GRE® Biology Test
Practice Book

This practice book contains
- one actual, full-length *GRE*® Biology Test
- test-taking strategies

Become familiar with
- test structure and content
- test instructions and answering procedures

Compare your practice test results with the performance of those who took the test at a GRE administration.

www.ets.org/gre

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Test takers with disabilities or health-related needs who need test preparation materials in an alternate format should contact the ETS Office of Disability Services at **stassd@ets.org**. For additional information, visit **www.ets.org/gre/disabilities**.

Overview

The *GRE*® Biology Test consists of approximately 190 five-choice questions, a number of which are grouped in sets toward the end of the test and are based on descriptions of laboratory and field situations, diagrams, or experimental results. Testing time is 2 hours and 50 minutes; there are no separately-timed sections.

This publication provides a comprehensive overview of the GRE Biology Test to help you get ready for test day. It is designed to help you:

- Understand what is being tested
- Gain familiarity with the question types
- Review test-taking strategies
- Understand scoring
- Practice taking the test

To learn more about the GRE Subject Tests, visit **www.ets.org/gre**.

Test Content

The content of the test is organized into three major areas: cellular and molecular biology, organismal biology, and ecology and evolutionary biology. In addition to the total score, a subscore in each of these subareas is reported.

The approximate distribution of questions by content category is shown below.

I. Cellular and Molecular Biology (33-34%)

Fundamentals of cellular biology, genetics, and molecular biology are addressed. Major topics in cellular structure and function include prokaryotic and eukaryotic cells, metabolic pathways and their regulation, membrane dynamics and cell surfaces, organelles, cytoskeleton, and cell cycle. Major areas in genetics and molecular biology include viruses, chromatin and chromosomal structure, genomic organization and maintenance, and the regulation of gene expression. The cellular basis of immunity and the mechanisms of antigen-antibody interactions are included. Attention is also given to experimental methodology.

A. Cellular Structure and Function (16-17%)

1. Biological compounds
2. Enzyme activity, receptor binding, and regulation
3. Major metabolic pathways and regulation
4. Membrane dynamics and cell surfaces
5. Organelles: structure, function, synthesis, and targeting
6. Cytoskeleton: motility and shape
7. Cell cycle: growth, division, and regulation (including signal transduction)
8. Methods (microscopy, separation, immunological)

B. Genetics and Molecular Biology (16-17%)

1. Genetic foundations
2. Chromatin and chromosomes
3. Genome sequence organization
4. Genome maintenance
5. Gene expression and regulation in prokaryotes and eukaryotes: mechanisms
6. Gene expression and regulation: effects
7. Immunobiology
8. Bacteriophages, animal viruses, and plant viruses
9. Recombinant DNA methodology

II. Organismal Biology (33-34%)

The structure, physiology, behavior, and development of organisms are addressed. Topics covered include nutrient procurement and processing, gas exchange, internal transport, regulation of fluids, control mechanisms and effectors, and reproduction in autotrophic and heterotrophic organisms. Examples of developmental phenomena range from fertilization through differentiation and morphogenesis. Responses to environmental stimuli are examined as they pertain to organisms. Major distinguishing characteristics and phylogenetic relationships of organisms are also covered.

A. Animal Structure, Function, and Organization (10%)

1. Exchange with environment
2. Internal transport and exchange
3. Support and movement
4. Integration and control mechanisms
5. Behavior (communication, orientation, learning, and instinct)

6. Metabolic rates (temperature, body size, and activity)

B. Animal Reproduction and Development (6%)

　1. Reproductive structures
　2. Meiosis, gametogenesis, and fertilization
　3. Early development (e.g., polarity, cleavage, and gastrulation)
　4. Developmental processes (e.g., induction, determination, differentiation, morphogenesis, and metamorphosis)
　5. External control mechanisms (e.g., photoperiod)

C. Plant Structure, Function, and Organization, with Emphasis on Flowering Plants (7%)

　1. Organs, tissue systems, and tissues
　2. Water transport, including absorption and transpiration
　3. Phloem transport and storage
　4. Mineral nutrition
　5. Plant energetics (e.g., respiration and photosynthesis)

D. Plant Reproduction, Growth, and Development, with Emphasis on Flowering Plants (5%)

　1. Reproductive structures
　2. Meiosis and sporogenesis
　3. Gametogenesis and fertilization
　4. Embryogeny and seed development
　5. Meristems, growth, morphogenesis, and differentiation
　6. Control mechanisms (e.g., hormones, photoperiod, and tropisms)

E. Diversity of Life (6%)

　1. Archaea
　2. Bacteria
　3. Protista
　4. Fungi
　5. Animalia with emphasis on major phyla
　6. Plantae with emphasis on major phyla

III. Ecology and Evolution (33-34%)

The interactions of organisms and their environment, emphasizing biological principles at levels above the individual are addressed. Ecological topics range from physiological adaptations to the functioning of ecosystems. Although principles are emphasized, some questions may consider applications to current environmental problems. Topics in evolution range from genetic foundations through evolutionary processes and their consequences. Evolution is considered at the molecular, individual, population, and higher levels. Some quantitative skills, including the interpretation of simple mathematical models, may be required.

A. Ecology (16-17%)

　1. Environment/organism interaction
　2. Behavioral ecology
　3. Population ecology
　4. Community ecology
　5. Ecosystems

B. Evolution (16-17%)

　1. Genetic variability
　2. Macroevolutionary and microevolutionary processes
　3. Evolutionary consequences
　4. History of life

Preparing for the Test

GRE Subject Test questions are designed to measure skills and knowledge gained over a long period of time. Although you might increase your scores to some extent through preparation a few weeks or months before you take the test, last minute cramming is unlikely to be of further help. The following information may be helpful.

- A general review of your college courses is probably the best preparation for the test. However, the test covers a broad range of subject matter, and no one is expected to be familiar with the content of every question.

- Use the practice test to become familiar with the types of questions in the GRE Biology Test, taking note of the directions. If you understand the directions before you take the test, you will have more time during the test to focus on the questions themselves.

