

Q. THIS SECTION IS FOR THE SURVEY QUESTIONS IN THE AP STUDENT PACK. (DO NOT PUT RESPONSES TO EXAM QUESTIONS IN THIS SECTION.) BE SURE EACH MARK IS DARK AND COMPLETELY FILLS THE OVAL.

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DO NOT COMPLETE THIS SECTION UNLESS INSTRUCTED TO DO SO.

R. If this answer sheet is for the French Language, French Literature, German Language, Spanish Language, or Spanish Literature Examination, please answer the following questions. (Your responses will not affect your grade.)

1. Have you lived or studied for one month or more in a country where the language of the exam you are now taking is spoken? Yes No
2. Do you regularly speak or hear the language at home? Yes No

INDICATE YOUR ANSWERS TO THE EXAM QUESTIONS IN THIS SECTION. IF A QUESTION HAS ONLY FOUR ANSWER OPTIONS, DO NOT MARK OPTION (E). YOUR ANSWER SHEET WILL BE SCORED BY MACHINE. USE ONLY NO. 2 PENCILS TO MARK YOUR ANSWERS ON PAGES 2 AND 3 (ONE RESPONSE PER QUESTION). AFTER YOU HAVE DETERMINED YOUR RESPONSE, BE SURE TO COMPLETELY FILL IN THE OVAL CORRESPONDING TO THE NUMBER OF THE QUESTION YOU ARE ANSWERING. STRAY MARKS AND SMUDGES COULD BE READ AS ANSWERS, SO ERASE CAREFULLY AND COMPLETELY. ANY IMPROPER GRIDDING MAY AFFECT YOUR GRADE.

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FOR QUESTIONS 76-151, SEE PAGE 3.

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BIOLOGY

SECTION I

Time—1 hour and 30 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 then fill in the corresponding oval on the answer sheet.

1. In humans, the HIV virus primarily attacks which of the following types of cells?

(A) Epidermal cells
 (B) Red blood cells
 (C) White blood cells
 (D) Glial cells
 (E) Neurons

2. In an experiment on birds learning to sing, young male chicks were exposed only to the songs sung by another species. Later, as they approached maturity, songs of their own species were played to them. When the birds reached maturity, they were able to sing neither the typical song of their species nor the full song of the second species. Which of the following accounts for this result?

(A) Birds innately sing the song typical of their species.
 (B) Birds pass through a critical period early in life when learning their species-typical song is possible.
 (C) Birds can learn their typical song if they hear it at any time.
 (D) Birds must be able to practice their song in order to develop it.
 (E) Birds are capable of imitating any song that they hear.

3. A biologist counted 2,500 cells from an embryo on a microscope slide and recorded the following data.

Stage	Number of Cells
Prophase	125
Metaphase	50
Anaphase	50
Telophase	25
Interphase	<u>2,250</u>
Total	2,500

If these cells had been dividing randomly, it could be reasonably concluded that

- (A) the duration of anaphase is approximately one-half that of telophase
 (B) prophase is approximately three times as long as telophase
 (C) metaphase is the shortest stage of the cell cycle
 (D) interphase is the longest stage of the cell cycle
 (E) the chromosomes can first be seen in prophase
4. The different species of finches on the Galapagos Islands are believed to have arisen as a result of natural selection acting on populations of finches that had experienced
- (A) convergent evolution
 (B) gene flow
 (C) the bottleneck effect
 (D) geographic isolation
 (E) hybrid sterility

5. Which of the following describes the mechanism by which a plant stem grows toward light?
- (A) The plant seeks light in order to maximize photosynthesis.
 - (B) Nerve-like impulses stimulate contractile cells on the lighted side of the stem.
 - (C) Cells on the dark side of the stem elongate more than those on the lighted side.
 - (D) The plant grows into an open area where its leaves will not be shaded by competing plants.
 - (E) The greater energy supply on the lighted side of the stem stimulates metabolism and growth on that side.
6. The LEAST effective means of controlling pest species such as rats or roaches over a long period of time is generally to
- (A) limit food supplies
 - (B) reduce the number of potential habitats
 - (C) distribute pesticides throughout the habitat
 - (D) introduce predators of the pest
 - (E) introduce a disease which affects only the pest
7. Which of the following levels of organization includes all of the others?
- (A) Population
 - (B) Ecosystem
 - (C) Community
 - (D) Organism
 - (E) Habitat
8. All of the following statements concerning characteristics of predator-prey relationships are correct EXCEPT:
- (A) A rise in the population of prey is often followed by a rise in the population of predators.
 - (B) A rise in the population of predators is followed by a decrease in the population of prey.
 - (C) Camouflage is an adaptation that protects prey.
 - (D) The production of large numbers of offspring within very short periods of time ensures the survival of some prey populations.
 - (E) The population of predators most often eliminates the population of prey.
9. The function of which of the following organelles directly requires oxygen?
- (A) Ribosome
 - (B) Mitochondrion
 - (C) Nucleus
 - (D) Centriole
 - (E) Golgi apparatus
10. Flowering plants are capable of fertilization in the absence of water because the
- (A) processes of pollination and fertilization occur in the soil
 - (B) pollen tubes deliver the sperm to the eggs
 - (C) eggs develop without sperm by parthenogenesis
 - (D) eggs have a structure that aids in their dispersal by wind
 - (E) sperm contain large amounts of cytoplasm

Section I

11. Adaptations that have enabled vertebrates to survive on land include all of the following EXCEPT
- (A) a water-resistant epidermis
 - (B) development of a bony skeleton
 - (C) development of lungs
 - (D) external fertilization
 - (E) embryos enclosed within membranes
12. An animal that has a high surface-area-to-volume ratio of the body, and takes in all the oxygen it needs through its outer epithelium is most likely which of the following?
- (A) a fish
 - (B) an earthworm
 - (C) a mammal
 - (D) an insect
 - (E) a snake
13. Toads in a particular population vary in size. A scientist observes that in this population, large males mate with females significantly more often than small males do. All the following are plausible hypotheses to explain this observation EXCEPT:
- (A) Females select large males more often than they select small males as mates.
 - (B) Small females are more likely to mate with small males and large females are more likely to mate with large males.
 - (C) Large males are successful in competing for mates more often than small males are.
 - (D) Large males occupy more breeding territory than small males do.
 - (E) The calls produced by large males are more attractive to females than the calls made by small males.
14. In the development of a seedling, which of the following will be the last to occur?
- (A) Initiation of the breakdown of the food reserve
 - (B) Initiation of cell division in the root meristem
 - (C) Emergence of the root
 - (D) Expansion and greening of the first true foliage leaves
 - (E) Imbibition of water by the seed
15. Which of the following behaviors involves the LEAST learning?
- (A) A lion capturing its prey
 - (B) A newborn human grasping something placed in its hand
 - (C) A mouse finding food in the kitchen of a house
 - (D) A mockingbird singing the song of a different species
 - (E) A chimpanzee finding its way through a forest
16. In most vertebrates, the sperm cell normally contributes which of the following to the new organism?
- (A) Many mitochondria
 - (B) Significant amounts of RNA
 - (C) A haploid complement of chromosomes
 - (D) Most of the cytoplasm of the zygote
 - (E) Two sex chromosomes
17. Most cells that have become transformed into cancer cells have which of the following characteristics when compared to normal, healthy cells?
- (A) Shorter cell cycle
 - (B) More carefully regulated rates of cell division
 - (C) Lower rates of mitosis
 - (D) Higher rates of protein translation
 - (E) Identical DNA

18. If organisms *A*, *B*, and *C* belong to the same order but to different families and if organisms *D*, *E*, and *F* belong to the same family but to different genera, which of the following pairs of organisms would be expected to show the greatest degree of structural homology?
- (A) *A* and *B*
 - (B) *A* and *C*
 - (C) *B* and *D*
 - (D) *C* and *F*
 - (E) *E* and *F*
19. A prokaryotic cell has which of the following?
- (A) Centrioles
 - (B) Lysosomes
 - (C) Plasma membrane
 - (D) Mitochondria
 - (E) Endoplasmic reticulum
20. Which of the following statements regarding coenzymes is true?
- (A) They are essential for metabolic reactions in animals but not in plants.
 - (B) They can facilitate metabolic reactions by combining with enzymes at their active sites.
 - (C) They are minerals that alter the pH of cells and thus increase the probability of chemical reactions.
 - (D) They are synthesized in the rough endoplasmic reticulum of eukaryotic cells.
 - (E) They typically work best at temperatures below 37°C.
21. An animal with anterior, posterior, dorsal, and ventral surfaces on its body must exhibit
- (A) protostomic development
 - (B) coelomate development
 - (C) segmentation
 - (D) radial symmetry
 - (E) bilateral symmetry
22. The fruit produced by angiosperms is an evolutionary adaptation that most often
- (A) nourishes the seeds within the fruit on ripening
 - (B) aids in seed dispersal
 - (C) attracts pollinators
 - (D) inhibits seed germination until favorable environmental conditions occur
 - (E) provides an energy source for the plant egg cell prior to fertilization
23. Which of the following types of chemicals released into the air by female gypsy moths and female silk moths attract males of their respective moth species?
- (A) Ecdysones
 - (B) Pheromones
 - (C) Auxins
 - (D) Phytotoxins
 - (E) Neurotransmitters
24. Which of the following best describes opportunistic, or *r*-strategy, organisms?
- (A) They reach sexual maturity rapidly.
 - (B) They reach their adult size slowly.
 - (C) They attain a large body size.
 - (D) They live for a long time.
 - (E) The size of their population remains fairly constant.

