

# AP® Biology

## Practice Exam

The questions contained in this AP® Biology Practice Exam are written to the content specifications of AP Exams for this subject. Taking this practice exam should provide students with an idea of their general areas of strengths and weaknesses in preparing for the actual AP Exam. Because this AP Biology Practice Exam has never been administered as an operational AP Exam, statistical data are not available for calculating potential raw scores or conversions into AP grades.

This AP Biology Practice Exam is provided by the College Board for AP Exam preparation. Teachers are permitted to download the materials and make copies to use with their students in a classroom setting only. To maintain the security of this exam, teachers should collect all materials after their administration and keep them in a secure location. Teachers may not redistribute the files electronically for any reason.

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**AP® Biology**  
**Directions for Administration**

The AP Biology Exam is three hours in length and consists of a multiple-choice section and a free-response section.

- The 80-minute multiple-choice section contains 100 questions and accounts for 60 percent of the final grade.
- The 100-minute free-response section consists of a 10-minute reading period and a 90-minute writing period. It contains 4 questions and accounts for 40 percent of the final grade.

The actual AP Exam is administered in one session. Students will have the most realistic experience if a complete morning or afternoon is available to administer this practice exam.

Total scores on the multiple-choice section are based only on the number of questions answered correctly. No points are deducted for incorrect answers and no points are awarded for unanswered questions.

- The use of calculators, or any other electronic devices, is not permitted during the exam.
- It is suggested that the practice exam be completed using a pencil in Section I and a blue or black pen in Section II to simulate an actual administration.
- Teachers will need to provide paper for the students to write their free-response answers. Teachers should provide directions to the students indicating how they wish the responses to be labeled so the teacher will be able to associate the student's response with the question the student intended to answer.
- Remember that students are not allowed to remove any materials, including scratch work, from the testing site.

# **Section I**

## **Multiple-Choice Questions**

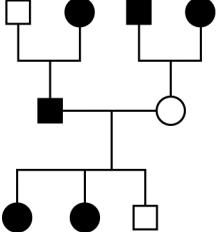
**BIOLOGY**  
**SECTION I**  
**Time—1 hour and 20 minutes**

**Directions:** Each of the questions or incomplete statements below is followed by five suggested answers or completions. Select the one that is best in each case and place the letter of your choice in the corresponding box on the student answer sheet.

1. Which of the following is true of both mitochondria and chloroplasts?
  - (A) They are found in the cells of eukaryotic autotrophs and heterotrophs.
  - (B) They include stacks of membranes that absorb light.
  - (C) They include compartments where hydrogen ions are concentrated.
  - (D) They produce sugars using energy harvested in the cytoplasm.
  - (E) They break down sugar to produce ATP.
2. The tertiary structure and function of a polypeptide is principally determined by the
  - (A) length of the polypeptide
  - (B) number of nucleotides present in the polypeptide
  - (C) repeated units of glycerol making up the polypeptide
  - (D) interactions between amino acids present in the polypeptide
  - (E) number of introns within the polypeptide
3. In a species that has five different alleles for a gene at a particular locus, how many different alleles may be present in the somatic cells of one diploid individual?
  - (A) One
  - (B) Two
  - (C) Three
  - (D) Four
  - (E) Five
4. If red blood cells cultured in an isotonic medium are placed in distilled water, they will most likely
  - (A) remain unchanged
  - (B) shrivel
  - (C) swell and lyse
  - (D) divide
  - (E) become dormant
5. The best evidence that the giant panda is more closely related to bears than is the raccoonlike lesser panda involves
  - (A) comparative anatomy
  - (B) comparative embryology
  - (C) DNA sequence comparisons
  - (D) behavioral similarities
  - (E) fossil records
6. Which of the following structures contains highly oxygenated blood?
  - (A) Vena cava
  - (B) Right ventricle
  - (C) Pulmonary artery
  - (D) Pulmonary vein
  - (E) Jugular vein
7. Metabolism of which of the following molecules results in the greatest net usable energy per gram?
  - (A) A triglyceride
  - (B) A tripeptide
  - (C) An alpha-linked disaccharide
  - (D) A beta-linked disaccharide
  - (E) An anabolic steroid

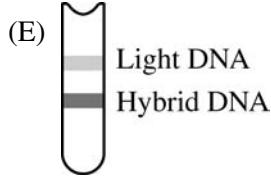
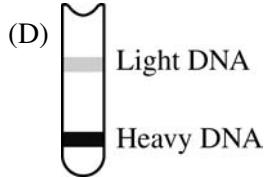
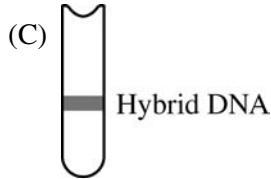
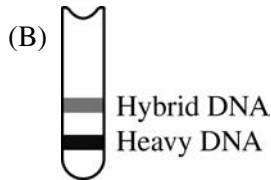
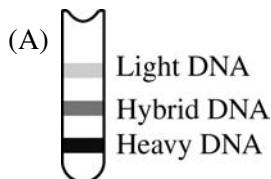
8. Cells that make up salivary glands would be expected to contain a relatively large amount of
- (A) smooth endoplasmic reticulum  
(B) rough endoplasmic reticulum  
(C) genetic material  
(D) lipids  
(E) peroxisomes
9. Which of the following characteristics distinguishes prokaryotic organisms from eukaryotic organisms?
- (A) Prokaryotes are unicellular, while all eukaryotes are multicellular.  
(B) Prokaryotes are aquatic, while eukaryotes are terrestrial.  
(C) Prokaryotes are structurally less complex than eukaryotes are.  
(D) Prokaryotes require a host to replicate, while eukaryotes do not.  
(E) Prokaryotes lack a cell membrane, while eukaryotes do not.
10. An important role of soil microbes in biological systems is the
- (A) recycling of matter  
(B) creation of biomass  
(C) causing of disease  
(D) production of energy  
(E) degradation of energy
11. Which of the following diseases is caused by the lack of a functional gene responsible for a specific enzyme?
- (A) Down Syndrome  
(B) Tay-Sachs disease  
(C) Ricketts  
(D) Malaria  
(E) Influenza
- $AaBb \times AaBb$
12. How many different genotypes are possible from the cross shown above?
- (A) 2  
(B) 4  
(C) 7  
(D) 9  
(E) 16
13. All of the following statements concerning the theory of evolution by natural selection are true EXCEPT:
- (A) Organisms produce far more offspring than are required for replacement.  
(B) The individuals in a population show variation in survivability and in their ability to cope with environmental stress.  
(C) The number of offspring that survive to reproduce varies among individuals.  
(D) The bodies of organisms in a population change by use and disuse, and the changes are inherited by the next generation.  
(E) Some of the variation in adaptation is the result of genetic differences that may be passed on to the next generation.
14. Which of the following sequences best represents the life cycle of a typical angiosperm?
- (A) Gametophyte → meiosis → gametes → fertilization → sporophyte → spores → zygote → gametophyte  
(B) Gametophyte → gametes → meiosis → fertilization → sporophyte → spores → zygote → gametophyte  
(C) Sporophyte → meiosis → gametophyte → spores → fertilization → zygote → sporophyte  
(D) Sporophyte → meiosis → gametophyte → gametes → fertilization → zygote → sporophyte  
(E) Sporophyte → spores → gametophyte → meiosis → gametes → fertilization → zygote → sporophyte