Test-Taking Strategies

The questions in the practice test in this book illustrate the types of multiple-choice questions in the test. When you take the actual test, you will mark your answers on a separate machine-scorable answer sheet.

Following are some general test-taking strategies you may want to consider.

- Read the test directions carefully, and work as rapidly as you can without being careless. For each question, choose the best answer from the available options.

- All questions are of equal value; do not spend time pondering individual questions you find extremely difficult or unfamiliar.

- You may want to work through the test quite rapidly, first answering only the questions about which you feel confident, then going back and answering questions that require more thought, and concluding with the most difficult questions if there is time.

- If you decide to change an answer, make sure you completely erase it and fill in the oval corresponding to your desired answer.

- Questions for which you mark no answer or more than one answer are not counted in scoring.

- Your score will be determined by subtracting one-fourth the number of incorrect answers from the number of correct answers. It is unlikely that pure guessing will raise your score; it may lower your score. However, if you have some knowledge of a question and are able to rule out one or more of the answer choices as incorrect, your chances of selecting the correct answer are improved, and answering such questions will likely improve your score.

- Record all answers on your answer sheet. Answers recorded in your test book will not be counted.

- Do not wait until the last five minutes of a testing session to record answers on your answer sheet.

What Your Scores Mean

Your raw score — that is, the number of questions you answered correctly minus one-fourth of the number you answered incorrectly — is converted to the scaled score that is reported. This conversion ensures that a scaled score reported for any edition of a GRE Biology Test is comparable to the same scaled score earned on any other edition of the test. Thus, equal scaled scores indicate essentially equal levels of performance regardless of the test edition taken.

GRE Biology Test scores are reported on a 200 to 990 score scale in ten-point increments. Three subscores (Cellular and Molecular Biology; Organismal Biology; and Ecology and Evolution) are also reported on a 20-99 score scale in one-point increments.

Test scores should be compared only with other scores on the GRE Biology Test. For example, a 680 on the Biology Test is not equivalent to a 680 on the GRE Biochemistry, Cell and Molecular Biology Test.

Taking the Practice Test

The practice test begins on page 7. The total time that you should allow for the practice test is 2 hours and 50 minutes. An answer sheet is provided for you to mark your answers to the test questions.

It is best to take the practice test under timed conditions. Find a quiet place to take the test and make sure you have a minimum of 2 hours and 50 minutes available.

To simulate how the administration will be conducted at the test center, print the answer sheet (pages 63 and 64). Then go to page 60 of this test book and follow the instructions for completing the identification areas of the answer sheet. When you are ready to begin the test, note the time and begin marking your answers on the answer sheet. Stop working on the test when 2 hours and 50 minutes have elapsed.

Scoring the Practice Test

The worksheet on page 61 lists the correct answers to the questions. Columns are provided for you to

mark whether you chose the correct (C) answer or an incorrect (I) answer to each question. Draw a line across any question you omitted, because it is not counted in the scoring.

At the bottom of the page, enter the total number correct and the total number incorrect. Divide the total incorrect by 4 and subtract the resulting number from the total correct. Then round the result to the nearest whole number. This will give you your raw score. Use the score conversion table on page 62 to find the scaled score that corresponds to your raw score.

Example: Suppose you chose the correct answers to 91 questions and incorrect answers to 39. Dividing 39 by 4 yields 9.75. Subtracting 9.75 from 91 equals 81.25, which is rounded to 81. The raw score of 81 corresponds to a scaled score of 630.

The subscore columns in the worksheet can be similarly used to tally your correct and incorrect responses to the questions that contribute to each subscore. We suggest that you circle the "•" if you chose the correct answer, and put a minus sign beside the "•" for an incorrect answer. Space is provided at the bottom right of the worksheet to calculate and enter your three raw subscores. The subscore conversion table will show you the scaled subscores that correspond to your subscores.

Evaluating Your Performance

Now that you have scored your test, you may wish to compare your performance with the performance of others who took this test.

The data in the worksheet on page 61 are based on the performance of a sample of the test takers who took the GRE Biology Test in October 2012. This sample was selected to represent the total population of GRE Biology Test examinees tested between July 1, 2011, and June 30, 2014.

The numbers in the column labeled "P+" on the worksheet indicate the percentages of examinees in this sample who answered each question correctly. You may use these numbers as a guide for evaluating your performance on each test question.

Interpretive data based on the scores earned by test takers in a recent three-year period are available in Table 2, *Subject Tests Total Score Interpretive Data Used on Score Reports*, and Table 3, *Subject Tests Interpretive Data for Subscores*, at

www.ets.org/gre/subject/scores/understand. Each table shows selected scaled scores and the corresponding percentage of test takers who received lower scores. Note that these interpretive data are updated annually and appear on GRE score reports. To compare yourself with this population, in Table 2 look at the percentage next to the total scaled score you earned on the practice test. If a total scaled score you earned does not appear in the table, look at the scaled scores (and corresponding percentages) above and below the score you earned to assess your performance on the total test. Similarly, in Table 3, look at the percentages corresponding to the subscores you earned on the practice test. If a subscore that you earned does not appear in the table, look at the scaled scores (and corresponding percentages) above and below the score you earned to assess your performance in each subscore area.

Your three subscores show your relative strengths or weaknesses in the three subfield areas of the GRE Biology Test. The raw subscores are scaled in such a way that they are related to the total scores on the test. On the average, a person who has a comprehensive background in the field can expect to have subscores equal to about one-tenth of his or her total score. Thus, if you have a total score of 600, and your undergraduate program placed equal emphasis on the three areas of biology represented by the subscores, you would expect to have a scaled score of about 60 in each area. If, however, your subscores differ by more than a few points, you may take this as an indication that your lower score shows weakness, and you may wish to concentrate your review efforts on topics in that area.

