

2007 AP[®] BIOLOGY FREE-RESPONSE QUESTIONS

BIOLOGY

SECTION II

Time—1 hour and 30 minutes

Directions: Answer all questions.

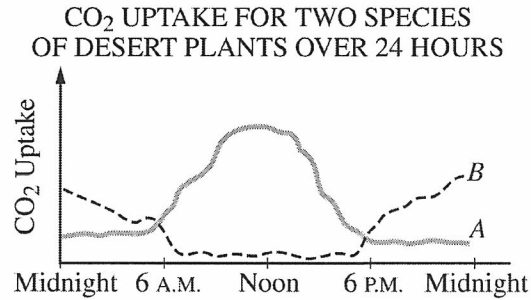
Answers must be in essay form. Outline form is not acceptable. Labeled diagrams may be used to supplement discussion, but in no case will a diagram alone suffice. It is important that you read each question completely before you begin to write. Write all your answers on the pages following the questions in this booklet.

1. Membranes are essential components of all cells.
 - (a) **Identify** THREE macromolecules that are components of the plasma membrane in a eukaryotic cell and **discuss** the structure and function of each.
 - (b) **Explain** how membranes participate in THREE of the following biological processes:
 - Muscle contraction
 - Fertilization of an egg
 - Chemiosmotic production of ATP
 - Intercellular signaling

2. Cephalization and the development of a brain were important steps in animal evolution.
 - (a) **Discuss** the evolutionary origin and adaptive significance of cephalization in animal phyla.
 - (b) **Describe** the development of the nervous system in the vertebrate embryo.
 - (c) At the sound of shattering glass, people quickly turn their heads. **Discuss** how the human nervous system functions to produce this type of response to an external stimulus.

2007 AP[®] BIOLOGY FREE-RESPONSE QUESTIONS

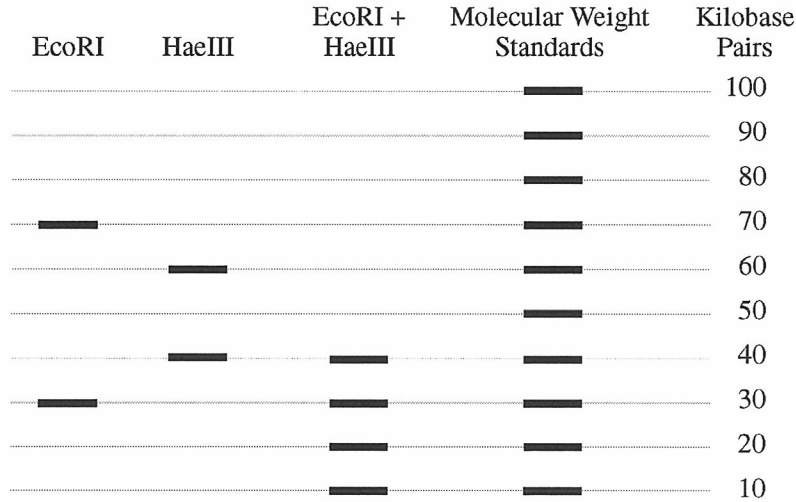
3. Compared with other terrestrial biomes, deserts have extremely low productivity.
- Discuss** how temperature, soil composition, and annual precipitation limit productivity in deserts.
 - Describe** a four-organism food chain that might characterize a desert community, and **identify** the trophic level of each organism.
 - Describe** the results depicted in the graph. **Explain** one anatomical difference and one physiological difference between species *A* and *B* that account for the CO₂ uptake patterns shown. **Discuss** the evolutionary significance of each difference.



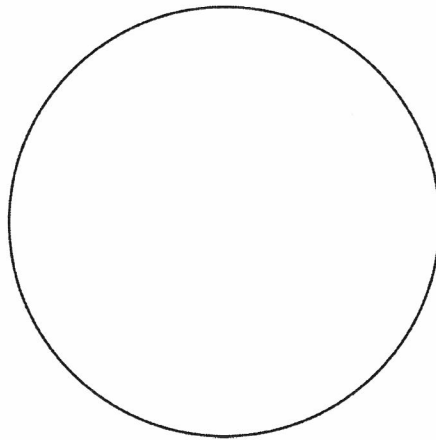
2007 AP[®] BIOLOGY FREE-RESPONSE QUESTIONS

4. A bacterial plasmid is 100 kb in length. The plasmid DNA was digested to completion with two restriction enzymes in three separate treatments: EcoRI, HaeIII, and EcoRI + HaeIII (double digest). The fragments were then separated with electrophoresis, as shown.

