BIO.2 CHEMICAL AND BIOCHEMICAL PROCESSES ARE ESSENTIAL FOR LIFE

a) **water** chemistry has an influence on life processes;
b) **macromolecules** have roles in maintaining life processes;
c) **enzymes** have a role in biochemical processes;
d) **protein synthesis** is the process of forming proteins which influences inheritance and evolution; and
e) the processes of **photosynthesis** and **respiration** include the capture, storage, transformation, and flow of energy.

*Central Idea: **Organisms** are **complex** systems that require **energy** and **materials** to support biochemical processes that maintain **metabolism**.*

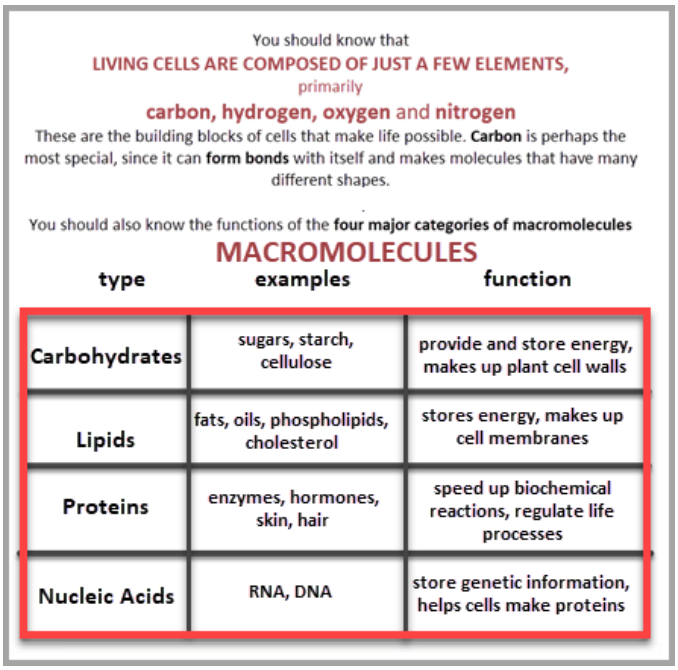
a) water chemistry

The **structure** of an object or living thing determines many of its **properties** and **functions**.

- **Water** has chemical and physical properties that facilitate metabolic activities in living cells.
  - Water is a **solvent** and **dissolves chemicals**, minerals, and nutrients that are used to support life processes.
  - The **polarity** of water molecules causes them to be **strongly attracted** to one another and gives rise to **surface tension** and **cohesion**.
  - Water is also a **thermal regulator** in living systems.

b) macromolecules

- **Carbon** and other elements play a key role in determining the structure and function of **macromolecules** needed to sustain life processes.
  - **Life processes** include growth and repair, reproduction, gas exchange, metabolism, and response
- Cells make a variety of **macromolecules** needed for life processes from a relatively small set of **monomers**.
  - These **macromolecules** include **carbohydrates**, **proteins**, **nucleic acids**, and **lipids**.
- **Carbon**, **hydrogen**, and **oxygen** from **sugar** molecules may combine with other elements to form **amino acids** and/or other large carbon-based molecules.


You should know that
LIVING CELLS ARE COMPOSED OF JUST A FEW ELEMENTS,
primarily
carbon, hydrogen, oxygen and nitrogen
These are the building blocks of cells that make life possible. **Carbon** is perhaps the most special, since it can **form bonds** with itself and makes molecules that have many different shapes.

You should also know the functions of the **four major categories of macromolecules**

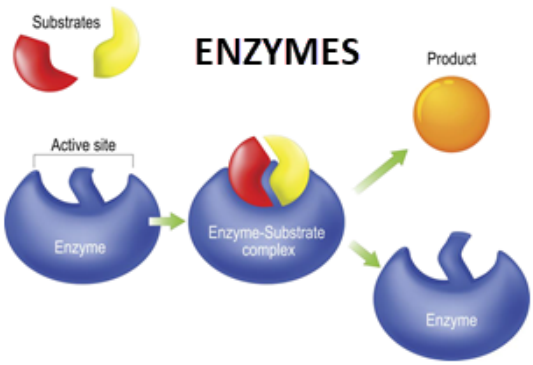
MACROMOLECULES

type	examples	function
Carbohydrates	sugars, starch, cellulose	provide and store energy, makes up plant cell walls
Lipids	fats, oils, phospholipids, cholesterol	stores energy, makes up cell membranes
Proteins	enzymes, hormones, skin, hair	speed up biochemical reactions, regulate life processes
Nucleic Acids	RNA, DNA	store genetic information, helps cells make proteins

c) enzymes

The structure of **enzymes** moderates their function in chemical reactions in living things.

- **Enzymes** are a group of **proteins** that function to **moderate the rate of metabolic reaction** by acting as **catalysts**.