It is important to realize that the conditions under which you tested yourself were not exactly the same as those you will encounter at a test center. It is impossible to predict how different test-taking conditions will affect test performance, and this is only one factor that may account for differences between your practice test scores and your actual test scores. By comparing your performance on the practice test with the performance of other individuals who took the GRE Biology Test, however, you will be able to determine your strengths and weaknesses and can then plan a program of study to prepare yourself for taking the GRE Biology Test under standard conditions.

GRE

FORM GR1224

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GRADUATE RECORD EXAMINATIONS®

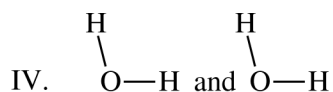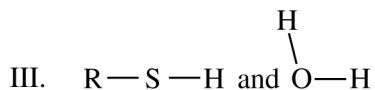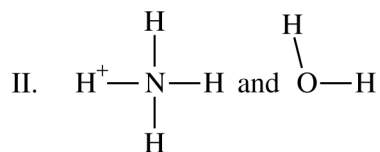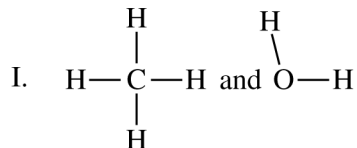# BIOLOGY TEST

NO TEST MATERIAL ON THIS PAGE

BIOLOGY TEST
Time—170 minutes
194 Questions

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 completely fill in the corresponding space on the answer sheet.

1. Which of the following pairs of molecules would form hydrogen bonds?

   I.
   $$H-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-H \quad \text{and} \quad O-H$$

   II.
   $$H^+-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{N}}-H \quad \text{and} \quad O-H$$

   III.
   $$R-S-H \quad \text{and} \quad O-H$$

   IV.
   $$O-H \quad \text{and} \quad O-H$$

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

2. Proteins destined to be secreted move through the secretory pathway in which of the following orders?

   (A) Smooth ER → Golgi transport vesicle → Golgi cisternae → secretory vesicle → cell surface
   (B) Rough ER → Golgi transport vesicle → Golgi cisternae → secretory vesicle → cell surface
   (C) Golgi cisternae → ER transport vesicle → smooth ER → secretory vesicle → cell surface
   (D) Golgi cisternae → ER transport vesicle → rough ER → secretory vesicle → cell surface
   (E) Rough ER → smooth ER → Golgi transport vesicle → Golgi cisternae → secretory vesicle → cell surface

3. Stabilization of the unique coiled structure of an alpha helix in a protein is primarily attributed to

   (A) hydrogen bonding between the peptide backbone atoms
   (B) disulfide bridges between cysteine side chains
   (C) carbohydrate moieties attached to polar amino acids
   (D) peptide linkages that covalently bond amino acids
   (E) an abundance of amino acids with electrically charged side chains

GO ON TO THE NEXT PAGE.

4. A DNA strand with the sequence 5′ CGA TTG 3′ would be complementary to the sequence

   (A) 5′ GCU AAC 3′
   (B) 5′ GCT AAC 3′
   (C) 5′ GTT AGC 3′
   (D) 5′ CAA TCG 3′
   (E) 5′ CUU TCG 3′

5. A cell nucleus contains which of the following?

     I. DNA
    II. Protein
   III. RNA

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

6. Which of the following best explains how mutations in DNA can result in the expression of a new phenotype?

   (A) A different polypeptide is produced.
   (B) The polarity of tRNA becomes the opposite of that of DNA.
   (C) Nucleic acids are methylated.
   (D) The gene is now read in the 3′ to 5′ direction.
   (E) Eukaryotes and prokaryotes have similar ribosomes.

7. Which of the following techniques could be used to demonstrate protein binding to specific DNA sequences?

   (A) Western blot hybridization
   (B) Northern blot hybridization
   (C) Southern blot hybridization
   (D) Electrophoretic mobility shift assay
   (E) Polymerase chain reaction

8. In cloning experiments on the frog *Xenopus laevis*, nuclei were removed from intestinal cells of tadpoles and transplanted into zygotes whose nuclei had been removed. A small percent of these zygotes developed into normal frogs, suggesting that

   (A) intestinal cells can be transformed into all cell types
   (B) frogs do not have the same developmental constraints as other species
   (C) intestinal cell nuclei are highly specialized
   (D) the genomes of all somatic cells are equivalent
   (E) the zygotic nucleus cannot be successfully inactivated

9. In garden peas, the allele for tall plants (*D*) is completely dominant to the allele for dwarf plants (*d*) and the allele for violet flower color (*W*) is completely dominant to the allele for white flower color (*w*). In a cross between a tall violet plant, with the genotype *DDWw*, and a dwarf white plant, what phenotypic ratio of the progeny would be expected from this cross?

   (A) All tall violet
   (B) 1 tall violet: 1 dwarf violet
   (C) 1 tall violet: 1 tall white: 1 dwarf violet: 1 dwarf white
   (D) 1 tall violet: 1 tall white
   (E) All dwarf white

GO ON TO THE NEXT PAGE.

10. Which of the following best explains why enzymes are effective in facilitating chemical reactions?

   (A) They raise the temperature of the reaction mixture, thereby speeding up the conversion of reactants to products.
   (B) They alter the equilibrium constant of a reaction (K_{eq}) so that more reactant can be converted to product.
   (C) They increase the maximal rate of the chemical reaction (V_{max}).
   (D) They lower the activation energy, thereby speeding up the conversion of reactants to products.
   (E) They donate energy to reactions, thereby allowing nonspontaneous reactions to proceed.

11. Targeting of a newly synthesized protein is most likely to require two different signal peptides for which of the following destinations?