RESULTS OF GEL ELECTROPHORESIS



- (a) Using the circle provided, **construct** a labeled diagram of the restriction map of the plasmid. **Explain** how you developed your map.
- (b) **Describe** how:
- recombinant DNA technology could be used to insert a gene of interest into a bacterium
 - recombinant bacteria could be identified
 - expression of the gene of interest could be ensured
- (c) **Discuss** how a specific genetically modified organism might provide a benefit for humans and at the same time pose a threat to a population or ecosystem.



AP[®] BIOLOGY
2007 SCORING GUIDELINES

Question 1

Membranes are essential components of all cells.

- (a) **Identify** THREE macromolecules that are components of the plasma membrane in a eukaryotic cell and **discuss** the structure and function of each. **(6 points maximum; 1 point for each macromolecule + structure, 1 point for each macromolecule + function)**

NOTE: Only first three molecules mentioned will be scored.

Macromolecule	Structure	Function (must match selected macromolecule)
Phospholipids OR Lipid with phosphate	<ul style="list-style-type: none"> • Glycerol, two fatty acids, and polar head group w/phosphate • Amphipathic • Hydrophilic or polar (head) and hydrophobic or nonpolar (tails) • Forms a lipid bilayer 	<ul style="list-style-type: none"> • Selectively permeable • Fluidity • Creates compartment/ separates cell from environment; barrier • Signals, inositol pathway (IP3) diacylglycerol (DAG)
Cholesterol	<ul style="list-style-type: none"> • Ring structure • Steroid • Amphipathic • Embedded in bilayer 	<ul style="list-style-type: none"> • Moderates fluidity • Stabilizes membrane
Proteins OR <u>The following specific types must indicate that they are proteins</u> Integral Peripheral Pump Receptor Transport Recognition Tight junction Desmosomes Gap junctions Integrins Enzyme Channel	<p style="text-align: center;"><u>General Structure</u></p> <ul style="list-style-type: none"> • Polypeptides; amino acids • 2°, 3°, 4° structure description <p style="text-align: center;"><u>Specific Structure</u></p> <ul style="list-style-type: none"> • Integral, transmembrane, embedded; forms a channel • Peripheral, on surface • Structure fit to substrate or ligand 	<ul style="list-style-type: none"> • Transport • Enzyme, catalysis • Signal transduction • Attachment: extracellular matrix (ECM)-cytoskeleton • Recognition • Cell junction
Glycolipid/Glycoprotein	<ul style="list-style-type: none"> • Carbohydrate (chains) linked to lipid/protein 	<ul style="list-style-type: none"> • Cell recognition • Attachment to external molecule or another cell

AP[®] BIOLOGY

2007 SCORING GUIDELINES

Question 1 (continued)

- (b) **Explain** how membranes participate in THREE of the following biological processes:
(6 points maximum; 2 points maximum per section)

Muscle contraction

- Motor neuron or axon terminal releases neurotransmitter or acetylcholine (ACh)
- ACh binds to receptors
- Depolarization or Na^+ moves in through membrane channels or membrane depolarizes
- Action potential propagates along cell membrane (sarcolemma) or T tubules
- Depolarization changes permeability of sarcoplasmic reticulum (SR) or Ca^{2+} released from SR
- Ca^{2+} active transport into SR (reuptake of Ca^{2+})
- Repolarization or maintenance of membrane potential (Na^+/K^+ pump)
- Smooth or cardiac muscle gap junctions directly transfer membrane potential between cells

Fertilization of an egg

- Part of the acrosomal reaction or sperm acrosome releases hydrolytic enzymes (by exocytosis)
- Sperm binds to receptors on egg
- Fusion of sperm and egg plasma membranes
- Change in membrane electrical charge or fast block (depolarization) to prevent further fertilization (polyspermy)
- Cortical reaction or slow block by exocytosis (prevents polyspermy) or “hardening” of membrane
- Separation of fertilization membrane (envelope)
- Fusion of egg and sperm nuclear membranes or nuclei

