

# Cell Growth and Reproduction

## Module B, Anchor 1

### Key Concepts:

- The larger a cell becomes, the more demands the cell places on its DNA. In addition, a larger cell is less efficient in moving nutrients and waste materials across the cell membrane.
- Asexual reproduction is the production of genetically identical offspring from a single parent.
- Offspring produced by sexual reproduction inherit some of their genetic information from each parent.
- Chromosomes make it possible to separate DNA precisely during cell division.
- During the cell cycle, a cell grows, prepares for division, and divides to form two daughter cells.
- During prophase, the genetic material inside the nucleus condenses. During metaphase, the chromosomes line up across the center of the cell. During anaphase, the chromosomes separate and move along spindle fibers to opposite ends of the cell. During telophase, the chromosomes, which were distinct and condensed, begin to spread out into tangle of chromatin.
- The cell cycle is controlled by regulatory proteins both inside and outside the cell.
- Cancer cells do not respond to the signals that regulate the growth of most cells. As a result, the cells divide uncontrollably.
- The diploid cells of most adult organisms contain two complete sets of inherited chromosomes and two complete sets of genes.
- In prophase I, replicated chromosomes pair with corresponding homologous chromosomes. At metaphase I, paired chromosomes line up across the center of the cell. In anaphase I, chromosome pairs move toward opposite ends of the cell. In telophase I, a nuclear membrane forms around each cluster of chromosomes. Cytokinesis forms two new cells. As the cells enter prophase II, their chromosomes become visible. The final four phases of meiosis II result in four haploid daughter cells.
- In mitosis, when the two sets of genetic material separate, each daughter cell receives one complete set of chromosomes. In meiosis, homologous chromosomes line up and then move to separate daughter cells. Mitosis does not normally change the chromosome number of the original cell. Meiosis reduces the chromosome number by half. Mitosis results in the production of two genetically identical diploid cells, whereas meiosis produces four genetically different haploid cells.
- Alleles of different genes tend to be inherited together from one generation to the next when those genes are located on the same chromosome.

### Cell Growth, Division, and Reproduction:

1. What are the reasons why cells divide? How does division address these issues?

2. Describe what is meant by each of the following: cell volume, cell surface area, ratio of surface area to volume. Why is the ratio of surface area to volume important to cell survival?
3. In order for cells to divide successfully, the cell must first
  - A. duplicate its genetic information
  - B. decrease its volume
  - C. increase its number of chromosomes
  - D. decrease its number of organelles
4. Compare and contrast sexual and asexual reproduction.
5. Which type of reproduction is best suited to a changing environment? Why?

**Cell Cycle/mitosis:**

1. List and describe the stages of interphase. Illustrate each description.
2. List and describe the stages of M phase. Illustrate each stage.

3. If a cell has 12 chromosomes before division, how many chromosomes will be in each of its daughter cells after mitosis and cytokinesis? Why is this important?
  
4. Describe how a eukaryotic cell's chromosomes change as a cell prepares to divide. Why is it advantageous to package DNA into chromosomes for cell division?
  
5. What is the relationship between interphase and cell division? Why must the DNA be duplicated before cell division can occur?
  
6. How is the process of cell division different in prokaryotes and eukaryotes?
  
7. Compare and contrast cell division in plant and animal cells.
  
8. What type of cells are produced by mitosis?

**Meiosis:**

1. List and describe the stages of meiosis I.
  
  
  
  
  
  
  
  
  
  
2. List and describe the phases of meiosis II.

3. Compare and contrast meiosis I and meiosis II.
  
4. What type of cells are produced by meiosis? How do the end products of meiosis differ in males and females?
  
5. Compare and contrast meiosis and mitosis.
  
6. What events ensure that the cells produced by mitosis are genetically identical diploids, while the cells produced by meiosis are genetically different haploids?
  