   (A) Plasma membrane
   (B) Lysosome
   (C) Cytosol
   (D) Chloroplast
   (E) Endoplasmic reticulum

12. Approximately what fraction of the human genome encodes proteins?

   (A) 2%
   (B) 25%
   (C) 50%
   (D) 90%
   (E) 99%

13. Which of the following contain DNA sequences required for the segregation of chromosomes in mitosis and meiosis?

   (A) Telomeres
   (B) Centromeres
   (C) Nucleosomes
   (D) Spliceosomes
   (E) Ribosomes

14. Of the graphs shown below, which is most representative of the kinetics of ion transport through a membrane channel?

(A)

(B)

(C)

(D)
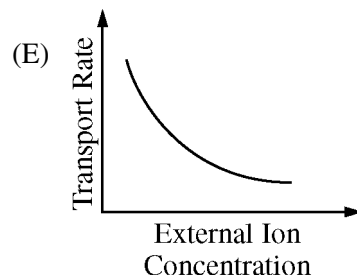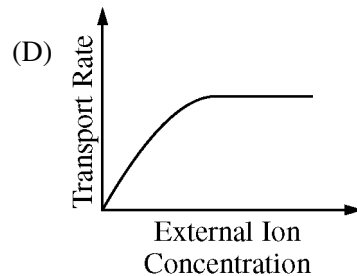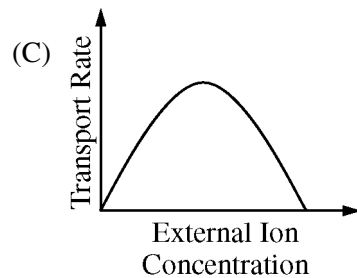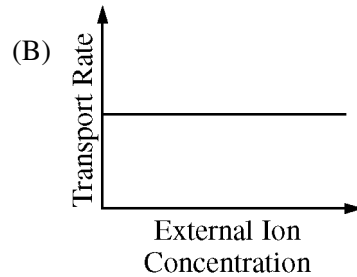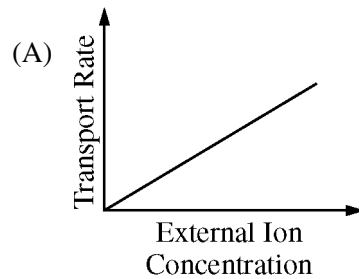
(E)

15. In eukaryotic photosynthetic cells, which of the following occurs when electrons flow cyclically through the electron transport chain associated with photosystem I?

(A) Synthesis of ATP
(B) Reduction of $NADP^+$ to NADPH
(C) Release of O_2
(D) Reduction of CO_2 to sugar
(E) Formation of H_2O

16. In the presence of alcohol dehydrogenase, the rate of reduction of acetaldehyde to ethanol increases as the concentration of acetaldehyde is increased. Eventually, the rate of the reaction reaches a maximum, after which point further increases in the concentration of acetaldehyde have no effect. Which of the following is true at the maximal rate of reaction?

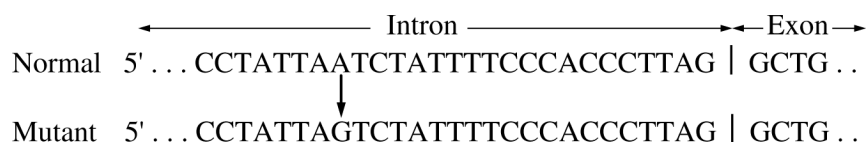(A) Nearly all of the enzyme molecules are interacting with acetaldehyde molecules.
(B) The activation energy of the reaction decreases.
(C) The change in free energy of the reaction decreases.
(D) The enzyme is no longer specific for acetaldehyde.
(E) The enzyme has mostly been used up in earlier phases of the reaction.

17. When an influenza virus enters a cell, it immediately starts to do which of the following?

(A) Incorporate viral DNA into the host cell's chromosome
(B) Destroy the host cell's transcriptional machinery
(C) Replicate its genetic material and synthesize viral proteins
(D) Use a viral copy of reverse transcriptase to manufacture viral DNA
(E) Destabilize membrane proteins and lyse the host cell

18. The action of an inhibitor that diminishes the rate of catalysis by binding reversibly at the active site is best described as

(A) facultative
(B) competitive
(C) constitutive
(D) allosteric
(E) cooperative

19. All of the following may serve as intracellular messengers EXCEPT

(A) calcium ions
(B) cAMP
(C) acetylcholine
(D) inositol 1,4,5-triphosphate
(E) 1,2-diacylglycerol

20. In chloroplasts, a certain protein is found in the lumen of the thylakoid (thylakoid space). It is transcribed in the nucleus and synthesized on cytoplasmic ribosomes. How many membrane bilayers must this protein cross to reach its final location?

(A) One
(B) Two
(C) Three
(D) Four
(E) Five

21. Which of the following statements about mitochondria and chloroplasts is generally true?

(A) Plants have chloroplasts but no mitochondria; animals have mitochondria but no chloroplasts.
(B) Plants have chloroplasts but no mitochondria; fungi have mitochondria but no chloroplasts.
(C) Plants and fungi have chloroplasts but no mitochondria; animals have only mitochondria.
(D) Plants and fungi have both chloroplasts and mitochondria; animals have only mitochondria.
(E) Plants have both chloroplasts and mitochondria; animals and fungi have only mitochondria.

22. The following pairs were placed in solution together. Which two could be separated by performing low-speed centrifugation?

(A) DNA and mRNA
(B) Nuclei and secretory vesicles
(C) Golgi apparatus and endoplasmic reticulum
(D) Lysosomes and endosomes
(E) Ribosomes and signal-recognition particles (SRP's)

23. Phalloidin is a toxin made by the death cap mushroom. The toxin binds to actin subunits and disrupts actin function. Which of the following structures would be most directly affected by phalloidin?

(A) Intermediate filaments
(B) Collagen fibers
(C) Microfilaments
(D) Microtubules
(E) Keratin fibers

24. Mitochondria isolated and placed in a buffered solution with a low pH begin to manufacture ATP. Which of the following is the best explanation for the effect of low external pH?

(A) It increases the concentration of OH^-, causing the mitochondria to pump H^+ to the intermembrane space.
(B) It increases the OH^- concentration in the mitochondria matrix.
(C) It increases the acid concentration in the mitochondria matrix.
(D) It increases diffusion of H^+ from the intermembrane space to the matrix.
(E) It causes a decrease in H^+ in the intermembrane space.

