Massachusetts Tests for Educator Licensure®

TEST INFORMATION BOOKLET

13 Biology

MA-SG-FLD013-04

Massachusetts Department of Education

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Test Information Booklet Order Form

Biology (Field 13)

Test Overview Chart

Sample Test Items

Answer Key and Sample Responses

Test Objectives

Test Overview Chart: Biology (13)

Subareas	Approximate Number of Multiple-Choice Items	Number of Open-Response Items
I. Scientific Inquiry	17–19	2
II. Cells and Cell Theory	10–12	
III. Characteristics of Organisms	10–12	
IV. Human Biology	15–17	
V. Principles of Heredity and the Evolution of Life	12–14	
VI. Matter and Energy in Ecosystems	10–12	

The Biology test is designed to assess the candidate's knowledge of the subject matter required for the Massachusetts Biology Teacher certificate. This subject matter knowledge is delineated in the Massachusetts Department of Education *Regulations for the Certification of Educational Personnel in Massachusetts* (April 1995), 603 C.M.R. 7.12, "Competencies for Specific Certificates," Section (11) (a) 2. "Competency I: Subject Matter Knowledge."

The Biology test assesses the candidate's proficiency and depth of understanding of the subject at the level required for a baccalaureate major, according to Massachusetts standards. Candidates are typically nearing completion of or have completed their undergraduate work when they take the test.

The multiple-choice items on the test cover the subareas as indicated in the chart above. The open-response items may relate to topics covered in any of the subareas and will typically require breadth of understanding of the biology field and the ability to relate concepts from different aspects of the field. Responses to the open-response items are expected to be appropriate and accurate in the application of subject knowledge, to provide high-quality and relevant supporting evidence, and to demonstrate a soundness of argument and understanding of the biology field.

Sample Test Items: Biology (13)

1. Which of the following procedures should be followed when using a microscope to prevent accidental breakage of a glass slide?

   A. Use the coarse and fine adjustments to focus the specimen under low power; then turn to high power and use only the fine focus adjustment.

   B. Avoid adjusting the microscope's lamp too close to the bottom of the stage in order to prevent the slide from heating up too much.

   C. When a slide is on the microscope, always turn the focus adjustments in one direction only, such that the stage and objectives always move away from one another.

   D. Always remove the clips from the slide before attempting to move the slide around under the field of view.

2. A biologist is using a computer modeling program simulating the population growth and dispersal patterns of an insect species known to damage crops. The primary advantage of using a simulation program is that it allows the biologist to:

   A. explore how various combinations of factors are likely to affect the population growth and dispersal patterns of this insect species.

   B. study in detail the reproductive anatomy and physiology of this insect species.

   C. draw conclusions about the population growth and dispersal patterns of a wide variety of other insect species.

   D. develop chemicals that are likely to be effective in limiting the damage to crops this insect species causes.

3. In terms of the cell cycle, cancer cells differ from normal cells in which of the following ways?

   A. Cancer cells pass through the phases of the cell cycle in a sequence different from that of normal cells.

   B. Cancer cells do not stop dividing when they come in contact with other cells as normal cells do.

   C. Cancer cells divide a set number of times, while normal cells can divide continuously when nutrients are available.

   D. Cancer cells are more sensitive to changes in external factors than are normal cells and alter their division rates accordingly.

4. In mammals, which of the following body systems are responsible for control and coordination of the body's regulatory mechanisms?

   I. circulatory

   II. endocrine

   III. nervous

   IV. excretory

   A. I and II only

   B. I and III only

   C. II and III only

   D. III and IV only

5. The table below lists characteristics of four phyla of algae. Based on this information, which line in the table represents the alga phylum from which green plants are most likely descended?