Chemiosmotic production of ATP

- Electron transport chain (ETC) in membrane pumps H^+ across membrane
- H^+ gradient established across membrane
- H^+ move through ATP synthase embedded in membrane to produce ATP
- Membrane infolding increases surface area

Intercellular signaling

- Release of chemical signals by exocytosis
- Receptors in membrane bind ligands or chemical signals or chemical signals pass through the membrane (examples: neurotransmitters, hormones, pheromones)
- Ligand-gated ion channels opening/closing
- Cascade of cellular events, including enzymatic reactions and second messengers (examples: G-proteins, cAMP, IP_3 , Ca^{2+})
- Antibodies activate immune function
- Descriptions of gap junctions, plasmodesmata (communicating junctions)

AP[®] BIOLOGY
2007 SCORING GUIDELINES

Question 2

Cephalization and the development of a brain were important steps in animal evolution.

(a) **Discuss** the evolutionary origin and adaptive significance of cephalization in animal phyla. **(3 points)**

- **Cephalization (1 point)**

Defined: The concentration of the nervous system toward the anterior end of the organism

OR

Association: Cephalization tied to bilateral symmetry development

- **Origin (1 point)**

Origin identification: (Platyhelminthes/flatworms)

OR

Evolutionary progression of development

- **Adaptive Significance/Advantage (1 point)**

Efficient response to a stimulus (e.g., protection, predation, avoidance, movement toward or away)

During movement sensory organs encounter the environment first

(b) **Describe** the development of the nervous system in the vertebrate embryo. **(4 points maximum)**

- **Tissue of origin (1 point)**

- Ectoderm gives rise to the nervous system.

- **Processes of development (2 points)**

- Neurulation described (neural tube formation) Note: The notochord does not become the nerve cord.
- Other nerve development processes
 - Neural crest cells migrate to form the peripheral nervous system
 - Anterior portion of the neural tube/cord bulges to become the brain or brain regions

- **Endpoints with structures described at the end of a process step of development (1 point)**

- The ectoderm folds into the neural crest/tube or dorsal nerve/spinal cord
- Neural tube expands or develops into developmental brain region (e.g., fore-mid-hind brain, prosen-mesen-rhombencephalon)
- Spinal column/vertebrae/cranium that protects the CNS

- **Signaling (1 point)**

- Notochord (mesodermal in origin) signals or directs development of neural tube (ectodermal in origin)
- *Hox* genes, morphogens (diffusible developmental signal)

AP[®] BIOLOGY
2007 SCORING GUIDELINES

Question 2 (continued)

(c) At the sound of shattering glass, people quickly turn their heads. **Discuss** how the human nervous system functions to produce this type of response to an external stimulus. **(5 points)**

- **Stimulus/Intermediating Structure of Receptor Action (1 point)**
Stimulus (sound waves, pressure, heat, etc.) producing an appropriate receptor action (eardrum vibrating, cochlear hairs vibrating or bending, pressure receptors firing, heat receptors firing, etc.)
- **Input/Sensory/Afferent (1 point)**
Signal direction toward the central nervous system
- **Integration (1 point)**
Processing/Interpretation by CNS
Interneurons/Association/Communicating/Internuncial
- **Output/Motor/Efferent Response (1 point)**
Signal direction toward effectors (peripheral NS) **or** description of the response or autonomic nervous response (e.g., increase in blood pressure or heart rate, muscle contraction **but not just** turning of head)
- **Possible Elaboration (1 point)**
Neural electrophysiology (e.g., action potential, neurotransmitters, synapse)
Neuron structure and impulse pathway
Sensory physiology

AP[®] BIOLOGY
2007 SCORING GUIDELINES

Question 3

Compared with other terrestrial biomes, deserts have extremely low productivity.