25. Which of the following sets of reactions occurs in the stroma of the chloroplast in plant cells?

(A) Calvin cycle
(B) Krebs cycle
(C) Fermentation
(D) Decarboxylation
(E) Ammonification

26. Which of the following is typically NOT found in normal somatic cells of a human male?

(A) The entire genetic information possessed by the original zygote
(B) An inactivated X chromosome
(C) Forty-four autosomes
(D) A diploid nucleus
(E) A Y chromosome

27. Which of the following is the most direct cause of polyteny in somatic cells of certain organisms?

(A) RNA transcription
(B) Supercoiling of chromatin
(C) Chromosome replication without cell division
(D) Chromosome recombination
(E) Amplification of sex chromosomes

28. In humans, a hereditary disorder called xeroderma pigmentosum (XP) can result in the inability to repair ultraviolet damage to DNA. Which of the following molecular lesions is most likely to accrue in individuals with XP?

(A) Thymine dimers
(B) Deamination of cytosine
(C) Depurination
(D) Single strand DNA breaks
(E) Double strand DNA breaks

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                           ←──────── Intron ──────────→←─Exon─→
Normal   5'...CCTATTAATCTATTTTCCCACCCTTAG | GCTG..
                       ↓
Mutant   5'...CCTATTAGTCTATTTTCCCACCCTTAG | GCTG..
```

29. Portions of the DNA sequences of normal and mutant *β*-globin genes are shown above. The most plausible explanation for why the indicated mutation (changing an A to a G) results in the disease *β*-thalassemia is that the mutation

   (A) changes the amino acid specified by the codon of which the altered base is part
   (B) generates a recognition site for a restriction enzyme, so the gene is cut in two
   (C) creates a new splice site, so that a portion of the intron is not removed
   (D) results in an increase in the transcription of the *β*-globin gene
   (E) results in a translation stop codon being created at the site of the mutation

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30. Which of the following is encoded by the *src* oncogene and catalyzes the specific addition of phosphate groups to cellular proteins?

   (A) Protein phosphatase
   (B) Adenylate cyclase
   (C) G protein-linked receptor
   (D) Tyrosine kinase
   (E) Homeobox transcription factor

31. Mutation of homeotic cluster genes often results in which of the following developmental defects in *Drosophila* ?

   (A) Absence of a group of contiguous segments
   (B) Transformation of one segment into another
   (C) Polarity defects in every segment along the anterior-posterior axis
   (D) Tumor formation in imaginal discs
   (E) Absence of every other segment along the anterior-posterior axis

32. Monoclonal antisera are distinguished from polyclonal antisera in which of the following ways?

   (A) Each type of antibody in a monoclonal antiserum reacts against a single region of a single antigen; each type of antibody in a polyclonal antiserum reacts against multiple regions of different antigens.
   (B) A monoclonal antibody reacts against multiple regions of a single antigen; a polyclonal antibody reacts against a single region of related antigens.
   (C) A monoclonal antiserum contains antibodies secreted from the descendants of a single B lymphocyte; a polyclonal antiserum contains antibodies secreted from the descendants of different B lymphocytes.
   (D) A monoclonal antiserum contains antibodies secreted from the descendants of a single B lymphocyte; a polyclonal antiserum contains antibodies secreted from the descendants of both B and T lymphocytes.
   (E) A monoclonal antiserum is produced by the descendants of a single B lymphocyte; a polyclonal antiserum is produced by the descendants of a single T lymphocyte.

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33. Which of the following most accurately describes a retrotransposon?

(A) A DNA sequence that can move from one site in the genome to another without replicating
(B) A DNA sequence that can be deleted from the genome without consequence
(C) A DNA sequence that replicates via an RNA intermediate
(D) A DNA sequence that replicates via a protein intermediate
(E) A DNA sequence that causes base-substitution mutations at some other site on the chromosome

34. Which of the following cells are typically necessary for the production of a maximal humoral response upon initial exposure to a protein antigen?

(A) B lymphocytes only
(B) T lymphocytes only
(C) B lymphocytes and dendritic cells only
(D) B lymphocytes and T lymphocytes only
(E) B lymphocytes, T lymphocytes, and dendritic cells
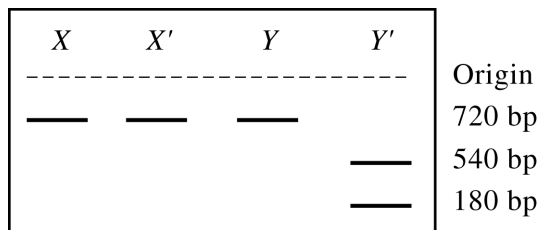
35. The figure above shows an intact linear DNA segment from two subspecies (lanes X and Y) and the same DNA segments digested by *Eco*RI (lanes X' and Y'), separated on an electrophoretic gel. Which of the following is the simplest explanation for the difference between the DNA segments of the two subspecies?

(A) X's DNA segment lacks any restriction sites.
(B) Y's DNA segment has one *Eco*RI restriction site; X's has none.
(C) Y's DNA segment has two *Eco*RI restriction sites; X's has only one.
(D) The Y segment has fewer nucleotides than the X segment.
(E) X has less DNA than Y does.

36. If the activity of an enzyme is constant over a broad range of pH values, it is likely that