Line	Photosynthetic Pigments	Carbohydrate Food Reserve	Cell Wall Components
1	chlorophyll *a*, carotenoids, phycobilins	floridean starch	cellulose with pectic materials
2	chlorophyll *a*, chlorophyll *b*, carotenoids	starch	cellulose
3	chlorophyll *a*, chlorophyll *c*, fucoxanthin	laminarin	cellulose with other poly-saccharides
4	chlorophyll *a*, chlorophyll *c*, carotenoids	starch	cellulose

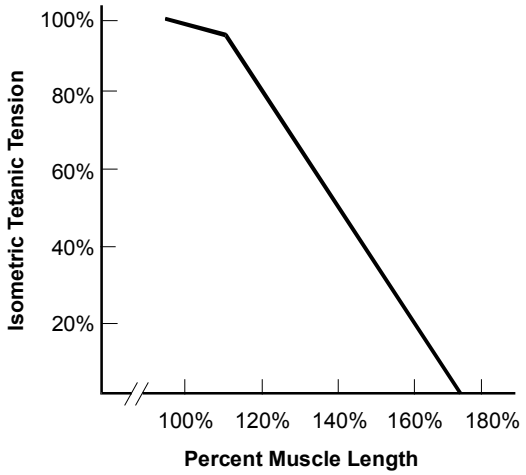
A. Line 1

B. Line 2

C. Line 3

D. Line 4

6. **Use the graph below to answer the question that follows.**



The graph above shows the variation in the isometric tetanic tension produced by a skeletal muscle as a function of its length. A length of 100% represents the normal resting length of the muscle, and a tension of 100% represents the maximum tension the muscle is able to produce. Which of the following best explains the decrease in muscle tension as the muscle is stretched beyond its normal resting length?

A. Stretching causes the membranes of the muscle fibers to become leaky to ions; therefore they are unable to initiate and propagate the action potentials that cause contractions.

B. Stretching reduces the amount of overlap between the thin and thick filaments in the muscle fibers, so fewer active cross bridges form and less tension is produced.

C. Stretching distorts the structure of the thin filaments in the muscle fibers so that cross bridges cannot bind to the actin and muscle tension cannot be created.

D. Stretching interferes with the production of ATP in a muscle fiber, so there is little energy available for muscular contraction.

7. A particular type of autoimmune disease causes antibodies to destroy acetylcholine receptors of neurons. Which of the following effects will this have on nervous system functioning?

   A. Presynaptic neurons will be unable to release neurotransmitters into the synaptic clefts.

   B. Neurons will be unable to propagate action potentials along their axons.

   C. Depolarized neurons will be unable to reestablish an ionic gradient across their membranes.

   D. Postsynaptic neurons will be unable to detect signals from presynaptic neurons.

8. In watermelons, the alleles for green color and short fruit are dominant over the alleles for striped color and long fruit. Two watermelon plants that are heterozygous for both characteristics are bred. What fraction of offspring from this cross would be expected to have green color and long fruit?

   A. $\frac{9}{16}$

   B. $\frac{7}{16}$

   C. $\frac{3}{16}$

   D. $\frac{1}{16}$

9. A team of researchers has isolated a chemical from a tropical tree that causes insects to die when they ingest it. The researchers determine that the chemical deactivates the enzyme RNA polymerase. This chemical likely causes the insects to die by interfering directly with:

   A. transcription of RNA from the DNA template.

   B. transport of RNA from the nucleus to the cytoplasm.

   C. translation of polypeptides from RNA molecules.

   D. excision of transcribed introns from an RNA molecule.

10. Chickens that are raised in very hygienic conditions are more susceptible to intestinal infections by *Salmonella* bacteria than are chickens raised under natural conditions. Researchers have found that feeding chickens a product that contains normal harmless intestinal bacteria reduces the incidence of *Salmonella* infection. Which of the following principles best explains the effectiveness of this product in preventing *Salmonella* infection?