- (a) **Discuss** how temperature, soil composition, and annual precipitation limit productivity in deserts. **(3 points maximum)**

Abiotic factor (description)	How abiotic factor limits productivity (must be linked) (1 point per factor)
Temperature Increase in transpiration/evaporation Desiccation Loss of water from tissues/guard cells Not optimal temperatures	Lowers photosynthetic rate Lowers plant growth Lowers biomass production PS/metabolic enzymes/proteins hindered
Soil composition Low organic content/nutrients Low water retention Sandy Compacted soil	Lowers photosynthetic rate/plant growth Lowers photosynthetic rate/plant growth Poor root anchorage limits plant growth Root limitations decrease photosynthesis
Annual precipitation Low rainfall Seasonal rainfall	Little water available for photosynthesis Lowers plant growth Period of high productivity/wildflowers

Clear definition/discussion of productivity: e.g., a measure of the amount of biomass produced by autotrophs/photosynthetic organism/plants... amount of light energy converted to chemical energy by autotrophs per unit time...reduced community productivity **(1 point)**

- (b) **Describe** a four-organism food chain that might characterize a desert community, and **identify** the trophic level of each organism. **(2 points)**

- **Written description** of a minimum of 4 organisms (must include a producer/plant) **(1 point)**
- **Clear identification** of 4 distinct trophic levels of the organisms discussed **(1 point)**
 (producer → primary consumer → secondary consumer → tertiary consumer
 or top carnivore or decomposer or scavenger)

AP[®] BIOLOGY
2007 SCORING GUIDELINES

Question 3 (continued)

- (c) **Describe** the results depicted in the graph. **Explain** one anatomical difference and one physiological difference between species *A* and *B* that account for the CO₂ uptake patterns shown. **Discuss** the evolutionary significance of each difference. **(6 points maximum)**

Graph interpretation (3 points)

- Describe graph (plant *A* takes up CO₂ during day AND plant *B* takes up CO₂ at night) **(1 point)**
- Species *B* as CAM **(1 point)**
- Species *A* as C₃ or species *A* as C₄ **(1 point)**

Anatomical difference (1 point)

- Species *A* is C₄ with bundle sheath/wreath/Kranz anatomy
- Stomata location (pits/crypts, underside stems) linked to CO₂ uptake
- Stomata density linked to CO₂ uptake
- In species *B*/CAM vacuole/mesophyll of organic acids (malate)

Physiological difference (1 point)

- Species *A* stomata open during day
- CAM/species *B* stomata open at night/closed during day
- Species *A* uses C₃ pathway; CAM/ species *B* uses C₄ pathway
- C₃ uses Rubisco/ C₄ uses PEP Carboxylase
- Organic acids synthesis for CO₂ storage
- Carbon fixation during day vs. night

Evolutionary significance (2 points)

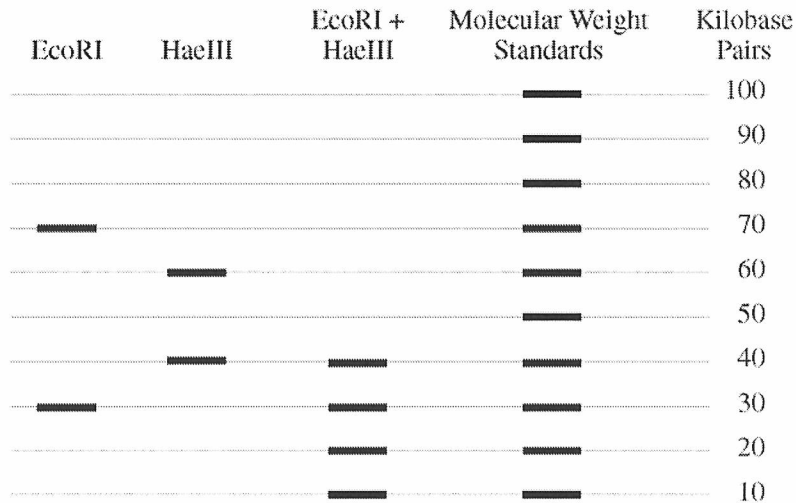
- Discuss the evolutionary significance linked to each difference **(2 points, 1 point per difference)**
e.g., increased evolutionary success due to decrease in water loss in the desert environment
e.g., C₄ pathway circumvents the problem of photorespiration

**AP[®] BIOLOGY
2007 SCORING GUIDELINES**

Question 4

A bacterial plasmid is 100 kb in length. The plasmid DNA was digested to completion with two restriction enzymes in three separate treatments: EcoRI, HaeIII, and EcoRI + HaeIII (double digest). The fragments were then separated with electrophoresis, as shown.