Section I

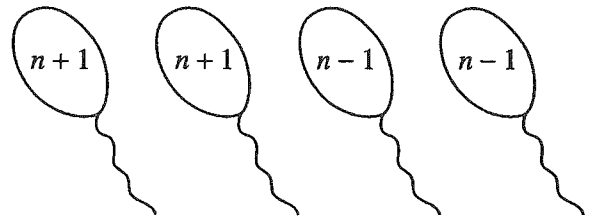
25. Which of the following terms refers to both the movement of a ribosome along a piece of mRNA and the movement of a piece of one chromosome to another chromosome?
- (A) Transduction
 - (B) Transgenesis
 - (C) Transformation
 - (D) Translocation
 - (E) Transplantation
26. Which of the following hormones is directly responsible for the maintenance of the uterine lining during pregnancy in mammals?
- (A) Melatonin
 - (B) Oxytocin
 - (C) Progesterone
 - (D) Prolactin
 - (E) FSH (Follicle-stimulating hormone)
27. The fact that tracheophytes can survive on land is due to which of the following?
- (A) Alternation of generations
 - (B) A dominant gametophyte stage
 - (C) Adaptation to damp habitats
 - (D) Water transport through vascular tissues
 - (E) Mechanisms other than photosynthesis for carbohydrate production
28. As the initial cleavage divisions proceed in a frog embryo, which of the following results?
- (A) The embryo increases in size.
 - (B) The cytoplasmic content of the individual cells increases.
 - (C) The yolk mass increases in size.
 - (D) Individual cells become smaller.
 - (E) Individual cells become haploid.
29. Which of the following provides the weakest evidence that mitochondria were once free-living prokaryotes?
- (A) Mitochondrial ribosomes resemble those of prokaryotes.
 - (B) Mitochondria have DNA that is circular and does not have associated protein.
 - (C) Enzyme pathways on mitochondrial membranes resemble those found on modern prokaryote membranes.
 - (D) Mitochondria reproduce by a process similar to binary fission.
 - (E) Mitochondria and prokaryotes both are found in a variety of sizes.
30. Which of the following is an actively dividing tissue in plants?
- (A) Cambium
 - (B) Xylem
 - (C) Endodermis
 - (D) Phloem
 - (E) Pith
31. Analysis of DNA sequences from two individuals of the same species results in a greater estimate of genetic variability than does analysis of amino acid sequences from the same individuals because
- (A) different DNA sequences can code for the same amino acid
 - (B) some amino acid variations cannot be detected by protein electrophoresis
 - (C) DNA sequencing is a more reliable technique than protein electrophoresis
 - (D) proteins are more easily damaged than is DNA
 - (E) DNA is more heat-sensitive and therefore varies more

32. Which of the following is correct concerning development of embryos in animals but not in plants?
- (A) Gastrulation occurs within the embryo.
 - (B) Fertilization produces a diploid embryo.
 - (C) Embryonic cell divisions are mitotic.
 - (D) Fusion of gametes results in a zygote.
 - (E) Cell differentiation occurs.
33. Which of the following physiological effects would likely occur first in a volunteer who was breathing air from which the CO_2 was removed?
- (A) Decreased blood pH
 - (B) Decreased respiratory rate
 - (C) Increased respiratory rate
 - (D) Increased pulse rate
 - (E) Increased blood pressure
34. Which of the following best describes why the polymerase chain reaction is a standard technique used in molecular biology research?
- (A) It uses inexpensive materials and produces perfect results.
 - (B) It can purify specific sections of a DNA molecule.
 - (C) It can produce large amounts of specific DNA sequences.
 - (D) It can duplicate the entire human genome.
 - (E) It can produce large amounts of mRNA.
35. Double fertilization in an ovule of a flowering plant results in which of the following?
- (A) Two embryos
 - (B) Two seeds in a fruit
 - (C) One embryo and one endosperm
 - (D) Two fruits joined together
 - (E) One endosperm and one cotyledon
36. Which of the following best describes the cells that result from the process of meiosis in mammals?
- (A) They are diploid.
 - (B) They can be used to repair injuries.
 - (C) They are genetically different from the parent cell.
 - (D) They are genetically identical to all the other cells in the body.
 - (E) They are identical to each other.
37. The function of which of the following structures is NOT directly related to diffusion or active transport across its membranes?
- (A) Aorta
 - (B) Small intestine
 - (C) Nephron tubule
 - (D) Capillary
 - (E) Alveolus
38. A part of the brain used in the transfer of information from one cerebral hemisphere to the other is the
- (A) medulla oblongata
 - (B) corpus callosum
 - (C) cerebellum
 - (D) hypothalamus
 - (E) pituitary
39. Fruits often ripen faster when placed in closed paper bags because of the effect of
- (A) cytokinin
 - (B) abscisic acid
 - (C) CO_2
 - (D) gibberellin
 - (E) ethylene

Section I

40. Simple diffusion and facilitated diffusion are related in that both
- (A) require protein carriers
 - (B) depend on a concentration gradient
 - (C) occur via contractions of cytoskeletal elements attached to membrane proteins
 - (D) are endergonic processes and thus require the hydrolysis of ATP
 - (E) occur in eukaryotic cells but not in prokaryotic cells
41. Which of the following statements about mitochondrial chemiosmosis is NOT true?
- (A) A proton gradient is established across the inner membrane of the mitochondrion.
 - (B) The potential energy released from the mitochondrial proton gradient is used to produce ATP.
 - (C) The mitochondrial proton gradient provides energy for muscle contraction.
 - (D) Proteins embedded in the inner mitochondrial membrane play an important role in ATP synthesis.
 - (E) Heat energy is required to establish the electron transport chain.
42. ATP serves as a common energy source for organisms because
- (A) it is the smallest energy molecule
 - (B) it stores the least energy of any energy source
 - (C) its energy can be easily transferred to do cellular work
 - (D) it is extremely stable and can be stored in the cell for long periods of time
 - (E) traces of it have been found in fossils of ancient organisms dating back to the beginning of life on Earth

43. A spermatocyte produces the following four sperm cells.



These cells are the result of nondisjunction during which of the following phases?

- (A) Interphase (G1 or G2)
 - (B) Interphase (S)
 - (C) Mitosis
 - (D) Meiosis I
 - (E) Meiosis II
44. Which metabolic process is common to both aerobic cellular respiration and alcoholic fermentation?
- (A) Krebs cycle
 - (B) Glycolysis
 - (C) Electron transport chain
 - (D) Conversion of pyruvic acid to acetyl CoA
 - (E) Production of a proton gradient
45. Which of the following is responsible for the cohesive property of water?
- (A) Hydrogen bonds between the oxygen atoms of two adjacent water molecules
 - (B) Covalent bonds between the hydrogen atoms of two adjacent water molecules
 - (C) Hydrogen bonds between the oxygen atom of one water molecule and a hydrogen atom of another water molecule
 - (D) Covalent bonds between the oxygen atom of one water molecule and a hydrogen atom of another water molecule
 - (E) Hydrogen bonds between water molecules and other types of molecules

46. All of the following correctly describe the fate of the embryonic layers of a vertebrate EXCEPT
- (A) neural tube and epidermis develop from ectoderm
 - (B) linings of digestive organs and lungs develop from endoderm
 - (C) notochord and kidneys develop from endoderm
 - (D) skeletal muscles and heart develop from mesoderm
 - (E) reproductive organs and blood vessels develop from mesoderm
47. Which of the following processes is associated with some prokaryotic cells but not with eukaryotic cells?
- (A) Photosynthesis
 - (B) Aerobic respiration
 - (C) Meiosis
 - (D) Nitrogen fixation
 - (E) Endocytosis
48. The control of breathing is centered in which of the following areas of the brain?
- (A) Anterior pituitary
 - (B) Corpus callosum
 - (C) Cerebellum
 - (D) Medulla oblongata
 - (E) Cerebrum
49. Certain metabolic pathways are affected by the buildup of a product which interacts with an enzyme catalyzing one of the initial steps of the pathway; this can be an example of
- (A) transcriptional regulation
 - (B) thermodynamic regulation
 - (C) translational regulation
 - (D) feedback inhibition
 - (E) posttranslational modification
50. All of the following statements about neurotransmitters are generally true EXCEPT:
- (A) They may cause depolarization or hyperpolarization of the postsynaptic membrane.
 - (B) They are actively transported across the synaptic cleft.
 - (C) They are released from membrane-bound packets called vesicles.
 - (D) They may be enzymatically degraded at the postsynaptic membrane.
 - (E) They bind to specific receptors on the postsynaptic membrane.

Section I

51. A customer observed that a particular potted plant in a restaurant was bigger and greener than other plants in the room. When asked, the owner said that he poured leftover club soda (carbonated water) into that plant's pot every day. Which of the following best explains how the club soda affected that plant's growth?
- (A) The basic pH of the club soda caused the plant to grow rapidly.
 - (B) The temperature of the club soda promoted faster growth.
 - (C) Oxygen bubbles from the club soda oxygenated the soil.
 - (D) The roots absorbed the CO_2 necessary for photosynthesis.
 - (E) The roots received more moisture, and the leaves were exposed to more CO_2 .
52. A major function of the Casparian strip of the endodermal cells of a root is to
- (A) protect the meristem as the root tip grows through the abrasive soil particles
 - (B) allow for expansion of the vascular cambium as the root grows laterally
 - (C) control the movement of materials into the vascular cylinder of the root
 - (D) initiate lateral root growth
 - (E) serve as a site for the storage of excess sugars in the form of starch
53. Which of the following is correct concerning a spherical cell?
- (A) As the diameter decreases, the surface area remains the same.
 - (B) As the diameter decreases, the surface area increases.
 - (C) As the diameter decreases, the surface-to-volume ratio increases.
 - (D) As the diameter increases, the volume decreases.
 - (E) The surface-to-volume ratio is independent of the diameter.
54. Which of the following directly produces the most ATP per mole of glucose during aerobic cellular respiration?
- (A) Glycolysis
 - (B) Electron transport chain and chemiosmosis
 - (C) Substrate-level phosphorylation
 - (D) Krebs's cycle
 - (E) Alcoholic fermentation
55. All of the following could reduce the yield of photosynthetic products EXCEPT
- (A) lower concentrations of carbon dioxide in the atmosphere
 - (B) increased photorespiration
 - (C) reduced carbon dioxide concentrations in the air spaces of the leaf
 - (D) increased frequency of stomatal openings
 - (E) fewer Calvin cycle enzymes

56. Which of the following is true about the production of polar bodies in humans?
- (A) It increases genetic variability.
 - (B) It provides the maximum amount of cytoplasm and resources to the ovum.
 - (C) It occurs in male and female vertebrates during meiosis I.
 - (D) It is completed prior to fertilization.
 - (E) It results in nondisjunction.
57. Coat color in mice is determined by genes at two loci. When black mice from a particular population mate, they produce offspring in the following ratios: 9 black : 3 brown : 4 white. These results suggest that white coat color is expressed as a result of
- (A) dominance
 - (B) incomplete dominance
 - (C) codominance
 - (D) a sex-linked trait
 - (E) epistasis
58. Which of the following can be diagnosed by examining a karyotype of an individual's white blood cells?
- (A) Sickle cell anemia
 - (B) Alzheimer disease
 - (C) Down syndrome
 - (D) Cystic fibrosis
 - (E) Duchenne muscular dystrophy
59. All of the following are common to C_3 and C_4 photosynthesis EXCEPT
- (A) Photolysis
 - (B) Initial step of CO_2 fixation
 - (C) Cyclic photophosphorylation
 - (D) Noncyclic photophosphorylation
 - (E) Chemiosmotic phosphorylation
60. In mammals, a decrease in body temperature results in which of the following responses?
- (A) Release of thyroxine decreases the rate of metabolism.
 - (B) Blood vessels close to the surface of the skin constrict.
 - (C) Increased secretion of epinephrine restricts the amount of sugar released into the circulatory system.
 - (D) The adrenal glands increase the release of acetylcholine into the circulatory system.
 - (E) Blood vessels in deep muscles constrict so that heat is conserved.