7. Why does mitosis produce diploid cells, while meiosis produces haploid cells?

### **Regulating the Cell Cycle:**

1. The timing in the cell cycle in eukaryotic cells is believed to be controlled by a group of closely related proteins known as:
  - A. chromatids
  - B. cyclins
  - C. centromeres
  - D. centrioles
  
2. Compare and contrast internal and external regulators. Give examples of each.
  
3. How do cancer cells differ from noncancerous cells? How are they similar?
  
4. What is apoptosis? What is the role of apoptosis in regulating the cell cycle?

# Genetics

## Module B, Anchor 2

### Key Concepts:

- An individual's characteristics are determined by factors that are passed from one parental generation to the next.
- During gamete formation, the alleles for each gene segregate from each other so that each gamete carries only one allele for each gene.
- Punnett squares use mathematical probability to help predict the genotype and phenotype combinations in genetic crosses.
- The principle of independent assortment states that genes for different traits can segregate independently during the formation of gametes.
- Mendel's principles of heredity, observed through patterns of inheritance, form the basis of modern genetics.
- Some alleles are neither dominant nor recessive. Many genes exist in several different forms and are therefore said to have multiple alleles. Many traits are produced by the interaction of several genes.
- Environmental conditions can affect gene expression and influence genetically determined traits.
- The DNA that makes up genes must be capable of storing, copying, and transmitting the genetic information in a cell.
- DNA is a nucleic acid made up of nucleotides joined into long strands or chains by covalent bonds.
- DNA polymerase is an enzyme that joins individual nucleotides to produce a new strand of DNA.
- Replication in most prokaryotic cells starts from a single point and proceeds in both directions until the entire chromosome is copied.
- In eukaryotic cells, replication may begin at dozens or even hundreds of places on the DNA molecule, proceeding in both directions until each chromosome is completely copied.
- The main differences between DNA and RNA are that (1) the sugar in RNA is ribose instead of deoxyribose; (2) RNA is generally single-stranded, not double-stranded; and (3) RNA contains uracil in place of thymine.
- In transcription, segments of DNA serve as templates to produce complementary RNA molecules.
- The genetic code is read three "letters" at a time, so that each "word" is three bases long and corresponds to a single amino acid.
- Ribosomes use the sequences of RNA codons to assemble amino acids into polypeptide chains.
- The central dogma of molecular biology is that information is transferred from DNA to RNA to protein.
- Mutations are heritable changes in genetic information.
- The effects of mutations on genes vary widely. Some have little or no effect; some produce beneficial variations. Some negatively disrupt gene function.
- Mutations often produce proteins with new or altered functions that can be useful to organisms in different or changing environments.
- Human genes follow the same Mendelian patterns of inheritance as the genes of other organisms. Many human traits follow a pattern of simple dominance. The alleles of other human genes display codominant inheritance. Because the X and Y chromosomes determine sex, the genes located on them show a pattern of inheritance called sex-linkage.
- Changes in a gene's DNA sequence can change proteins by altering their amino acid sequences, which may directly affect one's phenotype.
- If nondisjunction occurs during meiosis, gametes with an abnormal number of chromosomes may result, leading to a disorder of chromosome numbers.
- Recombinant DNA technology – joining together DNA from 2 or more sources – makes it possible to change the genetic composition of living organisms.
- Transgenic organisms can be produced by the insertion of recombinant DNA into the genome of a host organism.
- Ideally, genetic modification could lead to better, less expensive, and more nutritious food as well as less harmful manufacturing processes.
- Recombinant DNA technology is advancing the prevention and treatment of disease.
- DNA fingerprinting analyzes sections of DNA that vary widely from one individual to another.

## **Basic Mendelian Genetics:**

1. Different forms of a gene are called:

- A. hybrids
- B. dominant factors
- C. alleles
- D. recessive factors

2. Organisms that have two identical alleles for a particular trait are said to be:

- A. hybrid
- B. heterozygous
- C. homozygous
- D. dominant

3. What is the difference between a dominant and recessive allele?

4. State the principle of dominance. How does this explain the phenotype of heterozygous organisms? According to this principle, under what conditions will an organism show a recessive phenotype?

5. State the principle of segregation. How does this explain how two heterozygous organisms can produce homozygous offspring?

6. State the principle of independent assortment.

7. What is a punnett square? How are punnett squares used in genetics?

8. Show the cross between two guinea pigs. One is heterozygous for black color, the other is white. Record the genotypic and phenotypic ratios of the offspring.

## **Other Patterns of Inheritance:**

1. Compare and contrast codominance, incomplete dominance, and complete dominance.

2. Compare and contrast multiple alleles and polygenic traits.

3. Why do multiple alleles and polygenic traits produce many different phenotypes for a trait?
4. Can a trait show more than one inheritance pattern?
5. You would like to determine if a plant shows codominance or incomplete dominance. What type of cross would you perform and why? Explain how you would know whether the gene involved showed co- or incomplete dominance.
6. What is the relationship between genes and the environment?