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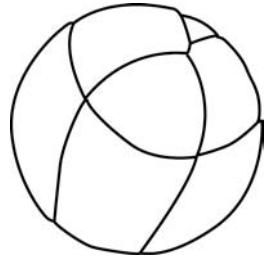
15. Birds associating the bright colors of certain butterflies with an unpleasant taste is an example of
- instinct
  - habituation
  - imprinting
  - insight learning
  - trial-and-error learning
16. Which of the following best describes allosteric inhibition of an enzyme?
- The inhibitor binds to the mRNA to prevent translation of the enzyme.
  - The inhibitor binds to the enzyme substrate.
  - The inhibitor binds to the enzyme but not at its active site.
  - The inhibitor binds to the enzyme at its active site.
  - The inhibitor binds to the gene that encodes for the enzyme.
17. Which of the following organelles is correctly matched with its function?
- Lysosome . . lipid hydrolysis
  - Nucleolus . . protein synthesis
  - Ribosome . . carbohydrate synthesis
  - Mitochondrion . . Calvin cycle
  - Endoplasmic reticulum . . transcription
- 
- 
18. The occurrence of a particular genetic condition in a family is shown in the pedigree above. Which of the following is the most likely inheritance pattern for the individuals with the condition? Squares represent males, circles represent females, and shaded symbols represent individuals who exhibit the condition.
- Autosomal dominant
  - Sex-linked dominant
  - Y linked
  - Autosomal recessive
  - Sex-linked recessive
19. Rates of adaptive radiation typically are at their highest in which of the following situations?
- When Earth is exposed to increased electromagnetic waves caused by Sun flares
  - In very large, randomly mating populations
  - When new niches become available
  - When many species are competing for the same limited resource
  - When food is abundant
20. Which of the following led to the increased function of the invertebrate nervous system?
- Development of an advanced cerebellum
  - Evolution of a ventral nerve cord, thus increasing the ability to move
  - Cephalization of the major sensory organs and the cerebrum
  - Specialization of the sympathetic and parasympathetic systems within the nervous system
  - Occurrence of highly developed olfactory lobes in the invertebrate brain
21. Which of the following is the most direct result of the heating up of pond water during the summer?
- The water's ability to hold oxygen decreases.
  - The water's ability to act as a buffer changes.
  - The viscosity of the water increases.
  - Hydrogen bonding at the surface of the water increases.
  - Less light penetrates the surface of the water.
22. A protein is synthesized in the cytoplasm and transported to the plasma membrane. Which of the following summarizes the protein's pathway in the cell?
- Smooth endoplasmic reticulum → nucleus → vesicle → plasma membrane
  - Plastid → rough endoplasmic reticulum → plasma membrane
  - Nucleus → vesicle → rough endoplasmic reticulum → plasma membrane
  - Smooth endoplasmic reticulum → microfilament → vesicle → plasma membrane
  - Rough endoplasmic reticulum → Golgi complex → vesicle → plasma membrane

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23. In the experiments by Meselson and Stahl that demonstrated the semiconservative replication of DNA, the researchers cultured bacteria in a medium containing a heavy isotope of nitrogen,  $^{15}\text{N}$ . They then moved the bacteria to a medium containing  $^{14}\text{N}$ , the lighter, more common isotope of nitrogen. After each round of replication, the researchers extracted the DNA and centrifuged the solution to separate the DNA bands by density. The test tubes below illustrate the possible banding pattern found after two bacterial generations (two rounds of DNA replication). Which test tube best illustrates the bands predicted by the semiconservative model of DNA replication?



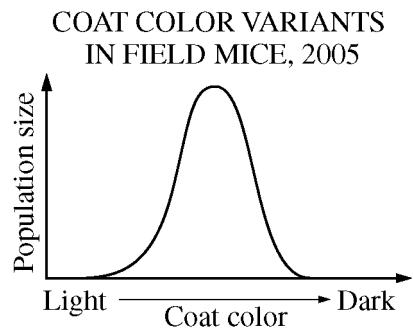
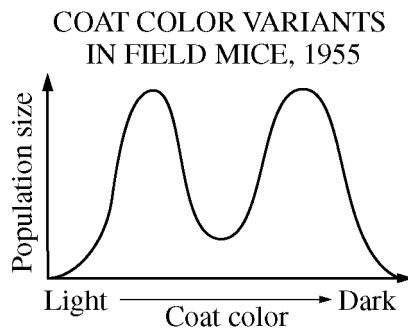
24. In most dicot seeds, which of the following structures is responsible for the storage of carbohydrates?
- (A) Seed coat  
(B) Cotyledon  
(C) Radicle  
(D) Plumule  
(E) Embryo
25. In mammals, which of the following substances is produced in a muscle that operates anaerobically?
- (A) Acetyl CoA  
(B) Citrate  
(C) NADPH  
(D) Lactate  
(E) Oxygen
26. Which of the following immune system cells is most severely depleted by HIV/AIDS?
- (A) Plasma B cells  
(B) Memory B cells  
(C) Helper T cells  
(D) Cytotoxic (“Killer”) T cells  
(E) Memory T cells
27. The primary producers of the deep sea communities associated with hot water vents are
- (A) plants  
(B) tube worms  
(C) photosynthetic algae  
(D) cyanobacteria  
(E) chemoautotrophic bacteria
28. A scientist studying the oxygen concentration in sealed chambers containing cultured plant cells finds that when the chambers are illuminated, the concentration of oxygen increases. However, when the chambers are kept in the dark, the concentration of oxygen decreases. Why does the oxygen concentration decrease when the chamber is kept in the dark?
- (A) Plant cell mitochondria consume oxygen by aerobic respiration.  
(B) Plant cell chloroplasts run the photosynthetic pathways backward to consume oxygen.  
(C) Plant cell chloroplasts switch their structure and function and become mitochondria.  
(D) The chambers must not be properly sealed, so that oxygen is leaking out.  
(E) The cultures in the chambers must be contaminated with some animal cells, since only animal cells consume oxygen.
- 



29. The unequal division of the cytoplasm among frog embryo cells during early cleavage, as shown in the diagram, results from
- (A) different amounts of DNA  
(B) gastrulation of the embryo  
(C) formation of the blastula  
(D) segregation of the maternal and paternal cells  
(E) uneven distribution of yolk

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30. Production of ATP occurs in all of the following processes EXCEPT
- glycolysis
  - Krebs cycle
  - electron transport system and chemiosmosis
  - light-dependent reactions of photosynthesis
  - light-independent reactions of photosynthesis
31. Which of the following statements most correctly represents the organization of living systems from smallest to largest?
- Molecules → organs → cells → organisms
  - Cells → tissues → molecules → ecosystems → communities
  - Organisms → molecules → cells → atoms
  - Atoms → molecules → cells → organisms → ecosystems
  - Organs → plants → animals → cells
32. The functional similarity of the mandibles (hinged jaws) of insects and those of mammals is an example of
- homology
  - analogy
  - divergent evolution
  - adaptive radiation
  - punctuated equilibrium
33. Which of the following pairs of plants are most closely related?
- Broad bean (*Vicia faba*)
  - Soybean (*Glycine max*)
  - Kidney bean (*Phaseolus vulgaris*)
  - Barley (*Hordeum vulgaris*)
  - Scarlet runner bean (*Phaseolus coccineus*)
34. Milk kept past the expiration date often spoils, tastes sour, and develops stringy curds. This can be explained by which of the following?
- Fermentation produces ethanol and fibrous by-products.
  - Yeasts form citric acid, which causes the yeast cells to form long chains.
  - Bacteria produce lactic acid, which lowers the pH and denatures the milk proteins.
  - The Krebs cycle is converted to the Calvin cycle.
  - The production of fatty acid raises the temperature and polymerizes lactose.



35. A research study sampled populations of field mice annually over the course of 50 years. The population was categorized by coat color. Data from the beginning and end of the study are graphed above. What type of selection is represented by the change in the data from 1955 to 2005?
- Directional selection
  - Stabilizing selection
  - Bimodal selection
  - Disruptive selection
  - Sexual selection

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36. Which of the following occurs in both fermentation and aerobic cellular respiration?
- (A) Oxygen and carbon dioxide are consumed.
  - (B) FAD is reduced, driving ATP synthesis.
  - (C) Proton gradients are produced across membranes.
  - (D) ATP is synthesized from ADP and inorganic phosphate.
  - (E) Most of the energy from glucose is released as carbon dioxide.
37. Which of the following best summarizes the theory of punctuated equilibrium?
- (A) After periods of directional selection, the allelic frequencies in a population will reach equilibrium and then undergo disruptive selection.
  - (B) Most species evolve gradually, with discrete changes appearing in the fossil record at short, regular intervals.
  - (C) Once one species achieves evolutionary dominance, all of the remaining species must compete among themselves for selective advantages; only then will the dominant species be challenged.
  - (D) To ensure survival of the fittest, natural selection eliminates those species that disrupt the balance of nature.
  - (E) Most taxa experience relatively short periods during which they undergo rapid change, followed by relatively long periods during which they undergo relatively little change.
38. Which of the following organisms possesses both a system of blood vessels and a digestive tract in which food travels in only one direction?
- (A) Sponges
  - (B) Flatworms
  - (C) Annelids
  - (D) Roundworms
  - (E) Sea anemones
39. Which of the following features are common to all gas exchange systems in animals?
- (A) Active transport removes carbon dioxide from the respiratory structures.
  - (B) Materials flow in one direction only.
  - (C) An intake system is comprised of a series of tubes.
  - (D) Transfer is made by counter-current exchange.
  - (E) Gasses diffuse across a moist membrane.
40. Which of the following occurs in the immediate fight-or-flight response to danger or fear?
- (A) An increase in glycogen synthesis
  - (B) An increase in digestive activity
  - (C) Release of ACTH from the pituitary
  - (D) An increase in glucose catabolism
  - (E) A decrease in noradrenaline
41. During the fall, a chipmunk experiences a sustained period of cold weather. The chipmunk's thyroid gland responds by secreting a greater quantity of thyroxin. Which of the following represents the most accurate pathway from the central nervous system (CNS) to the target cells?
- (A) CNS → hypothalamus → anterior pituitary → thyroid → thyroxin → target cells.
  - (B) CNS → adrenal medulla → thyroid → thyroxin → target cells.
  - (C) CNS → motor neurons → muscle cells → thyroxin → target cells.
  - (D) CNS → posterior pituitary → oxytocin → thyroid → thyroxin → target cells.
  - (E) CNS → pancreas → insulin → sugar into cells → target cells.
42. Which of the following ions is significantly involved in the opening and closing of the stomata?
- (A) Calcium
  - (B) Nitrogen
  - (C) Potassium
  - (D) Magnesium
  - (E) Iron
43. Which of the following best explains why many different species can live together within an ecosystem with limited resources?
- (A) Each species lives in a slightly different habitat.
  - (B) Each species occupies a different niche.
  - (C) Each species inhabits a different biome.
  - (D) Each species makes up a different population.
  - (E) Each species functions at a different trophic level.