Item 61 was not scored.

Section I

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

Questions 62-65 refer to the following enzymes.

- (A) DNA ligase
 - (B) DNA polymerase
 - (C) RNA polymerase
 - (D) Restriction enzyme
 - (E) Reverse transcriptase
62. Enzyme used in the synthesis of mRNA
63. Enzyme used during replication to attach Okazaki fragments to each other
64. Enzyme found in retroviruses that produce DNA from an RNA template
65. Enzyme used to position nucleotides during DNA replication

Questions 66-69 refer to the probabilities below.

Assume that the alleles referred to all assort independently.

- (A) 0
 - (B) 1/16
 - (C) 1/4
 - (D) 1/2
 - (E) 3/4
66. Probability that the genotype Aa will be produced by the parents $Aa \times Aa$
67. Probability that the genotype $ccdd$ will be produced by the parents $CcDd \times CcDd$
68. Probability that the genotype Rr will be produced by the parents $Rr \times rr$
69. Probability that the genotype $TTSs$ will be produced by the parents $TTSs \times TtSS$

Questions 70-73 refer to the following groups of biological compounds.

- (A) Proteins
- (B) Carbohydrates
- (C) Nucleic acids
- (D) Lipids
- (E) Steroids

- 70. Synthesized at the ribosome
- 71. Includes glycogen, chitin, cellulose, and glucose
- 72. Used for insulation and buoyancy in marine Arctic animals
- 73. Used to carry the genetic code

Questions 74-77 refer to the following.

- (A) Echinoderms
 - (B) Annelids
 - (C) Arthropods
 - (D) Cnidarians (coelenterates)
 - (E) Chordates
- 74. These organisms often have both a polyp form and a medusa form in their life cycle.
 - 75. These organisms have pharyngeal gill slits and a dorsal hollow nerve cord at some time in their development.
 - 76. These organisms have radial symmetry and a water vascular system and are generally bottom-dwellers.
 - 77. These organisms have a chitinous exoskeleton and jointed appendages.

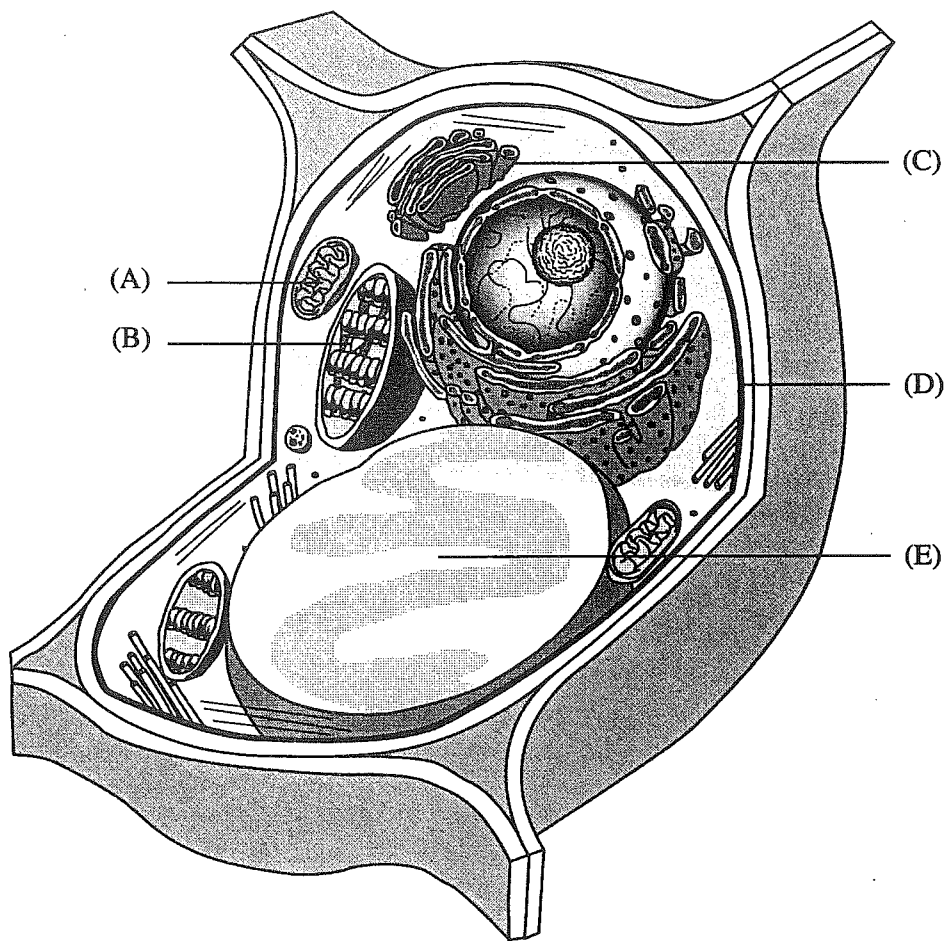
Section I

Questions 78-81 refer to molecules of the following substances.

- (A) Cytochrome
- (B) FADH_2
- (C) NAD^+
- (D) NADP^+
- (E) Oxygen (O_2)

78. A membrane-bound electron carrier found in the electron transport systems of both aerobic respiration and photosynthesis
79. Coenzyme that transfers electrons from the Krebs cycle to the mitochondrial electron-transport chain at a lower energy level than that of electrons entering at the beginning of the chain
80. An intermediate electron acceptor for oxidations that occur in both glycolysis and in Krebs cycle reactions
81. The final electron acceptor for cellular respiration

Questions 82-86 refer to the following diagram of a plant cell.



82. Site of glucose synthesis

83. Site of conversion of chemical energy of glucose to ATP

84. Site of modification and packaging of proteins and lipids prior to export from the cell

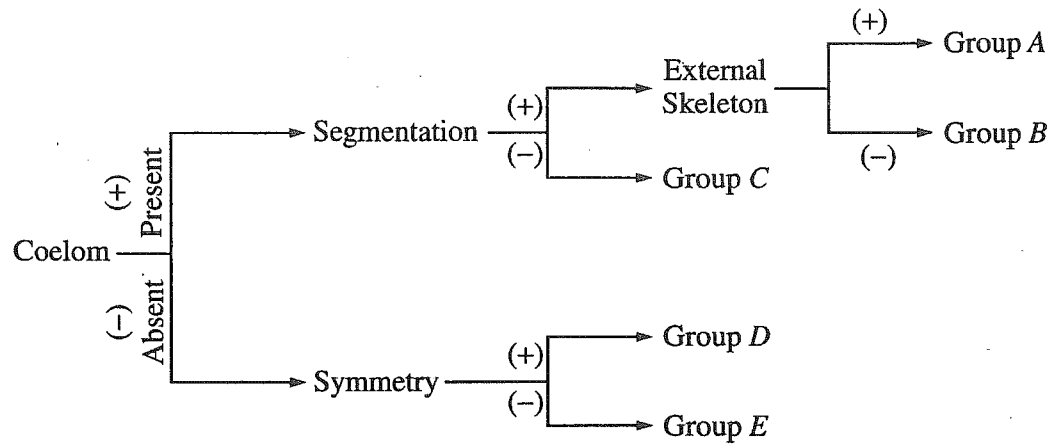
85. Site of transport of materials into and out of the cell

86. Evolved from a photoautotrophic prokaryote

Section I

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 oval on the answer sheet.

Questions 87-89 refer to the following dichotomous key.



87. Centipedes and millipedes should NOT be placed in group *B* because they

- (A) have an exoskeleton
- (B) display radial symmetry
- (C) lack a coelom
- (D) are unsegmented
- (E) have an endoskeleton

89. Clam, octopus, and oyster are classified in which group?

- (A) *A*
- (B) *B*
- (C) *C*
- (D) *D*
- (E) *E*

88. Which of the following phyla is represented by group *E*?

- (A) Mollusca
- (B) Cnidaria (Coelenterata)
- (C) Porifera
- (D) Chordata
- (E) Annelida

Questions 90-92 are based on the following.

In the 1940's, Avery, MacCleod, and McCarty transformed nonencapsulated bacteria into encapsulated forms by growing the nonencapsulated cells in a culture containing an extract made from dead encapsulated cells. The transformed cells produced colonies of encapsulated bacteria. Three different procedures and their results are outlined below.

Procedure I:

Extract made from dead encapsulated cells added to culture medium.
Nonencapsulated bacteria added to culture medium.

Results: Both nonencapsulated and encapsulated bacteria grow.

Procedure II:

Extract made from dead encapsulated cells treated with protein-degrading enzymes before adding extract to culture medium.
Nonencapsulated bacteria added to culture medium.

Results: Both nonencapsulated and encapsulated bacteria grow.

Procedure III:

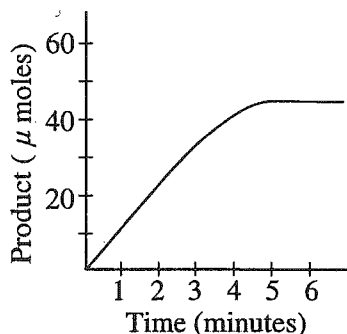
Extract made from dead encapsulated cells treated with DNase (an enzyme that selectively destroys DNA) before adding extract to culture medium.
Nonencapsulated bacteria added to culture medium.

Results: Only nonencapsulated bacteria grow.