**DNA Structure:**

1. Thoroughly describe the structure of a DNA molecule.
2. What are the base pairing rules? If the percentage of adenine in a sample goes up 5%, what will happen to the percentage of thymine? What will happen to the percentage of guanine?
3. What are the three roles of DNA? Explain how the structure of DNA aids in each role.
4. What happens when a piece of DNA is missing?
  - A. Genetic information is stored
  - B. Genetic information is transmitted
  - C. Genetic information is lost
  - D. Genetic information is copied

**DNA Replication:**

1. Thoroughly describe the process of DNA replication.
2. Compare and contrast DNA replication in prokaryotes and eukaryotes.
3. What is base pairing and how is it involved in DNA replication?

4. When a DNA molecule is replicated, how do the new molecules compare to the original molecule? How does replication ensure that this occurs?

**Transcription:**

1. Thoroughly describe the process of transcription.

2. What is made during transcription?

3. Why is transcription necessary for protein synthesis?

4. Suppose you start with a DNA strand ACCGTCACG. Use the rules of base pairing to determine the complementary RNA strand.

5. Compare and contrast DNA and RNA structure. How does the different structure of RNA relate to its different function in cells?

6. Compare and contrast DNA replication and transcription.

7. Describe the process of RNA editing.

**Protein Synthesis:**

1. List the three types of RNA. Describe the role of each in protein synthesis.

2. What is made during protein synthesis?

3. What are codons and anticodons? How do they work together during protein synthesis?



4. Thoroughly describe the process of protein synthesis.
5. Explain why controlling the proteins in an organism controls the organism's characteristics.
6. What is the correct sequence of transfer of genetic information in most organisms?
  - A. RNA, DNA, protein
  - B. DNA, RNA protein
  - C. protein, DNA, RNA
  - D. RNA, protein, DNA
7. What are the roles of endoplasmic reticulum and ribosomes in protein synthesis?
8. Does protein synthesis occur in all organisms?

**Mutation:**

1. What is a mutation?
2. What are some causes of mutation?
3. List and describe the types of gene mutations.
4. What types of gene mutations are most severe? Why?
5. List and describe the types of chromosome mutations.
6. How does the repetitive nature of the genetic code help to reduce the damage done by mutations?
7. One difference between a gene mutation and a chromosomal mutation is
  - A. A gene mutation affects the DNA of more genes than a chromosomal mutation.
  - B. A gene mutation can involve an insertion or deletion, but cannot involve a frameshift
  - C. A chromosomal mutation can affect the number of chromosomes in a cell
  - D. A chromosomal mutation is more likely to be passed on to offspring or daughter cells

8. Most mutations
- A. have no effect on the organism
  - B. are beneficial
  - C. are harmful
  - D. are fatal

**Human Heredity:**

1. A normal human zygote contains
- A. 23 chromosomes
  - B. 46 chromosomes
  - C. 44 chromosomes
  - D. XYY chromosomes
2. What is a nondisjunction? How does a nondisjunction cause chromosome disorders?
3. What is the difference between autosomes and sex chromosomes?
4. What are sex-linked traits? How are they inherited differently between males and females?
5. Which of the following forms a Barr body:
- A. one of the Y chromosomes in a male cell
  - B. one of the X chromosomes in a male cell
  - C. one of the X chromosomes in a female cell
  - D. both of the X chromosomes in a female cell

**Genetic Engineering:**

1. Organisms that contain genes from other organisms are called
- A. transgenic
  - B. mutagenic
  - C. donors
  - D. clones
2. Describe what happens during a polymerase chain reaction. What is the use of PCR?
3. Explain what genetic markers are and describe how scientists use them.
4. What are transgenic organisms? What are the potential benefits of transgenic organisms? Concerns?

5. How can genetic engineering impact human health?

6. Describe the uses of DNA fingerprinting.

7. A gene that makes it possible to distinguish a bacterium that has been transformed from one that has not is:

- A. a resistance gene
- B. an antibiotic
- C. a genetic marker
- D. a clone

8. Explain what a DNA probe is and describe how it could be used to identify a person who has an allele for a genetic disorder.