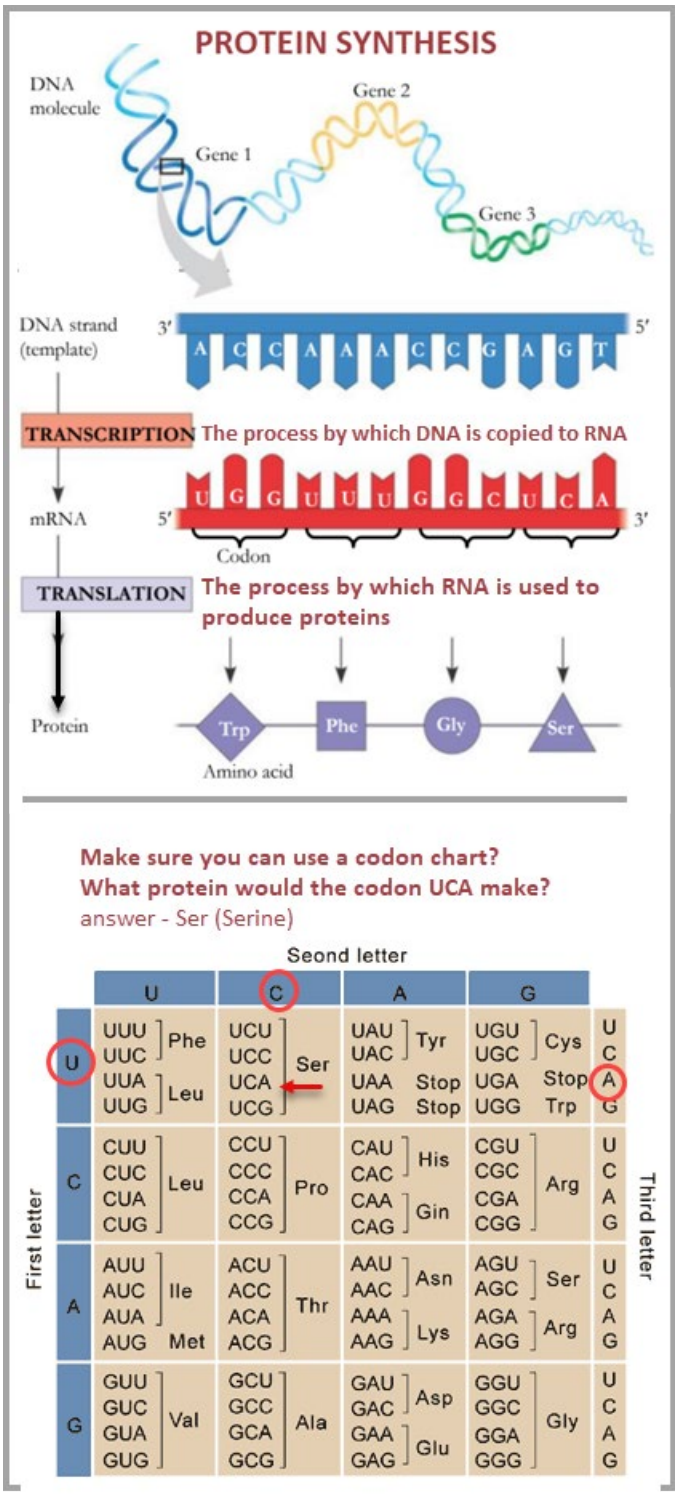


Enzymes are proteins that act as **catalysts**. That means they help **speed up chemical reactions** in the human body, converting **substrates** into **products**. They bind to molecules and alter them in specific ways. They are essential for respiration, digesting food, muscle and nerve function, among thousands of other roles.

d) protein synthesis (forming proteins)

The **structure** of **DNA** serves as a **code** for the production of **proteins** through the process of **protein synthesis**.

- **Proteins** carry out the essential functions of life processes through systems of **specialized cells**.
- **Protein synthesis** is a biochemical process that uses information **coded in DNA** to **construct proteins**.



Make sure you can use a codon chart?
What protein would the codon UCA make?
answer - Ser (Serine)

Seond letter

First letter	U	C	A	G	Third letter
U	UUU Phe, UUC Phe, UUA Leu, UUG Leu	UCU Ser, UCC Ser, UCA Ser, UCG Ser	UAU Tyr, UAC Tyr, UAA Stop, UAG Stop	UGU Cys, UGC Cys, UGA Stop, UGG Trp	U C A G
C	CUU Leu, CUC Leu, CUA Leu, CUG Leu	CCU Pro, CCC Pro, CCA Pro, CCG Pro	CAU His, CAC His, CAA Gln, CAG Gln	CGU Arg, CGC Arg, CGA Arg, CGG Arg	U C A G
A	AUU Ile, AUC Ile, AUA Ile, AUG Met	ACU Thr, ACC Thr, ACA Thr, ACG Thr	AAU Asn, AAC Asn, AAA Lys, AAG Lys	AGU Ser, AGC Ser, AGA Arg, AGG Arg	U C A G
G	GUU Val, GUC Val, GUA Val, GUG Val	GCU Ala, GCC Ala, GCA Ala, GCG Ala	GAU Asp, GAC Asp, GAA Glu, GAG Glu	GGU Gly, GGC Gly, GGA Gly, GGG Gly	U C A G

e) photosynthesis and respiration (the capture, storage, transformation, and flow of energy)

Sustaining life processes requires substantial **energy** and **matter** inputs.

The complex structural organization of organisms accommodates the capture, transformation, and elimination of the matter and energy needed to sustain life.

- As **matter and energy** flow through different organizational levels of living systems, **chemical elements are recombined** in different ways to form different products.
  - As a result of these **complex chemical processes**, **energy is transferred** from one system of interacting molecules to another
- The **breakdown of nutrient molecules** provides **energy** to the cell.
  - This energy is **stored** in specific chemicals that are used to carry out the life functions of the cells.
- **Metabolism** refers to all **interactions among molecules** within the well-ordered environment of the **cell**.
  - **Photosynthesis** and **cellular respiration** are two important **metabolic activities** within living cells important in the **transfer** and **transformation** of **energy** for life processes.
  - **Energy transfer** and **transformation** are subject to **conservation laws**.
- **Chloroplasts** and **mitochondria** act as change agents within the cells of plants to **make energy available** for life processes.
- **Plant cells** and many **microorganisms** use **solar energy** to combine molecules of **carbon dioxide** and **water** into **complex, energy-rich organic compounds** and **release oxygen** into the environment.
- **Chloroplasts** convert **radiant** energy from **sunlight** into **chemical energy** with the help of the **pigment chlorophyll.**
  - **Chlorophyll** aids in the **energy transformation** of **sunlight (radiant energy) to chemical energy** in **sugar**.
- The **sugar molecules** produced from photosynthesis can be **used immediately** by plants and animals for **energy**, **stored** for later use, or **rearranged** into other compounds to carry out life processes.
- Within individual organisms, **food** moves through a series of **chemical reactions** in which it is **broken down and rearranged** to form new molecules, to support growth, or to release energy.
  - In most animals and plants, **oxygen reacts with carbon-containing** molecules (sugars) to provide energy (in the form of **ATP**) and produce **carbon dioxide** and **water**.
- **Cellular respiration** is a chemical reaction in which the bonds of **food molecules** and **oxygen** molecules are **broken** and new compounds are formed that **store energy** in a useful form for use by living cells.
- The **energy released** during cellular **respiration** comes from **chemical bonds.**
  - When these **bonds** are **broken**, **energy is released.**
  - Most of this **energy is lost** as **thermal energy** but some is captured in the bonds of small molecules of **ATP**.
  - **ATP bonds** are **broken** each time energy is needed by the cell for life processes.
- explain how biological systems use **energy** and **matter** to maintain organization, to grow, and to reproduce
- illustrate and explain the process in which **photosynthesis transforms light** energy into stored chemical energy
- explain the interrelatedness of **photosynthesis** and **cell respiration**, including **energy transfer**
  - describe how the presence of **oxygen** affects the amount of **energy** available to an organism
  - Students are not expected to know the complex multistep processes of photosynthesis and respiration.