90. A reasonable conclusion to draw from the results of the experiment is that
- (A) DNA is the genetic material
 - (B) DNA replication is semiconservative
 - (C) DNA is a double helix
 - (D) DNA is translated into protein
 - (E) mutation is a change in the genetic material
91. What was the purpose of treating the extract with protein-degrading enzymes in Procedure II ?
- (A) To demonstrate that the transforming factor is an enzyme
 - (B) To demonstrate that the transforming factor is not a protein
 - (C) To destroy nucleic acids in the extract
 - (D) To destroy any capsules in the extract
 - (E) To prevent the extract from being contaminated by nonencapsulated bacteria
92. What was the purpose of treating the extract with DNase in Procedure III ?
- (A) To remove the encapsulated bacteria from the extract
 - (B) To serve as a positive control by demonstrating that a protein in the extract is the transforming factor
 - (C) To serve as a negative control by demonstrating that transformation does not occur without DNA
 - (D) To destroy enzymes in the extract
 - (E) To destroy any capsules that might be in the extract

Section I**Questions 93-96**

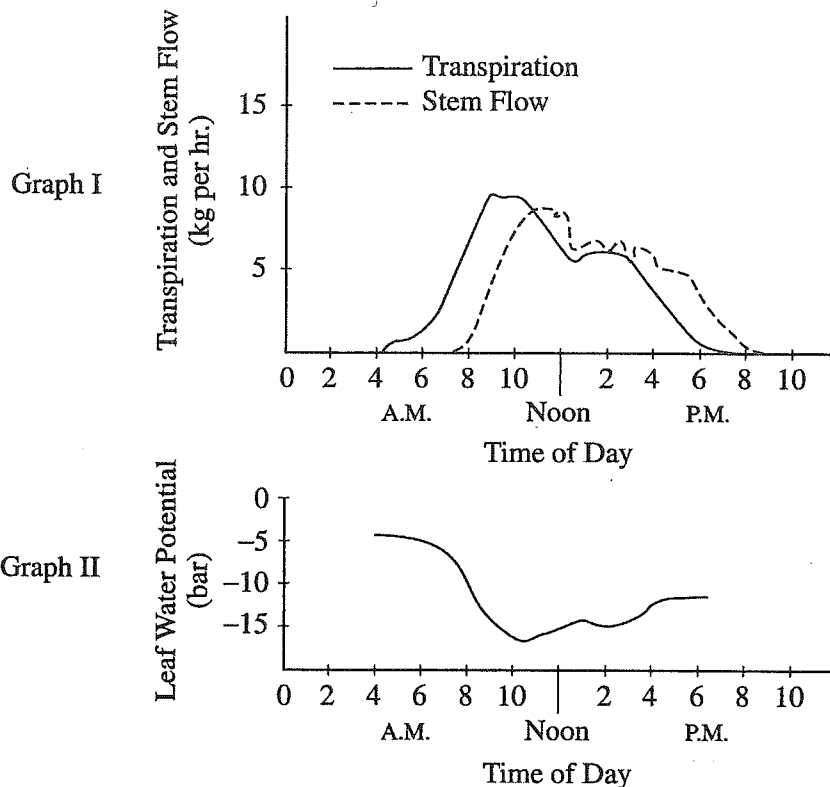
A scientist determined the rate of an enzyme-catalyzed reaction by measuring the amount of product formed over time. The following curve was generated from the data collected.



93. Based solely on the curve, what can be said concerning the calculated reaction rates at 1 minute and at 2 minutes?
- (A) The rate after 2 minutes is greater than the rate after 1 minute.
(B) The rates are the same at 1 minute and at 2 minutes.
(C) The rates are affected by high concentrations of inhibitors.
(D) The rates are both zero.
(E) The greater the rate, the faster the enzyme is denatured.
94. The rate of the reaction could also be determined by
- (A) measuring the change in the amount of enzyme
(B) measuring the change in the amount of substrate
(C) measuring the change in salt concentration
(D) adding more substrate
(E) adding more enzyme
95. What is the most likely explanation for the change in the slope of the line between 3 and 5 minutes?
- (A) The enzyme had denatured.
(B) The enzyme had achieved its maximum velocity.
(C) A large amount of the substrate had been consumed.
(D) An allosteric inhibitor appeared.
(E) There was a dramatic change in the pH.
96. During which time interval is the reaction rate lowest?
- (A) 0-1 minute
(B) 1-2 minutes
(C) 2-3 minutes
(D) 3-4 minutes
(E) 4-5 minutes

Questions 97-100 are based on the following.

The rate of transpiration, the flow of water through the stem, and leaf water potential are measured in a tree during a 24-hour period under normal environmental conditions. The results from these measurements are shown in the graphs below.



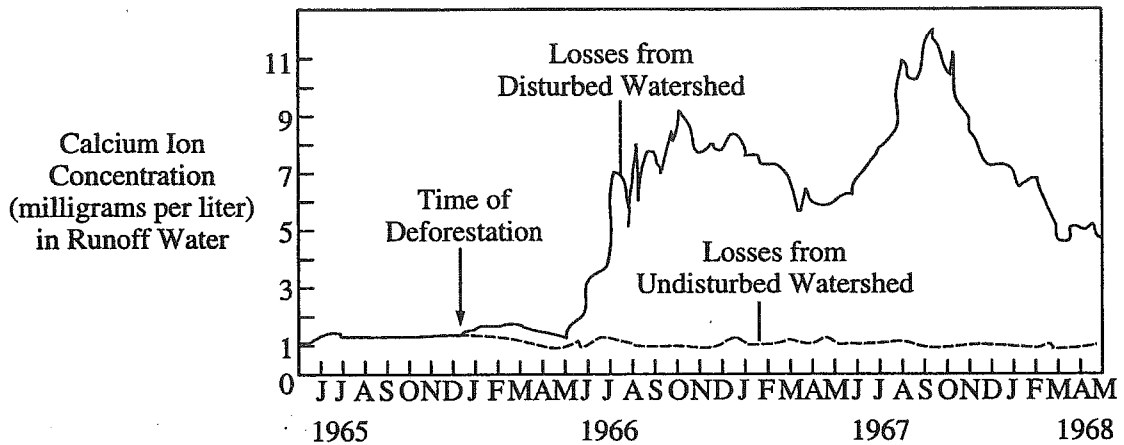
97. Based on graphs I and II, which of the following is the best conclusion that can be reached?
- Decreases in leaf water potential are caused by increased transpiration.
 - The increased rate of transpiration increases leaf water potential.
 - The flow of water through the stem has no effect on leaf water potential.
 - Leaf stomata are closed at 10 A.M.
 - Water is most likely to flow into the leaf at 4 A.M.
98. In this experiment, water flow up the stem could be measured in which of the following structures?
- Phloem
 - Xylem
 - Lenticels
 - Stomata
 - Casparian strip
99. What can be deduced from graph I ?
- The rate of transpiration is constant throughout this 24-hour period.
 - There is no correlation between the rate of transpiration and the flow of water through the stem.
 - The maximal flow of water through the stem lags behind the maximal rate of transpiration.
 - The rate of transpiration never reaches zero.
 - At noon, the rate of transpiration exceeds the rate of water flow through a stem.
100. All of the following changes would be likely to decrease the rate of transpiration at 8 A.M. EXCEPT
- causing the stomata to close
 - increasing the humidity of the atmosphere
 - increasing the water potential of the atmosphere
 - increasing the water potential of the soil
 - placing the plant in total darkness

Section I

Questions 101-105

In an experiment on the effects of deforestation of a portion of a northern temperate deciduous forest, all the trees were removed from a small mountainside watershed area and herbicides were applied for three years to prevent regrowth. Measurements of the concentration of calcium (an important nutrient) in runoff water were taken both before and after the deforestation. Monthly measurements also were made in a similar watershed in another part of the same forest that had been left undisturbed. The findings are displayed in the graph below.

MONTHLY MEASUREMENTS OF CALCIUM CONCENTRATION
IN RUNOFF WATER



101. Which of the following factors affecting the hydrologic cycle would have the LEAST impact on calcium loss from the disturbed watershed?

- (A) Total precipitation
- (B) Surface runoff
- (C) Evaporation
- (D) Transpiration
- (E) Porosity of soil

102. Based on the graph, which of the following best describes why losses of calcium did not occur immediately in the deforested watershed?

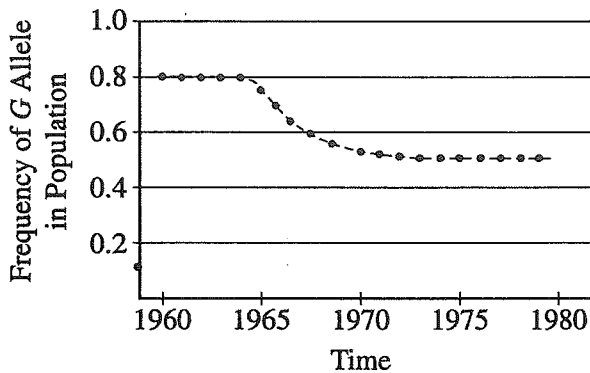
- (A) It takes months to leach calcium from the soil.
- (B) Other minerals were more soluble and were leached out first.
- (C) The deforestation occurred during the winter when runoff was low.
- (D) Calcium is hard to detect in small amounts.
- (E) Leaves do not appear on deciduous trees until the spring.

103. To estimate the total amount of calcium lost annually by each of the two watersheds, it would be most useful to measure which of the following variables?
- (A) Average daily temperature in each watershed
 - (B) Daily precipitation falling on each watershed
 - (C) Volume of water flowing out of each watershed each day
 - (D) Concentration of other ions in the soil of each watershed before and after deforestation
 - (E) Amount of calcium present in the precipitation falling on each watershed
104. What can be inferred from the data in the graph about the loss of calcium in the deforested watershed?
- (A) It occurs in no predictable pattern.
 - (B) It increases with time.
 - (C) It is at a peak when temperatures are highest.
 - (D) It appears to be correlated with the seasons.
 - (E) It increases after each application of herbicide.
105. Which of the following is best supported by the data?
- (A) Deforestation does not change the amount of water flowing through a watershed.
 - (B) The time of year during which deforestation occurs has no impact on the negative effects related to it.
 - (C) The loss of calcium affects several other variables in the forest ecosystem.
 - (D) Calcium loss can be rated as the most damaging aspect of mountainside deforestation.
 - (E) The presence or absence of plants greatly affects the loss of calcium from the soil.

Section I

Questions 106-110 refer to the following.

A moth's color is controlled by two alleles, G and g , at a single locus. G (gray) is dominant to g (white). A large population of moths was studied, and the frequency of the G allele in the population over time was documented, as shown in the figure below. In 1980 a random sample of 2,000 pupae was collected and moths were allowed to emerge.



106. During which of the following time periods could the population have been in Hardy-Weinberg equilibrium for the G locus?
- I. 1960-1964
 - II. 1965-1972
 - III. 1973-1980
- (A) I only
 (B) II only
 (C) III only
 (D) I and III only
 (E) I, II, and III

107. Assuming that the population was in Hardy-Weinberg equilibrium for the G locus, what percentage of moths in the natural population was white in 1962?

- (A) 2%
 (B) 4%
 (C) 8%
 (D) 20%
 (E) 64%

108. Assuming that the population was in Hardy-Weinberg equilibrium for the G locus, what percentage of the gray moths that emerged in 1980 was heterozygous?