    A. disruptive selection

    B. commensalism

    C. biological magnification

    D. competitive exclusion

11. **Use the information below to complete the exercise that follows.**

Mitochondria play an important role in energy metabolism in eukaryotic cells. Using your knowledge of cell biology, write an essay in which you discuss how mitochondria make energy available to cells. In your essay:

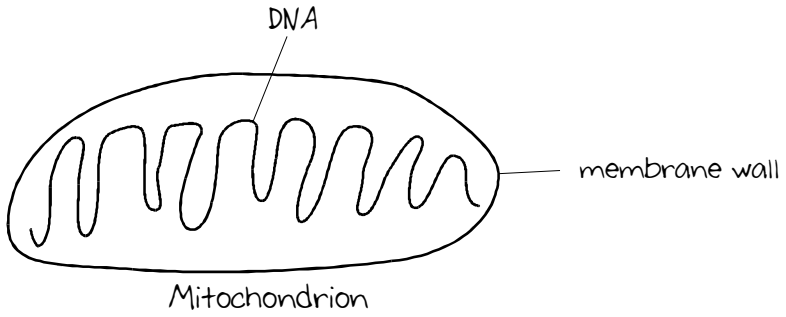
- use a labeled diagram to show the structure of a mitochondrion;
- describe the chemical reactions that take place in a mitochondrion (you may use diagrams);
- explain the relationship of these reactions to the structure of the mitochondrion; and
- explain the significance of these reactions to the cell.

Answer Key and Sample Responses: Biology (13)

Question Number	Correct Response	Test Objective*
1.	**A**	Apply procedures related to the proper use of tools, equipment, and materials (including chemicals and living organisms) commonly used in biology, and practices for maintaining safety during biological investigations.
2.	**A**	Understand the interrelationships between biology, society, technology, and other sciences and disciplines.
3.	**B**	Analyze cell growth, division, and differentiation.
4.	**C**	Analyze the anatomy and physiology of living organisms.
5.	**B**	Understand principles of taxonomy and classification in biology.
6.	**B**	Understand the structures and functions of the human skeletal, muscular, and integumentary systems.
7.	**D**	Understand the structures and functions of the human nervous and endocrine systems.
8.	**C**	Understand the principles of Mendelian and non-Mendelian genetics.
9.	**A**	Understand the synthesis of DNA, RNA, and protein.
10.	**D**	Understand populations and communities.

*Each test objective is clarified and further described by a descriptive statement, which provides examples of the types of knowledge and skills covered by the test objective. The test objectives for the Biology test begin on page 42.

The sample response below reflects a weak knowledge and understanding of the subject matter.



A mitochondria is sometimes called the powerhouse of the cell. Energy is made in the mitochondria through many complicated chemical reactions. The mitochondria takes energy from the sun and is able to make it into sugar (sucrose, glucose, etc.) and ATP that the cell can use to survive. The reaction that does this is

$CO_2 + H_2O$ + sunlight $\longrightarrow$ sugar + ATP

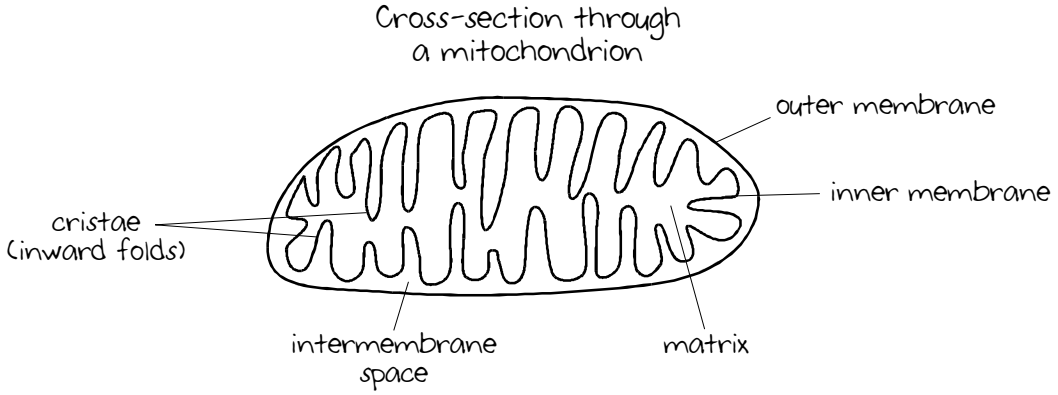
This reaction is related to the structure of the mitochondria because the membrane only lets certain substances in and out by the process of active transport. So, it only lets in carbon dioxide, water, and sunlight, and only lets out sugar and ATP.