RESULTS OF GEL ELECTROPHORESIS

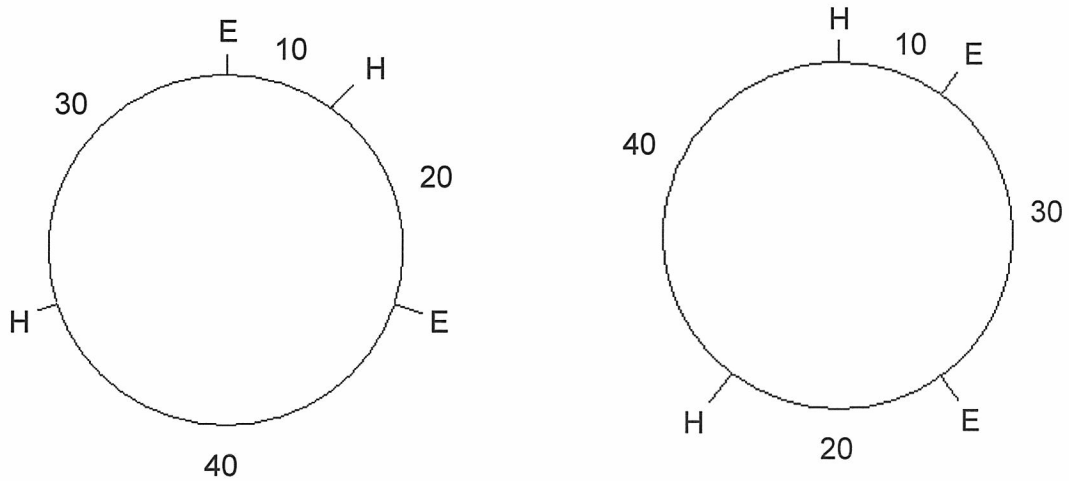


**AP[®] BIOLOGY
2007 SCORING GUIDELINES**

Question 4 (continued)

- (a) Using the circle provided, **construct** a labeled diagram of the restriction map of the plasmid. **Explain** how you developed your map.

Construct a labeled map and **explain (3 points maximum)**



E = EcoRI Restriction Point H = HaeIII Restriction Point

- Restriction sites correctly placed and kilobase sizes shown (**2 points**)
- Explanation (**1 point**)
(NO POINTS for explanation with incorrect or missing map OR for interpreting gel only)
 - trial and error discussion
 - restriction site within larger fragment

AP[®] BIOLOGY
2007 SCORING GUIDELINES

Question 4 (continued)

(b) **Describe** how:

- Recombinant DNA technology could be used to insert a gene of interest into a bacterium
- Recombinant bacteria could be identified
- Expression of the gene of interest could be ensured

Describe how to: (6 points maximum)

(1) Insert gene of interest (4 points maximum)

- Cut gene of interest from source and/or cut plasmid with restriction enzyme
- Use SAME restriction enzyme on both
- Anneal/ligate/mix/combine gene of interest with vector (plasmid/virus/phage)
- “Sticky ends”/bp matches/complementarity
- Treatment for competent cells (CaCl₂/heat shock); incubate together
- Chemical modification can prevent restriction enzyme activity (e.g., methylation)
- Gene = cDNA (without introns) to fit into plasmid

(2) Identify recombinant bacteria (1 point)

- Phenotypic selection (antibiotic resistance/blue-white colony selection/“glo” gene, product produced [e.g., insulin])
- Radioactively/fluorescently labeled probe (tag/dye) / mRNA
- Electrophoresis of cut recombinant vs. original (gene/plasmid) **OR** with sequence comparison of recombinant vs. original (gene/plasmid) **(Not bacterial genome)**

(3) Ensure expression of gene of interest (1 point)

- Promoter [for prokaryote]
- cDNA/removal of introns for prokaryotic expression
- Operon (e.g., nutrient/arabinose induced)

(c) **Discuss** how a specific genetically modified organism might provide a benefit for humans and at the same time pose a threat to a population or ecosystem. **(3 points maximum)**

Discuss GM, benefit to humans, and threat to population/ecosystem

- Nonhuman organism with specific, heritable GM trait
- Plausible benefit to humans related to the GM trait
- Plausible or unknown threat to population/ecosystem related to GM trait/modified organism

2007 AP[®] BIOLOGY FREE-RESPONSE QUESTIONS (Form B)

BIOLOGY

SECTION II

Time—1 hour and 30 minutes

Directions: Answer all questions.