44. Which of the following occurs in response to a rise in the blood sugar level?
- The gall bladder releases glucagon.
  - Glycogen is catabolized.
  - Alpha cells in the pancreas secrete glucagon.
  - Beta cells in the pancreas release amylase.
  - Beta cells in the pancreas release insulin.
45. In evolutionary terms, which of the following organisms is the most successful?
- The one that lives the longest
  - The one that grows the most rapidly
  - The one that leaves the greatest number of offspring that survive to reproduce
  - The one that has the best characteristics for the current environment
  - The one that has the biggest territory
- 
- 
- ```

graph LR
    P --- PQ[ ]
    Q --- PQ
    PQ --- PR[ ]
    R --- PR
    PR --- PS[ ]
    S --- PS
    PS --- PT[ ]
    T --- PT
  
```
46. Which of the following conclusions is best supported by the cladogram above?
- Species *Q* and *R* make up a monophyletic group.
  - Species *P* and *Q* are equally related to species *T*.
  - Species *P* and *T* do not share a common ancestor.
  - Species *S* evolved from species *R*.
  - Species *S* is more closely related to species *T* than to species *R*.
47. Which of the following statements about the process of excretion in animals is correct?
- Animals with closed circulatory systems usually have capillary beds associated with their excretory organs.
  - Aquatic animals usually secrete their nitrogenous wastes in the form of uric acid.
  - The contractile vacuole of a freshwater protozoan will become more active if the protozoan is placed in seawater.
  - Nephridia are found only in vertebrate animals.
  - In humans and other mammals, urea is produced in the kidneys.
48. Which of the following is true about a specialized companion cell of the phloem that is connected to the palisade mesophyll cell by plasmodesmata?
- The specialized companion cell and the palisade mesophyll cell have highly specialized unrelated functions.
  - The companion cell lacks a nucleus, and the palisade mesophyll cell has a nucleus at maturity.
  - Sieve plates would be found in the companion cell but not in the palisade mesophyll cell.
  - The companion cell would have a thicker secondary cell wall than the palisade mesophyll cell.
  - Materials synthesized in photosynthesis could be sent from the mesophyll cell to the companion cell.
49. The flow of which of the following into the mitochondrial matrix provides the chemiosmotic energy for the synthesis of ATP?
- Inorganic phosphate
  - ADP
  - Glucose
  - Protons
  - Electrons

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50. Fire has which of the following effects on a community?
- (A) It causes all of the plants and animals in the community to become dormant.
  - (B) It recycles dead plant material, thus nutrients become available.
  - (C) It prevents reestablishment of the prefire community.
  - (D) It allows for increased mutation rates in the surviving species.
  - (E) It forces predators to become omnivores.
51. As plants evolved from simple to more complex forms, which of the following occurred?
- (A) The sporophyte generation became more dominant than the gametophyte generation.
  - (B) The haploid generation was lost.
  - (C) The haploid generation became dominant.
  - (D) The gametophyte generation became dominant over the sporophyte generation.
  - (E) The gametophyte and the sporophyte generations gained equal prominence.
52. If a population is at Hardy-Weinberg equilibrium, which of the following can be predicted for the recessive alleles in the population?
- (A) They will eventually disappear.
  - (B) They will be selected against.
  - (C) They will be maintained at the same frequency.
  - (D) They will be expressed in the heterozygous condition.
  - (E) They will become dominant.
53. All of the following adaptations prevent dehydration in land plants EXCEPT
- (A) many guard cells in the flaccid condition
  - (B) many stomates on the top leaf surface
  - (C) water-resistant cuticle
  - (D) the presence of many epidermal hairs
  - (E) recessed stomates
54. A large assemblage of land snails is subdivided into two populations (*A* and *B*) by a river that effectively isolates the two populations for an indefinitely long period. From an evolutionary standpoint, which of the following is the LEAST likely to occur in the two populations?
- (A) Populations *A* and *B* will eventually differ in their ecological requirements.
  - (B) Population *A* may ultimately breed at a different time of the year than population *B* does.
  - (C) Population *A* may undergo instantaneous speciation by the doubling of its chromosome numbers (polyploidy).
  - (D) Under laboratory conditions, cross-fertilizations between members of the two populations may be successful even after a long period of geographical separation.
  - (E) The two populations may become morphologically very dissimilar.
55. Which of the following is TRUE of C<sub>4</sub> plants such as corn?
- (A) The Calvin cycle is confined to the bundle sheath cells.
  - (B) The plants are classified as cacti.
  - (C) The stomates open at night rather than during the day.
  - (D) They will not grow in climates where the temperature exceeds 70°F.
  - (E) They have an anatomy that is found only in gymnosperms.
56. Which of the following causes the rapid change of membrane polarity during an action potential?
- (A) Diffusion of neurotransmitters such as acetylcholine
  - (B) Diffusion of positively charged ions across the cell membrane
  - (C) Release of electrons from inside the cell
  - (D) Release of protons from inside the cell
  - (E) Active transport of cations by the sodium-potassium pump

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**Directions:** Each group of questions below consists of five lettered headings followed by a list of numbered phrases or sentences. For each numbered phrase or sentence, select the one heading to which it is most closely related and place the letter of your choice in the corresponding box on the student answer sheet. Each heading may be used once, more than once, or not at all in each group.

**Questions 57-60 refer to the following.**

- (A) Pancreas
- (B) Kidney
- (C) Liver
- (D) Gall bladder
- (E) Stomach

- 57. Structure that stores lipid-emulsifying salts
- 58. Structure where pepsin hydrolyses proteins
- 59. Structure that produces most of the hydrolytic enzymes that are active in the small intestine
- 60. Structure where glycogen typically occurs in large quantities as a storage product

**Questions 61-64 refer to the following.**

- (A) Phytochrome
- (B) Chlorophyll
- (C) Ethylene
- (D) Auxin
- (E) Abscisic acid

- 61. Molecule contains a porphyrin ring with a central magnesium atom
- 62. Causes plant shoots to bend toward light by stimulating cell elongation
- 63. Regulates flowering in plants that are sensitive to the length of the photoperiod
- 64. Molecule that can absorb photons of light and release electrons to the primary electron acceptor

**Questions 65-68 refer to the following.**

- (A) Nonsense codon
- (B) Anticodon
- (C) Ribosome
- (D) Exon
- (E) Poly-A tail

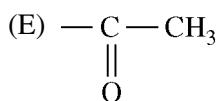
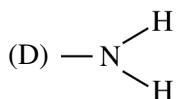
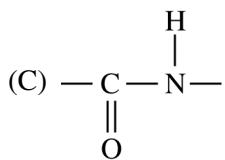
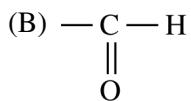
- 65. Protein synthesis termination triplet
- 66. Site of protein synthesis
- 67. Base sequence on messenger RNA that aids its transport across the nuclear envelope
- 68. Triplet on tRNA

**Questions 69-72 refer to the following types of hereditary material.**

- (A) Unpaired unreplicated linear chromosomes
- (B) Unpaired replicated linear chromosomes
- (C) Paired replicated linear chromosomes
- (D) Circular chromosomes
- (E) Extra-chromosomal circular DNA

- 69. Typical of prokaryotic cells after fission
- 70. Eukaryotic cells at prophase of mitosis
- 71. Eukaryotic cells at metaphase I
- 72. Plasmid exchanged by conjugating bacteria