(A) only ionizing groups on the enzyme participate in the reaction
(B) only ionizing groups on the substrate participate in the reaction
(C) ionizing groups on both the enzyme and substrate participate in the reaction
(D) no ionizing groups on the enzyme or substrate participate in the reaction
(E) the temperature should be changed in order to observe a pH effect
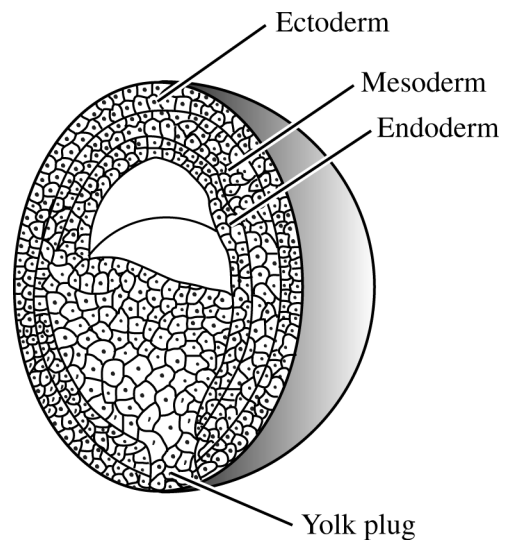
37. Which of the following developmental processes has been most recently completed in the amphibian embryo shown above?

(A) Neurulation
(B) Cleavage
(C) Blastula formation
(D) Gastrulation
(E) Segmentation

38. Which of the following plant cells undergoes programmed cell death to become functional?

(A) Phloem sieve tube member
(B) Xylem vessel member
(C) Stomatal guard cell
(D) Root cap cell
(E) Bundle sheath cell

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39. Which of the following provides visual evidence of genetic recombination during meiosis?

(A) Centromeres
(B) Synaptonemal complexes
(C) Haploid nuclei
(D) Chiasmata
(E) Secondary constrictions

40. A plant that possesses swimming sperm, xylem with tracheids, independent gametophyte and sporophyte phases, and no seeds is probably most closely related to

(A) mosses
(B) pines
(C) ferns
(D) liverworts
(E) flowering plants

41. The ability of the brain to detect differences in stimulus intensity is best explained by the fact that which of the following varies with the stimulus intensity?

(A) The amplitude of the action potential
(B) The threshold potential
(C) The number of action potentials per second
(D) The number of synapses crossed
(E) The final destination of the action potential

42. How do cyanobacteria differ from green unicellular algae?

(A) Cyanobacteria reduce sulfur compounds.
(B) Cyanobacteria lack cell walls.
(C) Cyanobacteria have no nuclei.
(D) Green algae produce cell membranes.
(E) Green algae contain lipids.

43. Experiments on song development in birds have shown that when a young male reared in isolation hears only the song of a different bird species, he will develop an adult song repertoire that lacks certain characteristics typical of his own species. This result shows that the song of his species is most likely

(A) entirely learned during development
(B) entirely instinctive
(C) both instinctive and learned
(D) dependent upon hormones for proper development
(E) dependent upon the presence of a female
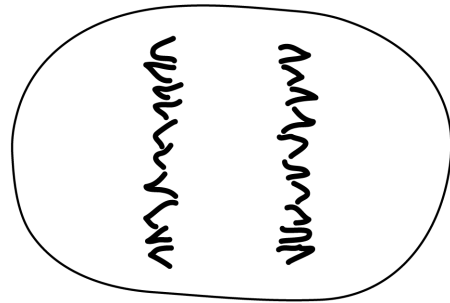
44. In *Zea mays* the diploid chromosome number equals 20. In which of the following tissues of the plant would the cell division illustrated in the diagram above occur?

(A) Apical meristem
(B) Anther
(C) Cambium
(D) Sepal
(E) Root primordia

45. Which of the following is the correct anatomical order of structures in the mammalian female reproductive tract?

(A) Oviduct, uterus, rete, vagina
(B) Oviduct, epididymis, uterus, vagina
(C) Ovary, oviduct, uterus, vagina
(D) Ovary, uterus, vagina, rete
(E) Ovary, epididymis, oviduct, uterus

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46. Which of the following sources makes the greatest contribution to the dry mass of organic matter that comprises an oak tree?

(A) Organic molecules from decaying matter in the soil that are taken up by the roots
(B) Mineral nutrients dissolved in groundwater that are taken up by the roots
(C) Water that is taken up by the roots and carbon dioxide from the air
(D) Endosperm located in the cotyledons of the acorn
(E) Light that is absorbed by the chloroplasts of leaf cells

47. In an experiment, the first cleavage plane of an amphibian zygote was manipulated so that the gray crescent was contained in only one of the two blastomeres that result from the first cleavage. The two blastomeres were then separated. What is the expected fate of the blastomeres?

(A) The blastomere with the gray crescent will grow in size more quickly than the one without the gray crescent.
(B) The blastomere with the gray crescent will form a complete, but small, embryo.
(C) The blastomere without the gray crescent will form a complete, but small, embryo.
(D) The blastomere with the gray crescent will stop dividing and die before the second cleavage.
(E) The blastomere without the gray crescent will develop into a complete embryo with reversed dorsal-ventral polarity.

48. Both C4 and CAM plants employ physiological and biochemical strategies to reduce photorespiration. Which of the following is an accurate comparison of the two strategies?

(A) C4 plants fix CO_2 as the 4-carbon acid oxaloacetate, while CAM plants fix CO_2 as the 5-carbon acid ribulose 1, 5-bisphosphate.
(B) C4 plants fix CO_2 in the mesophyll but carry out the Calvin cycle in the bundle sheath, while CAM plants fix CO_2 and carry out the Calvin cycle in the mesophyll.
(C) C4 plants fix CO_2 in the bundle sheath but carry out the Calvin cycle in the mesophyll, while CAM plants fix CO_2 and carry out the Calvin cycle in the bundle sheath.
(D) C4 plants store CO_2 as phosphoglycolate, while CAM plants store CO_2 as oxaloacetate.
(E) C4 plants carry out photosynthetic electron transport in the daytime, while CAM plants carry out photosynthetic electron transport at night.

49. Double fertilization is a unique feature of flowering plants. In this process, one sperm unites with the egg to yield a zygote. The second sperm unites with the polar nuclei to initiate the formation of the