BIO.3 CELLS HAVE STRUCTURE AND FUNCTION

a) the **cell theory** is supported by evidence;
b) structures in **unicellular** and **multicellular** organisms work interdependently to carry out life processes;
c) cell structures and processes are involved in **cell growth** and **division**;
d) the structure and function of the **cell membrane** support **cell transport**; and
e) **specialization** leads to the development of different types of cells.

*Central Idea: **All living things are composed of cells**. Although there are many different types of cells in terms of size, structure, and function, all cells have certain characteristics in common.*

*The **cell theory** encapsulates the **current understanding of the cell**.*

*Both **theories** and **laws** describe natural phenomena and are equal in terms of scientific validity.*

a) the cell theory

The **cell theory** is a shared understanding that encapsulates our current **understanding of the cell**. The development of this theory illustrates the **nature of science**.

Advances in science and **technology** have added to our understanding of the cell. In addition to the original three tenets of the cell theory (which students learned about in Life Science), the current **cell theory** contains the following: **metabolism occurs within cells, hereditary information (DNA) is passed from one cell to another, and all cells have the same basic composition.** Students are not responsible for describing the contributions of specific scientists.

- provide examples to illustrate how additions to the original cell theory illustrate the nature of science
- differentiate among a scientific hypothesis, theory, and law (BIO.3 a)

b) interdependent structures in unicellular and multicellular organisms

Organisms are **complex**, organized systems built on a hierarchical structure, with each level providing the matter and energy foundations for the next. This occurs from the chemical foundation of elements and atoms, to the cells and systems of individual organisms, to species and populations living and interacting in complex ecosystems.

- **Multicellular organisms** have a **hierarchical** structural organization, in which any one system is made up of numerous parts and is itself a component of the next level.
- Cells and organisms have **structures** that perform specific **functions** that allow for the movement of matter and energy to maintain life processes.
- Some organisms exist as a **single cell**, while others are composed of **many cells**, each **specialized** to perform distinct metabolic functions.
  - A **single-celled organism** has to conduct all life processes by itself.
  - A **multicellular organism** has groups of cells that **specialize** to perform specific functions (BIO.3 b).

Cellular activities necessary for life include chemical reactions that facilitate **energy acquisition, reproduction**, and the maintenance of **life processes.**

- compare how life processes are maintained within cells and within organisms (BIO.3 b)
- explain how the organelles function individually and in a system to support life processes (BIO.3 b)
- explain how the levels of cellular organization contribute to division of labor in multicellular organisms (BIO.3 b)
- use an argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells (BIO.3 b)
- plan and conduct an investigation to provide evidence that mechanisms maintain homeostasis within living things, such as heart rate response to exercise, stomate response to moisture and temperature, and root development in response to water levels (BIO.3 b)

c) cell growth and division;

Reproduction is a life process by which living things **transfer genetic information** to their offspring. Reproduction (of cells and organisms) is essential to the existence of all living things.

In multicellular organisms, **cell division** creates **new cells** for growth, development, and repair.

- A **typical cell** goes through a process of growth, development, and reproduction called the **cell cycle.**
- **Mitosis** refers to **division of the nuclear material** and produces **two genetically identical cells**.
  - **Cytokinesis** is the **division of the cytoplasm** and organelles.
- During **DNA replication**, **enzymes unwind** and unzip the **double helix** and each **strand** serves as a **template** for building a **new DNA molecule**.
  - Free **nucleotides** bond to the template **(A-T and C-G**), forming a **complementary strand**.
  - The final products of replication are **two identical DNA molecules**
- model and describe the parts of **cell cycle** to include the processes involved in **each stage of mitosis**
- explain the importance of **DNA replication** in cell division

d) cell membrane for cell transport;

Living things must **move materials** into, out of, and within the cell.

- The life processes of a cell are maintained by the **plasma membrane**, which is comprised of a variety of organic molecules.
  - The membrane controls the **movement of material** in and out of the cell, **communication** between cells, and the **recognition** of cells to facilitate multiple metabolic functions.
- Substances can move across the cell membrane **passively** (i.e., **osmosis** and **diffusion**) or **actively** (i.e., **active transport**).
- Two **passive** processes that allow for this exchange of materials are **diffusion** and **osmosis**.
  - These processes require **no energy** on the part of the cell.
  - Substances merely move toward **equilibrium** (from an area of **high concentration** to an area of **low concentration**).
- The processes of **diffusion**, **osmosis**, and **facilitated diffusion** require **no energy**.
- **Active transport** requires **energy**.
  - **Endocytosis** and **exocytosis** are examples of **active transport** .
- how the composition of the **cell membrane** contributes to cell function
- construct and use models and simulations to represent and explain how substances move across the cell **membrane by osmosis, diffusion, facilitated diffusion**, and **active transport**; evaluate the limitations of models used when appropriate
- describe how the cell's **surroundings** influence the direction and type of **cell transport**
- plan and conduct investigations related to how **concentration** affects the **rate of diffusion** across a **semipermeable membrane,** using proper sampling techniques, data collection, and analysis procedures
- compare the **energy** needed to move substances across the cell membrane by osmosis, diffusion, facilitated diffusion, and active transport

e) cell specialization

A key concept in science is that **form fits function**. In multicellular organisms, cells have **specialized shapes** that enable them to perform **specific roles** within the organism.

- **Organisms differ** from one another in cell structure and chemistry.
  - The **diversity** that exists ranges from simple **prokaryotic cells** to complex **multicellular organisms**.
- **Multicellular organisms** possess **different types** of cells to carry out life processes.
  - Each **specialized cell** type has a specific **structure** that helps it perform a specific **function** .
- **Organelles** perform **specific functions** in the cell.
  - Different types of cells have **different numbers** and **types** of **organelles**.
- describe the role of cell **specialization** (or lack thereof) in the life processes of unicellular and multicellular organisms
- provide evidence to support the idea that a **cell's form fits its function** within a multicellular organism

BIO.4 BACTERIA AND VIRUSES HAVE AN EFFECT ON LIVING SYSTEMS.

a) viruses depend on a host for metabolic processes;
b) the modes of reproduction/replication can be compared;
c) the structures and functions can be compared;
d) bacteria and viruses have a role in other organisms and the environment; and
e) the germ theory of infectious disease is supported by evidence.

*Central Idea: **Bacteria** have diverse structures and metabolic functions and affect other organisms and the environment.*

***Viruses** have similarities to living organisms but are **not living**, even though they affect host organisms.*

a) viruses depend on a host

Viruses can dramatically affect living things.