**Questions 73-76 refer to the following functional groups.**



73. Acetone contains this functional group.

74. Dopamine contains this functional group.

75. Formaldehyde contains this functional group.

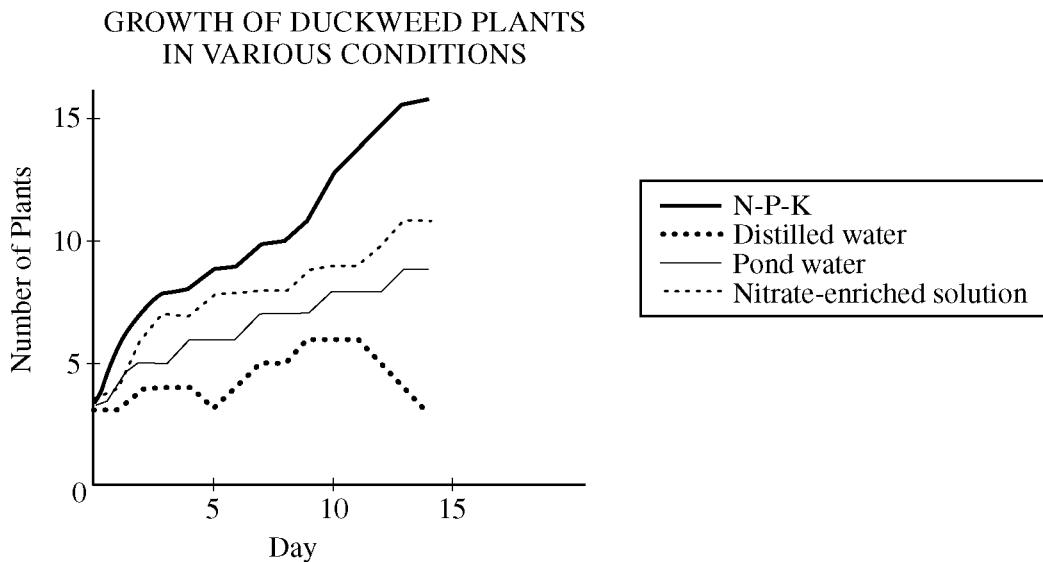
76. Ethanol contains this functional group.

**GO ON TO THE NEXT PAGE.**

**Directions:** Each group of questions below concerns an experimental or laboratory situation or data. In each case, first study the description of the situation or data. Then choose the one best answer to each question following it and fill in the corresponding box on the student answer sheet.

**Questions 77-80**

An experiment was performed to test the conditions in which duckweed, a small aquatic plant, can reproduce efficiently. Three duckweed plants were placed in each of four culture dishes at room temperature with the following solutions: 1) distilled water, 2) pond water, 3) an N-P-K fertilizer solution, and 4) a nitrate-enriched solution. The following graph summarizes the growth in numbers of duckweed plants over a two-week period.



77. After 10 days, the distilled water culture dish has approximately how many duckweed plants?

(A) 3  
(B) 6  
(C) 9  
(D) 12  
(E) 15

78. In pond water, the duckweed population grows at an average rate of

(A) 1 plant per day  
(B) 2 plants per day  
(C) 1 plant per 3 days  
(D) 3 plants per day  
(E) 9 plants per 15 days

79. Duckweed vegetatively reproduced at the fastest rate in

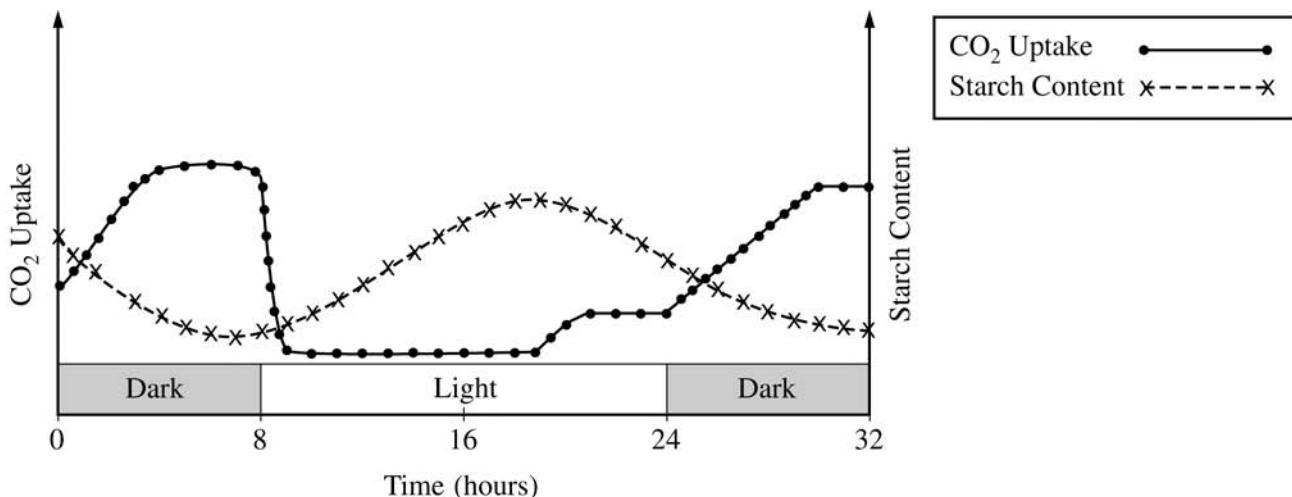
(A) pond water  
(B) nitrate-enriched distilled water  
(C) pond water with added chlorophyll  
(D) distilled water  
(E) N-P-K fertilizer solution

80. Under which of the following additional conditions would the duckweed population be most likely to grow faster?

(A) Oxygen gas bubbled through the culture dishes  
(B) The addition of an organism that eats duckweed  
(C) The addition of distilled water to every culture dish  
(D) An increase in light intensity  
(E) The addition of glucose to the culture medium

**Questions 81-84**

A new species of succulent epiphytic flowering plant was discovered in the canopy of a tropical rain forest. Experiments were carried out to determine the plant's photosynthetic capacity by measuring the net uptake of carbon dioxide and changes in tissue starch concentration over a 32-hour period with 8 hours of dark at the start and end of the measurement period and 16 hours of moderate light between the two dark periods. The changes in the rate of carbon dioxide uptake and the concentration of tissue starch are shown in the diagram below.



81. Which of the following is consistent with the data?
- The highest rate of carbon dioxide uptake occurs at the beginning of the light period.
  - The highest rate of carbon dioxide uptake occurs at the beginning of the dark period.
  - The highest rate of carbon dioxide uptake occurs near the end of the dark period.
  - The highest starch concentration occurs at the beginning of the light period.
  - The lowest starch concentration occurs at the end of the light period.

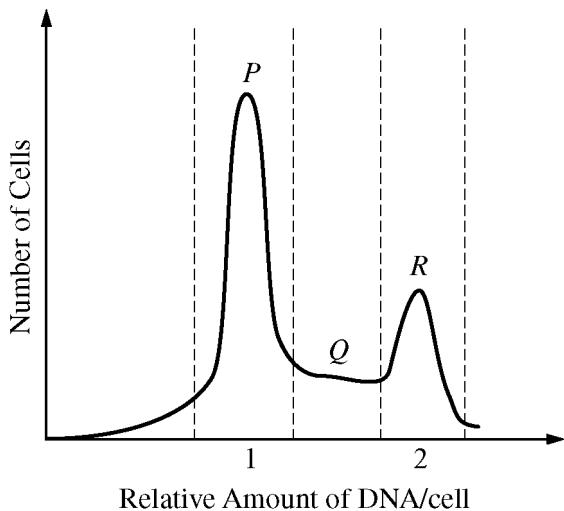
82. The photosynthetic pattern of this plant species is unusual for which of the following reasons?
- It has a higher rate of carbon dioxide uptake during the light period than during the dark period.
  - It has a higher rate of carbon dioxide uptake during the dark period than during the light period.
  - There is a positive correlation between the rate of carbon dioxide uptake and tissue starch concentration.
  - There is an inverse correlation between the rate of carbon dioxide uptake and tissue starch concentration.
- I only
  - II only
  - IV only
  - I and III
  - II and IV

83. A useful control for the experiment would have included which of the following?
- I. Expose the plant to 32 hours of continuous moderate light and measure rates of carbon dioxide uptake and tissue starch concentration.
  - II. Expose the plant to 32 hours of continuous dark and measure rates of carbon dioxide uptake and tissue starch concentration.
  - III. Measure the chlorophyll concentration in the plant's leaf tissue.
- (A) I only  
(B) II only  
(C) III only  
(D) I and II only  
(E) I, II, and III
84. The most likely adaptive significance of this photosynthetic mechanism is to
- (A) minimize water loss by taking up carbon dioxide at night
  - (B) maximize the production of starch at night
  - (C) maximize the ability to use bright light to take up carbon dioxide
  - (D) maximize water loss during the day so starch can be made
  - (E) minimize starch production during the day

**GO ON TO THE NEXT PAGE.**

**Questions 85-87**

The graph below shows the results of a study of a culture of cells in active mitotic proliferation. The cells were stained with a dye specific to nuclear DNA. The cells were then scanned to determine how much DNA was present per cell. The  $x$ -axis of the graph presents the relative amount of DNA per cell; the  $y$ -axis presents the number of cells for each value of DNA content.