- (A) 0%
 (B) 25%
 (C) 33%
 (D) 67%
 (E) 100%

109. Assuming that the population was in Hardy-Weinberg equilibrium for the G locus, what was the frequency of allele G in the gray moths that emerged in 1980?

- (A) 0.33
 (B) 0.50
 (C) 0.67
 (D) 0.75
 (E) 1.00

110. Which of the following is the most likely reason for the observed differences in the frequency of the G allele between 1965 and 1972?

- (A) Emigration of white moths from the population
 (B) Chance
 (C) Selection against gray phenotypes
 (D) Speciation
 (E) Mutation

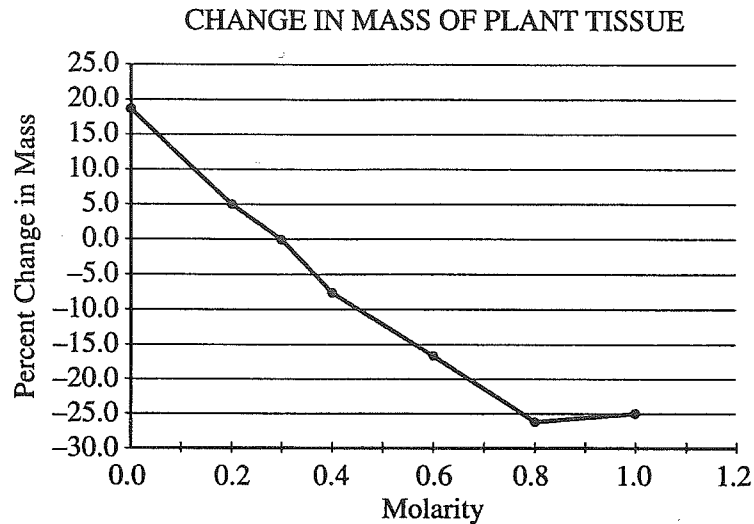
Questions 111-114

A student uses restriction enzymes to cut a DNA molecule into fragments. The digested DNA is loaded into the wells of an agarose gel and the gel is subjected to an electric current. Upon completion of the run, the gel is stained.

111. The rate of migration of the DNA fragments through the agarose gel is determined by the
- (A) ratio of adenine to cytosine in the fragment
 - (B) presence of hydrogen bonds between base pairs
 - (C) length of time the electrophoresis unit is allowed to operate
 - (D) number of nucleotides in the fragment
 - (E) volume of the starting sample
112. Which of the following is true of the dye used to stain the fragments?
- (A) It increases the contrast between the agar and the DNA fragments.
 - (B) It must be accounted for when calculating the molecular weight of the fragments.
 - (C) Its charged areas interfere with the migration of the DNA.
 - (D) It is bonded only to the sticky ends of the fragments and can directly determine the sequence of the DNA fragments.
 - (E) It gives a three-dimensional view of the structure of the DNA fragments.
113. The type and density of the gel are important because
- (A) they influence the rate of migration of the fragments
 - (B) they may cause some DNA molecules to replicate
 - (C) some DNA nucleotides may be lost due to chemical reactions with the gel
 - (D) some DNA molecules may sink to the bottom and not migrate
 - (E) some DNA molecules may cross-link
114. The procedures described can be used to do all of the following EXCEPT
- (A) isolate and purify certain DNA fragments
 - (B) synthesize novel DNA molecules
 - (C) study the activity of restriction enzymes
 - (D) calculate the size of DNA fragments
 - (E) identify the source of DNA material

Section I

Questions 115-117 refer to the graph below, which illustrates the percent change in the mass of pieces of plant tissue placed in solutions of different sucrose molarities.



115. Which of the following occurs in the tissue that is placed in 0.6 *M* sucrose?
- (A) The cells become turgid.
 - (B) The cells burst.
 - (C) The volume of the vacuoles decreases.
 - (D) The volume of the cytoplasm increases.
 - (E) The cells remain the same as before.
116. The approximate molarity of the solution in which the mass of the plant pieces would not change is
- (A) 0.0 *M*
 - (B) 0.1 *M*
 - (C) 0.3 *M*
 - (D) 0.5 *M*
 - (E) 0.7 *M*
117. Water enters and leaves the plant cells primarily by
- (A) endocytosis
 - (B) phagocytosis
 - (C) osmosis
 - (D) active transport
 - (E) facilitated diffusion

Questions 118-120

A culture of white-eyed fruit flies (*Drosophila melanogaster*) was maintained for many generations. Females from the stock white-eyed culture were crossed with red-eyed (wild-type) males. The F_1 females were crossed with the white-eyed males from the original culture. The resulting phenotypes of the progeny are summarized below.

Parental Generation CrossWhite-eyed females \times red-eyed males F_1 Generation (at least 500 flies)100% of females are red-eyed
100% of males are white-eyed F_1 Generation Cross F_1 red-eyed females \times white-eyed males F_2 Generation (at least 500 flies)50% of females are red-eyed and 50% are white-eyed
50% of males are red-eyed and 50% are white-eyed

118. The best explanation for the red-eyed F_1 females is

- (A) mutation
- (B) culture contamination
- (C) dominance
- (D) multiple loci
- (E) sex-influenced traits

120. Which of the following best describes the mode of inheritance of eye color in the white culture?

- (A) Autosomal
- (B) Dominant
- (C) Located on the *Y* chromosome
- (D) Sex-linked
- (E) Lethal

119. There are white-eyed females in the F_2 generation because

- (A) white is a dominant allele
- (B) the white allele is autosomal
- (C) a mutation has occurred
- (D) these F_2 females have two white alleles
- (E) the white allele is located on the *Y* chromosome

END OF SECTION I

BIOLOGY
SECTION II

Time—1 hour and 30 minutes

Number of questions—4

Percent of total grade—40

Suggested writing time per question—approximately 22 minutes.

Because each question will be weighted equally, you are advised to divide your time equally among them without spending too much time on any one question. You are expected to answer all four questions in this section. The parts within a question may not have equal weights. Suggested times will not be announced; you may proceed freely from one question to the next.

Each answer should be organized, well-balanced, and as comprehensive as time permits. Answers must be in organized, well-written prose form; outline form is NOT acceptable. Do not spend time restating the questions. If a specific number of examples are called for, no credit will be given for additional examples. For instance, if a question calls for two examples, you will receive credit only for the first two examples you provide. Diagrams may be used to supplement discussion, but in no case will a diagram alone suffice.

You are to write your answers in this book only, preferably in black or dark blue ink. Be sure to write CLEARLY and LEGIBLY. If you make an error, you may save time by crossing it out rather than trying to erase it.

The questions for Section II are printed in the pink booklet and in the green insert. Use the green insert to organize your answers and for scratchwork, but write your answers in the pink booklet.

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO.

Section II**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.

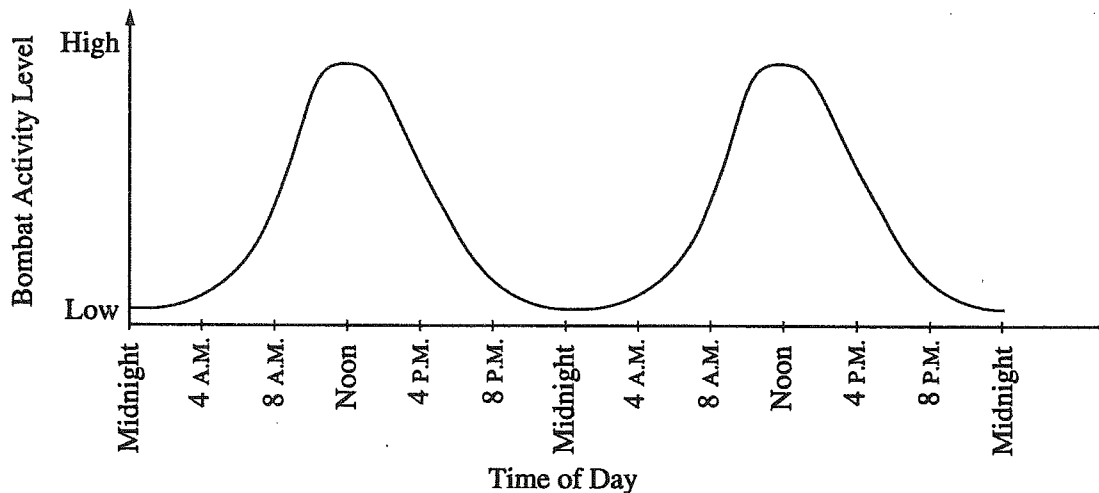
1. The human genome illustrates both continuity and change.

(a) **Describe** the essential features of two of the procedures/techniques below. For each of the procedures/techniques you describe, **explain** how its application contributes to understanding genetics.

- The use of a bacterial plasmid to clone and sequence a human gene
- Polymerase chain reaction (PCR)
- Restriction fragment length polymorphism (RFLP) analysis

(b) All humans are nearly identical genetically in coding sequences and have many proteins that are identical in structure and function. Nevertheless, each human has a unique DNA fingerprint. **Explain** this apparent contradiction.

2. The activities of organisms change at regular time intervals. These changes are called biological rhythms. The graph depicts the activity cycle over a 48-hour period for a fictional group of mammals called pointy-eared bombats, found on an isolated island in the temperate zone.



(a) **Describe** the cycle of activity for the bombats. **Discuss** how **three** of the following factors might affect the physiology and/or behavior of the bombats to result in this pattern of activity.

- temperature
- food availability
- presence of predators
- social behavior

(b) **Propose** a hypothesis regarding the effect of light on the cycle of activity in bombats. **Describe** a controlled experiment that could be performed to test this hypothesis, and the results you would expect.

3. The complexity of structure and function varies widely across the animal kingdom. Despite this variation, animals exhibit common processes. These include the following.
- transport of materials
 - response to stimuli
 - gas exchange
 - locomotion
- (a) Choose two of the processes above and for each, describe the relevant structures and how they function to accomplish the process in the following phyla.
- Cnidaria (e.g., hydra, jellyfish)
Annelida (e.g., earthworm)
Chordata (e.g., mouse)
- (b) Explain the adaptive (evolutionary) value(s) of the structural examples you described in part a.
4. The following experiment was designed to test whether different concentration gradients affect the rate of diffusion. In this experiment, four solutions (0% NaCl, 1% NaCl, 5% NaCl, and 10% NaCl) were tested under identical conditions. Fifteen milliliters (mL) of 0% NaCl were put into a bag formed of dialysis tubing that is permeable to Na^+ , Cl^- , and water. The same was done for each NaCl solution. Each bag was submerged in a separate beaker containing 300 mL of distilled water. The concentration of NaCl in mg/L in the water outside each bag was measured at 40-second intervals. The results from the 5% bag are shown in the table below.