- The influenza, West Nile, and Ebola viruses have **killed millions** of people.
- **Plants**, too, can be infected by viruses.
- By studying viruses, scientists can develop vaccines and antiviral medicines to reduce their lethality.

- **Viruses** are small, infectious agents **that replicate only inside the living cells** of organisms.

- Because **viruses transmit DNA or RNA into the host cell,** they can introduce **genetic variation** into the hosts.
- Viruses that **infect bacteria** may give an organism a **selective advantage** and enable it to fight off an infection .

- Viruses **do not share** many of the characteristics of **living** organisms.
  - Viruses are **not cells**.
  - Basic **viral structure** consists of a **nucleic acid core** surrounded by a **protein coat**.
  - Viruses can **reproduce only inside a living cell**, the host cell .
- explain in simple terms how **viruses infect host organisms**
- use evidence to support the description of **bacteria as living** and **viruses as nonliving**

b) reproduction/replication

- **Viruses reproduce** through the **lytic cycle**.
  - The **lysogenic cycle** results in **delayed viral reproduction** but eventually concludes with the lytic cycle.
- **Bacteria** reproduce **sexually** (**conjugation**) and **asexually** (**budding** and **binary fission**).
  - **Sexual reproduction** in bacteria is **rare**
  - Students are not expected to know other types of sexual reproduction in bacteria or the mechanisms of either sexual or asexual reproduction in bacteria.

c) structures and functions

- **Virus** structure consists of a **nucleic acid** (**single or double-stranded RNA or DNA**) and a **protein coat** (**capsid**) which serves as a protective covering.
- compare a **virus** and a **bacterium** in relation to **genetic material** and **reproduction** (BIO.4 b, c)

d) bacteria and viruses have a role in other organisms and the environment;

Viruses are important **microbial predators** that influence global biochemical cycles and drive microbial evolution.

Bacteria play important roles in the **global ecosystem,** including a lead role in the **cycling of nutrients**.

- **Bacteria** can also be **classified** according to how they obtain **energy** for cellular **respiration** or **fermentation**.
  - Bacteria may be **heterotrophs**, **photoautotrophs**, or **chemoautotrophs**.
- examine effects of **bacteria** and **viruses** on **human health**

e) the germ theory

The **germ theory** is a shared understanding that encapsulates our current understanding of **disease transmission**. The development of this theory illustrates the **nature of science**.

- Throughout history, people have created **explanations for disease.**
  - The introduction of the **germ theory** led to the understanding that many **diseases are caused by microorganisms**.
  - **Changes in health practices** have resulted from the acceptance of the **germ theory** of disease.
- Modern health practices emphasize **sanitation**, **the safe handling of food** and **water**, aseptic techniques to keep germs out of the body, and the development of **vaccinations** and other chemicals and processes to **destroy microorganisms** .
- **Vaccines** and **antibiotics** are used to prevent or cure diseases.
  - **Vaccines** are used to **prevent diseases by exposing hosts** to a **dead or weakened forms** of a virus.
  - The body's immune system builds an **immune response** that will be employed with **future exposure** to the same virus.
  - **Antibiotics** are used to cure a **bacterial disease** by **killing the bacterium** .
- provide an evidence-based explanation that connects the **germ theory** to the **nature of science**, such as describing the effects of **Pasteur's** and **Koch's** experiments on the understanding of disease transmission
- describe how **germ theory** exemplifies the **nature of science** as supported by evidence (BIO.4 e)
- use evidence from scientific literature and research to support a claim on the use or **misuse of vaccines** or **antibiotics**

BIO.5 COMMON MECHANISMS FOR INHERITANCE

a) DNA has structure and is the foundation for protein synthesis;
b) the structural model of DNA has developed over time;
c) the variety of traits in an organism are the result of the expression of various combinations of alleles;
d) meiosis has a role in genetic variation between generations; and
e) synthetic biology has biological and ethical implications.

*Central Idea: **Traits** of living things are influenced by **genetic makeup** and can be predicted using genetic information. Genetic information can be determined and **altered** through **synthetic means**.*

a) DNA - foundation for protein synthesis;

The **structure** and **function** of **DNA** are intimately **linked**.

- Scientists use 2-D, 3-D, and virtual **models** to represent the **structure** of **DNA**.
  - Models are used when the object is **too small or too complex** to be studied directly (BIO.5 a).
- **DNA** is a **helical macromolecule** consisting of **nucleotides**.
  - Each **nucleotide** is identified by the **base** it contains: **adenine (A), guanine (G), cytosine (C) or thymine (T)**.
- **Nucleotides** are connected by covalently bonded **sugar** and **phosphate** molecules.
- The **information encoded** in **DNA** molecules provides **instructions** for assembling **amino acids,** which ultimately form **protein molecules**.
  - The code for **specific amino acids** is virtually the same for **all life forms**.
- All cells contain **genetic information** in the form of **DNA** molecules.
  - **Genes** are **regions** in the DNA that contain the instructions that **code** for the formation of **proteins**.
- compare a variety of **DNA models** and evaluate them for their effectiveness in explaining its **structure** and **function**

b) the structural model of DNA has developed over time;

Modern advances (since 1990) in science and technology have added to our understanding of the **structure of DNA** and its function (e.g., **Sanger technique**, **Human Genome Project**, **sequencing chromosomes)**

  - Students are not responsible for describing the contributions of **specific scientists**.

A complex system functions to pass **characteristics (traits)** from one generation to the next. The interaction of heredity mechanisms and the environment creates both **stability** from one generation to the next and drives change that produces the **diversity** of life on our planet.

- provide examples to illustrate how **modern advances** related to DNA structure and function illustrate the nature of science (BIO.5 b)

c) the variety of traits in an organism are the result of the expression of various combinations of alleles

Organisms **transfer their genetic information** to their offspring when they **reproduce**.

- **Sexual reproduction** involves the production of **sex cells** (**gametes**).
  - **Sex cells** each carry **half** the parent's genetic material (on **chromosomes**) .
  - In **sexual reproduction**, each parent **contributes half** of the genetic information acquired by the offspring, resulting in **variation** between **parent** and **offspring**.
- **Genes** and **chromosomes** are present in **pairs** (e.g., **allele B or b**) in individuals (for **diploid organisms).**
  - All **genes assort independent** of other genes during **sex cell production** in **meiosis**.
  - The **probability** of a sex cell containing **either allele** from the pair is **50 percent .**
- **Asexual reproduction** produces offspring which are **genetically identical to** the parent (**mitosis**).
- **Genetically diverse** populations are more **likely to survive** changing environments.
  - **Recombination** and **mutation** provide for **genetic diversity**.
  - Some new **gene combinations** have **little effect**, some can produce organisms that are **better suited** to their environments, and others can be **deleterious**.
- Each **chromosome** consists of a **single, very long DNA molecule,** and each **gene** on the chromosome is a **particular segment** of that DNA.