(A) megagametophyte
(B) endodermis
(C) embryo
(D) endosperm
(E) epicotyl

50. The crouching of very young birds in response to a predator's shape overhead is an example of

(A) a conditioned response
(B) a fixed action pattern
(C) an imprinted behavior
(D) learned behavior
(E) habituation

51. A healthy person sitting at rest consciously begins to breathe too fast. Which of the following describes the change in the person's blood caused by this hyperventilation?

(A) A decrease in partial pressure of carbon dioxide and an increase in concentration of hydrogen ions
(B) A decrease in partial pressure of carbon dioxide and a decrease in concentration of hydrogen ions
(C) An increase in partial pressure of carbon dioxide and an increase in concentration of hydrogen ions
(D) An increase in partial pressure of carbon dioxide and a decrease in concentration of hydrogen ions
(E) An increase in partial pressure of carbon dioxide and an unchanged concentration of hydrogen ions

52. Which of the following would increase the rate at which a gas diffuses between the alveoli of the lung and the blood within a pulmonary capillary?

(A) Decreasing the partial pressure gradient of the gas
(B) Decreasing the solubility of the gas in water
(C) Increasing the total surface area available for diffusion
(D) Decreasing the rate of blood flow through the pulmonary capillary
(E) Increasing the thickness of the respiratory membrane

53. Evidence that sea urchins are more closely related to frogs than they are to snails is that echinoderms and chordates share which of the following embryological features?

(A) An embryonic notochord disappears by the adult stage.
(B) Larvae undergo metamorphosis.
(C) Early embryos are unable to compensate for missing cells.
(D) Dermis arises from somites.
(E) The pore that forms the mouth develops after the pore that forms the anus.
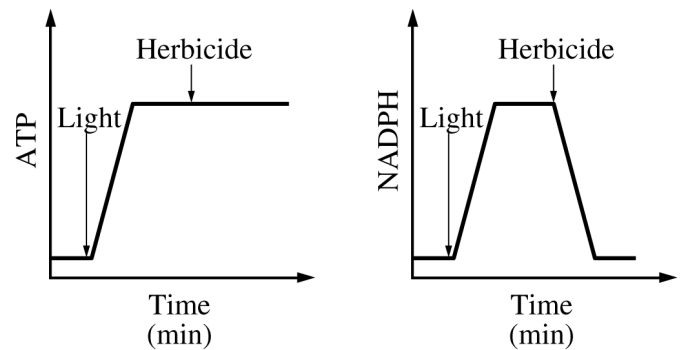
54. The graphs above show the amount of ATP and NADPH in isolated chloroplasts once these organelles are given light, and then later, after exposure to a herbicide. Based on the evidence presented in the graphs, it can be concluded that this herbicide affects photosynthesis by

(A) altering the movement of H^+ across membranes of mitochondria
(B) altering the movement of H^+ across membranes of chloroplasts
(C) inhibiting the reduction of $NADP^+$
(D) inhibiting the oxidation of NADH
(E) inhibiting the oxidation of NADPH

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55. All of the following statements about muscle contraction are true EXCEPT:

   (A) The ends of actin filaments move closer together.
   (B) The length of myosin filaments does not change.
   (C) Calcium-troponin binding precedes actin-myosin binding.
   (D) Calcium-tropomyosin binding precedes actin-myosin binding.
   (E) ATP hydrolysis precedes actin-myosin binding.

56. Mouse sperm contain receptor proteins that bind to a glycoprotein (ZP3) in the zona pellucida of mouse eggs. Binding of ZP3 receptors to ZP3 initiates the sperm's acrosomal reaction. All of the following experimental observations would be expected EXCEPT:

   (A) Injecting eggs with antibodies that bind to ZP3 blocks *in vitro* fertilization.
   (B) Incubating sperm with purified ZP3 prior to mixing sperm and eggs blocks *in vitro* fertilization.
   (C) Incubating eggs with antibodies that bind to ZP3 blocks *in vitro* fertilization.
   (D) Coating synthetic beads with a different glycoprotein, ZP2, fails to lead to sperm aggregation on the beads.
   (E) Coating synthetic beads with ZP3 leads to sperm aggregation on the beads.

57. Many marine birds drink seawater yet maintain their internal osmolarity at a constant level that is hypoosmotic to seawater. Which of the following physiological strategies best explains how the birds maintain their tissue osmolarity?

   (A) Marine birds absorb water from the environment through specialized salt-exchange glands and produce large volumes of dilute urine in the kidneys.
   (B) Marine birds absorb salts from the environment through specialized salt-exchange glands and produce large volumes of concentrated urine in the kidneys.
   (C) Marine birds excrete salts through specialized salt-exchange glands and excrete small volumes of urine.
   (D) Marine birds excrete salts and nitrogenous wastes through specialized nasal glands.
   (E) Marine birds sequester salts in specialized salt glands and secrete nitrogenous wastes primarily into the gut.

58. A stem-boring beetle has laid its eggs in the center of a 5-year-old wood twig, and the eggs have matured into larvae. In proper order (inside to outside), what tissues and tissue regions would the larvae encounter as they eat their way toward the outside of the twig? (For simplicity, assume that the epidermis has already fallen off completely.)

   (A) Pith; primary xylem; secondary xylem; vascular cambium; primary phloem; secondary phloem; cortex
   (B) Pith; secondary xylem; primary xylem; vascular cambium; secondary phloem; primary phloem; cortex
   (C) Pith; secondary xylem; primary xylem; vascular cambium; primary phloem; secondary phloem; cortex
   (D) Pith; primary xylem; secondary xylem; vascular cambium; secondary phloem; cortex; primary phloem