CONCENTRATION IN mg/L OF NaCl OUTSIDE THE 5% NaCl BAG

Time (seconds)	NaCl (mg/L)
0	0
40	130
80	220
120	320
160	400

- (a) On the axes provided, graph the data for the 5% NaCl solution.
- (b) Using the same set of axes, draw and label three additional lines representing the results that you would predict for the 0% NaCl, 1% NaCl, and 10% NaCl solutions. Explain your predictions.
- (c) Farmlands located near coastal regions are being threatened by encroaching seawater seeping into the soil. In terms of water movement into or out of plant cells, explain why seawater could decrease crop production. Include a discussion of water potential in your answer.

END OF EXAMINATION

Chapter III Answers to the 2002 AP Biology Examination

- Section I: Multiple Choice
 - Section I Answer Key and Percent Answering Correctly
 - Analyzing Your Students' Performance on the 2002 AP Biology Exam
 - Diagnostic Guide for the 2002 AP Biology Exam
- Section II: Free Response
 - Comments from the Chief Reader
- Scoring Guidelines, Sample Student Responses, and Commentary
 - Question 1
 - Question 2
 - Question 3
 - Question 4

Section I: Multiple Choice

Listed below are the correct answers to the multiple-choice questions, the percent of AP students who answered each question correctly by AP grade, and the total percent answering correctly.

Section I Answer Key and Percent Answering Correctly

Item No.	Correct Answer	Percent Correct by Grade					Total Percent Correct
		5	4	3	2	1	
1	C	98	95	91	84	71	89
2	B	91	86	80	69	49	77
3	D	98	96	91	82	65	88
4	D	90	83	76	64	45	73
5	C	87	69	50	31	13	52
6	C	48	38	33	25	19	33
7	B	97	96	94	90	76	92
8	E	93	84	73	55	31	70
9	B	99	94	83	63	37	78
10	B	91	78	64	48	30	64
11	D	89	77	66	55	39	67
12	B	88	79	70	57	39	68
13	B	92	86	81	72	52	79
14	D	91	84	79	72	60	78
15	B	81	75	71	64	52	70
16	C	99	96	90	76	46	84
17	A	76	60	48	39	33	52
18	E	96	88	78	60	28	73
19	C	87	74	64	51	37	64
20	B	71	72	71	66	48	68
21	E	83	69	60	51	39	61
22	B	75	59	47	35	21	49
23	B	96	91	83	69	43	79
24	A	75	57	44	34	25	48
25	D	78	69	69	69	62	70
26	C	80	68	59	48	36	59
27	D	77	63	50	39	25	52
28	D	73	52	35	20	11	39
29	E	92	84	75	63	38	73
30	A	70	50	39	29	19	42
31	A	93	85	75	60	39	73
32	A	77	60	44	28	16	46
33	B	66	58	51	42	33	51
34	C	78	60	49	40	30	52
35	C	79	55	37	21	14	42
36	C	92	76	56	32	16	57
37	A	95	82	64	40	20	63
38	B	63	46	36	25	15	38
39	E	76	57	41	27	16	44
40	B	95	88	80	65	35	76
41	E	83	70	53	34	21	54
42	C	95	90	84	75	56	82
43	D	58	41	29	20	15	33
44	B	91	76	58	41	27	60
45	C	87	70	53	39	29	57
46	C	55	34	23	15	13	28
47	D	87	70	53	37	21	55
48	D	63	46	35	25	19	38
49	D	91	78	62	44	28	62
50	B	57	28	13	8	11	23
51	E	63	51	42	34	26	44
52	C	66	43	29	19	16	35
53	C	75	57	44	30	21	47
54	B	88	72	54	35	20	56
55	D	70	51	41	31	20	44
56	B	56	33	19	11	14	26
57	E	46	29	19	12	6	23
58	C	48	27	17	12	11	23
59	B	58	32	19	13	13	27
60	B	75	58	46	32	20	47
61*	—	—	—	—	—	—	—
62	C	94	85	75	63	44	74
63	A	91	81	68	54	34	68
64	E	96	86	71	54	33	70
65	B	89	74	58	43	28	60
66	D	98	97	95	91	71	92
67	B	96	90	81	66	42	78
68	D	96	94	91	86	63	88
69	C	92	81	70	53	31	68
70	A	99	97	92	82	56	88
71	B	99	94	86	71	46	82
72	D	99	98	95	85	55	89
73	C	99	98	93	83	58	89
74	D	79	62	49	35	21	50
75	E	86	69	53	38	23	56
76	A	73	56	43	31	20	46
77	C	96	90	81	67	41	78
78	A	65	40	25	15	10	31
79	B	64	44	34	27	22	38
80	C	73	53	39	30	23	44

*Although 120 multiple-choice items were administered in Section I, item 61 was not used in scoring.

(answer key continues on page 44)

Item No.	Correct Answer	Percent Correct by Grade					Total Percent Correct
		5	4	3	2	1	
81	E	92	78	61	45	30	63
82	B	90	70	50	36	27	55
83	A	94	79	63	45	28	64
84	C	98	91	80	63	38	77
85	D	96	92	89	84	65	87
86	B	84	60	39	21	13	44
87	A	72	58	47	36	23	48
88	C	71	53	39	27	19	43
89	C	48	32	24	18	18	28
90	A	85	73	59	41	22	58
91	B	95	88	76	56	28	72
92	C	98	91	80	62	36	76
93	B	89	78	65	48	23	63
94	B	97	87	69	45	26	67
95	C	76	59	42	24	15	44
96	E	96	92	88	79	52	84
97	A	88	82	75	62	35	71
98	B	95	87	77	59	32	73
99	C	98	92	86	70	40	80
100	D	54	38	30	22	15	32

Item No.	Correct Answer	Percent Correct by Grade					Total Percent Correct
		5	4	3	2	1	
101	D	69	51	36	24	14	40
102	C	58	49	42	32	22	41
103	C	52	38	30	21	16	32
104	D	85	73	60	43	23	59
105	E	95	85	70	47	20	66
106	D	86	74	66	59	39	67
107	B	64	32	15	8	8	25
108	D	56	32	21	17	16	28
109	B C	66	67	64	59	44	62
110	C	87	75	60	40	20	59
111	D	89	69	50	32	17	53
112	A	90	75	58	39	19	58
113	A	91	80	67	48	24	64
114	B	65	49	36	25	17	39
115	C	89	74	60	47	39	63
116	C	87	71	56	38	20	56
117	C	97	91	79	62	43	77
118	C	46	31	26	27	29	31
119	D	85	62	44	28	17	48
120	D	81	62	47	38	29	52

Analyzing Your Students' Performance on the Multiple-Choice Section

If you give your students the 2002 exam for practice, you may want to analyze their results to find overall strengths and weaknesses in their understanding of AP Biology. The following diagnostic worksheet will help you do this; feel free to photocopy and distribute it to your students for completion.

1. In each section, students should insert a check mark for each correct answer.
2. Add together the total number of correct answers for each section.
3. Compare the student's number of correct answers for each section with the average number correct for that section.

In addition, under each item, the percent of AP students who answered correctly is shown, so students can analyze their performance on individual items.

This information will be helpful in deciding how students should plan their study time. Please note that one item may appear in several different categories, as questions can cross over different topics.

Section II: Free Response

Comments from the Chief Reader

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The 2002 AP Biology Exam's free-response questions were complicated, with multiple parts requiring recall of biological details as well as higher-level thinking by students who scored well. Question 1 required students to explain an apparent contradiction with which they may never have grappled. This in turn called for comparison of two ideas that students may have learned separately. Question 2 required students to design an actual controlled experiment to evaluate the effect of one variable on the observed cycle of bombat activity. Question 3 asked students to describe what structures relate to the function of specific biological processes that occur throughout three phyla of the animal kingdom. Question 4 required students to analyze data from an experiment, make predictions based upon these data, and to apply the concepts of molecular movement.

Scoring Guidelines, Sample Student Responses, and Commentary

The answers presented on the following pages are actual student responses to the free-response questions on the 2002 AP Biology Exam. The students gave permission to have their work reproduced at the time they took the exam. These responses were read and scored by the table leaders and readers assigned to each particular question and were used as sample responses for the training of readers during the AP Reading in June 2002. The actual scores that these students received, as well as a brief explanation of why, are indicated.

Question 1—Overview

In Part (a), students were asked about three procedures/techniques frequently used in molecular genetics and about the contributions of each of these to the understanding of the science of genetics. This allowed students to demonstrate recall of the essential steps in the procedures, as well as applications or contributions of the technology to the science. Many students have done one of the procedures in the school laboratory—cloning of a segment of DNA in a bacterial plasmid. Many students have also had some experience in making restriction fragments and separating them via electrophoresis. Fewer of them have had firsthand experience with PCR. However, the level of detail about each process expected by the question was fairly minimal. The explanation section for each was essentially a science, technology, and society theme question, which asked students to reflect on the practical and theoretical values of these technologies.

In Part (b), students were confronted with the apparent contradiction between the similarities in the coding sequences of human DNA and the uniqueness of a DNA fingerprint. A certain amount of higher-order thinking was required in order to recognize the origin of the differences, the reasons for the similarities, and/or the means by which the similarities and differences might be elucidated.

Scoring Guideline for Question 1

Part (a) (i)—Maximum of four points: one point for each bullet up to the maximum indicated.

Describe the use of plasmid for cloning/sequencing a human gene. (Maximum of three points)

- Cut plasmid with “restriction” enzyme
- Cut/isolate human sequence with the corresponding “restriction” enzyme
- Mix/anneal/ligate
- Introduce recombinant plasmid into bacteria
- Select recombinant bacteria (e.g., antibiotic resistance, fluorescence, reporter gene, etc.)
- Bacterial reproduction used to amplify the sequence
- Describe either degradative (Maxam-Gilbert) or dideoxy (Sanger) method to generate fragments
- Electrophoresis to separate fragments
- Read the sequence (automated method is O.K.)

Explain the contribution of this procedure. (Maximum of three points)

- Source of the DNA is immaterial to cloning
- Used to produce transgenic organisms
- Used to make human proteins (e.g., insulin, HGH)
- Understanding gene structure/regulation
- Comparative genomics
- Development of gene therapies
- Making gene library
- Amplifying a particular sequence

Part (a) (ii)—Maximum of four points.