- The instructions for forming **species' characteristics** are carried in **DNA**.
- **All cells** in an organism have the **same genetic content,** but the genes **used (expressed)** by the cell may be **regulated in different ways.**
- Not all DNA codes for a protein; some segments of DNA are involved in **regulatory** or **structural** functions, and some have **no as-yet-known** function.

- **Mendel's laws of heredity** are based on his mathematical analysis of observations of patterns of inheritance of **dominant-recessive traits**.
- **Geneticists** apply mathematical principles of **probability** to Mendel's laws of heredity to predict the results of **simple genetic crosses.**
  - The laws of probability govern simple **genetic recombinations.**
- A **Punnett square** is a mathematical **model** that shows the **probability** of certain **genetic combinations** in offspring.
- **Genotype** describes the **genetic make-up** of an organism and **phenotype** describes the organism's **appearance** based on its genes.
  - **Phenotype** describes the **observable physical** or **biochemical characteristics** of the organism .
- Variations of **dominant-recessive expression** of alleles include **incomplete dominance** and **co-dominance**. Students are not responsible for describing sex-linked and polygenic inheritance.
- relate the expression of a **phenotype** to a given **genotype**
- use a **Punnett square** to predict all possible combinations of gametes and the likelihood that a given combination will occur in **monohybrid** and **dihybrid crosses** (BIO.5 c)
- predict possible **genotypes** and **phenotypes** of **non-Mendelian traits**
- identify sources of **genetic diversity** and explain how it can be an **advantage** for **populations** (BIO.5 c)
- apply concepts of statistics and probability to explain the variation and distribution of **expressed traits** in a population (BIO.5 c)

d) meiosis & genetic variation

In **eukaryotes**, heritable information is passed to the next generation via processes that include the **cell cycle** and **mitosis** or **meiosis** plus **fertilization**.

- **Meiosis** refers to division of the **nuclear material**.
  - **Cytokinesis** is the division of the **cytoplasm** and **organelles**.
  - Students are not responsible for identifying the stages of meiosis.
- Many organisms combine **genetic information** from **two parents** to produce offspring.
  - **Sex cells (gametes)** are produced through **meiosis**.
  - This allows sexually reproducing organisms to produce **genetically differing offspring** and maintain their number of **chromosomes** (BIO.5 c).
- describe in general terms the **stages of meiosis** and explain the processes occurring at each stage; differentiate these from the end products of **mitosis**
- explain why **meiosis** is important for sexual reproduction
- compare the process of **mitosis** and **meiosis** and determine which conditions are necessary for each process to occur
- make and defend a claim based on evidence from scientific literature that **inheritable genetic variations** may result from
  - new genetic combinations through meiosis
  - viable errors occurring during replication
  - environmental factors

e) synthetic biology

Science and **technology** are tightly linked. Technologies have improved our understanding of DNA, its function, and how its code can be manipulated for a variety of purposes.

- **Genetic engineering techniques** are used in a variety of industries, in agriculture, in basic research, and in medicine.
  - There is great benefit in terms of **useful products** derived through genetic engineering (e.g.**, human growth hormone, insulin, and pest- and disease-resistant fruits and vegetable**s).
- **Synthetic biology** combines many different science disciplines to design and build **new biological parts, devices, and systems.**
  - Synthetic biology has many different applications.
- Tools and techniques are used in genetic engineering, such as **polymerase chain reaction**, **restriction enzymes**,

gel **electrophoresis**, **DNA ligase**, **bacterial plasmids**, and **CRISPR** have improved our ability to **genetically alter the DNA or organisms** for a specific purpose.

  - **Synthetic biology** employs different tools, depending on the desired product.

- evaluate and use credible, accurate, and unbiased resources to gather and summarize scientific and technical information about how **genetic engineering tool**s and technologies can be used to **alter the genome** of an organism (BIO.5 e)
- debate the **pros and cons** of synthetic biology
- evaluate data from databases or experimentation to support an argument for the **transmission of traits** across generations

BIO.6 MODERN CLASSIFICATION

a) organisms have structural and biochemical similarities and differences;
b) fossil record interpretation can be used to classify organisms;
c) developmental stages in different organisms can be used to classify organisms;
d) Archaea, Bacteria, and Eukarya are domains based on characteristics of organisms;
e) the functions and processes of protists, fungi, plants, and animals allow for comparisons and differentiation within the Eukarya kingdoms; and
f) systems of classification are adaptable to new scientific discoveries.

*Central Idea: **Taxonomic classification** is a hierarchal system for classifying organisms. Organisms are classified based on physiological structures, embryology and ontogeny, and phylogenetic relationships.*

*Evidence shows how **species** can **change over time.** Species are related to varying degrees, which can be determined through **evolutionary relationships**.*

a) organisms have structural and biochemical similarities and differences;

Classification relies on careful observation of patterns of **similarities** and **differences**. Classification is useful in explaining relationships and organizing objects or processes into groups.

- Organisms that live on Earth today, or once lived on Earth, are classified into a **hierarchy of groups** and subgroups based on similarities **of physiological structures, embryology** and **ontogeny** (development), and **phylogenetic (evolutionary)** relationships
- The organisms that live on Earth today **share many physiologic structures and metabolic processes**, including **cellular organization**; **common molecular mechanisms** for energy transformation, utilization, and maintenance of life processes; **common genetic code**; and mechanisms for the transmission of traits from one generation to the next.
- **Evolutionary relationships** can be represented using a **branching diagram** called a **cladogram** or **phylogenetic tree**, on which they are **organized by shared, derived characteristics**.
- **Biological classification** (**taxonomy**) uses a systematic method to name, organize, and show how organisms are related.
- **Binomial nomenclature** is a standard way of identifying a **species** with a **scientific two-word name**.
  - The first word is the **genus name** and the second is the **species name**.
  - **Species** is the **basic unit** of classification
- **Similarities** among organisms on the structural and metabolic levels are reflected in the large degree of **similarity in proteins** and **nucleic acids** of different organisms.
  - **Diversity** is the product of **variations** in these **molecules**
- arrange organisms in a **hierarchy** according to similarities and differences in structural and biochemical characteristics
- recognize scientific names as part of a **binomial nomenclature** (BIO.6 a)

b) fossil record in classification

- Information about relationships among living organisms and those that inhabited Earth in the past is gained by examining and interpreting the **fossil record.**
  - Fossils provide a **time-ordered record** of the unique characteristics of organisms over millions of years.
  - Data from fossils can be used to infer **phylogenetic relationships** among existing and extinct organisms.
- compare structural characteristics of an **extinct organism**, as evidenced by its **fossil record**, with present, familiar organisms

- analyze and interpret data for patterns in the fossil record that document the existence, diversity, extinction, and change of life forms throughout the history of life on Earth (under the assumption that natural laws operate today as in the past) (BIO.6 b)

- interpret a **cladogram** or **phylogenetic tree** to make inferences about the evolutionary relationships among organisms (BIO.6 b)

c) developmental stages for classification

A **cladogram** is a model (diagram) used to show relationships among organisms.