85. The cells found in the region of the graph labeled  $Q$  are involved in what major cell cycle activity?

- (A) Cell division
- (B) Active cell motility
- (C) Cell differentiation
- (D) Tetrad formation
- (E) DNA synthesis

86. The region on the graph labeled  $P$  represents cells in what stage of the cell cycle?

- (A)  $G_1$
- (B) S
- (C)  $G_2$
- (D) Mitosis
- (E) Cytokinesis

87. Cells in which region of the graph are ready to enter mitosis as the next step in the cell cycle?

- (A)  $P$  only
- (B)  $Q$  only
- (C)  $R$  only
- (D)  $P$  and  $Q$  only
- (E)  $Q$  and  $R$  only

## Questions 88-89

The table shows selected characters used to determine relationships among four species of mammals.

| Character                     | <i>Spermocyon</i> | <i>Castoropsis</i> | <i>Pseudofelis</i> | <i>Neomysticena</i> |
|-------------------------------|-------------------|--------------------|--------------------|---------------------|
| 3 toes on hindfeet            | X                 | X                  |                    | X                   |
| Naked tail (hairless)         | X                 | X                  | X                  | X                   |
| Incisors greatly enlarged     |                   | X                  |                    | X                   |
| Hair tufts protrude from ears |                   |                    |                    | X                   |

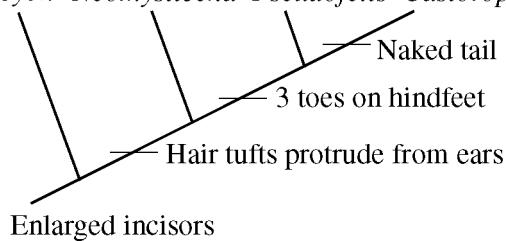
88. Which of the following characters is unique to *Neomysticena*?

- (A) Naked (hairless) tail
- (B) Three toes on hindfeet
- (C) Enlarged incisors
- (D) Hair tufts protruding from ears
- (E) Body hair

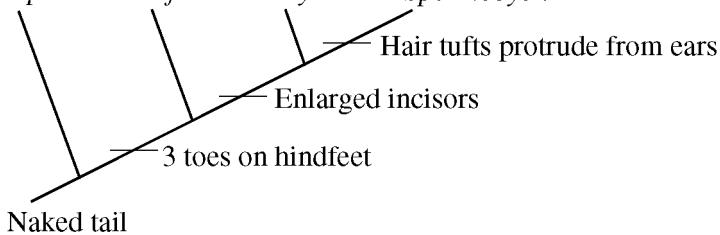
**GO ON TO THE NEXT PAGE.**

89. Which of the following cladograms correctly represents the relationships among these species?

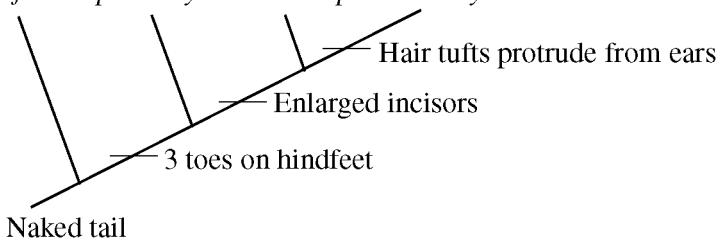
- (A) *Spermocyon* *Neomysticena* *Pseudofelis* *Castoropsis*



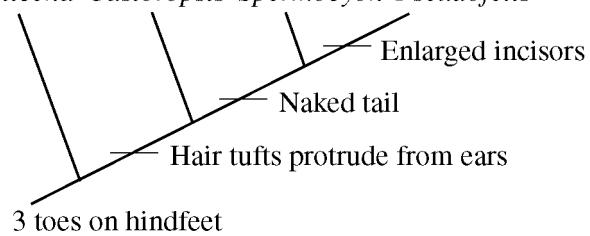
- (B) *Castoropsis* *Pseudofelis* *Neomysticena* *Spermocyon*



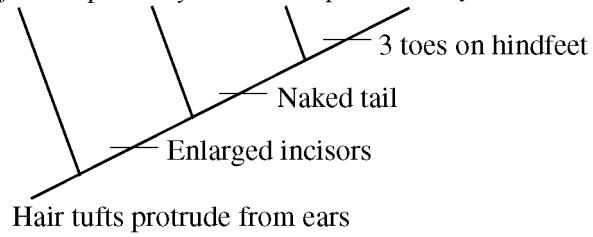
- (C) *Pseudofelis* *Spermocyon* *Castoropsis* *Neomysticena*



- (D) *Neomysticena* *Castoropsis* *Spermocyon* *Pseudofelis*



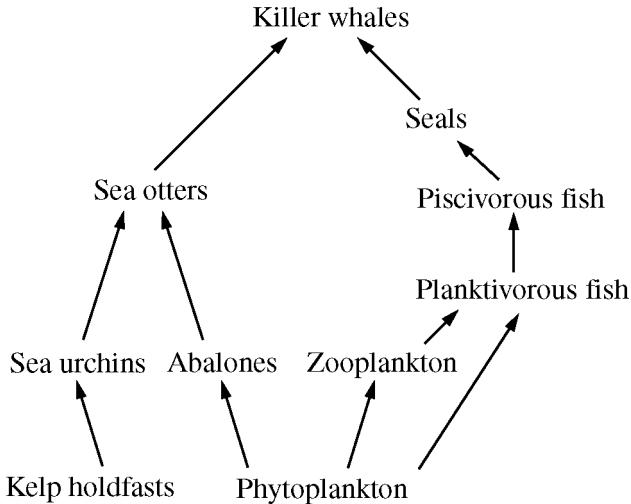
- (E) *Pseudofelis* *Spermocyon* *Castoropsis* *Neomysticena*



**GO ON TO THE NEXT PAGE.**

## Questions 90-93

The diagram below shows a food web of a simplified rocky coastal ecosystem dominated by kelp forests attached to rocky substrates by holdfasts (modified algal parts), which are eaten by sea urchins.



90. The minimum number of trophic levels in a food chain ending with killer whales is

- (A) 2
- (B) 3
- (C) 4
- (D) 5
- (E) 6

91. Species that feed at only one trophic level include which of the following?

- I. Zooplankton
  - II. Planktivorous fish
  - III. Killer whales
- (A) I only
  - (B) II only
  - (C) III only
  - (D) II and III only
  - (E) I, II and III

92. If a fat-soluble but poorly metabolized substance such as DDT gets into this ecosystem, the highest tissue concentrations will most likely occur in which of the following?

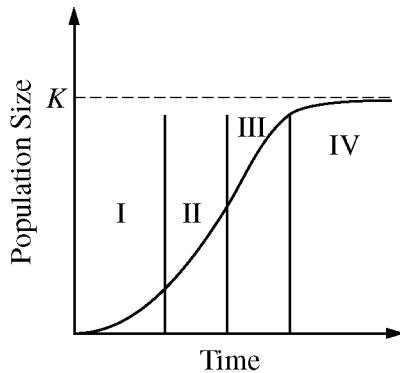
- (A) Phytoplankton
- (B) Zooplankton
- (C) Abalones
- (D) Sea otters
- (E) Seals

93. In similar rocky coastal ecosystems where sea otters have disappeared due to human harvesting or killer whale predation, the kelp forests also disappear and the species diversity of the community decreases drastically. In these ecosystems, the sea otter can best be described as a

- (A) top carnivore
- (B) keystone species
- (C) primary producer
- (D) secondary herbivore
- (E) dominant species

### Questions 94-95

The graph shows the pattern of population growth for a particular species.



94. The dotted line marked  $K$  indicates which of the following?

- (A) The annual reproductive rate
- (B) The proportion of a population that can be removed without destroying its ability to maintain a stable population size
- (C) The carrying capacity of the population
- (D) The maximum number of offspring that each pair of parents can produce in a single year
- (E) The intrinsic rate of reproductive increase of the population

95. In which region of the curve is population size most likely to exhibit regulation by availability of resources such as nutrients, nest sites, and places to hide from predators?