Describe polymerase chain reaction (PCR). (Maximum of three points)

- Heat to separate strands
- Add primers
- Cool to anneal
- Add polymerase and/or nucleotides
- Specification of heat stable (Taq) polymerase
- Description of thermocycling process
- Repetition of process

Explain the contribution of this procedure. (Maximum of three points)

- Allows amplification of very small samples
- Replicates/amplifies a defined region
- Can be automated to allow for faster expansion of knowledge
- Can be used for forensics
- Can be used for diagnosis
- Evolutionary applications
- Other

Part (a) (iii)—Maximum of four points.

Describe restriction fragment length polymorphism (RFLP) analysis. (Maximum of three points)

- DNA sample cut with “restriction” enzyme(s)
- Separation of fragments (electrophoresis)
- Description/elaboration of electrophoresis (charge/size/apparatus)
- Visualize fragments (probes, dyes, blots)
- Compare fragment sizes/mobility
- Compare single and double digests (two or more restriction enzymes)
- Compare individuals/species/organisms/tissue samples

Explain the contribution of RFLP analysis. (Maximum of three points)

- Trace RFLPs as genetic markers in families
- Diagnose disease/carriers/prenatal samples
- Prepare fingerprints (for forensics, etc.)
- Order fragments for physical mapping
- Compare genomes of different species/evolutionary relationships
- Locate the flanking regions of the gene/sequence
- Find mutations
- Individual bands can be used for further analysis
- Can determine presence of sequence without knowing its function

Part (b)

Explain the contradiction. (Maximum of four points)

Sources of difference in DNA fingerprint.

- Variation in noncoding material (introns, spacers, minisatellites, “junk,” transposable elements)
- Point mutations, small deletions, SNPs (single NT polymorphisms)
- Variable number of tandem repeats (VNTRs/STRs)

Recognition of differences.

- A small percent difference of a very large genome results in a large number of nucleotide differences
- PCR-based fingerprinting: differences found by where primers anneal
- Variation in restriction enzyme cutting sites

Similarities among proteins.

- Redundancy in the code for amino acids
- Neutral/silent mutation does not alter the function of the protein

CAUTION

- No explanation points earned in Part (a) without an attempted description of procedure.
- Order of procedure points is not important if they are logical and accurate.
- No credit for mutations leading to new phenotypes.
- Codons specify amino acids (not proteins).

Question 2—Overview

The intent of this question was two-fold: first, it required students to think about the observed behavior of an organism in a creative way, and second, it tested students' experimental design skills. The choice of a fictional

mammal, bombats, rather than a particular kind of animal that might be more familiar to some students on a regional basis, allowed all students to enjoy a level playing field.

Scoring Guideline for Question 2

Part (a)—Maximum of five points.

Description of the cycle of activity (one point)

Students could earn a point if they accurately summarized the graph. A simplistic statement like, "Bombats are active during the day and quiet at night," which ignored the shape and obvious peaks and valleys of the graph, did not receive the point. To earn this point, students had to identify the peak of activity at "noon," "midday," or "12 p.m.," and indicate a lower activity at "night." Students could also be specific about the lowest activity being at "midnight," or "12 a.m." The description had to be clearly distinguishable from the rest of the answer and not simply implied in another part of the response.

Discussion of how three factors might affect the physiology and/or behavior resulting in the cyclic activity pattern (one point each)

To earn points here, each of the descriptions had to 1) be biologically plausible and consistent with typical mammalian behavior and physiology (no fictional biology) and 2) indicate a cause-and-effect relationship beyond a simple restatement of the question. This had to include at least a very brief indication of how or why the factor had any effect at all on the bombat, or in some cases its prey. Finally, the discussion could not be inconsistent with the part of the curve described or the time of day referenced in the explanation.

Elaboration on any one of the three factors (one point)

Here the readers were looking for exemplary descriptions of physiology and/or behavior that reflected an unusual depth of understanding and clarity of expression. With special regard to temperature, a student who demonstrated an understanding that the activity curve was different from a temperature curve or that mammal physiology, unlike that of ectotherms, is typically insensitive to temperature could earn an elaboration point.

Part (b)—Maximum of seven points.

Hypothesis (one point)

Students were required to indicate that a change in the light (intensity, duration, wavelength) causes a change in the cycle of activity or biorhythm. There also could be a prediction of a change of light having no effect on the cycle of activity. Like the description of the curve above, the hypothesis statement had to be clearly distinguishable from the rest of the answer and not simply implied in another part of the response. Students may have failed to earn this point if the experiment they designed clearly used a different light characteristic (independent variable) and/or produced a different result (dependent variable) from the ones indicated in their hypothesis.

Experimental Design (Maximum of five points.)

If the experimental design used a factor other than light for the independent variable, and it satisfied at least three of the following standards, the answer was still allowed to earn one point total for this and the "Description of Results" section combined.

- Specified an appropriate control group for comparison. In this control, the environmental conditions had to be very similar to the natural conditions in which the bombard population is found. Students could not simply place them into the dark, etc. **(one point)**
- Indicated that the independent variable (light) was manipulated. This was usually a change in light intensity or photoperiod. **(one point)**
- Held confounding variables constant or indicated that all variables other than the independent variable are held constant. To earn the point for listing the variables being held constant, the student had to list at least two. **(one point)**
- Verified results with reasonable sample size (at least two bombats in each group) and/or repeated trials. With repeated trials, the point was not awarded if the same bombat was used over and over. **(one point)**
- "Measured," "recorded," and so on (using quantitative terminology) bombard activity levels (dependent variable). If the student used the verb "observe," then some measurement activity had to be specified. **(one point)**
- Included a mathematical and/or statistical comparison of control and experimental groups, or of observed and expected results. A specific kind of inferential statistic (e.g., chi square, t-test, etc.) did not need to be mentioned. A comparison of slopes of curves on a graph was also acceptable. **(one point)**

Description of Results (one point)

Students who earned *at least three points* in the "Experimental Design" section became eligible for one point earned for a graph, data table, and/or description of results *consistent* with the experimental design.

Question 3—Overview

This question asked students to describe what structures relate to the function of specific biological processes that occur throughout three phyla of the animal kingdom. The student could choose two out of the four biological processes given and describe the structures that allow the processes to occur. The function had to

be given for the structures. One point for the description of the structure was awarded only after a link between structure and function had been made. The adaptive values of the structures given for each phylum needed to be explained.

Scoring Guideline for Question 3

Points can be awarded for three categories: Structure/Function, Description, and Adaptive Value.

One point awarded for correct structure *linked* to its function. Maximum is six points, with only one point given per phylum per process.

One point awarded for elaborate description of the structure if the related structure/function is correct and appropriate. This cannot be a single word. Maximum is three points.

One point awarded for adaptive value *linked* to structure. This value should clearly establish a selective advantage. Maximum is three points. One point maximum may be awarded for natural selection being used throughout all phyla, but it must still be coupled to a correct structure.


	Process I	Process II	Elaborate Description (I or II) (3 points maximum)	Adaptive Value (3 points maximum)
Cnidaria	1 point Structure + Function	1 point Structure + Function	1 point (only with	1 point (only when
Annelida	1 point Structure + Function	1 point Structure + Function	1 point proper	1 point linked with
Chordata	1 point Structure + Function	1 point Structure + Function	1 point Structure + Function link)	1 point proper structure)

Note: An asterisk (*) in the charts that follow indicates an answer that can be connected to any structure(s) option.

Transport of Materials

Must be a mover of nutrients, oxygen, wastes, hormones, gametes, and chemicals.

Cnidarians

Structure	Function	Description	Adaptive Value (tied to structure)
Molecular level Amebocytes/ gastrodermal cell	Undergoes phagocytosis	Mobile cells found in mesoglea	Nutrient transport to body surface
GVC 	Circulates water and nutrients	Fluid-filled/extends into tentacle/hollow cavity/ digestive sac with one opening	*Importance of material transport
Circulatory canal	Connects all branches of canals, circulates gametes		*Maintains optimal concentration gradients, permits for large body size and complexity
Cilia	Keeps fluids moving	Tiny hairs	

Annelids

Molecular level Membranes— nephridia, typhlosole, capillary	Method of transport needs to be specific (diffusion/facilitated/active)	Semipermeable, transport proteins, elaborate descrip- tion of structure	*Importance of material transport
System level (mover must be named) Circulatory Digestive Reproductive Respiratory (<i>not to include same examples as in gas exchange</i>)	Tissue or organ must have function related to material being transported (<i>Example: Aortic arch/ pseudoheart, muscular activity, muscular contractions</i>)	Tissue or organ must be described to show how structure relates to function (<i>Example: Dorsal, ventral, segmental conducting tubes, muscular, five pairs</i>)	*Maintains optimal concentration gradients, permits for larger body size and complexity

Chordates

<p>Molecular level</p> <p>Membranes— nephron, villi, capillary</p>	<p>Method of transport needs to be specific (diffusion/facilitated/active)</p>	<p>Semipermeable, transport proteins, elaborate description of structure</p>	<p>*Importance of material transport</p>
<p>System level</p> <p>(mover must be named)</p> <p>Circulatory Digestive Reproductive Respiratory (not to include same examples as in gas exchange)</p> <p>Lymphatic Excretory</p>	<p>Tissue or organ must have function related to material being transported (<i>Example:</i> Pumping heart, peristalsis by muscular activity, diaphragm contract- ing, frog gular movement, uterine contractions, muscular contraction)</p>	<p>Tissue or organ must be described to demonstrate how structure relates to function</p>	<p>*Maintains optimal concentration gradients, permits for larger body size and complexity</p>

Response to Stimuli

(Detection, transmission, and/or effector—two of these must be present)

Cnidarians

Structure	Function	Description	Adaptive Value
Receptor	Detects stimulus and transmits	Must demonstrate how structure relates to function	Radial symmetry allows for multidirectional response/coordinated response
Nerve net/ring	Detects stimulus and transmits or Transmits + Responds		
Contractile fiber/cell	Tentacle movement/ body contraction		
Nematocyte/ Cnidocyte/ Cnidoblast Nematocyst/ Stinging cell/ Stinging tentacles	{ Stings prey/toxic or poisonous, defense		
			*Prey capture and defense

Annelids

Sensory receptor	Detects stimulus and transmits	Photo, tactile, chemo	*More complex behavior
Special segments	Integration/transmission	Cephalized, anterior, or paired bundles of nerves	*Directed response
Ganglia/brain	Integration/transmission	Rudimentary/primitive	Complex locomotion
Nerve cord	Segmental control	Ventral or paired bundles of nerves/segmented nerves	
Effector organ/structure (gland, muscle, setae, reproductive)	Contraction/movement/secretion	Proper description	