  - A **cladogram** uses lines that branch off in different directions, ending at a **group of organisms** with a **common ancestor** (clade) (BIO.6 b).

- **Embryology** is the study of an **organism's embryological development** and may reveal that there are features present in **early stages** that that are **absent in the adult** form of the organism (BIO.6 c).

- recognize similarities in **embryonic stages** in diverse organisms in the animal kingdom, from zygote through embryo, and infer relationships (BIO.6 c)

d) domains - Archaea, Bacteria, and Eukarya are

- Information about the physical features and activities of living things are organized into a **hierarchy of increasing specificity** (BIO.6).

- Characteristics used to classify organisms into **domains** include, but are not limited to, whether the organism is **prokaryotic vs. eukaryotic**, differences in **sequences of nucleic acids (RNA),** and the **cell membrane and/or cell wall structure**.

e) Eukarya kingdoms - protists, fungi, plants, and animals

f) systems of classification are adaptable to new scientific discoveries.

Characteristics used to group organisms into **kingdoms** include, but are not limited to, **prokaryote vs. eukaryote**, **unicellular vs. multicellular**, **cell wall vs. no cell wall**, **level of organization** of cells into tissues, **autotroph vs. heterotroph**, and within heterotrophs, **decomposer vs. ingestion** (BIO.6 e).

- **Protists** are **simple**, predominately **unicellular**, **eukaryotic** organisms (BIO.6 e).

- **Fungi** are **unicellular** or **multicellular**, **eukaryotic** organisms.
  - The cells of fungi have **cell walls** but are **not** organized into **tissues**.
  - They are **heterotrophs** and obtain nutrients through **absorption**.

- **Plants** are **multicellular**, **eukaryotic** organisms.
  - The cells of plants have **cell walls** and are organized into **tissues**.
  - Plants are **autotrophs** and obtain nutrients through **photosynthesis** and **absorption**.
  - **Plant divisions** include **mosses, ferns, conifers**, and **flowering plants**.

- **Animals** are **multicellular**, **eukaryotic** organisms.
  - The cells of animals do **not have a cell wall.**
  - Animals are **heterotrophs** and are **mobile** for at least a part of their life cycles.

- apply classification criteria to categorize examples of organisms as representatives of the **three domains**: **Archaea, Bacteria, and Eukarya** (BIO.6 d)

- apply classification criteria to categorize examples of organisms as representatives of the **six kingdoms**: archaebacteria, eubacteria, protista, fungi, plantae, and animalia (BIO.6 e)

- recognize new attributes (physical and chemical) that affect the taxonomic group into which an organism is (or was) placed (BIO.6 f).

BIO.7 POPULATIONS CHANGE THROUGH TIME.

a) evidence is found in fossil records and through DNA analysis;
b) genetic variation, reproductive strategies, and environmental pressures affect the survival of populations;
c) natural selection is a mechanism that leads to adaptations and may lead to the emergence of new species; and
d) biological evolution has scientific evidence and explanations.

Central Idea: Similarities and differences in inherited characteristics of organisms alive today or in the past can be used to infer the relatedness of any two species,

changes in species over time, and lines of evolutionary descent. Speciation, extinction, and changes in population genetics result from evolution.

a) evidence is found in fossil records and through DNA analysis;

Genetic variation, reproductive strategies, and environmental pressures affect the **survival of populations**

- A **fossil** is **any evidence** of an organism that lived long ago.
  - Scientists have used the **fossil record** to construct a **history of life on Earth**.
  - Although there is not a complete record of ancient life for the past 3.5 billion years, a great deal of **modern knowledge** about the history of life comes from the **fossil record**.
- Having **similar DNA** is a strong indicator that organisms share a **common ancestor**.
  - Identifying **DNA sequences** through comparative genomics has helped to identify and better understand **similarities in DNA sequences** across species.
- determine the **relative age** of a fossil, given information about its **position in the rock** and **absolute dating** by **radioactive decay** (BIO.7 a)
- differentiate between **relative** and **absolute dating** based on fossils in biological evolution (BIO.7 a)
- explain how advancements in our **understanding of DNA** and its function contribute to the understanding that **species change over time** (BIO.7 a)
- explain how advancements in **genetic technology** contribute to the understanding that **species change** over time (BIO.7 a)

b) genetic variation, reproductive strategies, and environmental pressures affect the survival of populations;

Variations within a population for a given trait can arise through **mutations**, **gene flow**, and **sexual reproduction**.

- **Mutations** are **changes** in the sequence of DNA **nitrogenous bases**.
  - The **accumulation of mutations** within a population over time can result in **changes to the gene pool**.
  - The **movement of genes** from one **population** to another also provides **greater genetic variation**.
  - The **genetic shuffling** that takes place during **meiosis** and sexual reproduction introduces **new gene combinations** within a population.
- Organisms possess **reproductive strategies** and rates that maximize the probability that their **offspring**, and thus the **population, can survive**.
- **Populations** produce **more offspring** than the environment can support.
  - Organisms with **certain genetic variations** will be favored to **survive** and **pass their variations on** to the next generation.
- **Variations within populations** sometimes arise abruptly in response to strong **environmental selective pressures**.
- provide evidence to support the argument that **variations** for a given **trait** within a population may be **helpful or harmful** to the survival of a population when **environmental pressures** arise (BIO.7 b)
- discuss **sources of genetic variation** within a population (BIO.7 b)
- describe the effect of **reproductive strategies** and rates on a **population's survival** (BIO.7 b)
- predict the effects of environmental pressures on populations (BIO.7 b)

c) natural selection is a mechanism that leads to adaptations and may lead to the emergence of new species; and

Natural selection is a mechanism that leads to **adaptations** and may lead to the emergence of **new species.**

- Natural selection occurs only if there is both variation in the **genetic information** among organisms in a population and variation in the **expression** of that genetic information that leads to **differences in performance** among individuals.
- The **unequal ability** of individuals to survive and reproduce leads to the gradual **change in a population,** generation after generation, over many generations.
- Traits that **positively affect survival** are more likely to be **reproduced** and are more common in the population.
- **Natural selection** leads a population dominated by organisms that are anatomically, behaviorally, and physiologically **well suited to survive** and **reproduce** in a specific environment (BIO.7 c).

- explain how natural selection leads to **changes in gene frequency** in a population over time (BIO.7 c)

d) biological evolution has scientific evidence and explanations.

- Depending on the **selective pressure,** these changes can be **rapid** over few generations (i.e., antibiotic resistance) or may take **millions of years** to develop (BIO.7 d).
- **Speciation**, the emergence of **new species**, occurs when a lineage has split into groups that **can no longer naturally interbreed** and produce **fertile offspring** and/or are no longer genetically aligned.
- If a population is **not able to respond** to environmental pressures, it may become **extinct** (BIO.7 c).
- **Biological evolution** is supported by **scientific evidence** from many disciplines.
- **Natural selection** may lead to the permanent change in the frequency of a gene in a given population. This is called **biological evolution** (BIO.7 c).
- **Biological evolution** is supported by scientific evidence from **many disciplines** such as, but not limited to, paleontology, geology, embryology, anatomy, biology, genetics, and biochemistry (BIO.7 d).
- compare **punctuated equilibrium** with **gradual change** over time (BIO.7 d)
- construct an explanation for the **anatomical similarities and differences** among modern organisms and between **modern and fossil organisms** to infer **evolutionary relationships** (BIO.7 d)
- construct an explanation based on evidence that the process of **evolution primarily results from**
- the potential for a species to **increase in number**
- the **heritable genetic variation** of individuals in a species due to **mutation** and **sexual reproduction**
- **competition** for limited resources
- o the proliferation of those organisms that **are better able to survive** and reproduce in the environment (BIO.7 a, b, c, d)
- evaluate evidence supporting the claim that changes in environmental conditions may result in an **increased number of some species**, the emergence of **new species** over time, and/or the **extinction** of other species (BIO.7 b, c, d).

BIO.8THERE ARE DYNAMIC EQUILIBRIA WITHIN POPULATIONS, COMMUNITIES, AND ECOSYSTEMS.

a) interactions within and among populations include carrying capacities, limiting factors, and growth curves;
b) nutrients cycle with energy flow through ecosystems;
c) ecosystems have succession patterns; and
d) natural events and human activities influence local and global ecosystems and may affect the flora and fauna of Virginia.

Central Idea: Organisms are part of living systems and demonstrate interdependence with other organisms and the environment.

a) interactions within and among populations include carrying capacities, limiting factors, and growth curves;

All biological systems from cells and organisms to populations, communities, and ecosystems are affected by **complex biotic and abiotic interactions** involving **exchange in matter and energy.**

Carrying capacity is the **number of organisms** that can be supported by the **resources in an ecosystem**.

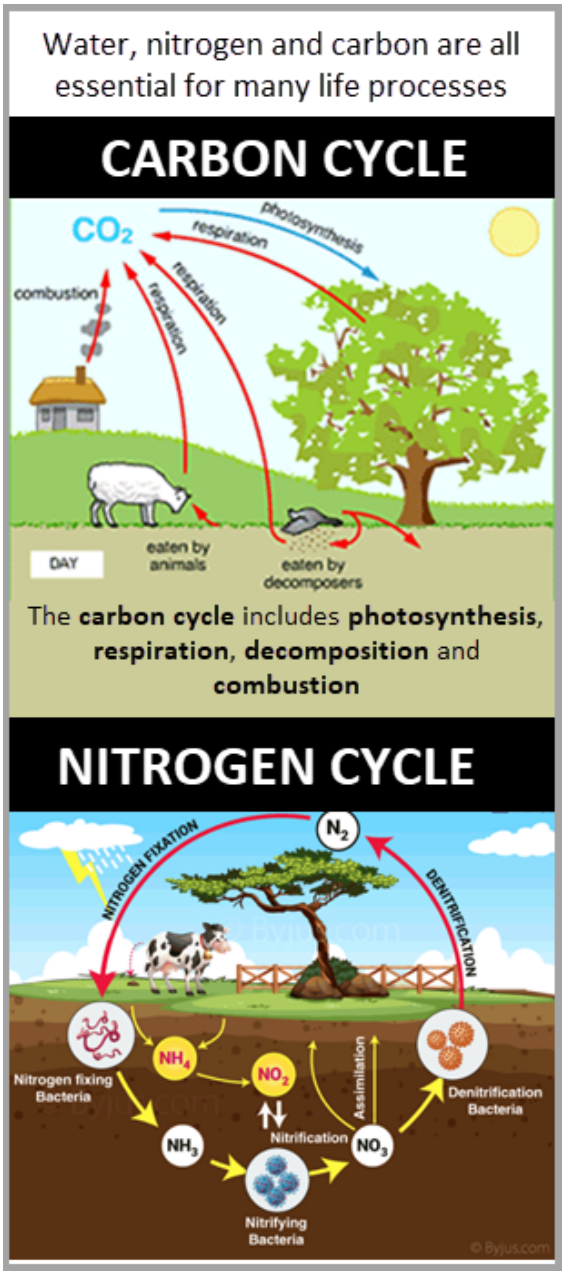
- Ecosystems have **carrying capacities**, which refer to the **limits** to the numbers of organisms and populations **ecosystems can support**.
  - These **limits** result from such factors as the availability of living and nonliving **resources** and from such challenges such as **predation**, **competition**, and **disease**.
  - Organisms would have the capacity to produce populations of great size were it not for the fact that **environments and resources are finite**.
  - This fundamental tension affects the **abundance (number of individuals) of species** in any given ecosystem (BIO.8 a).
- **Populations** are **groups of interbreeding individuals** that live in the **same place** at the **same time** and **compete** for food, water, shelter, and mates.
- **Group behavior** has evolved because membership can **increase the chances of survival** for individuals and their genetic relatives.

- As any population of organisms grows, it is **held in check** by interactions among a variety of **biotic and abiotic factors** (BIO.8 a).
  - **Abiotic factors** are the nonliving elements in an ecosystem, such as **temperature, moisture, air, salinity, and pH.**
  - **Biotic factors** are all the **living** organisms that inhabit the environment, including **predators**, **food** sources, and **competitors**.
- **Communities** are composed of **populations of organisms** that interact in complex ways.
  - **Members of a population interact** with other populations in a **community**.
  - These organisms **compete** to obtain the **matter** and **energy** they need for basic **resources**, **mates**, and
  - . They also **cooperate** to meet basic needs and carry out life processes.
- **Population growth curves** exhibit many characteristics, such as **initial growth stage, exponential growth, steady state, decline, and extinction**.
  - **Limiting factors** are the components of the environment that **restrict the growth** of populations.
- use mathematical representations such as charts, graphs, histograms, and population change data, to support explanations of factors that affect **carrying capacity** of ecosystems (BIO.8 a)
- make predictions about changes that could occur in population numbers as the result of population interactions (BIO.8 a)
- graph and interpret a **population growth curve** and identify the **carrying capacity** of the populations (BIO.8 a)

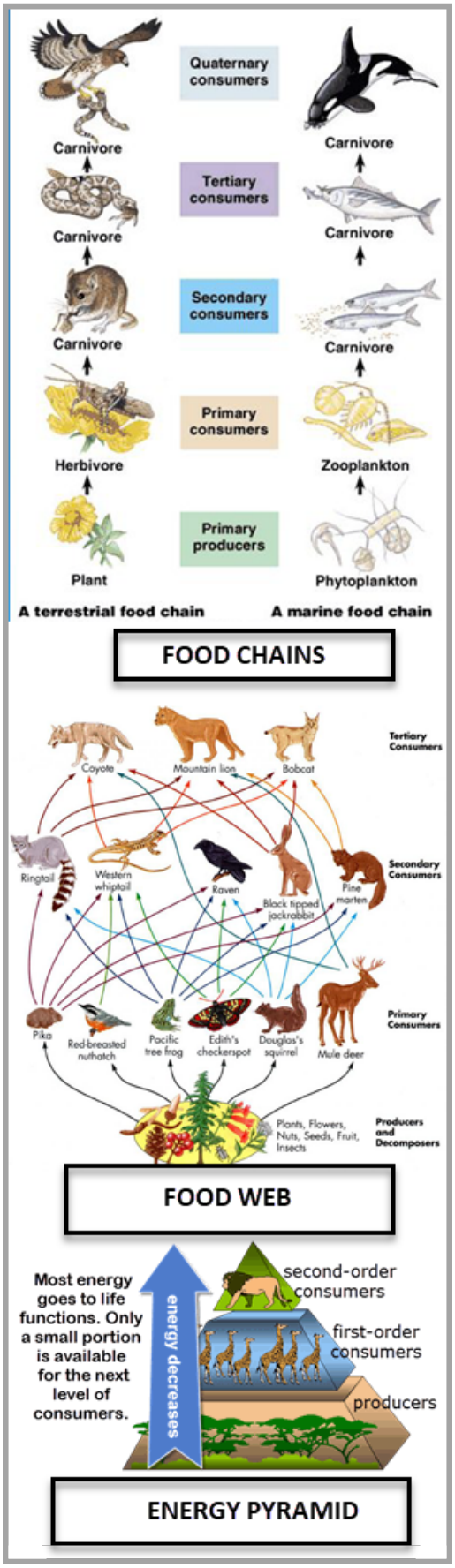
b) nutrients cycle with energy flow through ecosystems;

Systems are dynamic and change in response to inputs and outflows of **energy and matter**. A healthy ecosystem has a state of **dynamic equilibrium**, when the inflow and outflow of **energy and matter is steady**. When one of the variables is **out of balance**, the health of the **ecosystem changes**.

- **Ecosystems** demonstrate an **exchange of energy** and **nutrients** among inhabiting organisms (BIO.8 b).
- An ecosystem consists of all the **interacting species** and the **abiotic environment** in a given geographic area.
  - All **matter**, including essential nutrients, **cycle through an ecosystem**.
  - The most common examples of such matter and nutrients include **carbon**, **nitrogen**, and **water**.
- **Photosynthesis** and **cellular respiration** are important components for the **carbon cycle,** in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes.
- The main components of the **nitrogen cycle** include **nitrogen fixation**, **nitrification**, **assimilation**, **ammonification**, and **de-nitrification.**
- The main components of the **carbon cycle** include **photosynthesis**, **respiration**, **combustion**, and **decomposition**.



Energy pyramids, food webs and food chains all show how energy flows through the ecosystem.



c) ecosystems have succession patterns

Ecological succession is the process by which the structure of a **biological community evolves** over time.

- **Ecological succession** is a **predictable change** in the sequence of species that establish in an area over time.
- A **climax community** occurs when **succession slows** and a **stable community** is established.
  - The **climax community** in most of Virginia is a **deciduous oak-hickory (hardwood) forest**.

PRIMARY SUCCESSION

Primary succession begins in a **lifeless** area with **no soil**, only rocks, perhaps after volcano eruption.

A **pioneer species like** lichens or moss grow and decompose into soil which slowly builds up.

SECONDARY SUCCESSION

Starts with an event like fire, but much **faster** than primary succession because **soil is left behind**. Grasses grow back first, then shrubs and small trees.

BOTH TYPES OF SUCCESSION END IN A STABLE **CLIMAX COMMUNITY**

In **Virginia**, the most common **climax community** is the deciduous oak-hickory (hardwood) forest

d) natural events and human activities influence local and global ecosystems and may affect the flora and fauna of Virginia.

Human and natural activities **affect ecosystems** on local, regional, and global scales.

- As the **human population increases**, so does **the human impact** on the environment.
  - **Human activities,** such as reducing the amount of **forest** cover, increasing the amount and variety of **chemicals** released into the environment, and intensive **farming**, have changed Earth's land, oceans, and atmosphere.
  - Some of these changes have **decreased the capacity** of the environment to support some life forms.
- **Large-scale changes** that influence ecosystems include the **addition of excess nutrients** to the system (**eutrophication**), which alters environmental balance; dramatic **changes in climate**; and **catastrophic events,** such as fire, drought, flood, and earthquakes.

EUTROPHICATION

The **excess nutrients** in **fertilizer** used for farms and lawns causes an **overgrowth of algae** seen here. The overgrowth of algae blocks light needed by organisms below the surface. The decomposing algae causes **low levels of dissolved oxygen** needed by other organisms.