- (A) I only
- (B) II only
- (C) I and II
- (D) II and III
- (E) III and IV

## Questions 96-100

Allele *T* codes for the ability to taste phenylthiocarbamide (PTC), and the gene locus is identified as *TAS2R38*. One combination of 3 single nucleotide polymorphisms in noncoding sequences (SNPs) correlates in humans with the ability to taste PTC. The restriction site for enzyme *X* includes one of the SNPs associated with the ability to taste PTC.

In the lab, students collect samples of cheek cells, extract the DNA, and amplify a portion of the *TAS2R38* locus using polymerase chain reaction (PCR). This, in addition to restriction enzyme analysis and electrophoresis, will enable a prediction about the ability of the cell donors to taste PTC.

96. Which of the following is the most appropriate method to prepare a sample of cheek cells for PCR ?
- (A) Obtain cells with saline mouthwash, boil, and chelate out any contaminating metals
  - (B) Scrape cheek cells from inside the mouth; treat with nucleases
  - (C) Using sterile technique, obtain a small punch biopsy specimen and keep at room temperature
  - (D) Use cheek cells obtained by rinsing the mouth with an antibacterial wash, and subject the cells in culture to a strong antibiotic
  - (E) Use a swab to obtain cells from the outer surface of the cheek after carefully washing the area

97. In order to amplify the sequence with part of the *TAS2R38* gene, which of the following would be the appropriate primers to use?
- (A) Primers that complement the telomeric sequences of the chromosomes
  - (B) Primers that correspond to the 5' and 3' ends of the sequence near the SNP sites
  - (C) RNA primers that complement the cDNA of the sequence of the whole gene
  - (D) Degenerate DNA primers that will amplify both wild-type and SNP sequences
  - (E) DNA primers for the chromosome known to include the *TAS2R38* gene
98. Why does digesting the DNA with enzyme *X* enable a prediction of the cell donor's ability to taste?
- (A) The nontaster allele (*t*) will not be cut and will therefore generate a larger fragment.
  - (B) Tasters will have three cutting sites instead of one.
  - (C) The taster allele (*T*) will produce a larger protein than the nontaster allele (*t*).
  - (D) Nontasters lack recognition sites for any restriction enzymes.
  - (E) Enzyme *X* will cut within the coding sequence of gene *TAS2R38*.

99. Following amplification and restriction enzyme digestion, the presence of the *T* allele is recognized on the electrophoresis gel by two bands: one of 177 base pairs (bp) and another of 44 bp. The heterozygote (*Tt*) will show three bands on the gel. Which of the following describes their sizes?
- (A) 44, 133, and 177  
(B) 44, 89, and 133  
(C) 44, 133, and 221  
(D) 44, 177, and 221  
(E) 89, 133, and 221
100. The students further studied DNA sequence data from various primates in order to explore the evolution of this gene sequence. The study revealed that each of the other primates has the same SNP pattern as human tasters. Which of the following is the most reasonable inference that can be made about the evolution of this gene sequence?
- (A) The ability to taste bitter foods gave humans a selective advantage over other primates.  
(B) Since the ability to taste is dominant, it had to have evolved first.  
(C) Ancestral humans must have acquired the nontaster SNPs from nonprimates.  
(D) Lack of the ability to taste must have a selective advantage for humans.  
(E) The ability to detect bitter taste must have some selection advantages for nonhuman primates.

**END OF SECTION I**

**IF YOU FINISH BEFORE TIME IS CALLED, YOU MAY  
CHECK YOUR WORK ON THIS SECTION.**

**DO NOT GO ON TO SECTION II UNTIL YOU ARE TOLD TO DO SO.**

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## **Section II**

### **Free-Response Questions**

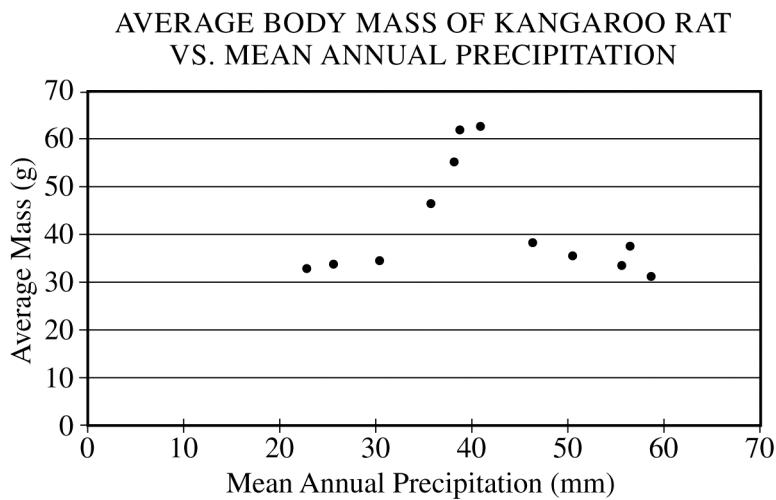
**BIOLOGY**  
**SECTION II**  
**Time—1 hour and 30 minutes**

**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.

1. Kangaroo rats, like other organisms, show specific adaptations to the environments in which they live. Kangaroo rats can survive in the desert with no free water. They can survive by obtaining water from dry seeds and grass that they eat, and have specialized kidneys that allow them to excrete urea with very little output of water.

The graph shows the average body mass for kangaroo rats at twelve locations throughout the southwestern United States as a function of mean annual precipitation at each location.



- (a) **Describe** the trends shown in the graph.  
(b) **Develop** a hypothesis that would explain the data and **design** an experiment that would test the hypothesis.  
(c) **Discuss** TWO evolutionary adaptations, other than those described above, found among other desert organisms that help to conserve water.
2. Environmental factors have a profound effect on the size and growth rate of populations of living organisms.
  - (a) **Describe** *r*- and *K*-life-history strategies.  
(b) For EACH of the following, **identify** the life-history strategy, and **describe** the population growth curve and limiting factor.
    - Yeast cells growing in a closed flask with an initial volume of nutrient broth
    - A blue whale (the largest baleen whale) living in the ocean
  - (c) **Describe** the growth of the global human population for the last 10,000 years (you may want to include a labeled graph as part of your discussion). **Discuss** TWO factors that affect human population growth.

3. Eukaryotes depend on energy stored in biological molecules.
- (a) **Compare** and **contrast** how ATP is produced in the following two pathways.
- Oxidative phosphorylation in mitochondria
  - Photophosphorylation in chloroplasts
- (b) For THREE of the following, **describe** the specific role of ATP.
- Muscle contraction in animals
  - Transport of water into root hairs
  - Movement of chromosomes during anaphase
  - DNA replication
4. Certain human conditions result from changes in the DNA sequence. The following is a segment of the template strand of an open reading frame of a functional gene.

3' . . . GTT CAT CTA ACC CCT GAG GAG . . . 5'

- (a) Using the segment shown above, **determine** the sequence of the corresponding mRNA sequence. Indicate the 5' and 3' ends.
- (b) Using the table provided, **determine** the amino acid sequence of the polypeptide fragment.
- (c) The mutation results in the following sequence:

3' . . . GTT CAT CTA ACC CCT GTG GAG . . . 5'

- Determine** the change in the primary structure of the protein due to this mutation, and **explain** how this change may lead to a change in the function of the protein.
- (d) **Describe** ONE common human genetic condition that is caused by this type of mutation, including the effect of the change in protein function on the health of the affected individual.
- (e) **Describe** TWO techniques that can be used to identify the presence of this type of genetic change.