Chordates

Sensory receptor	Detects stimulus and transmits	Photo, chemo, auditory, equilibrium, touch, tactile, olfactory	*Improved homeostasis
Spinal/nerve cord	Integration/transmission	Dorsal/hollow	*More complex behavior
Brain	Integration/transmission	Specialized regions/complex	*Directed response
Effectors	Contraction, movement, secretion	Proper description	

Gas Exchange

(Diffusion of oxygen and carbon dioxide)

Cnidarians

Structure	Function	Description	Adaptive Value
Body wall/outer epithelium/epidermis or gastrovascular cavity (GVC)	$\left\{ \begin{array}{l} \text{Diffusion of O}_2 \text{ and} \\ \text{CO}_2/\text{moving} \\ \text{toward } [\downarrow] \end{array} \right.$	<p>Two layers thick</p> <p>Fluid-filled, continuous with outside water</p>	<p>*Increased surface area</p> <p>*Increased rate of exchange</p>

Annelids

Skin/ integument/ epidermis/ epithelium	Diffusion of O ₂ and CO ₂ /moving toward [↓]	Moist, thin, vascularized (<i>must have two</i>)	*Increased surface area
Parapodia	Diffusion of O ₂ and CO ₂ /moving toward [↓]	Must demonstrate understanding of how structure relates to function	*Increased oxygen/ carbon dioxide exchange efficiency/ rate of exchange
Gills	Diffusion of O ₂ and CO ₂ /moving toward [↓]	Must demonstrate understanding of how structure relates to function	
Hemoglobin/ other respiratory pigment	Carries oxygen/ carbon dioxide	Respiratory pigment/ transport protein	

Chordates

Gills/lamellae	Diffusion of O ₂ and CO ₂ / moving toward [↓] Countercurrent exchange	Must demonstrate understanding of how structure relates to function (<i>Example: Sheet-like, flat, vascularized</i>)	*Increased surface area
Modified swim bladder	Diffusion of O ₂ and CO ₂ / moving toward [↓]	(<i>Example: Sac pouch connected to pharynx</i>)	*Internalization to avoid dehydration/ damage
Skin (amphibian)	Diffusion of O ₂ and CO ₂ / moving toward [↓]	(<i>Example: Moist and vascularized</i>)	*Increased oxygen/ carbon dioxide exchange efficiency/ rate of exchange
Lung/alveoli	Diffusion of O ₂ and CO ₂ / moving toward [↓]	(<i>Example: Compartmentalized lung/ vascularized alveoli/alveolar sacs/membranous sac</i>)	
Avian supplemental air sacs	Diffusion/moving toward [↓]		
Hemoglobin/RBC	Carries oxygen/carbon dioxide	Respiratory pigment/transport protein	

Locomotion

(Moves organism from point A to point B)

Cnidarians

Structure	Function	Description	Adaptive Value
Hydrostatic skeleton with contractile fibers (muscles)	Contractile fibers/ muscle acting on hydrostatic skeleton to move organism	Concept of hydrostatic	*Expands food-gathering options, avoidance, promotes gene flow
GVC	Contractile fibers/ muscle acting on hydrostatic skeleton to move organism	Fluid-filled cavity	
Contractile fibers/ muscle	Tumbling, somersaulting, looping, floating (with explanation)		
Cilia on larvae (planulae)	Swimming	Tiny hair-like	Dispersion

Annelids

Hydrostatic skeleton/coelom with muscles <i>or</i> muscles acting on fluid-filled cavity	Contractions allow for shortening/lengthening of body Directed movement	Concept of hydrostatic Longitudinal, circular, segmental	*Oriented response *Food gathering, improved mobility
Skin	Mucous aids in movement	Mucous used as a lubricant	
Suckers	Anchoring		
Setae, parapodia, lateral flaps	Pushing, burrowing, anchoring, acting against resistance	Bristles, flap-like, paddle-like	Dispersion, predator avoidance
Cilia on larva (trochophore)	Swimming	Tiny hair-like	

Chordates

Skeleton and muscles	Movement associated with muscle contraction	Muscles attached to bone/endoskeleton, cartilage	*Efficient, predator/prey interaction, food gathering *Promotes gene flow, sexual selection, habitat selection
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Question 4—Overview

The purpose of this question was to determine students' ability to analyze data from a NaCl diffusion experiment, make predictions based upon these data, and apply the concepts of molecular movement. Students were first asked to graph a set of five data points. This required them to identify the independent and dependent variables and place each on the correct axis. To successfully complete the graph, students also had to label the axes with the name of the variable and provide the units of measurement; correct scaling of the units was also necessary. To complete Part (a) students then had to plot the data. The objective of this part of the question was to assess students' ability to correctly represent data in graphical form.

The second part of the question asked students to make predictions based upon analysis of the data presented in Part (a). Students were required to add three additional lines to the graph. They were expected to recognize the relationship between solute concentration and rate of diffusion and to be able to express this relation-

ship in a graphical format. They were then asked to explain their predictions; this required students to be able to justify the expected outcomes in a written format. Students also needed to understand that if no solute was present, diffusion could not occur.

To earn points in the third part of the question, students needed to exhibit an understanding of osmosis and water potential and be able to apply this to a real-life environmental problem. Students had to demonstrate an understanding of the effect that increased soil salinity would have on water movement in plant cells and the effect that this would have on crop production. This section of the question required students to understand that seawater in the soil would increase the concentration of solutes in the soil, so that the cells would now have a higher water potential than the soil. As a result of this higher water potential, the plants would lose water due to osmosis. Students then had to connect this water loss to specific effects on cells and on crop production.

Scoring Guideline for Question 4

Part (a)—Maximum of three points.

- Correct orientation with dependent variable (concentration) on y- (vertical) axis and independent variable (time) on x- (horizontal) axis. **(one point)**
- Correct axes labels with units and scaling for 5% line on axes provided. **(one point)**
- Correct plotting of all data points, including zero (0,0); line is not necessary but if drawn must not extend beyond last data point; dashing line beyond last data point is O.K.; arrow at end of line is O.K. **(one point)**

Part (b)—Maximum of four points.

- Correct prediction and legend (or label) for 0%, 1%, and 10% lines (0% line flat, 1% line below 5% line, 10% line above 5% line). **(one point)**

Explanation points

- Correct explanation for 0% line (e.g., "Since there is no NaCl in the bag no Na^+Cl^- can diffuse into the water in the beaker"). **(one point)**
- Correct explanation for 1% line (must include a discussion of rate); connects concentration of NaCl with diffusion rate. **(one point)**
- Correct explanation for 10% line (must include a discussion of rate); connects concentration of NaCl with diffusion rate **(one point)**

OR

- General explanation that solute concentration affects the rate of diffusion; answers that attempt to explain the 0%, 1%, or 10% NaCl lines are not eligible to receive this point. **(one point)**

Part (c)—Maximum of four points.

- Statement that water will leave the plant and description of the effect this has on plant cell (e.g., loss of turgor, plasmolysis, decrease in cell volume, decrease in central vacuole volume). **(one point)**
- Concept of osmosis (e.g., movement of water across a selectively permeable membrane [cell or cell membrane] from solution with lower solute concentration [hypotonic] to solution with higher solute concentration [hypertonic]). **(one point)**
- Explanation that water moves from solution with higher (more positive/less negative) water potential (ψ) to solution with lower (more negative) water potential (ψ). **(one point)**
- Explanation of how water loss can cause decreased crop production (e.g., stomates close, transpiration stops, photosynthesis stops, decreased metabolism). **(one point)**

Table 4.2 — AP Biology Scoring Worksheet

Section I: Multiple Choice

$$\left[\frac{\text{Number correct (out of 119)}}{\text{Number correct (out of 119)}} - \left(\frac{1}{4} \times \frac{\text{Number wrong}}{\text{Number wrong}} \right) \right] \times 0.7563 = \text{Weighted Section I Score}$$

(If less than zero, enter zero.)
(Do not round)

*Handwritten: (119 - 1/4 * 5.5) * 0.7563 =*

Section II: Free Response

Question 1 $\frac{\text{Score}}{\text{(out of 10)}} \times 1.5000 = \text{Score} \text{ (Do not round)}$

Question 2 $\frac{\text{Score}}{\text{(out of 10)}} \times 1.5000 = \text{Score} \text{ (Do not round)}$

Question 3 $\frac{\text{Score}}{\text{(out of 10)}} \times 1.5000 = \text{Score} \text{ (Do not round)}$

Question 4 $\frac{\text{Score}}{\text{(out of 10)}} \times 1.5000 = \text{Score} \text{ (Do not round)}$

Sum = _____

Weighted Section II Score (Do not round)

**AP Grade Conversion Chart
Biology**

Composite Score Range*	AP Grade
91-150	5
70-90	4
58-69	3
45-57	2
0-44	1

*Students' scores are weighted according to formulas determined in advance each year by the Development Committee to yield raw composite scores; the Chief Reader is responsible for converting composite scores to the 5-point AP scale.

Composite Score

Weighted Section I Score + Weighted Section II Score = Composite Score (Round to nearest whole number)

Table 4.3 — Grade Distributions

Nearly 65 percent of the AP students who took this exam earned a qualifying grade of 3 or above.

	Examination Grade	Number of Students	Percent at Grade
Extremely well qualified	5	16,703	17.5
Well qualified	4	21,887	22.9
Qualified	3	23,083	24.2
Possibly qualified	2	22,157	23.2
No recommendation	1	11,688	12.2
Total Number of Students		95,518	
Mean Grade		3.10	
Standard Deviation		1.28	

7562

Table 4.4 — Section I Scores and AP Grades

For a given range of multiple-choice scores, this table shows the percentage of students receiving each AP grade. If you have calculated the multiple-choice score (**Weighted Section I Score**) by using the formula shown in Table 4.2, you can use this table to figure out the most likely grade that the student would receive based only on that multiple-choice score.

Multiple-Choice Score	AP Grade					Total
	1	2	3	4	5	
76 to 90	0.0%	0.0%	0.0%	0.3%	99.7%	3.9%
61 to 75	0.0%	0.0%	0.2%	32.9%	66.8%	18.9%
46 to 60	0.0%	0.5%	40.1%	56.1%	3.3%	28.9%
31 to 45	0.1%	51.1%	47.0%	1.8%	0.0%	26.6%
16 to 30	41.4%	58.3%	0.3%	0.0%	0.0%	16.2%
0 to 15	99.7%	0.3%	0.0%	0.0%	0.0%	5.5%
Total	12.2%	23.2%	24.2%	22.9%	17.5%	100.0%