These reactions are important to the cell because it needs sugar and ATP to supply energy for various cellular processes. The reactions are so important that some scientists think that mitochondria started out as separate organisms that invaded other cells without killing them billions of years ago. Eventually the invading organisms and the cells came to depend on each other so much that they couldn't survive apart. This explains why the mitochondria has its own DNA. When it was a separate organism, it needed the DNA to reproduce, and it kept it even after it became part of the cell it invaded.

There are other cell organelles that scientists believe became a part of cells in the same way. However, regardless of how they became a part of the cell, all the organelles have specific functions in the cell, but they still work together to keep the cell functioning. And certainly without mitochondria playing their role, cells would not be able to stay alive.

The sample response below reflects a strong knowledge and understanding of the subject matter.

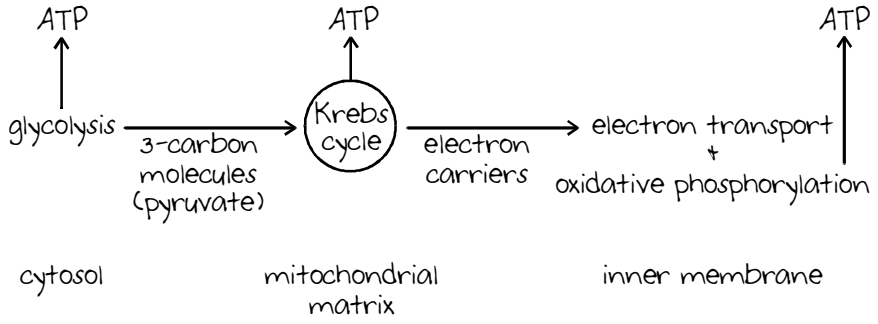
Mitochondria are cellular organelles that supply the energy needed for cellular functions through the process of cellular respiration. The major structures of a mitochondrion are labeled in the following diagram.



Cellular respiration is the process by which organisms convert energy stored in organic food molecules into ATP, a form of energy that can be used for cellular functions. The overall equation for cellular respiration is:

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

In eukaryotic cells, the process of cellular respiration involves several steps, which are summarized in the following diagram.



The process of glycolysis occurs outside the mitochondrion in the cytosol, but it provides the precursor for the Krebs cycle. During glycolysis, the glucose molecule is split in half, yielding two pyruvate molecules. The pyruvate molecules enter the mitochondrial matrix, where they are further broken down in the Krebs cycle. The Krebs cycle involves many enzyme-mediated reactions, during which CO_2 is released and electrons are transferred to electron carrier molecules, such as NADH. The Krebs cycle also regenerates its starting compound so it can break down additional pyruvate molecules.

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During both glycolysis and the Krebs cycle, a few ATP molecules are generated, but most of the ATP from respiration is generated by the combination of electron transport and oxidative phosphorylation. The electron carrier molecules generated by the Krebs cycle transfer electrons to the electron transport chain located in the inner membrane. The electron transport chain is a series of molecules, ending with oxygen, along which the electrons are passed, releasing energy in the process. The energy is used to pump H^+ ions across the inner membrane from the matrix to the intermembrane space, creating a concentration gradient. The H^+ ions diffuse back into the matrix through enzyme molecules embedded in the membrane. The enzyme uses the release of energy resulting from the movement of H^+ from an area of higher concentration to an area of lower concentration to drive the phosphorylation of ADP to ATP.