**GO ON TO THE NEXT PAGE.**

CODON TABLE  
Second Letter

|   | U                        | C                 | A                        | G                        |                     |                          |                    |                  |
|---|--------------------------|-------------------|--------------------------|--------------------------|---------------------|--------------------------|--------------------|------------------|
| U | UUU<br>UUC<br>UUA<br>UUG | phe<br>ser<br>leu | UCU<br>UCC<br>UCA<br>UCG | UAU<br>UAC<br>UAA<br>UAG | tyr<br>stop<br>stop | UGU<br>UGC<br>UGA<br>UGG | cys<br>stop<br>trp | U<br>C<br>A<br>G |
| C | CUU<br>CUC<br>CUA<br>CUG | leu               | CCU<br>CCC<br>CCA<br>CCG | CAU<br>CAC<br>CAA<br>CAG | his<br>gln          | CGU<br>CGC<br>CGA<br>CGG | arg                | U<br>C<br>A<br>G |
| A | AUU<br>AUC<br>AUU<br>AUG | ile               | ACU<br>ACC<br>ACA<br>ACG | AAU<br>AAC<br>AAA<br>AAG | asn<br>thr<br>lys   | AGU<br>AGC<br>AGA<br>AGG | ser<br>arg         | U<br>C<br>A<br>G |
| G | GUU<br>GUC<br>GUA<br>GUG | val               | GCU<br>GCC<br>GCA<br>GCG | GAU<br>GAC<br>GAA<br>GAG | asp<br>ala<br>glu   | GGU<br>GGC<br>GGA<br>GGG | gly                | U<br>C<br>A<br>G |

Third Letter (3' End)

**STOP**

**END OF EXAM**

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**AP® Biology**  
**Student Answer Sheet for Multiple-Choice Section**

| No. | Answer |
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**AP® Biology**  
**Multiple-Choice Answer Key**

| No. | Correct Answer |
|-----|----------------|
| 1   | C              |
| 2   | D              |
| 3   | B              |
| 4   | C              |
| 5   | C              |
| 6   | D              |
| 7   | A              |
| 8   | B              |
| 9   | C              |
| 10  | A              |
| 11  | B              |
| 12  | D              |
| 13  | D              |
| 14  | D              |
| 15  | E              |
| 16  | C              |
| 17  | A              |
| 18  | A              |
| 19  | C              |
| 20  | C              |
| 21  | A              |
| 22  | E              |
| 23  | E              |
| 24  | B              |
| 25  | D              |
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| No. | Correct Answer |
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| 31  | D              |
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| 36  | D              |
| 37  | E              |
| 38  | C              |
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| 58  | E              |
| 59  | A              |
| 60  | C              |

| No. | Correct Answer |
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| 63  | A              |
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| 88  | D              |
| 89  | C              |
| 90  | C              |

| No. | Correct Answer |
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| 91  | A              |
| 92  | E              |
| 93  | B              |
| 94  | C              |
| 95  | E              |
| 96  | A              |
| 97  | B              |
| 98  | A              |
| 99  | D              |
| 100 | E              |

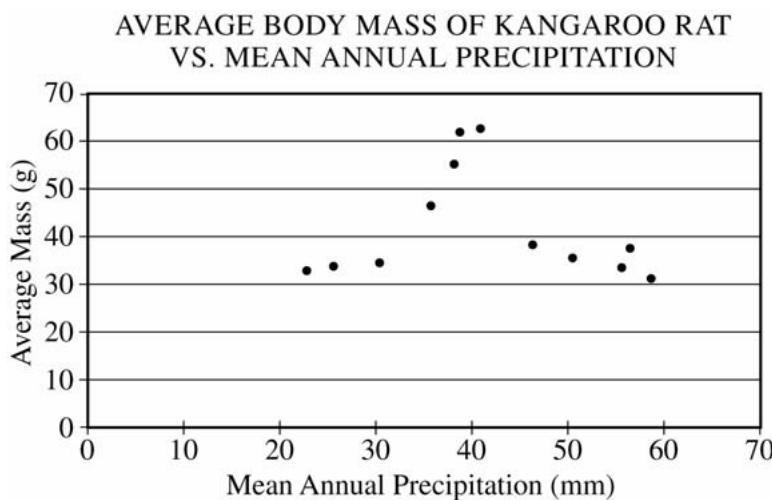
**AP® Biology**  
**Free-Response Scoring Guidelines**

**Note:** To earn 10 points for a specific question, students must earn at least 1 point in every part of that question.

**Question 1**

*Kangaroo rats, like other organisms, show specific adaptations to the environments in which they live. Kangaroo rats can survive in the desert with no free water. They can survive by obtaining water from dry seeds and grass that they eat, and have specialized kidneys that allow them to excrete urea with very little output of water.*

*The graph shows the average body mass for kangaroo rats at twelve locations throughout the southwestern United States as a function of mean annual precipitation at each location.*



- (a) **Describe the trends shown in the graph. (2 points maximum: 1 point for basic explanation, must be a complete description similar to the example below; 1 point for additional elaboration)**

Kangaroo rats have their highest body mass around 40 mm precipitation/year; increasing from 25 mm to 40 mm and decreasing from 40 mm to 60 mm of precipitation/year.

- (b) **Develop a hypothesis that would explain the data (5 points maximum for part (b): 1 point for a reasonable, testable hypothesis; 5 points for experimental design)**

**Note:**

- With some hypotheses offered, we may have to assume that increased body mass implies increased survivability and increased fitness.
- A hypothesis stating that the condition of 40 mm precipitation is best suited to the behavioral and physiological adaptations of the kangaroo rat should not receive credit. (The data presented has already shed light on this.)

Some potential hypotheses might include, but are not limited to, the following:

- 40 mm of precipitation is a condition that produces most of the kangaroo rat's preferred seeds and grasses.
- Rainfall amounts of less than 40 mm/year do not support the kangaroo rat's preferred grasses and seeds.

**AP® Biology**  
**Free-Response Scoring Guidelines**

**Question 1 (continued)**

- Rainfall amounts of more than 40 mm/year promote competition between the kangaroo rat's preferred species and other plants adapted to the desert.
- Kangaroo rat predators do not survive well at or around 40 mm of precipitation/year.
- Diseases and parasites of kangaroo rats are most contagious in precipitation conditions less than or greater than 40 mm/year.
- Kangaroo rat competitors (food, space, or other biologically sound resource) do not thrive well at conditions at or around 40 mm precipitation/year.

*(b) (continued) and design an experiment that would test the hypothesis. (5 points maximum: 1 point for any of the following included in the experimental design)*

**Note:** Experiment must test the stated hypothesis.

- Identification of a control set-up
- Identification of the variable that is being treated and at what levels
- Implication of what is being measured; what quantitative data is being assessed
- Discussion of confounding variables staying the same
- Repeated trials and/or large sample size in experiment
- Use of statistical analysis and/or graphs/tables to show patterns with data

*(c) Discuss TWO evolutionary adaptations, other than those described above, found among other desert organisms that help to conserve water.*

**(4 points maximum: 2 points per adaptation; 1 point for the adaptation, 1 point for appropriate discussion)**

**Note:** The following list of adaptations is not all-inclusive.

- Leaves reduced or absent
- Waxy cuticle
- Spines
- Storage of water
- Burrowing
- Nocturnal
- Crepuscular
- Taproot
- Extensive fibrous root system
- Pale coloration
- Periods of dormancy

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**Question 2**

*Environmental factors have a profound effect on the size and growth rate of populations of living organisms.*

(a) **Describe r- and K-life-history strategies. (2 points maximum: 1 point for each bullet)**

- r-selection—exponential growth, quick reproduction and maturity
- K-selection—produce few offspring, parental care high, long gestation

(b) **For EACH of the following, identify the life-history strategy, and describe the population growth curve and limiting factor. (6 points maximum: 1 point for each biologically sound description from each of the boxes below)**

*Yeast cells growing in a closed flask with an initial volume of nutrient broth  
A blue whale (the largest baleen whale) living in the ocean*

| Species     | Life-History Strategies | Growth Curve                                                                                                                                                                 | Limiting Factors                                                                                                                                                                       |
|-------------|-------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Yeast Cells | r-selection             | Exponential growth to carrying capacity and then die because of closed system<br>Crash due to waste build-up (alcohol or CO <sub>2</sub> ) or food/space resources exploited | Waste accumulation in a closed system<br>Gas exchange<br>Food depletion<br>Temperature, etc.                                                                                           |
| Blue Whale  | K-selection             | Exponential growth when species first established<br>Growth slows and population becomes stable near carrying capacity                                                       | Food availability<br>Pollution<br>Bioaccumulation<br>Finding a mate<br>Predation (of young)<br>Overexploitation<br>Disease/accidents/parasites<br>Competition with other baleen whales |

(c) **Describe the growth of the global human population for the last 10,000 years (you may want to include a labeled graph as part of your discussion). (4 points maximum for part (c): 1 point for any of the bullets below to a maximum of 2 points)**

- Relatively flat population from 10,000 years ago until the agricultural revolution
- Slight increase in population as a result of the agricultural revolution (circa 6000–7000 BCE)
- Indication of an approximate 25 percent decrease in population due to the plague during the Middle Ages (circa 1400 CE)
- Increase in population growth rate due to the industrial revolution (circa eighteenth century).
- Technological and agricultural mechanization (“green revolution”) and increased medical treatments (twentieth century)
- Exponential growth continues, perhaps beyond a stable carrying capacity

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**Question 2 (continued)**

(c) (continued) ***Discuss TWO factors that affect human population growth. (1 point for any of the bullets below to a maximum of 2 points)***

- Resource availability
  - Arable land
  - Water
  - Food
- Intraspecific competition = wars
- Density dependent spread of disease, parasites, etc. = pandemics, plagues
- Depletion of nonrenewable resources

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**Question 3**

*Eukaryotes depend on energy stored in biological molecules.*

- (a) **Compare and contrast** how ATP is produced in the following two pathways.

*Oxidative phosphorylation in mitochondria*

*Photophosphorylation in chloroplasts*

**Note:** Correct answers include the following, but the table is not all-inclusive.

**(6 points maximum: 2 points for each correct comparison; 1 point may be earned if information is only correct for one of the two organelles)**

|                         | Mitochondria                                                                                                                                                                                                                                                                                       | Chloroplasts                                                                                                                                                                                                                                      |
|-------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Energy Source           | High-energy electrons are produced by the stepwise breakdown of glucose in the processes of glycolysis and the Krebs cycle.                                                                                                                                                                        | Light energy is absorbed by photosynthetic pigments that ultimately excite electrons.                                                                                                                                                             |
| Electron Acceptors      | These electrons are delivered to the electron transport chain by reduction of the hydrogen acceptors NAD <sup>+</sup> and FADH <sub>2</sub> . (NADH and FADH <sub>2</sub> )                                                                                                                        | These excited electrons are transferred to primary electron acceptors in Photosystem II.                                                                                                                                                          |
| Proton Gradient         | As electrons are passed down from proteins embedded in the mitochondrial membrane between the inner and outer compartment, H <sup>+</sup> ions are passed from the inner to the outer compartment creating a “chemiosmotic” gradient of H <sup>+</sup> ions accumulating in the outer compartment. | As electrons are passed down from proteins embedded in the thylakoid membranes, H <sup>+</sup> ions are passed from the stroma into the thylakoid space creating a “chemiosmotic” gradient of H <sup>+</sup> ions accumulating in the thylakoids. |
| ATP Synthesis           | Protons flow across the membrane through ATP synthases. ATP is generated out of ADP + P. (As they flow through the channel, these H <sup>+</sup> ions transfer their chemiosmotic potential to ATP.)                                                                                               | Protons flow across the membrane through ATP synthases. ATP is generated out of ADP + P. (As they flow through the channel, these H <sup>+</sup> ions transfer their chemiosmotic potential to ATP.)                                              |
| Final Electron Acceptor | Electrons combine with H <sup>+</sup> and O <sub>2</sub> , forming H <sub>2</sub> O.                                                                                                                                                                                                               | These low-energy electrons can be reenergized by Photosystem I where they can be recycled to trickle down the electron transport chain again to form NADPH <sub>2</sub> .                                                                         |

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**Question 3 (continued)**

(b) For THREE of the following, **describe** the specific role of ATP. (6 points maximum for part (b): 2 points maximum for each bullet)

*Muscle contraction in animals*

*Transport of water into root hairs*

*Movement of chromosomes during anaphase*

*DNA replication*

- Muscle contraction in animals
  - ATP binds to myosin head, converts to ADP + P, and myosin is phosphorylated (energized).
  - Ca<sup>++</sup> exposes the binding sites for actin filaments; Ca<sup>++</sup> binds to troponin causing tropomyosin to expose positions on the actin filament for attachment of myosin heads.
  - Cross bridges between actin and myosin form.
  - ADP + P are released, and the sliding motion occurs (change in shape between actin and myosin, which generates a sliding movement and, when amplified many times, results in the pulling of many myofibrils together).
- Transport of water into root hairs
  - Ions are actively transported from the soil into cells by protein carriers.
  - ATP phosphorylates the proteins, changing their confirmation and powering the ion transport.
  - The transported ions create a concentration gradient (water potential).
  - Water passively diffuses into the cell down the concentration gradient.
- Movement of chromosomes during anaphase
  - During anaphase, kinetochore microtubules shorten to “walk” toward respective poles.
  - Using energy from ATP, motor proteins reduce tubulin into subunits.
  - As microtubules move apart, the spindle poles move apart, elongating the cell.
- DNA replication
  - ATP “hydrolysis” is needed for the following processes:
    - Formation of other deoxynucleotide phosphates: GTP, CTP, and TTP.
    - Elongation of the growing strand (can be powered by ATP or other deoxynucleotide triphosphate).
    - Ligation (can be powered by ATP or other deoxynucleotide triphosphate).
    - Movement of the DNA polymerase complex.
    - Unwinding the helix.

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**Question 4**

*Certain human conditions result from changes in the DNA sequence. The following is a segment of the template strand of an open reading frame of a functional gene.*

3' . . . GTT CAT CTA ACC CCT GAG GAG . . . 5'

- (a) *Using the segment shown above, determine the sequence of the corresponding mRNA sequence. Indicate the 5' and 3' ends. (2 points maximum: 1 point for correct sequence with a maximum of one error; 1 point for proper orientation of the 5' and 3' ends)*

5' . . . CAA GUA GAU UGG GGA CUC CUC . . . 3'

- (b) *Using the table provided, determine the amino acid sequence of the polypeptide fragment. (2 points for correct sequence; only 1 point if sequence contains an error)*

gln – val – asp – trp – gly – leu – leu

- (c) *The mutation results in the following sequence:*

3' . . . GTT CAT CTA ACC CCT GTG GAG . . . 5'

**Determine the change in the primary structure of the protein due to this mutation, and explain how this change may lead to a change in the function of the protein. (1 point for correct substitution; 1 point for accurate description of a problem; 1 point for elaboration)**

gln – val – asp – trp – gly – his – leu

Changed AA may lead to a change in the structure of the protein.

Possible elaboration points:

- Change is in the folding into the tertiary or quaternary structure.
- Some AA side groups are more important than others, e.g., cysteine forms disulfide bridges.
- Some AA can be interchanged with no effect on the structure due to lack of interactive side groups.
- Change to enzyme's active or allosteric site is especially damaging.
- Others as appropriate.

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**Question 4 (continued)**

(d) **Describe ONE common human genetic condition that is caused by this type of mutation, including the effect of the change in protein function on the health of the affected individual. (2 points maximum: 1 point for the condition and 1 point for discussion of effect of change on the health of the affected individual)**

Common conditions include:

- Tay-sachs
- Sickle-cell anemia
- Increased cancer risk (P53 gene)
- Cystic fibrosis
- Hemophilia
- Others as appropriate

(e) **Describe TWO techniques that can be used to identify the presence of this type of genetic change. (2 points maximum: 1 point for each description)**

Techniques include:

- Microarray assays to compare novel and mutant DNA
- DNA sequencing
- RFLP markers
- Presence of diagnostic phenotype
- Specific marker for mutated sequence
- Others as appropriate (Note: VNTR and Karyotyping are not appropriate techniques.)

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**Question 4 (continued)**

|                       |                          | CODON TABLE              |                          |                     |                          | Third Letter (3' End) |                  |
|-----------------------|--------------------------|--------------------------|--------------------------|---------------------|--------------------------|-----------------------|------------------|
|                       |                          | Second Letter            |                          |                     |                          |                       |                  |
| First Letter (5' End) | U                        | C                        | A                        | G                   |                          |                       |                  |
|                       | UUU<br>UUC<br>UUA<br>UUG | UCU<br>UCC<br>UCA<br>UCG | UAU<br>UAC<br>UAA<br>UAG | tyr<br>stop<br>stop | UGU<br>UGC<br>UGA<br>UGG | cys<br>stop<br>trp    | U<br>C<br>A<br>G |
|                       | CUU<br>CUC<br>CUA<br>CUG | CCU<br>CCC<br>CCA<br>CCG | CAU<br>CAC<br>CAA<br>CAG | his<br>pro<br>gln   | CGU<br>CGC<br>CGA<br>CGG | arg                   | U<br>C<br>A<br>G |
|                       | AUU<br>AUC<br>AUU<br>AUG | ACU<br>ACC<br>ACA<br>ACG | AAU<br>AAC<br>AAA<br>AAG | asn<br>thr<br>lys   | AGU<br>AGC<br>AGA<br>AGG | ser<br>arg            | U<br>C<br>A<br>G |
|                       | GUU<br>GUC<br>GUA<br>GUG | GCU<br>GCC<br>GCA<br>GCG | GAU<br>GAC<br>GAA<br>GAG | asp<br>ala<br>glu   | GGU<br>GGC<br>GGA<br>GGG | gly                   | U<br>C<br>A<br>G |