   (E) Pith; primary xylem; secondary xylem; vascular cambium; secondary phloem; primary phloem; cortex

59. During the mammalian cardiac cycle, a volume of blood equivalent to ventricular stroke volume is transferred from the more compliant venous side to the less compliant arterial side of the circulation. In terms of pressures within the venous and arterial compartments, this transfer results in

(A) no change in pressure in either compartment
(B) no effect on venous pressure and a small increase in arterial pressure
(C) an increase in venous pressure and an equal but opposite decrease in arterial pressure
(D) little effect on venous pressure and a large increase in arterial pressure
(E) a decrease in venous pressure and an equal but opposite increase in arterial pressure

60. Which of the following tissues in an actively photosynthesizing plant would have the highest rate of oxygen production?

(A) Cortex
(B) Palisade mesophyll
(C) Epidermis
(D) Vascular cambium
(E) Endodermis

61. Which of the following is a correct statement about the cohesion-tension theory for the ascent of water in the xylem?

(A) The evaporation of water from leaf mesophyll cells generates tension in the water column.
(B) Water moves from a source region with high hydrostatic pressure to a sink region with low hydrostatic pressure.
(C) The cohesion of water molecules is responsible for the formation of embolisms (air bubbles) in the water column.
(D) Living cells of the xylem provide the main conduit for an ascent of water.
(E) Turgor pressure prevents the collapse of xylem cells that are under tension.

Upper Epidermis

L: Vascular Bundle

M: Intercellular Spaces

Lower Epidermis

P: Guard Cell

O: Stomate

Q: Atmosphere Outside the Leaf
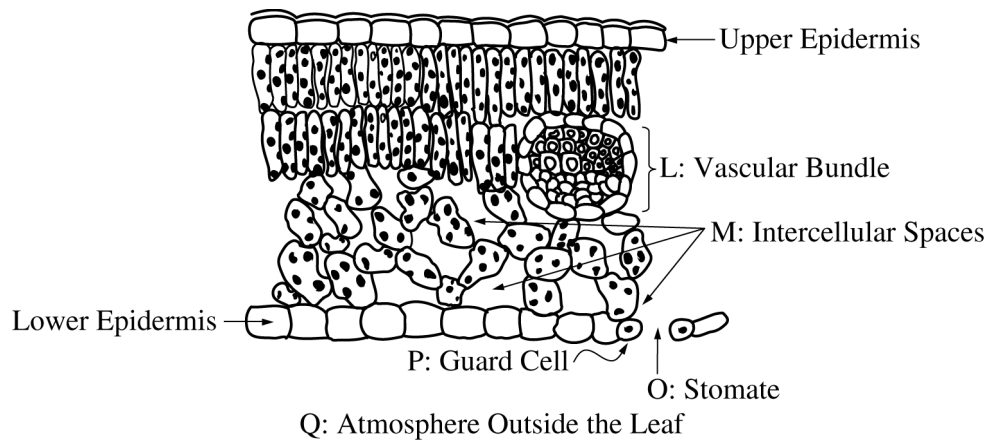
62. A transverse section of a leaf is represented in the diagram above. Transpiration in the leaf depends on the transport of potassium ions

(A) into O
(B) into P
(C) from M to L
(D) from M to Q
(E) from P to L

63. Which of the following is the symplastic pathway for the movement of sucrose from the site of photosynthesis in mesophyll cells into the phloem?

(A) Fibers, phloem parenchyma, companion cell, sieve tube
(B) Phloem parenchyma, fibers, bundle sheath, tracheids
(C) Companion cells, phloem parenchyma, fibers, sieve tube
(D) Bundle sheath, phloem parenchyma, companion cell, sieve tube
(E) Bundle sheath, companion cell, fibers, sieve tube

64. In plants, proton pumps are involved in the process of loading sugars into the phloem for transport. Which of the following is true about this process?

(A) It is passive.
(B) It depends on DNA.
(C) It requires ATP.
(D) It translocates starch.
(E) It is an oxidation/reduction reaction.

65. According to the pressure-flow model of movement of phloem contents, photosynthate movement from source to sink is driven by

(A) an ATP-dependent pressure-flow pump
(B) a water-pressure potential gradient
(C) transpiration
(D) apoplastic diffusion
(E) a pH gradient

66. All of the following statements about plant embryogenesis are correct EXCEPT:

(A) The suspensor is derived from the basal cell.
(B) Cotyledons are derived from the apical cell.
(C) Shoot apical meristem formation occurs after seed formation.
(D) Precursors of all three plant tissue systems are formed during embryogenesis.
(E) Late stages of embryogenesis involve desiccation of embryonic tissues.

67. In an experiment, a plant cell was placed into a medium containing a 1.0 mM concentration of Ca^{++}. The electrochemical potential across the plasma membrane was measured at -110 mV. The Nernst equation predicted that the intracellular concentration of Ca^{++} would be 5,400 mM. The actual concentration of Ca^{++} in the cell was 1.5 mM. This value suggests that calcium

(A) is actively transported into the cell
(B) is not transported across the plasma membrane
(C) is passively transported out of the cell
(D) is actively transported out of the cell
(E) diffuses freely across the plasma membrane

68. Which of the following statements about fungi is NOT true?

(A) They all are eukaryotic.
(B) They all have rigid cell walls.
(C) Most are filamentous.
(D) Some are photosynthetic.
(E) Many are capable of both sexual and asexual reproduction.

Embryo   Endosperm
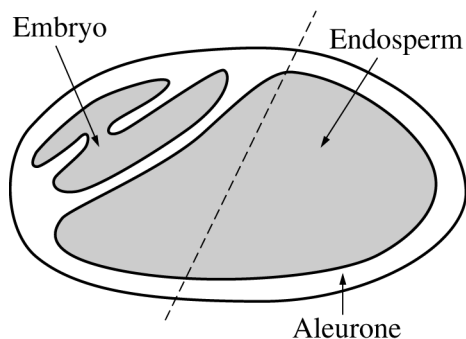
Aleurone

69. Barley seeds are divided in half, as shown in the diagram above, and the halves containing only endosperm and aleurone are then treated with different concentrations of gibberellin. After 8 hours of incubation, reducing sugars appear and a calibration curve is developed for the relation between gibberellin concentration and the production of reducing sugars.

The most important reason for removing the embryo of the seeds used in the experiment is to

(A) prevent the seeds from germinating during the experiment
(B) facilitate the absorption of gibberellin into the cut seeds
(C) remove the natural source of gibberellin
(D) prevent the inhibition of gibberellin activity
(E) remove the glucose contained in the embryo

70. Which of the following would be the most dependable environmental signal that a plant in a temperate ecosystem could use to initiate flowering at the correct time of the year?

(A) Circadian rhythm
(B) Photoperiod
(C) Changing air temperature
(D) Fluctuations in abscisic acid levels
(E) Changing amounts of precipitation

71. