the 5-C molecule, a 6-C molecule forms and immediately splits into two 3-C molecules. The two 3-C molecules formed are called PGA molecules (phosphoglyceric acid). These molecules are converted into two 3-C sugars, PGAL (phosphoglyceraldehyde), using the hydrogens of NADPH + H+ and energy from ATP. Some of these sugars leave the cycle and are used to form other complex carbohydrates.

Three Main Reactions of Cellular Respiration:
1. Glycolysis – break down glucose into pyruvic acid
2. Krebs Cycle – Breaks down pyruvic acid to produce molecules used in the electron transport chain.
3. Electron Transport Chain – a series of proteins in the mitochondrial membranes that convert ADP to ATP by transferring electrons.

Using Energy––Cellular Respiration

The general equation for cellular respiration is as follows:

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ + energy (36 ATPs)

Once light energy is used to make carbohydrates, any organism can then use the carbohydrates for energy for life processes. Organisms get energy from carbohydrates through the process of cellular respiration to make ATP.

Glycolysis – Glycolysis takes place in the cell's cytoplasm and is anaerobic (w/o oxygen). First, glucose enters a cell by active transport. The glucose is broken down by enzymes into pyruvic acid. Glycolysis produces 2 ATP molecules.

Krebs Cycle - The Krebs cycle takes place in the mitochondria and breaks down the products of glycolysis, releasing CO2 and 2 ATP. The main function of the Krebs cycle is to move high energy electrons to molecules for the electron transport chain, the second main part of cellular respiration.

Electron Transport Chain - The electron transport chain takes place in and across the inner membrane of the mitochondrion. High energy electrons travel through the proteins and makes 34 ATPs. The process of cellular respiration releases carbon dioxide and water.

1. Explain what occurs in the 2 steps in photosynthesis.

2. Define photosynthesis.

1. Explain what occurs in the 3 steps in respiration..

2. Define cell respiration.

Compare the structures and functions in organisms of different kingdoms
Understand the evolutionary basis of modern classification systems

The Six Kingdoms

The number of kingdoms in early classification systems varied greatly. In Aristotle's time, scientists had not yet studied geological time frames. These early classification systems were based on structural differences that were seen. As scientists discovered evolutionary relationships among species, the classification system changed or was modified to fit these new discoveries. Comparisons of DNA sequences and similarities in proteins have helped to identify relationships between different organisms. From Aristotle's two divisions, plants and animals, we now have the **six kingdom system**.

All prokaryotic organisms are either in the kingdom **Archaebacteria** or the kingdom **Eubacteria** (true bacteria). The Eubacteria contain all of the bacteria that cause disease as well as the bacteria that are beneficial. The Archaebacteria are mainly found in extreme environments such as the deep oceans, hot springs, and swamps. The **Protists** kingdom contains eukaryotic organisms that are either unicellular or multi-cellular. They lack complex organ systems and live in moist environments. **Fungi** are consumers that do not move. They are unicellular or multi-cellular heterotrophic eukaryotes that absorb nutrients from decomposing dead organisms and wastes in the environment. **Plants** are photosyntheticmulti-cellular eukaryotes. Most plants have cellulose cell walls and tissues that have been organized into organs and organ systems. **Animals** are multi-cellular eukaryotic consumers. Animal cells do not have cell walls. Their tissues have been organized into complex organ systems.

Taxonomy is the branch of biology dealing with the grouping and naming of organisms. The person who studies taxonomy is called a **taxonomist**. There is a vast array of organisms that we know of, but taxonomists are still identifying newly-discovered organisms. They compare the internal and external structures, analyze the chemical makeup, and compare the evolutionary relationships of species

Levels of Classification
Domain
Kingdom
Phylum
Class
Order
Family
Genus
Species

The Modern Classification System

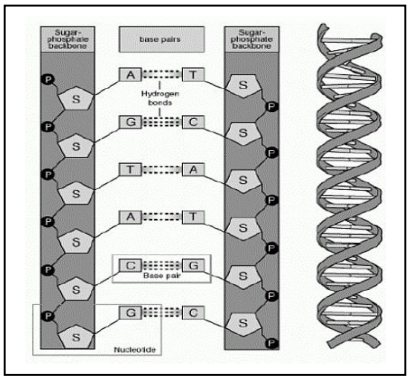
In an attempt to make sense of the diversity of life, one tool that scientists use is the classification system. **Classification** is the grouping of objects based on similarities. Modern classification uses the following levels to classify organisms:
All organisms are grouped into kingdoms based on genetic and anatomic similarities. At the phylum level, organisms are subdivided again based on evolutionary traits. Organisms are further divided into different classes based upon shared physical characteristics. Within each class, organisms are grouped into orders based on a more specific and limited set of characteristics. This subdividing and grouping has 7 levels in the modern classification system. The most specific level is Species. Members of a species are considered to be the same "kind" of animal and can reproduce with other members of the same species.

Compare and contrast viruses with living organisms

Viruses are infectious particles made of a protein shell called a capsid, which contains either DNA or RNA. The genetic material is single-stranded or double-stranded, depending on the kind of virus. Some viruses have an outer membranous envelope which covers the capsid. These viral envelopes, derived from the host cell membrane, may contain both viral and host cell lipids and proteins. Viruses are not considered living organisms because they are not cells and they cannot reproduce outside of a host cell. Viruses must infect a living cell, a host, in order to reproduce their viral genetic material and to make new viral proteins. Like living organisms, viruses contain genetic material (either DNA or RNA), can reproduce, respond to their environment, and evolve. Unlike living organisms, viruses are not cells, do not contain organelles, and are unable to reproduce in the absence of a host cell. Further, viruses are able to form crystals and still be viable. Living cells are not able to survive crystallization.

Distinguish between DNA and RNA
Explain the role of DNA in storing and transmitting cellular information

Genetics is the branch of biology that studies heredity, the passing on of characteristics (traits) from parents to offspring.



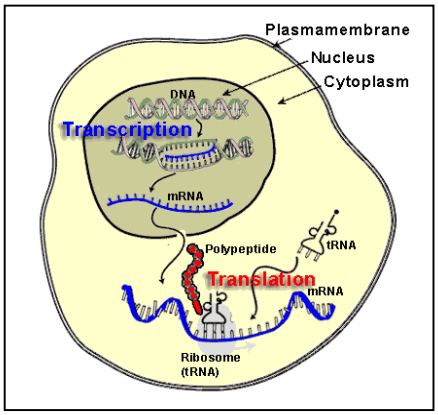
DNA

DNA forms a complex biological polymer called a **nucleic acid** used for information storage. Nucleic acids are made up of smaller subunits called **nucleotides**. The components of a DNA nucleotide are deoxyribose, a phosphate group, and a nitrogen base. DNA has four nitrogen bases—adenine (A), guanine (G), cytosine (C), and thymine (T). In DNA, nucleotides combine to form two long spiral chains called a **double helix**. The two strands of nucleotides are held together by hydrogen bonds between the nitrogen-containing bases. The sides of the ladder consist of phosphate groups alternating with five-C sugars called deoxyribose. The hydrogen bonding in DNA allows for only certain base pairings. In DNA, adenine bonds with thymine (A-T), and guanine bonds with cytosine (G-C). DNA carries information in a triplet code; each sequence of three nucleotides codes either for a particular amino acid, or indicates the beginning or end of a sequence. The genetic code (order of nucleotides) is unique for each organism.

DNA has the unique ability to make an exact copy of itself in a process called **replication**. During DNA replication, an enzyme breaks the hydrogen bonds between nitrogen bases that hold the two DNA strands together. This enzyme "unzips" the two DNA molecules, allowing free nucleotides to bond to the two single strands by base-pairing. This process will continue until the entire molecule has been replicated. Each new strand formed is a complement of one of the original, or parent, strands. At the end of replication, there are two copies of the genetic information that will be passed on to new cells through mitosis or to new generations through meiosis. In eukaryotic cells, DNA is found inside the nucleus, coiled into chromosomes. Prokaryotes lack nuclei and their DNA is either attached to the cell membrane or is free floating in the cytoplasm.

RNA

RNA, like DNA, is made of nucleotides. The sugar in RNA is **ribose** and the nitrogen-containing base **uracil** replaces the thymine found in DNA. The uracil in RNA pairs with adenine during complimentary base pairing. RNA is a single strand of nucleotides.



Transcription is the process of using DNA as a template to make messenger RNA (mRNA), only one strand of nucleotides is formed. The mRNA carries the genetic information from DNA to the ribosome in the cytoplasm.

Translation is the process of converting the information in the mRNA into a sequence of amino acids that make proteins. Transfer RNA (tRNA) brings the amino acids to the mRNA at the ribosomes so protein synthesis can take place. To have the correct translation of the code, mRNA **codons** must join with the correct **anticodon** of the tRNA. A codon is a group of 3 nitrogenous bases on an mRNA molecule that carries the code for a specific amino acid. An anticodon is a set of 3 nitrogenous bases on a tRNA molecule that matches a codon on an mRNA molecule. The amino acids are lined up in the coded sequence to form a specific protein.

DNA	**Differences**	RNA

1. Define replication. When and where does it occur in the cell?

2. Define transcription and translation. Include RNA's involved in these processes. Where does each step occur in the cell?

Using Mendel's laws, explain the role of meiosis in reproductive variability
Describe the relationships between changes in DNA and appearance of new traits

Gregor Mendel, an Austrian monk, was the first to succeed in predicting how traits are carried from one generation to the next. He used pea plants in his experiments because they reproduce sexually. He was very careful to study one trait at a time to control the variables. He would manipulate flower parts in order to fertilize the female gamete with the male gamete in the desired parent plants. Mendel discovered that when he crossed tall plants with short plants, the first generation of offspring (F1) were all tall. When he let the F1 plants self-pollinate, Mendel found that three-fourths of their offspring (F2) were tall and one-fourth of the F2 plants were short. The short trait had reappeared in the second generation (F2). Mendel came to the conclusion that each organism has two factors for each of its traits. Mendel called the trait that appeared in the first generation **dominant** and the trait that seemed to disappear **recessive**. Today, scientists call these factors **genes**. Genes are located on the chromosomes and can exist in alternative forms called **alleles**. Alleles are found on different copies of chromosomes, one from the female and the other from the male.

The **genotype** is a list of the alleles for a particular trait in an organism. The **phenotype** is the physical appearance of an organism, or how the alleles influence the function of that particular gene in the organism. If the two alleles in a pair are identical, then the trait is called **homozygous**. If the two alleles are different, then the trait is called **heterozygous**. Genetic crosses that involve one trait are called **monohybrid** crosses, while **dihybrid** crosses involve two traits. Outcomes of genetic crosses can be predicted by using the laws of probability. Using a Punnett square will give the possible results of genetic crosses.

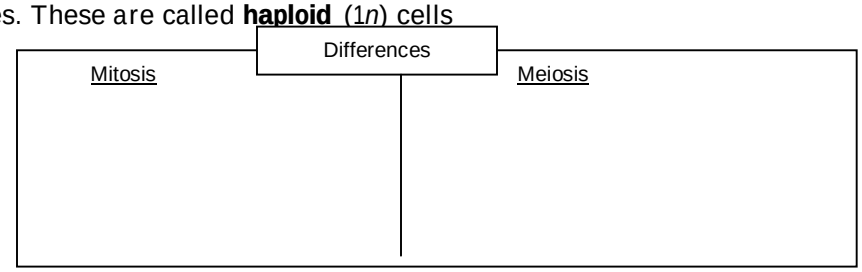
Genetic terms
? Allele
? Dihybrid
? Dominant
? Gene
? Genotype
? Heterozygous
? Homozygous
? Monohybrid
? Phenotype
? Recessive
? Trait

Mendel's work can be summarized in three laws:
- **Law of Dominance** states that the dominant allele will prevent the recessive allele from being expressed. The recessive allele will appear ONLY when it is paired with another recessive allele.
- **Law of Segregation** (separation) states that gene pairs separate when gametes are formed, so each gamete (sex cell) has only one allele of each pair.
- **Law of Independent Assortment** states that different pairs of genes separate independently of each other when gametes are formed.

Complete a monohybrid cross using this example:
In whales thin skin is recessive to thick skin. Cross a heterozygous whale with a thin skin whale. Identify the phenotype and genotype.

Meiosis is the process by which gametes (sex cells) are produced. In males, gametes are called sperm, and in females, they are called eggs. Meiosis reduces the number of chromosomes in the gamete to one-half the number of chromosomes in the parent's body cells. When fertilization occurs, the union of two gametes, a zygote is formed. Fertilization restores the original chromosome number in the resulting zygote (new individual). Meiosis occurs in two phases, meiosis I and meiosis II.

Meiosis occurs only in the formation of sex cells and consists of 2 cell divisions but only 1 chromosome replication.
- The first meiotic division produces two cells containing half the number of double stranded chromosomes. These are called **diploid** (2*n*) cells.
- The second meiotic division results in the formation of four cells, each containing half the number of single-stranded chromosomes. These are called **haploid** (1*n*) cells



Sources of Variation during Meiosis

The process of meiosis provides the opportunity for the shuffling of chromosomes and the genetic information they contain. The way that the chromosome pairs line up at the equator during meiosis influences how they are distributed to the gametes. For example, Mendel studied the pea plant that has seven pairs of chromosomes. Each of these seven pairs of chromosomes lines up during meiosis in two different ways, producing 128 (27) different combinations of traits. The number of possible combinations will greatly increase as the number of chromosomes increase within a given species. Human gametes have 23 chromosomes. So the number of different kinds of genetic combinations a person can produce is astounding—more than 8 million! When fertilization occurs, 223x 223 different genetic combinations can occur. That is 70 trillion!

Another source of variation during meiosis is **crossing over**. Crossing over occurs when two chromosomes physically overlap and exchange chromosome material. This process occurs more often on some chromosomes than other chromosomes and changes the DNA sequence within each chromosome. This results in an endless number of different possible genetic combinations. Whether by crossing-over or by independent assortment of homologous chromosomes, the end result is a re-assortment of chromosomes and the genetic information they carry. This is known as **genetic recombination**.

Explain how crossing over and independent assortment lead to genetic variation in the daughter cells.

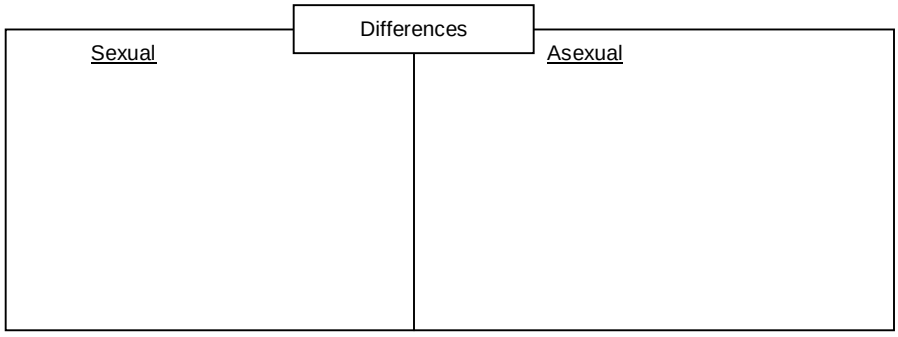
Compare the advantages of sexual and asexual reproduction in different situations

Advantages of Sexual and Asexual Reproduction

Single-celled and many multi-celled organisms reproduce asexually by a process called **mitosis**, which is simple cell division. In mitosis, DNA is divided equally between two daughter cells. In mitosis in eukaryotes, the DNA is sorted into the two new nuclei formed. A separate process divides the cytoplasm in two. Mitosis keeps the number of chromosomes constant from one cell generation to the next. In multi-cellular organisms, cell division allows them to grow (i.e., increase the size of the organism), develop from a single cell into a multi-cellular organism, and make other cells to repair and replace worn-out cells.

Asexual reproduction does not require another partner, is quicker than sexual reproduction, and the resulting organism is identical genetically to the parent organism. Organisms that reproduce asexually can produce many identical offspring in a short period of time. Asexual reproduction is an advantage in a stable environment where the parental genotype is well-suited. Many colonizers of new environments reproduce asexually.

Sexual reproduction involves much more time than asexual reproduction. Gametes must be formed through the process of meiosis and mating must occur between two organisms of different sexes. There is also time involved in the growth and development of the offspring. The benefit of sexual reproduction is the genetic variability that results from the process of meiosis. Genetic recombination allows offspring greater diversity and increases the likelihood that some offspring will have more advantageous traits than the parents. Sexual reproduction is an advantage in a rapidly changing environment because the diversity of the population increases the possibility that some organisms will both survive and reproduce.



DNA mutations

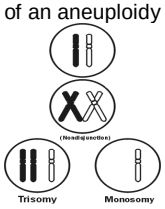
Every so often genes do change. Changes in the nucleotide sequence of a DNA molecule are known as gene **mutations**. Mutations may cause a change in the protein resulting from the genetic code for that gene. Some mutations are the result of exposure to agents such as ultraviolet light, ionizing radiation, free radicals, and substances in tobacco products and other chemical compounds. These agents that harm DNA are called **mutagens.** Mutations can also occur in the absence of these mutagens. Spontaneous mutations may occur as a result of replication errors.

Point Mutations - Base pair substitutions occur when one nucleotide base is replaced by another. This change may lead to the substitution of one amino acid for another during protein synthesis. An example of this is sickle-cell anemia, a genetic disorder that has structural and physiological consequences. A **base insertion** mutation is an addition of an extra nucleotide base into the DNA sequence. A **base deletion** mutation is the removal of a nucleotide base from the DNA sequence. In both base insertion mutations and base deletion mutations, a frame shift occurs. A deletion or insertion in a gene region will shift this reading frame, causing an abnormal protein to be synthesized. Whether a gene mutation is harmful, neutral, or beneficial will depend on how the resulting proteins interact with other proteins and with the environment in which they are placed.

1. What is a mutation? List 2 mutagenic factors and explain how these factors can affect protein synthesis.

2. How do point mutations affect the proteins that are produced?

Define nondisjunction. Use the diagram to help explain how nondisjunction can lead to an aneuploidy cell. List an example of an aneuploidy disorder.



Examine the use of DNA technology in forensics, medicine, and agriculture

DNA Technology and Genetic Engineering

New DNA technologies have resulted in advances in medicine, forensics, and agriculture. Certain genetic diseases may be cured by reinserting a corrected gene back into the patient to replace a damaged gene. Forensic labs use DNA technology to identify people through DNA fingerprinting. Crime scene evidence such as blood or hair samples can be used to connect suspects to the crime by looking for DNA sequence similarities. Plant biologists have used DNA technology to produce plants with many desirable traits. These include increased disease resistance, herbicide resistance, and increased nutritional content.

Explain how transgenic organisms are impacting our medical and agriculture in America.

Today, researchers use recombinant DNA technology to analyze genetic changes. They cut, splice together, and insert modified DNA molecules from different species into bacteria or other types of cells that rapidly replicate and divide. The cells copy the foreign DNA right along with their own DNA. An example of this is the gene for human insulin. When the gene is transferred into a bacterium, the bacterium will use the "recombined" genetic code to produce human insulin. This is how human insulin is mass-produced. This insulin has saved the lives of many people with diabetes. Not only does genetic engineering have applications in medicine and the environment, it also has uses in industry and agriculture. Sheep are used in the production of alpha-1 antitrypsin, which is used in the treatment of emphysema. Goats are also producing a human protein used in the treatment of cystic fibrosis. In the plant world, the buds of cotton plants are vulnerable to worm attacks. The buds of a genetically modified cotton plant resist these worms, resulting in increased cotton production. These gene insertions are ecologically safer than pesticides because they affect only the targeted pest. Scientists today have developed genetically altered bacteria to eat up oil spills, manufacture alcohol and other chemicals, and process minerals. There is, however, concern about possible risks as genetically engineered bacteria are introduced into the environment. It is important to remember that recombinant DNA technology and genetic engineering have a great potential for application in medicine, agriculture, and industry. As with any new technology, the potential risks must be taken into account, including social and environmental risks.

Investigate the relationships among organisms, populations, communities, ecosystems, and biomes

Ecology is the scientific study of the interactions between different kinds of living things and their environment. Ecology is the study of our planet—Earth. An **ecologist** is a scientist who studies ecology. The term **biosphere** includes all organisms and the environments in which they live (biotic and abiotic factors). Organisms adapt to survive particular environments. Penguins are adapted to live in cold water and ostriches are adapted to live on dry savannas. They have adaptations for obtaining food, for protection, and for reproducing. Within an ecosystem, two types of environmental factors can be found: biotic factors and abiotic factors. All the living organisms in an ecosystem are known as **biotic factors**, while the nonliving factors are known as **abiotic factors**.

Organization of Life

Ecologists study the interactions of organisms at five main levels of organization. Yet all the levels are interdependent. To study only one level would not give the ecologist the whole picture.

Organisms — Ecologists study the daily movements, feeding, and general behavior of individual organisms.

Populations — A population includes all the organisms in the same species in a given area. Ecologists study the relationships between populations and the environment, focusing on population size, density, and rate of growth.

Communities — A community is a collection of populations that interact with each other in a given area. Ecologists study the interactions between the different populations in a community and the impact of additions to or losses of species within communities.

Ecosystems — An ecosystem includes all biotic and abiotic factors in a given area. Ecologists study interactions of the biotic and abiotic factors of an ecosystem with emphasis on factors that may disrupt an ecosystem.

Biomes — A group of ecosystems in the same region having similar types of vegetation governed by similar climatic conditions. Ecologists study biomes such as tropical rain forests, prairies, and deserts.

Populations

A **population** is a group of organisms of one species that lives in the same place at the same time. Organisms in a population compete for food, water, mates, and other resources. The way that organisms in a population share the resources of their environment will determine how far apart the members of the population will live and how large that population will be. **Population density** is the number of organisms living in a given area. Some organisms, such as tigers, require much space, while others, such as pine trees, can live close together. Keep in mind that some species have adaptations that minimize the competition within a population. An example is the frog. The first stage of a frog's life is a tadpole. Tadpoles are completely different from adult frogs. Their food source is different. They have gills and live in the water. Many insects have juvenile stages that require very different resources from their adult counterparts. This minimizes competition within a population.

Communities

A population usually does not live independently of other species. Each population is connected. A **community** is made up of several populations interacting with each other. This is where balance becomes very important. If there is a change in one population, it can dramatically affect the others living within the community. An increase in one population can cause a decrease in another, sometimes with devastating effects. This change in population size is known as **growth rate**. A growth rate can be positive, negative, or zero. If a population is provided with ideal conditions, it will increase in number. Healthy organisms reproduce at a rate greater than their death rate. As long as these ideal conditions continue, as the population grows larger the rate of growth increases. This growth is called **exponential growth**. This pattern of exponential growth is in the shape of a J curve. But growth has limits. If bacteria were allowed to continually reproduce, the planet would be overrun with bacteria! However, as the population increases, the resources that are available become limited, and the growth of the population slows and begins to stabilize. This pattern of **logistic growth** is an S-shaped curve. The point at which the population becomes stable is known as the **carrying capacity**. It is the maximum stable population size an environment can support over time.

When a population reaches its carrying capacity, a number of factors help stabilize it at that size. They are called density-dependent and density-independent limiting factors. Within each community, particular species have particular jobs to help maintain balance. An example would be a forest community. On a forest floor fungi have the job of breaking down the organic material from a decaying log. Underneath the log are worms, centipedes, and beetles also at work. At first glance, it looks like they are all competing for food. But a closer look reveals that they are feeding on different things, in different ways, and at different times. The role that a species plays in its community is called its **niche**. A niche includes not only what an organism eats, but also where it feeds and how it affects the energy flow in an ecosystem. The place where the organism lives is called its **habitat**. Even though several species may share a habitat, the food, shelter and other resources of that habitat can be divided into several niches.

Density-Dependent Limiting Factors
Competition
Predation
Parasitism
Crowding/Stress

Density-Independent Limiting Factors
Weather
Fires
Droughts/Floods
Human Activities

Ecosystems

Ecologists also study the interactions between populations (biotic factors) and their physical surroundings (abiotic factors). An **ecosystem** is the interactions among the populations in a community and the physical surroundings of the community. Earth supports a diverse range of ecosystems. The type of ecosystem in a particular part of the world largely depends on the climate of that region. Ecosystems are identified by their climax communities.

Biomes

Biomes are a group of ecosystems in the same region having similar types of vegetation & similar climatic conditions.

Tundra
Abiotic Factors: 40 C to 10 C, annual precipitation is less than 25 cm, windy, permafrost
Biotic Factors: vegetation—nearly treeless, mainly grasses, and lichens; animals—arctic hare, lemming, arctic fox, snowy owl

Tropical Rain Forest
Abiotic Factors: 20 C to 30 C, annual precipitation is greater than 200 cm
Biotic Factors: vegetation—broad-leafed evergreen trees, ferns; animals—monkey, tapir, flying squirrel, birds/parrots, jaguar

Desert
Abiotic Factors: from 30C to 38C in cool deserts to 20C up to 49C in hot deserts; annual precipitation < 25 cm
Biotic Factors: vegetation—brush, cacti, small plants; animals—camels, antelope, rabbits, many reptiles, arachnids

Grassland
Abiotic Factors: 10 C to 25 C, annual precipitation 25 to 75 cm
Biotic Factors: vegetation—grasses, small plants, mosses, lichens; animals—grazing herbivores & herbivore predators

Taiga
Abiotic Factors: 30 C to 20 C, annual precipitation 30 to 50 cm, soil thaws completely in summer
Biotic Factors: vegetation—coniferous trees, ferns, mosses; animals—snowshoe hare, timber wolf, weasel, black bear, woodpecker

Temperate Deciduous Forest
Abiotic Factors: 10 C to 25 C, annual precipitation 75 to 125 cm
Biotic Factors: vegetation—birch, pine, oak, flowering plants, moss; animals—white-tailed deer, cottontail rabbit, squirrel, raccoon

Open Ocean
Abiotic Factors: temperature range varies with latitude and water depth, sunlight decreases with water depth, water density changes with temperature and salt content, etc.
Biotic Factors: phytoplankton, fish, dolphins, whales, seals, sea birds, etc.

Rocky Intertidal
Abiotic Factors: alternating exposure to direct sunlight and submergence, salinity changes, rocky substrate, etc.
Biotic Factors: algae, sea urchins, clams, mussels, starfish, etc.

Estuaries
Abiotic Factors: large fluctuations in salinity, extreme temperature changes, etc.
Biotic Factors: algae, mosses, aquatic plants, insects, shrimp, crabs, amphibians, birds, etc.

Freshwater
Abiotic Factors: seasonal fluctuations of depth and temperature
Biotic Factors: freshwater plants, algae, insects, fish, wading birds, phytoplankton, zooplankton

Explain the flow of matter and energy through ecosystems

Energy Flow

Energy is constantly flowing through ecosystems. The primary source of this energy is the Sun. Plants and some bacteria are **producers.** Producers harness the Sun's energy to make energy-rich molecules that they and all other organisms can use to make living tissues. The process of photosynthesis uses the Sun's energy to convert carbon dioxide and water into glucose and oxygen. Glucose is the molecule that provides all organisms with a source of energy. Producers are also called **autotrophs**, meaning "self-feeding" because they do not need other organisms to provide them with energy-rich molecules. Because animals cannot harness energy from the Sun, they need to eat other organisms to obtain energy and matter. Animals are **consumers**. They are also known as **heterotrophs**,

Herbivores eat plants
Carnivores eat other animals
Omnivores eat both plants and animals
Decomposers break down dead organisms (bacteria)

Animals store energy in their bodies in the forms of complex carbohydrates, fats, and proteins. **Decomposers** are organisms that feed on dead bodies of animals and plants or on their waste products. Organisms are grouped into **trophic levels** based on their source of energy—organisms with the same energy sources are on the same trophic level. Because energy cannot be recycled, there must be a way for it to move through an ecosystem. As sunlight hits the Earth, the energy flows first to primary producers, then to consumers, and finally to decomposers. This is called a **food chain**. A food chain shows how energy and matter flow through an ecosystem.

A food chain is a simplified way for ecologists to study how energy and matter flow. But it is not always that simple. Relationships exist between organisms that feed on more than one species. In an actual ecosystem there are many more plants and animals involved. A more complex interconnected system of food chains is called a **food web**. Ecologists use energy pyramids to show how energy decreases at each succeeding trophic level. The total energy transfer from one trophic level to the next is only about 10%. Not all the food consumed at each level is actually used for growth. Every time one organism eats another, most of the energy is used for energy by the organism or lost as heat rather than being stored as living tissue. Ecologists construct energy pyramids based on the available energy at each trophic level. This explains why population sizes decrease through the trophic levels.

Recycling of Matter

Unlike energy, which flows in one direction through an ecosystem, matter is recycled. Matter (or elements)cycles from one organism to another through food webs. Matter cannot be replenished in an ecosystem, unlike the energy from the Sun. For example, carbon is found in the environment as carbon dioxide (CO_2) gas. From the atmosphere, carbon dioxide is used in photosynthesis to form sugar. Respiration and decay are two ways that carbon returns to the atmosphere as a gas. Carbon also returns to the atmosphere when fossil fuels are burned.
As a second example, nitrogen gas makes up 78% of Earth's atmosphere, but it is in an unusable form. Lightning and some bacteria convert atmospheric nitrogen into usable nitrogen-containing compounds. Plants use these nitrogen compounds to make proteins and nucleic acids. Herbivores eat the plants and convert plant proteins into animal proteins and nucleic acids. Organisms return nitrogen to the atmosphere through decay.

Relate environmental conditions to successional changes in ecosystems

Succession

Ecosystems are constantly changing. Some changes happen quickly, such as a forest fire, flood, or volcanic eruption. Some changes happen slowly over a period of time, such as new saplings growing into tall, mature trees. When an ecosystem changes, the organisms in that ecosystem may need to change to survive. Succession is the natural change that takes place within a community of an ecosystem. There are two types of succession that ecologists study.

Primary succession is the gradual development of a new community where no organisms have lived before. An example is the changes that take place after a volcanic eruption and the lava flow cools, hardens, and weathers. In 1963, scientists were able to observe the birth of a new volcanic island, named Surtsey. The island measured 1 square mile. Seabirds were the first to arrive. Seeds, whether airborne or "hitchhikers" on the feathers of the birds, then reached the island. The first plant, a sea rocket, bloomed in 1965. Spiders were visible, and lichens and mosses soon grew. As these pioneer organisms died, their remains formed soil. Seals used Surtsey's beaches to have their young. However, over time, Surtsey has lost about one-fourth of its mass due to erosion.
Eventually, primary succession slows down and the community becomes stable. This community is known as a **climax community**.

Secondary succession occurs when a natural disaster or human activity partially destroys a community. Like primary succession, the community of organisms inhabiting an area changes over time. However, when secondary succession takes place, soil is already present. In secondary succession, the species replacing the pioneer species are often different. It also takes less time to become a climax community. In Yellowstone National Park, thousands of acres burned as a result of a lightning strike. After the fire, wildflowers grew first. Wildflowers do not usually grow in forest shade. Within three years, flowers, grasses, ferns, and saplings began to take hold and grow. Once the saplings began to grow, they shaded the forest floor and a mature forest began to develop.

Assess and explain human activities that influence and modify the environment

In today's world there is high demand for resources. There are natural resources that humans use everyday. When we turn on a light to read a book that is made from paper we are using natural resources. They include soil, plants, water, crops, animals, gas, and oil. A natural resource that is replaced or replenished by natural processes is known as a **renewable resource**.

Nonrenewable resources are those that are available only in limited amounts. Once they are gone, they are gone! Metals such as tin, silver, gold, uranium, and copper are some examples of nonrenewable resources. Minerals, such as phosphorus, are recycled so slowly in the environment that they are considered nonrenewable. Topsoil is also considered a nonrenewable resource because it takes hundreds of years to develop from decomposed plant material. Fossil fuels are always being formed, but they too are considered nonrenewable because they form slowly over long periods of time. Humans use them faster than they are replaced.

One of the major ways humans affect the environment is pollution. **Pollution** is the contamination of soil, water, or air and is a result of human activity. Although pollution has been around for many years, it has increased worldwide as countries have become more industrialized. Pollution affects living organisms, including humans, as well as the physical environment. Cow and horse manure can be considered a good plant fertilizer. But if too much manure is produced due to overcrowding, and the decomposers cannot break the manure down as fast as it is produced, large amounts of nitrogen run off into waterways. This nitrogen will increase the growth rate of algae in water systems, causing a decrease in the amount of oxygen in the water. This can result in the death of the fish, insects, and other animals in the water.

Air pollution is caused primarily by the burning of fossil fuels to produce electricity. However, the burning of fuel for other activities such as driving cars, heating homes, and flying planes has also contributed to air pollution. Examples of air pollutants include dust, smoke, ash, carbon monoxide, and sulfur oxides. Smoke that is released by burning fuels contains gases and **particulates**. These are solid particles of soot that can harm living organisms now or have an impact later in life. Workers in coal mines develop black lung disease from breathing in the dust from the coal. A combination of smoke, gases, and fog is called **smog**. Smog containing sulfur oxides reacts with water vapor in the atmosphere to produce sulfuric acid. This sulfuric acid falls to the ground as **acid rain**, which damages crops, kills organisms in aquatic ecosystems, and erodes buildings and monuments. Acid precipitation leaches calcium, potassium, and other valuable nutrients from the soil, making the soil less fertile. This causes a decrease in the

number of living things that can grow (plants, trees, ferns). It also has a great effect on lake ecosystems by causing a decrease in the pH level. This excess acidity disrupts the natural balance of the organisms living there.
Another form of air pollution is the increased production of carbon dioxide. When fossil fuels such as oil, coal, and natural gas are burned, carbon dioxide is released into the atmosphere. Excess carbon dioxide in the air can contribute to the greenhouse effect, which is believed to cause global warming. Gases in the atmosphere trap much of the radiant energy from the Sun that reaches the surface of the Earth. The surface of the Earth heats up and radiates back into the atmosphere. The atmosphere prevents much of this heat from escaping. This is known as the **greenhouse effect**. If this process did not occur, the Earth would be too cold for any living things to survive. All the Sun's energy would be radiated back into space. The **ozone layer** that surrounds the Earth prevents lethal doses of ultraviolet radiation from the Sun from reaching organisms here on the Earth.
Scientists have discovered that the ozone layer is thinning because of the release of CFCs (chlorofluorocarbons) into the atmosphere. CFCs are manufactured for coolants in refrigerators and air conditioners as well as for making Styrofoam.

Water pollution is caused by contaminants from sewers, industries, farms, and homes, which enter water sources such as lakes, rivers, groundwater, and oceans. Sewage, chemical wastes, fertilizer, and dirty wash water can enter lakes, streams, rivers, and eventually oceans. Pollutants that trickle down through the soil can make their way to the underlying groundwater, which is the source of drinking water for some people. Humans are, however, becoming more aware of the possible negative effects they have had on the environment and are trying to offset past damage. As a result, greater efforts are being made to conserve energy resources, to protect and conserve material resources, and to control pollution. For example, wildlife conservation efforts protect species from habitat loss, overhunting, and pollution.

People are making an effort to conserve energy by limiting the use of energy resources, such as fossil fuels, through the increased use of public transportation and carpooling. Another way energy resources are being conserved is to reduce energy waste by making homes and buildings more energy efficient. Using alternative forms of energy can also conserve energy resources. For example, solar energy and wind energy provide an unlimited supply of energy with minimal impact on the environment. You've probably heard of the "three Rs" of conservation: reduce, reuse, and recycle. Reducing, reusing, and recycling resources can decrease the amount of new material taken from the earth. For example, buying products in recyclable packages or products that can be recycled helps conserve material resources. Another way to conserve material resources is to reuse materials instead of throwing them away. What happens to the materials that are not recycled or cannot be recycled or reused? They probably end up in the garbage, which is hauled to a landfill to be buried underground. In a sanitary landfill, layers of compacted garbage are spread between layers of soil and eventually covered with grass and other plants. New techniques of sanitation and waste disposal are also being developed.

Relate plant adaptations, including tropisms, to the ability to survive stressful environmental conditions

Even though plants do not have nervous systems, they do possess mechanisms that enable them to respond to their environment. These responses are known as tropisms. It is a Greek word that means "to turn." Plants will shift the positions of their roots, stems, leaves, and flowers in response to environmental conditions such as sunlight, temperature, water, and gravity. There are several types of tropisms. **Geotropism** is the response of seedlings to the force of gravity. It is important when seeds are sprouting. Geotropism causes the roots to grow downward and the stems to grow upward, no matter what the position of the seed when it is planted.

Tropism—a plant's response to its environment
Geotropism—a plant's response to gravity
Phototropism—a plant's response to light
Thigmotropism—a plant's response to touch

Phototropism is the ability of the plant to respond to light. If a plant is placed near a window or another light source, the plant will grow in the direction of the light source. A phototropic response can happen so quickly that even a seedling will respond within a few hours. **Thigmotropism** is the response of a plant to touch. Climbing plants, ivy, and vines use thigmotropism in order to find their way up or around a solid object for support. It is also used by some plants for protection. Some plants respond to other stimuli from the environment such as length of day and the seasons. Some flowers bloom once a year, while some others, like some cacti, bloom at night.

Most plants control their growth in response to environmental stimuli by using chemical messengers known as **hormones**. A hormone is a chemical that is produced in one part of an organism and transferred to another part to affect the activities of that part of the plant. One type of hormone is called **auxin**. Auxins are responsible for regulating phototropism in a plant by stimulating the elongation of cells. The cells on the auxin-rich shaded side of a stem will grow longer than the cells on the other side, causing the stem to bend toward the light. High concentrations of auxin help promote the growth of fruit and minimize the falling off of fruit from the plant. When auxin concentrations decrease in the autumn, the ripened fruit will fall. The plants will begin to lose their leaves. **Gibberellins** are growth hormones that cause plants to grow taller. They also increase the rate of seed germination and bud development. There are certain tissues in the seeds that release large amounts of gibberellins to signal that it is time to sprout. There are also hormones that do the opposite: they inhibit plant growth and cell division. **Abscisic acid** is one of these. It inhibits plant growth during times of stress, such as cold temperatures or drought. In studying these hormones, scientists have found that it is the balance of different hormones that determines the plant growth, rather than one hormone by itself.

Examples of Adaptations

Seeds of many plants will go dormant in unfavorable conditions. In a drought period, many will lay dormant until the rains come. Then they will sprout. Roots and stems are modified in many plants into storage organs in order to survive through winter or drought underground. Tulips, daffodils, and crocuses are examples. Many trees drop their leaves and go dormant for the winter. The leaves of conifers have a waxy coating over them to reduce evaporation and to conserve water. The bark on conifers is thick, helping to insulate the tissues from fire. The branches of the conifers are flexible, allowing for them to bend instead of break under the weight of ice and snow. These adaptations help plants survive adverse conditions in their environment. Plants also have adaptations for reproduction. For example, flowers can be pollinated in many ways including wind, insects, birds, or other animals. Maple trees produce seeds that are shaped like wings and are carried over long distances by the wind. Some plants produce seeds that have hooks or barbs on them that attach to the fur of passing animals. These have the nickname "hitchhikers." Many flowers are brightly colored and fragrant, to draw attention of insects that aid in pollination. Pollen will rub off on the insect and then is carried to another flower. The coconuts from palm trees float which allows seeds to travel from one island to another. Several species of pine have seeds that are resistant to fire. They are in cones that must be exposed to fire to open and release the seeds. The modified leaves conserve moisture. The pollen blows easily; therefore, insect and bird activity isn't necessary to spread the pollen from tree to tree. The color of the bark does not make the tree resistant to disaster. Bark thickness is a more important characteristic.

Relate animal adaptations, including behaviors, to the ability to survive stressful environmental conditions

Behavior

Behavior is defined as anything an animal does in response to stimuli in its environment. A squirrel gathering nuts and acorns in the autumn is a behavior that is stimulated by shorter days and colder weather. Gathering food for themselves and their young, caring for their young, avoiding predators, seeking shelter, and finding a mate are important behaviors to the survival of many animals. Many animals have learned and inherited behaviors.

Inherited Behavior

Inheritance plays an important role in an animal's behavior. An animal's genetic composition determines how it responds to stimuli. An animal's hormonal balance, in combination with its nervous system, affects how sensitive an animal is to stimuli. Inherited behavior of animals is also known as **innate behavior**. It includes both automatic responses and instinctive behaviors. When a person touches a hot surface, they automatically withdraw their hand from the source of heat. Bright lights make eyes automatically blink. Such **reflex** behaviors are simple, automatic responses that require no thinking at all.

Instincts are a complex pattern of innate behaviors. Reflexes can happen within a second. Instinctive behaviors may take longer and may be a combination of behaviors.

For example, an animal's courtship behavior is instinctive. Animals will recognize certain behaviors exhibited by members of the same species. Each species has its own specific courtship behaviors. The male and female black-headed gull dance in unison side by side and turn their heads away from each other. The female taps the male's bill and he gives her a regurgitated fish. Then the courtship is over and the pair will mate. Different species of fireflies flash distinctive patterns of light. The female will respond only to the male that exhibits the species-correct flashes.

Territorial Behavior

A **territory** is a physical space that contains the breeding grounds, feeding area, shelter,or potential mates of an animal. Animals that have territories use different behaviors to defend their space against an animal of the same or different species. Setting up territories is a way to reduce conflict, control populations, and decrease competition. It also is a problem solver in that it helps provide for efficient use of environmental resources by spacing animals out over an area. There is a greater chance for survival of young, increasing the survival rate of the species. Aggression is another behavior exhibited by animals to fend off predators and competitors. It is a way to protect young and to protect food sources. Animals of the same species will not usually fight to the death. Usually it will be the stronger animal that will stop the fighting when the weaker animal shows signs of submission.

Migration

Migration is the instinctive, seasonal movement of a species. Over half of the birds that nest in the United States fly south for the winter. Many head to South America where food is more abundant during the winter months. Then they fly north in the spring to breed. Arctic terns migrate between the Arctic Circle and Antarctic. Animals use various environmental cues to navigate during migration. Scientists believe that some species use geographical clues such as mountain ranges. Other species use the Earth's magnetic field. Scientists have also found that migration is triggered in part by hormones that are produced in response to environmental changes, such as changing day length. Migration also takes place in response to changing environmental conditions, such as overcrowding or reduced food supplies. Many animals that do not migrate undergo physiological changes that reduce their need for energy. Some animals and birds **hibernate** during cold winter months. Hibernation is a condition in which the animal's body temperature drops, oxygen consumption decreases, and breathing rates decrease to just a few breaths per minute. **Estivation** is a condition in which animals reduce the rate of their metabolism due to extreme heat, lack of food, or long periods of drought.

Learned Behavior

Learned behavior is a result of previous experiences of an animal that modifies their current behavior. Learned behavior has survival value because it allows animals to change their behavior in a changing environment. It allows animals to increase the chance for survival. Feral horses learn to allow people to ride them. Deer have learned to come into yards to feed with no fear of people or barking dogs. This type of learned behavior is called **habituation**. It occurs when an animal is repeatedly given a stimulus that is not harmful and does not have a negative impact on the animal. **Imprinting** is another form of a learned behavior. An example is when an animal returns to the place of its birth to lay its eggs, or when an animal imprints on its mother or other organism in its environment. Kemp's Ridley sea turtles will return to the beach where they were hatched to lay their eggs. It is not yet known exactly what the turtles imprint on, whether it is the sand or in the water. Salmon also return to the same river to spawn.

Adaptations for Defense

Most species of plants and animals have adaptations that serve as a defense against a predator. They fall into two categories: mechanical defense and chemical defense.

- **Mechanical defense** is incorporated into the physical structure of the organism.
- **Chemical defense** occurs when the animal produces stinging sensations, paralysis, poisoning, or just a bad taste.

Mechanical Defenses

Many animal defenses are physical structures such as claws, sharp ivory tusks, stingers, and shells. Octopuses squirt a liquid ink that darkens the water and allows them to escape predators. An animal's size is sometimes enough to deter a predator from attacking. Plants also have mechanical defenses. Many have thorns, spines, and stiff hairs that repel a predator. Some grasses in the African savannas have a thick deposit of silica that wears away the teeth of grazing animals. However, some of these grazing animals have counter-adapted and have developed large, hard molars that resist the abrasive action of the mineral.

Another defense is **camouflage**. It involves colors and patterns that enable the organism to blend into its environment or appear to be something it is not. **Cryptic coloration** is when an organism has the same color or pattern as its background. Gecko lizards, tree frogs and leafhoppers are examples. **Disruptive coloration** is another example in which an organism's silhouette is broken up by color patterns. **Counter shading** is when an organism is two-toned. Light and dark colors reduce visual cues to predators. Many ocean fish are dark on top and light on the bottom. Predators on top can't see the fish against the dark waters below. Fish and some mammals form large groups (schools and herds) to confuse predators and make choosing one individual more difficult.

Chemical Defenses

Chemical defenses are used in a variety of strategies for deterring predators. Many marine organisms have neurotoxins in their tissues that attack the nervous system of their attackers. Bombardier beetles shoot out a boiling-hot chemical to irritate would-be predators. Other chemical defenses include poisons and venoms, which are used by snakes, toads and stinging bees and wasps. Some animals take on the chemical defenses of other species. The monarch butterfly is an example. As larva, monarchs feed on milkweed plants, which contain compounds which are poisonous to vertebrates and many insects. After pupation, the tissues of the adult monarch are saturated with the milkweed's poison. Birds that eat the monarch will vomit violently and learn to avoid the monarch's bright coloration. Chemical defenses are also used in plants. Some plants contain chemical compounds that taste bad, while others contain sap that is an irritant or poison. Another defense is **nutrient exclusion**. Some plants aren't worth eating because their tissues are lacking a sufficient amount of nutrients.

Trace the history of the theory

The Origins of the Theory

Evolution is most often connected to the name of Charles Darwin. But the concept of evolution began much earlier than Darwin. In fact, in 1809, the year that Darwin was born, a French zoologist named Jean Baptiste de Lamarck presented a new evolutionary theory. Lamarck believed that all life forms evolved and that the driving force of evolution was the inheritance of acquired characteristics. He believed that organisms changed due to the demands of their environment. This "passing on of acquired characteristics" helped lower life forms climb the ladder of life to become more complex organisms. The example that he used in explaining his theory is that of a giraffe's neck. He believed that in order for the giraffe to reach its food, it had to stretch its neck. So, over many generations, an elongated neck became part of the giraffe's body. He also believed that if a body part of an organism wasn't used, that body part would be lost. Lamarck's work has an important relationship to Darwin's theory that evolution of living things proceeds according to natural laws. Geologists were also discovering ancient bones, shells, and fossilized plants in England in the late 1800s. These findings caused people to look for an explanation for the existence of the fossils and would soon become a fundamental theory, explaining the diversity of organisms.

Charles Darwin

When Charles Darwin set sail in 1831 on the HMS *Beagle*, he carried with him Charles Lyell's *Principles of Geology*, published in 1830. While on the *Beagle*, Darwin read Lyell's proposal that plant and animal species had arisen, developed variations, and then became extinct over time. Lyell also believed that the Earth's physical landscape changed over a long period of time. Darwin also read an essay written in 1798 by Thomas Malthus called *An Essay on the Principle of Population.* In his essay, Malthus proposed that populations outgrew their food supplies, causing competition between organisms and a struggle for one species to survive against another. But the most important impact on Darwin was his 40,000-mile trip on the *Beagle*. Darwin found a vast treasure of fossilized bones. He saw a variety of plants and animals that were very different due to their geographical location. In the Galapagos Islands, Darwin found many species specific to the various islands. He saw large iguanas swimming in the ocean and eating seaweed. He also found giant tortoises with carvings on their backs from whalers that had passed through a hundred years before. From all the information gathered, two concepts emerged to form the basis of his theory of evolution. First, Darwin observed that variations within a species were dependent on the environment. **Adaptations** are genetically coded traits that occur in organisms and enable them to be more successful in their environment. Darwin reasoned that the importance of these adaptations is to ensure the survival through reproduction of that species. Successful adaptations help organisms to both survive and reproduce, so that these advantageous adaptations are passed on to future generations. **Natural selection** is a mechanism that explains changes in a population that occur when organisms with favorable variations for that particular environment survive, reproduce, and pass these variations on to the next generation.

Secondly, the organisms on the Galapagos Islands had become geographically separated from one another. This resulted in **reproductive isolation**. There is no interbreeding between organisms of the same species that are located on different islands. For example, finches on one island could not cross the ocean to mate with finches of the same species on another island. He theorized that within a population of a species, adaptations would arise due to reproductive isolation. The organisms would develop adaptations to their specific environment over time that would result in significant differences between the same species on different islands. While Darwin was composing a theory of evolution, another man, Alfred Russel Wallace, was also formulating his own theory of evolution. He studied plants and animals in Brazil and in Southeast Asia. Wallace's emphasis was based on the idea of competition for resources as the main force in natural selection. Darwin focused on reproductive success. It was the tremendous amount of data gathered by Darwin that supported his idea, and the comprehensive explanation that he put together became the dominant evolutionary theory.

Darwin knew nothing about genes or principles of heredity. It wasn't until the rediscovery of Mendel's work that scientists were able to put together the concepts of natural selection with genetics. This opened the door for scientists to account for phenotypic variations in populations.

Explain the history of life in terms of biodiversity, ancestry, and the rates of evolution

The work of Charles Darwin and Gregor Mendel laid a foundation to explain the large diversity of species found today. **Adaptive radiation**is when species diversity occurs in a relatively short time. It occurs when a population colonizes a new area. A good example is the large number of finch species that Darwin observed on the different Galapagos Islands. He counted over a dozen different species of finches that he believed evolved from a single founding species. Another mode of evolution is **convergent evolution**. This is where unrelated species may independently evolve superficial similarities because of their adaptations to similar environments. When molecular biologists developed new techniques for analyzing DNA new understanding developed about how these different modes of evolution can occur.

As more and more data were gathered, evolutionary biologists became intrigued with DNA and the information that it provided about the relationships between organisms. Data collected show that segments of DNA, and even entire sequences of the amino acids in some proteins, seem to be identical in many organisms. One structure of great interest is the ribosome. Molecular biologists have found that the DNA sequences that build bacterial ribosomes are similar to the genes that make human ribosomes. Another example is myosin. **Myosin** is a protein found in muscle cells of humans and other multi-cellular organisms. Myosin reacts with other proteins to cause muscles to contract, causing movement. Myosin is also found in yeast cells. Yeast have organelles that require movement. This is accomplished when the myosin interacts with other proteins to make the organelles move within cells. The similarity between DNA of all living organisms shows that once life began, it diversified by changing the genetic code of organisms. This resulted in the biodiversity of life on Earth today. **Biodiversity** is the variety of organisms, their genetic information, and the communities in which they live. Researchers use three different terms when talking about biodiversity: In theory, DNA changes should occur at a constant rate. In reality, it is complicated by a number of factors. Different positions in DNA sequences acquire mutations faster than others. Different organisms acquire mutations at different rates. Some genes are under a more intense pressure from natural selection *not* to change. So, in order for researchers to time recent evolutionary events, they must use "time clocks" that tick fairly quickly. But to estimate how long ago there was a shared ancestry, they must use clocks that tick very slowly. **Molecular clocks** are proteins that have changed very slowly and are shared by many species.

Speciation is the evolution of a new species that occurs due to changes in gene flow in populations of the ancestral species. Evolution of new species due to **geographic isolation** occurs when physical barriers cause populations to divide and prevent mating of individuals. Volcanoes, sea-level changes, and earthquakes are a few examples of natural occurrences that divide populations. So over time, each smaller population will adapt to their new environment through the process of natural selection. Eventually, this causes the gene pool of each group to become different so that a new species is formed.

1. **Ecosystem diversity** includes the variety of habitats, communities, and ecological processes in the living world.
2. **Species diversity** includes the vast number of different organisms on Earth.
3. **Genetic diversity** refers to the sum total of all the different forms of genetic information carried by all living organisms on Earth. It gives rise to inheritable variation.

Gradualism is evolution that occurs over a long period of time when adaptive changes accumulate slowly and steadily over time in a population. Darwin believed in gradualism.

Punctuated equilibrium states that speciation occurs quickly in rapid bursts, with long periods of stability. Whether the rate of evolution occurs slowly over long periods of time or rapidly, the debate will continue as new evidence is compiled and alternative theories are brought to light. It is the nature of science to modify theories as new evidence becomes available.

Explain how fossil and biochemical evidence support the theory

The fossil record provides biologists with an incomplete picture of the evolution of plants and animals. Most fossils are the remains of the hard parts of an organism. Shells, bones or the remains of plants with thick cell walls are most likely to leave a fossil. Very few fossils capture the details of skin or internal organs. There are also impressions left behind in sediments along rivers and lakes. One problem with the fossil record is that there are few remains of any "intermediate" or transition forms. There are several reasons that few transition species are found. Approximately two-thirds of all the organisms that ever lived were soft-bodied. It also depended on where and how an organism died as to whether their remains could be fossilized. Fossils also could have been destroyed by erosion or pressure from overlaying rocks. Exposure to wind, rain, and soil erosion could prevent fossils from forming.

Fossil Age - Biologists use **radioisotope dating** to determine the relative ages of fossils within a time period. These isotopes act as clocks for measuring time. To use this method, scientists must know:
1. the half-life of the isotope being measured
2. how much of the isotope was originally present in the fossil or in the rock containing the fossil
3. how much of the isotope is left Carbon 14 (14C) is the primary isotope used in radioisotope dating. When an organism dies there is no additional carbon that is added to it. Scientists measure this carbon 14 to carbon 12, which is in living matter (that is, the ratio of14C to 12C).

Biologists use a number of ways to determine the age of fossils. They recognize distinct groups of fossils in specific rock layers. By matching rock layers with fossils, geologists can determine the age of the rocks, while paleontologists can determine the age of the fossils. This is called **relative dating**. By using the ages of fossils, interrelationships between organisms can be determined. Organizing similar fossils by age show how species become more complex over time. An example of advancing complexity is horse evolution. A phylogeny is a description of the lines of descent of plants and animals. A phylogenetic tree shows the interrelationship of several species. Fossil collections are often not complete enough to determine any evolutionary patterns or traits. In many cases, a biologist will infer likely phylogenies by comparing morphological features, DNA sequences, and chromosomal characteristics.

Extinction is the permanent loss of a species. Extinctions have occurred over time. Paleontologists have come to the conclusion that there have been five mass extinctions, resulting in a great number of species being completely wiped out. They believe one of these mass extinctions occurred at the end of the Permian period, when 96% of marine invertebrates became extinct. The other extinction occurred at the end of the Cretaceous period, when they believe 60–75% of marine species died.

Relate natural selection to changes in organisms

Remember that the key to Darwin's theory of evolution came from the concept that some organisms have an advantage over others. This advantage increases the organism survival rate and increases the chances that this favorable advantage will be passed on to the next generation. Within each species is a vast array of phenotypic differences. Natural selection acts on an organism's phenotype and indirectly on its genotype. Natural selection results in adaptations that allow populations to survive in their environments.

Fitness
Geneticists define the term fitness as the relative reproductive efficiency of various individuals or genotypes in a population. The fitness of an individual depends on the probability that the one individual will both survive and reproduce successfully. It is not necessarily the strongest, biggest, or most aggressive animal that has the highest fitness rating. It is a measure of how well the organism's structure, physiology, biochemistry, and behavior allow the organism to survive and reproduce in their environment. When a population has a variety of phenotypes and biological capabilities, it enables the population to survive under a wide range of environmental factors.

Environment plays an important role in determining which alleles are optimum for a population's survival. Natural selection does not always increase the complexity of an organism's structures or behaviors. Also, natural selection does not produce new genotypes and phenotypes, but it eliminates the less fit, leaving the more fit to reproduce and ensure the species' survival. If environmental conditions change so that a population lacks alleles for survival, the population (and possibly the species) goes extinct.

Stabilizing Selection

Stabilizing selection, also called normalizing selection, is responsible for maintaining the status quo for an organism's genetic makeup in an environment. It is common in environments that have remained stable over long periods of time. Possibly, the phenotype has not changed much because it has become very well adapted to its environment, such as the open sea or the high-pressured regions of the sea floor.

Directional Selection

Directional selection involves changes from one phenotypic property to a new one. When environmental conditions favor the survival of individuals carrying a genetic variant, the outcome is an increase in the frequency of that variant in the population. Many insects have become resistant to pesticides. Those with the ability to survive the insecticides sprayed on them reproduce, passing on the genes for this survival ability.

Disruptive Selection

Disruptive selection results in the disappearance of forms that are considered intermediate between several extreme variants. Disruptive selection will split a species into two or more groups by strongly selecting against the intermediate or average phenotypes. Natural selection can take on many forms and produce diverse effects on populations. In summary, natural selection may maintain the status quo for a population in its genotype or in its phenotype. Trends may occur in different directions; decreasing a species or increasing a species. Increasing the diversity in genotype and phenotype may result in a new species.

Recognize the role of evolution to biological resistance

New techniques in molecular biology have given researchers new insight into genetic mechanisms that may be involved in some types of directional selection. Directional selection involves change from one phenotypic property to a new one. For example, when a bed of oysters in Malpeque Bay was infected with a lethal pathogen in 1915, it almost wiped out the oyster industry. But 10 years later, the oysters were making a comeback. By 1940, the Malpeque Bay was producing more oysters than it ever had. They began to repopulate other areas that had been wiped out. What brought about this drastic change for the oyster? Directional selection

Out of the 50 million or so offspring that were produced each year by the oysters, a fraction of those offspring carried an allele that was resistant to this pathogen. So when the environmental conditions were favorable for the offspring that carried this allele, the outcome was an increase in that variant in the population. This resulted in an increase in healthy oysters. Many insects have developed resistance to insecticides. Mutations can modify a protein so the insect is no longer susceptible to an insecticide. In a swamp treated with an insecticide, surviving mosquitoes had a gene that produced a protein making these mosquitoes resistant to the insecticide. Successive generations of mosquitoes in this swamp had greater resistance to the insecticide.

Viruses are another organism that are constantly evolving in response to changes in their environment. Some don't change quickly, like smallpox or measles. This gave biologists time to create a vaccine against them. Others change very quickly, such as the flu. The flu virus mutates rapidly, constantly changing its genotype and phenotype, so the flu virus changes year to year. The human body does not recognize the new virus as anything harmful, so it doesn't send out anything to attack it. Another adaptation of viruses is that certain viruses can live in two or more different hosts. One virus may originally live in pigs and geese and then move on to live in humans and ducks. Viruses carry their genetic information on eight pieces of DNA. So if two strains of the virus infect the same cell, some of those genes will get mixed up, resulting in a new strain of the virus. This can cause major problems for the host.