There is an important relationship between the structure of the mitochondrion and the reactions that occur there. First, the folding of the inner membrane provides a large surface area over which electron transport and oxidative phosphorylation can occur. Second, the division of the mitochondrion into two separate compartments, the matrix and inter-membrane space, makes it possible for H^+ gradients to be created. Without the energy provided by the movement of H^+, much less ATP could be produced from the breakdown of a glucose molecule.

Overall, the reactions that are involved in respiration are important to the cell because they convert the energy contained in an organic molecule to a more biologically useful molecule, ATP. The cell can use the energy that results from the conversion of ATP to ADP to fuel many processes, from protein synthesis to active transport.

Test Objectives: Biology (13)

SUBAREAS:

SCIENTIFIC INQUIRY
CELLS AND CELL THEORY
CHARACTERISTICS OF ORGANISMS
HUMAN BIOLOGY
PRINCIPLES OF HEREDITY AND THE EVOLUTION OF LIFE
MATTER AND ENERGY IN ECOSYSTEMS

SCIENTIFIC INQUIRY

0001 Apply procedures for gathering, organizing, interpreting, evaluating, and communicating data.

For example: identifying appropriate questions to ask in a given biological science context; systematically observing phenomena; gathering information from a variety of sources; selecting and using measurement devices; using, manipulating, and interpreting metric units; organizing data gathered through observation and experimentation; communicating and interpreting data presented in a variety of formats (e.g., graphs, flow charts, tables, step-by-step directions, reports); making predictions and drawing conclusions based on data; and evaluating, reporting, and applying simple descriptive statistics.

0002 Apply principles and procedures of research and experimental design.

For example: selecting an appropriate biological problem to be solved through planned experimentation; identifying procedures and considerations in setting up and conducting experiments; applying sampling techniques; using control and experimental groups to test hypotheses; and recognizing variables being held constant, variables being manipulated, and variables responding.

0003 Apply procedures related to the proper use of tools, equipment, and materials (including chemicals and living organisms) commonly used in biology, and practices for maintaining safety during biological investigations.

For example: proper practices and techniques related to the safe use and storage of tools, equipment, and materials; proper practices and requirements related to the use and care of living organisms; and procedures for preventing accidents in biology classrooms and laboratories.

0004 Understand historical and social aspects of biological study and contributions made to biology by various people.

For example: the historical development and significance of key biological ideas from different periods and cultures; the cultural and social contexts of biology; and the historical development of important biological breakthroughs.

0005 Understand the interrelationships between biology, society, technology, and other sciences and disciplines.

For example: the effects of biological science and technology on society; the application of biology in personal decision making; the implications of biological discoveries for technological advances; the use of technology in biology; the use of mathematics and chemistry to describe and analyze biological phenomena; and themes and concepts (e.g., energy, systems, constancy) that link biology to other sciences and disciplines.

0006 Analyze the nature of scientific thought and inquiry.

For example: science as the study of natural phenomena; the reliance of scientific investigation on empirical data, verifiable evidence, reasoning, and logical arguments; the importance of avoiding researcher bias in scientific investigations; and the evaluation of scientific claims and arguments.

0007 Understand processes for decision making related to biological problems and issues.

For example: identifying sources of information that aid in decision making; analyzing pros and cons of an issue; evaluating the validity of conclusions; and recognizing issues (e.g., ethical) that influence decisions related to biology.

CELLS AND CELL THEORY

0008 Understand cell structure and function and the cell theory.

For example: the structures, functions, and interrelationships between cell organelles and other cell components; specializations of cells and the relationship between a cell's structure and its function; comparison of different types of cells (e.g., plant and animal cells, prokaryotic and eukaryotic cells); and the basic tenets and implications of cell theory.

0009 Understand the chemical components of living systems and basic principles of biochemistry.

For example: the physical and chemical characteristics of water and its role in living organisms; the chemical characteristics of carbon, acids, bases, salts, and buffers and their roles in living organisms; and structures, functions, and composition of lipids, carbohydrates, proteins, amino acids, and nucleic acids.

0010 Analyze physiological processes of cells.

For example: the processes of protein synthesis, photosynthesis, and respiration (anaerobic and aerobic) and the role of enzymes in regulating these processes; and the processes by which cells obtain nutrients and maintain homeostasis (e.g., diffusion, facilitated diffusion, osmosis, active transport, exocytosis, endocytosis).

0011 Analyze cell growth, division, and differentiation.

For example: the cell cycle; the processes of mitosis and meiosis; cell structures involved in mitosis and meiosis; the consequences of normal and abnormal mitotic and meiotic divisions; the role of mitosis and meiosis in living organisms; factors that affect cell growth, division, and differentiation; and the role of cell differentiation in development.

CHARACTERISTICS OF ORGANISMS

0012 Understand principles of taxonomy and classification in biology.

For example: the characteristics of biological classification (e.g., hierarchy of taxonomic levels, importance of heritable characteristics in classifying organisms, relationship of taxonomic classification to evolutionary history); the biological species concept; organization and characteristics of the five-kingdom system; procedures and criteria used to classify organisms; taxonomic relationships among organisms (including both living and extinct organisms); and classification of organisms on the basis of given characteristics.

0013 Analyze reproduction, development, and life cycles of living organisms.

For example: characteristics of sexual and asexual reproduction; advantages and disadvantages of sexual and asexual reproduction; reproductive strategies of common organisms; characteristics of developing embryos of plants and animals; processes related to developing embryos (e.g., cleavage, gastrulation); and life cycles of common organisms.

0014 Analyze the processes used by living organisms to obtain, store, and use energy.

For example: comparisons of processes used by organisms from the five kingdoms to obtain energy; structures used to store food; structures and processes involved in the distribution of food to all parts of an organism; and ways in which organisms use food.

0015 Analyze the anatomy and physiology of living organisms.

For example: anatomical structures and physiological processes that allow organisms from the five kingdoms to carry out specific life functions (e.g., maintaining homeostasis, respiration, photosynthesis); levels of biological organization (i.e., tissues, organs, organ systems) in multicellular organisms; functions of and relationships among given tissues, organs, and organ systems; and adaptations of structures and processes.

HUMAN BIOLOGY

0016 Understand the structures and functions of the human skeletal, muscular, and integumentary systems.

For example: types, structures, and functions of bone, muscle, and connective tissues; the importance of muscle and bone arrangement in joint movement; the physiology of muscle contraction; the relationship between the structure of the skin and its functions; common diseases and disorders of the skeletal, muscular, and integumentary systems; and the homeostatic roles of the skeletal, muscular, and integumentary systems within the body.

0017 Understand the structures and functions of the human circulatory and immune systems.

For example: structures and processes of the circulatory and immune systems; factors that affect heart function and cardiac output; the relationship between the pattern of circulation and transport of materials in the blood; characteristics and regulation of immune responses; components and functions of blood and lymph; common diseases and disorders of the circulatory and immune systems (e.g., AIDS); and the homeostatic roles of the circulatory and immune systems within the body.

0018 Understand the structures and functions of the human respiratory and excretory systems.

For example: structures and processes of the respiratory and excretory systems; the relationship between surface area and volume in the functioning of the respiratory and excretory systems; the exchange of materials and gases between the blood and other tissues; the principle of countercurrent exchange and its role in kidney function; common diseases and disorders of the respiratory and excretory systems; and the homeostatic roles of the respiratory and excretory systems within the body.

0019 Understand the principles of human nutrition and structures and functions of the human digestive system.

For example: the roles in the body of basic nutrients found in foods (e.g., water, vitamins, proteins, carbohydrates, lipids); structures and processes of the digestive system, including accessory organs (e.g., salivary glands, pancreas, liver); processes by which nutrients are transported from the intestinal lumen to other parts of the body; common diseases and disorders of the digestive system; and the homeostatic role of the digestive system within the body.

0020 Understand the structures and functions of the human nervous and endocrine systems.

For example: differences in the structures and functions of the central and peripheral nervous systems; processes involved in the transmission of nerve impulses within and between neurons; structures of the endocrine system and the functions of specific hormones; comparisons of nervous and hormonal signals; the role of feedback mechanisms in nervous system and endocrine system functioning; common diseases and disorders of the nervous and endocrine systems; and the homeostatic roles of the nervous and endocrine systems within the body.

0021 Understand the structures and functions of the human reproductive systems and the processes of embryonic development.

For example: structures and functions of the male and female reproductive systems; the role of hormones in the development and function of the reproductive systems; the processes of gametogenesis and fertilization; processes and stages of embryonic development and factors that may influence development (e.g., drugs, alcohol, radio-activity); common diseases and disorders of the human reproductive systems; and the homeostatic role of the reproductive system within the body.

PRINCIPLES OF HEREDITY AND THE EVOLUTION OF LIFE

0022 Understand the principles of Mendelian and non-Mendelian genetics.

For example: evidence that certain characteristics are inherited; basic principles of heredity (e.g., independent assortment); the relationship of Mendelian genetics to the structure and behavior of chromosomes; crossing-over and its effect on genotype and phenotype; sex-linked characteristics; incomplete dominance and co-dominance; polygenic inheritance; non-nuclear inheritance; and application of genetic principles to solve problems involving genetic crosses.

0023 Understand the synthesis of DNA, RNA, and protein.

For example: processes of replication, transcription, and translation; the relationship of molecular structure to these processes; and the genetic code (including analysis of problems involving codons and anticodons).

0024 Understand genes, chromosomes, and changes in genetic material.

For example: modern theories regarding gene structure and function; the relationship between genes and chromosomes; types of mutations and their consequences; the influence of environment on heredity; basic methods used in genetic engineering; and applications of genetic engineering/recombinant DNA technology (including positive effects and potential risks).

0025 Analyze the process of natural selection.

For example: the concept of variation in populations (including genetic and phenotypic variation); the concept of selection pressure; the influence of selection pressure on species adaptations; the concept of biological fitness; and the role of selection pressure on the survival of organisms and species and on the evolution of species.

0026 Analyze the theory of evolution.

For example: evidence that species change over time; research methods used to investigate evolutionary history; evolutionary relationships among familiar species and taxonomic groups, including hominids; and modern and historic theories of evolution.

MATTER AND ENERGY IN ECOSYSTEMS

0027 Understand populations and communities.

For example: basic requirements of organisms (e.g., food, habitat, shelter); factors that affect population size (e.g., carrying capacity, competition, predation); common patterns of interdependence and interrelationships among species in a community (including the roles of producers, consumers, and decomposers); the concept of niche; and energy relationships within food chains and food webs.

0028 Understand types and characteristics of ecosystems and biomes and factors affecting their change over time.

For example: common patterns of interdependence and interrelationships among species in an ecosystem; biotic and abiotic factors that affect ecosystems; types and characteristics of biomes; typical flora and fauna of biomes; and the process of ecological succession.

0029 Analyze the cycling of materials through an ecosystem.

For example: characteristics and processes of biogeochemical cycles (e.g., water, carbon-oxygen, nitrogen, phosphorus); roles of organisms in biogeochemical cycles; the concept of limiting factors; and implications of biogeochemical cycles for living things.

0030 Understand human ecology and the physical and societal effects of human activities on the environment.

For example: characteristics and consequences of human population growth; food production and the world food supply; issues related to the availability, distribution, and use of water, space, and energy; types, sources, and effects of pollution (e.g., depletion of the ozone layer); chemical and physical mechanisms (e.g., burning of fossil fuels) by which pollutants (e.g., acid precipitation) are created; consequences of habitat destruction; and methods of pollution control, resource conservation (e.g., recycling), land reclamation, and environmental preservation.