Answers must be in essay form. Outline form is not acceptable. Labeled diagrams may be used to supplement discussion, but in no case will a diagram alone suffice. It is important that you read each question completely before you begin to write. Write all your answers on the pages following the questions in the goldenrod booklet.

1. Without adaptive behaviors, animals would not survive.
 - (a) **Describe** what innate and learned behaviors are. **Explain** the adaptive value of each of these two categories of behavior to an individual animal.
 - (b) During mating season, male snakes exhibit tracking behavior when they follow chemical pheromone trails deposited on the ground by females. **Design** a controlled experiment to determine whether a male garter snake will track only a female of his species or will also follow the female of a related species.

2. The defenses of the human body to the entry and establishment of a pathogen (disease-causing organism) can be divided into nonspecific responses and specific responses.
 - (a) **Explain** how THREE types of nonspecific defenses can prevent the entry and/or establishment of a pathogen in a person's body.
 - (b) **Discuss** how the immune system responds to an initial pathogenic exposure, and how this initial exposure can lead to a quicker response following a second exposure to the same pathogen.
 - (c) **Explain** the biological mechanisms that lead to the rejection of transplanted organs.

2007 AP[®] BIOLOGY FREE-RESPONSE QUESTIONS (Form B)

3. A molecule of messenger RNA (mRNA) has just been synthesized in the nucleus of a human cell.
- (a) What types of modifications may occur to this RNA before it leaves the nucleus?
 - (b) Once in the cytoplasm, how is the mRNA translated to a protein?
 - (c) If the cell is a secretory cell, how is the protein from part (b) eventually targeted, packaged, and secreted to the exterior of the cell?
4. The energy flow in ecosystems is based on the primary productivity of autotrophs.
- (a) **Discuss** the energy flow through an ecosystem and the relative efficiency with which it occurs.
 - (b) **Discuss** the impact of the following on energy flow on a global scale.
 - Deforestation
 - Global climate change

STOP

END OF EXAM

AP[®] BIOLOGY
2007 SCORING GUIDELINES (Form B)

Question 1

Without adaptive behaviors, animals would not survive.

- (a) **Describe** what innate and learned behaviors are. **Explain** the adaptive value of each of these two categories of behavior to an individual animal.

One point for each of the following explanations/identifications (4 points maximum):

- Description or definition of innate behavior
- Description or definition of learned behavior (change with experience/trial and error)
- Explanation of how innate behavior is adaptive
- Explanation of how learned behavior is adaptive

- (b) During mating season, male snakes exhibit tracking behavior when they follow chemical pheromone trails deposited on the ground by females. **Design** a controlled experiment to determine whether a male garter snake will track only a female of his species or will also follow the female of a related species.

One point for each of the following explanations/identifications (7 points maximum):

- Hypothesis/prediction of results
- Description of the independent variable (female of same species and female of different species)
- Description of how to measure movement (e.g., sensors, observation)
- Description of how to measure male's choice (e.g., Y-maze, *in situ* observation)
- Verification of results (e.g., repetitions, number of snakes)
- Statistical analysis
- Control group (no female snakes)
- Control of at least one variable (e.g., sexually mature snakes, temperature, light, mating season)

AP[®] BIOLOGY
2007 SCORING GUIDELINES (Form B)

Question 2

The defenses of the human body to the entry and establishment of a pathogen (disease-causing organism) can be divided into nonspecific responses and specific responses.

- (a) **Explain** how THREE types of nonspecific defenses can prevent the entry and/or establishment of a pathogen in a person's body.

One point for each of the following explanations/identifications (3 points maximum):

- Barrier (skin)
- Traps (mucous membranes, cilia, hair, ear wax)
- Phagocytosis (white blood cells)
- Elimination (coughing, sneezing, urination)
- Unfavorable pH (stomach acid, sweat, saliva, urine)
- Unfavorable environment (normal flora, fatty acids, enzymes)
- Cell destruction (complement, natural killer cells)
- Interference with viral replication (interferon)
- Lysozyme action (tears, sweat)
- Inflammatory response (increase in body temperature, capillary permeability, attraction of macrophages, histamine release, vasodilation)

- (b) **Discuss** how the immune system responds to an initial pathogenic exposure, and how this initial exposure can lead to a quicker response following a second exposure to the same pathogen.

One point for each of the following explanations/identifications (6 points maximum):

- APCs (macrophages, dendritic cells, B cells) present antigen
- B cells/plasma cells produce/secrete antibodies
- Helper T cells activate B cells, cytotoxic T cells, and/or macrophages
- Cytotoxic T cells cause cell death (apoptosis)
- Ag presented on MHC
- Explanation of how antibodies destroy the pathogen
- Secretion of cytokines (or interleukins) to signal or activate
- Memory cells produced in primary response speed up secondary response

- (c) **Explain** the biological mechanisms that lead to the rejection of transplanted organs.

One point for each of the following explanations/identifications (3 points maximum):

- Cell-mediated response or explanation of cytotoxic T, CD8, killer T cells, or natural killer cells
- Concept of nonself (foreign) or MHC incompatibility
- Explanation of the role of cell death or apoptosis or cell lysis

Note: To obtain a score of 10, the student must earn the memory cell point in part (b).

AP[®] BIOLOGY
2007 SCORING GUIDELINES (Form B)

Question 3

A molecule of messenger RNA (mRNA) has just been synthesized in the nucleus of a human cell.

(a) What type of modifications may occur to this RNA before it leaves the nucleus?

One point for each of the following explanations/identifications (3 points maximum):

- Difference between introns and exons
- Description of splicing
- 5' cap added or description of function
- 3' poly A tail added or description of function

(b) Once in the cytoplasm, how is the mRNA translated to a protein?

One point for each of the following explanations/identifications (6 points maximum):

- Description of the role of tRNA in the transport of amino acids
- Description of the ribosome/rRNA
- Peptide bond formation (or the connecting of amino acids into a polypeptide chain)
- Concept of codon-anticodon binding
- Concept of the role of the genetic code (e.g., mRNA bases determine the sequence of amino acids)
- Description of stages (initiation, elongation, and termination)
- Elaboration point for a detailed explanation—examples of acceptable answers include, but are not limited to, the following:
 - Description of 40S and 60S ribosomal subunits
 - Role of aminoacyl-tRNA synthetase
 - Structure of tRNA
 - Use of GTP as energy source

(c) If the cell is a secretory cell, how is the protein from part (b) eventually targeted, packaged, and secreted to the exterior of the cell?

One point for each of the following explanations/identifications (3 points maximum):

- Role of chaperones in folding a polypeptide into the protein
- Modification of the protein or addition of sugars and/or phosphate
- Concept of the endomembrane system (description of protein moving from ER to Golgi to vesicles)
- Exocytosis through the fusion of the vesicle with the cell membrane

AP[®] BIOLOGY
2007 SCORING GUIDELINES (Form B)

Question 4

The energy flow in ecosystems is based on the primary productivity of autotrophs.

(a) **Discuss** the energy flow through an ecosystem and the relative efficiency with which it occurs.

One point for each of the following explanations/identifications (6 points maximum):

- Conversion of light (or inorganic chemical) energy to cellular chemical energy
- Explanation that conversion is the result of photosynthesis or chemoautotrophy
- Concept that energy moves from one trophic level to another
- Understanding that there is a dramatic decrease in the amount of energy transferred from one trophic level to the next
- Energy loss is the result of metabolic activity/heat loss from one trophic level to the next
- Explanation of the concept of primary productivity

(b) **Discuss** the impact of the following on energy flow on a global scale.

- Deforestation
- Global climate change

One point for each of the following explanations/identifications (6 points maximum):

Deforestation (3 points)	Global climate change (3 points)
<p><u>Impact</u></p> <ul style="list-style-type: none"> • Loss of energy • Removal of primary producers • Destruction of habitat decreases food supply • Disruption of ecosystem • Natural succession—NO change in energy flow • Clear-cutting for agriculture increases primary productivity • Clear-cutting for development decreases primary productivity 	<p><u>Definition</u></p> <ul style="list-style-type: none"> • Alternation of climate/global warming or cooling <p><u>Impact</u></p> <ul style="list-style-type: none"> • Increase or decrease in numbers of producers • Increase or decrease in energy • Increase or decrease in metabolism/energy • Changes in respiratory heat depending on the ecosystem • Replacement of productive ecosystems with less productive ones (desertification, tundraification)