# Theory of Evolution

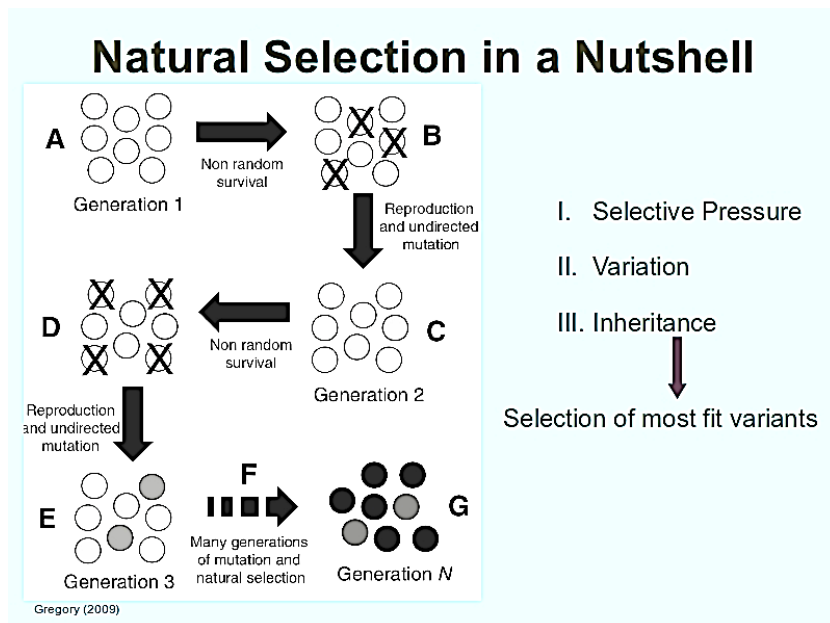
## Module B, Anchor 3

### Key Concepts:

### Mechanism for Evolution

Charles Darwin concluded that biological evolution occurs as a result of natural selection, which is the theory that in any given generation, some individuals are more likely to survive and reproduce than others. In order for natural selection to occur in a population, several conditions must be met:

- **Individuals in the population must produce more offspring than can survive.** Human beings are somewhat unique among living things in that we can make conscious choices about how many offspring we have. Most other organisms, however, produce as many offspring as they can.
- **Those individuals must have different characteristics.** During Darwin's time, no one knew where these differences came from. Now scientists know that differences in organisms arise due to mutations in DNA combined with the mixing of genetic information during sexual reproduction.
- **Offspring must inherit some characteristics from their parents.** During Darwin's time, the laws of inheritance were just beginning to be figured out, so Darwin didn't know exactly how parents passed on their traits. Modern scientists know that traits are inherited when parents pass genes on to their offspring.
- **Organisms with the best-suited characteristics for their environment are more likely to survive and reproduce.** This is the heart of natural selection. If there's competition for survival and not all the organisms are the same, then the ones with the advantageous traits are more likely to survive. If these traits can be inherited, then the next generation will show more of these advantageous traits.



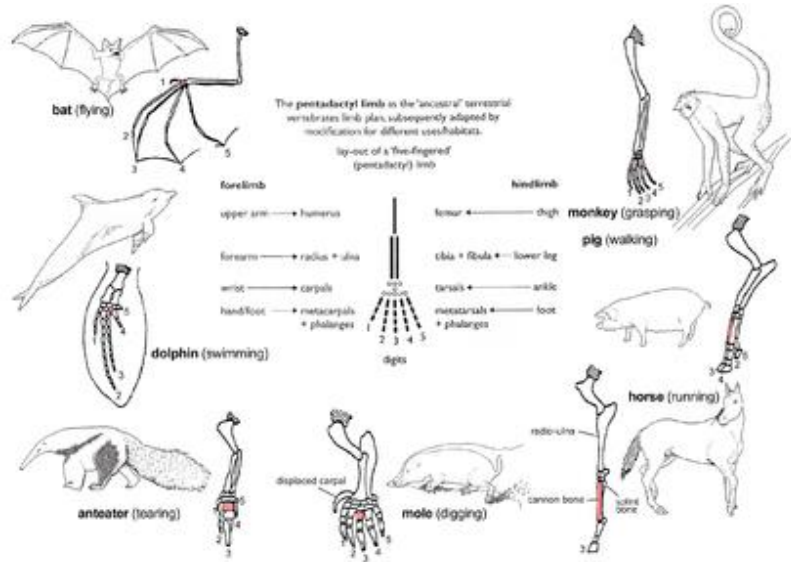
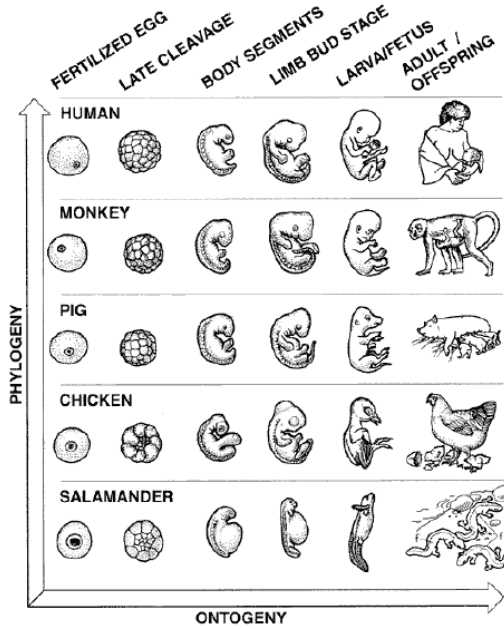
If these four conditions are met, then the new generation of individuals will be different from the original generation in the frequency and distribution of traits, which is pretty much the definition of biological evolution.

In addition, two other factors affect the genetic variability of a species

- **Genetic drift:** Either through a bottleneck (population crashes and greatly reduces number and diversity of population) or the founder effect (small group leaves to start anew...reduces number and diversity of population); the "new" population does not have the same frequencies or amounts of traits that were previously in the larger population
- **Gene flow:** organisms of the same species are able to move back and forth between areas to increase the variation of the population through sexual reproduction.

# Evidence for Evolution

Previously, the main evidence for evolution was based on **anatomy** (structures) or **physiology** (functions) of organisms. Currently, comparing **biochemical evidence** (DNA, RNA, or protein sequences) provides scientists with the most detailed information. In general, the more similarities two organisms share, the more recently they diverged from a common ancestor.

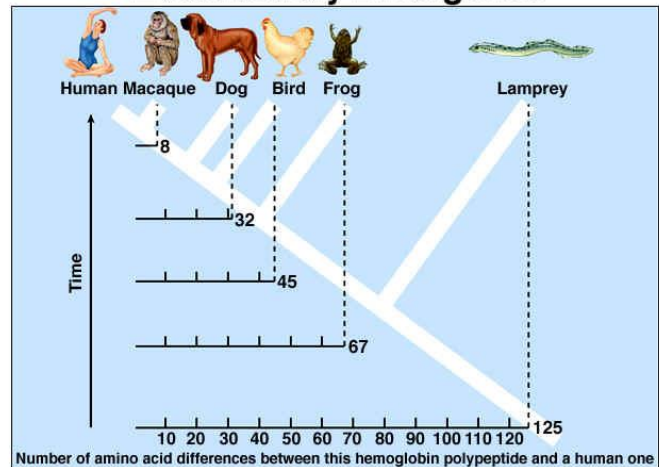


**EMBROLOGY** compares the embryos of different species. The similar development patterns of the species above indicates that they shared a common ancestor

**HOMOLOGOUS STRUCTURES** are structures that have the same shape/form, but are used differently. The bones in the center are from the common ancestor, but each species has evolved to use them differently

## Evolutionary Divergence

|           |  | Fore foot            | Hind foot  | Molar teeth                                     |                                |
|-----------|--|----------------------|--|---|--------------------------------|
| Recent    |  | Equus                | One Toe<br>Spine of 24 vertebrae                                   | One Toe<br>Spine of 24 vertebrae                | Long-Crowned, Crested, covered |
| Pliocene  |  | Protolionyx          | Three Toes<br>Side toes not touching the ground                    | Three Toes<br>Side toes not touching the ground |                                |
| Miocene   |  | Mesobonyx            | Three Toes<br>Side toes touching the ground, spine of 27 vertebrae | Three Toes<br>Side toes touching the ground     |                                |
| Oligocene |  | Protolionyx          | Four Toes  | Three Toes<br>Side toes touching the ground     | Short-Crowned, without Crest   |
| Eocene    |  | Hyrachyus (Elkippus) | Four Toes<br>Spine of 27 vertebrae                                 | Three Toes<br>Spine of 27 vertebrae             |                                |



**FOSSIL EVIDENCE** links present day organisms to the common ancestors. Here we see the bones of modern horses (top) and how much it has changed from common ancestors (bottom)

**BIOCHEMICAL EVIDENCE** compares the differences in either DNA or proteins (in this case, proteins). The lamprey has the most differences from humans, which indicates we diverged from the lampreys (are less related) much longer ago than the macaques (more related)

Not shown are **vestigial structures**, which are structures reduced in size that are no longer needed but were present in a common ancestor (think of the human tail bone or wisdom teeth. In addition, whales have tiny little hip bones but no legs, which suggests that that the ancestor of the whale walked on land and returned to the sea!). Also not shown are **analogous structures**, which are structures that look the same but are made out of different materials. This shows that species have changed to adapt to the environment in a similar manner.

## **Basic Evolutionary Theory:**

1. Explain what the term “evolution” means. Provide an example.
2. What is natural selection? How does natural selection relate to evolution?
3. Describe the conditions necessary for natural selection to occur.
4. How does natural variation affect evolution? What are the sources of genetic variation within populations? Explain how each increases genetic variation.
5. How does natural selection account for the great diversity of organisms on the Earth today?
6. An inherited characteristic that increases an organism’s ability to survive and reproduce in its specific environment is called a(n)
7. How well an organism survives and reproduces in its environment can be described as its
8. How are fitness and adaptation related?
9. Why is reproduction, as opposed to simply survival, needed for fitness?
10. What is the role of the environment in determining fitness?
11. Why does natural selection work only on heritable characteristics, as opposed to acquired characteristics?
12. What is the principle of common descent?

13. Use the theory of natural selection to explain how two unrelated organisms, such as sharks and dolphins, come to possess very similar physical adaptations.

**Natural Selection and Genetics:**

1. The combined genetic information of all members of a particular population forms a:

2. How is evolution defined, genetically speaking?

3. Explain what the term relative frequency means, include an example illustrating your answer. How does evolution change the relative frequency of alleles in a gene pool? Why does this happen?

4. The frequency of a particular allele changes from 30% to 10%. Is this population evolving? Why or why not?

5. Does natural selection work directly or indirectly on genotype? Explain your answer.

6. What is necessary for speciation to occur? Why is this necessary?

7. Describe the types of reproductive isolation.

Geographic –

Behavioral –

Temporal –

Mechanical –

8. Can two populations be separated by more than one isolating mechanism? Yes or No

9. Describe the genetic changes which occur between populations after reproductive isolation has occurred.

## Evidence for Evolution:

1. Explain how each of the following provide evidence for evolution:

Vestigial structures –

Homologous structures –

Analogous structures –

Biogeography –

Fossils –

Embryology –

Molecular biology –

2. If species A and B have very similar genes and proteins, do they share a relatively OLD or RECENT common ancestor? Explain.

# Ecology

## Module B, Anchor 4

### Key Concepts:

- The biological influences on organisms are called biotic factors. The physical components of an ecosystem are called abiotic factors.
- Primary producers are the first producers of energy-rich compounds that are later used by other organisms. Organisms that rely on other organisms for energy and nutrients are called consumers.
- Energy flows through an ecosystem in a one-way stream, from primary producers to various consumers. Pyramids of energy show the relative amount of energy available at each trophic level of a food chain or food web. A pyramid of biomass illustrates the relative amount of living organic matter available at each trophic level of an ecosystem. A pyramid of numbers shows the relative number of organisms at each trophic level in an ecosystem.
- Unlike the one-way flow of energy, matter is recycled within and between ecosystems.

*Water continuously flows between the oceans, the atmosphere, and land – sometimes outside organisms and sometimes inside organisms. Every organism needs nutrients to build tissues and carry out life functions. Like water, nutrients pass through organisms and the environment through biogeochemical cycles. The carbon, nitrogen, and phosphorus cycles are particularly important for life.*

- A region's climate is defined by year-after-year patterns of temperature and precipitation. Global climate is shaped by many factors, including solar energy trapped in the biosphere, latitude, and the transport of heat by winds and ocean currents.
- A niche is the range of physical and biological conditions in which a species lives and the way the species obtains what it needs to survive and reproduce.
- By causing species to divide resources, competition helps determine the number and kinds of species in a community and determine the number and kinds of species in a community and the niche each species occupies.



- Predators can affect the size of prey populations in a community and determine the places prey can live and feed. Herbivores can affect both the size and distribution of plant populations in a community and can determine the places certain plants can survive and grow.
- Biologists recognize three main classes of symbiotic relationships in nature: mutualism, parasitism, and commensalism.
- Ecosystems change over time, especially after disturbances, as some species die out and new species move in. Secondary succession in healthy ecosystems following natural disturbances often reproduces the original climax community. Ecosystems may or may not recover from human disturbances.
- Biomes are described in terms of abiotic factors like climate and soil type, and biotic factors like plant and animal life.
- Ecologists typically divide the ocean into zones based on depth and distance from shore.
- The factors that can affect population size are the birthrate, the death rate, and the rate at which individuals enter or leave the population.
- Under ideal conditions with unlimited resources, a population will grow exponentially. Logistic growth occurs when a population's growth slows and then stops, following a period of exponential growth.
- Acting separately or together, limiting factors determine the carrying capacity of an environment for a species.
- Birthrates, death rates, and the age structure of a population help predict why some countries have high growth rates while other countries grow more slowly.
- Humans affect regional and global environments through agriculture, development, and industry in ways that have an impact on the quality of Earth's natural resources, including soil, water, and the atmosphere. Sustainable development provides for human needs while preserving the ecosystems that produce natural resources.
- Biodiversity's benefits to society include contributions to medicine and agriculture, and the provision of ecosystem goods and services. Humans reduce biodiversity by altering habitats, hunting, introducing invasive species, releasing pollution into food webs, and contribution to climate change.

### **Energy Flow in Ecosystems:**

1. What is a trophic level? List and describe the different trophic levels in ecosystems.
  
2. How do producers and consumers differ in how they obtain energy?
  
3. Describe how energy moves through an ecosystem. How is energy lost from ecosystems? What rule describes this loss?
  
4. What is the ultimate source of all energy on Earth?
  
5. Compare and contrast food webs and food chains.
  
6. Compare energy pyramids, biomass pyramids, and pyramids of numbers in terms of the information they give about ecosystems.

## **Biogeochemical Cycles:**

1. Compare and contrast the movement of energy and matter in ecosystems.
2. List the steps of the water cycle. Which steps add water to the atmosphere? Which steps remove it?
3. List the steps of the carbon cycle. Which steps add carbon to the atmosphere? Which steps remove it?
4. How is the carbon cycle related to climate change?
5. List the steps of the nitrogen cycle. What makes nitrogen available to living things?
6. Describe the phosphorus cycle.
7. What is nutrient limitation?

## **Climate and Climate Change:**

1. What factors influence global climate? Describe each.
2. How do climate and weather differ?
3. What is the greenhouse effect? Why is it so vital to life on Earth?
4. What are the possible natural causes of global climate change?
5. What are the possible human causes of global climate change?

6. What is the evidence for global climate change?

7. What are the potential impacts of climate change?

### **Ecosystems and Communities:**

1. What is a niche? What factors define a niche? How is it different from a habitat?

2. What is competition? How does competition affect the niche of an organism?

3. How do predation and herbivory affect prey/plant populations?

4. What is a keystone species? Why is the elimination of keystone species of such concern?

5. List and describe the types of symbiotic interactions between organisms.

6. What is succession? Describe the steps involved in both types of succession?

7. List the major biomes. What are the factors used to define a biome?

### **Population Growth:**

1. Describe the different factors used to study populations.

2. What four factors affect the size of a population? Which increase it? Which decrease it?

3. Compare and contrast exponential and logistic growth.

4. What is a limiting factor? Compare and contrast density-dependent and density-independent limiting factors.

5. What is carrying capacity? How is carrying capacity related to limiting factors?

6. If a limiting factor was increased, what would happen to the population over time? Why?

7. What is the trend of human population growth over time? What challenges does this present for global ecosystems?

### **Humans and the Environment:**

1. Compare and contrast renewable and nonrenewable resources. Provide examples of each.

2. Describe several problems associated with human resources use.

3. Describe several problems associated with agriculture.

4. Describe several problems related to increased human development.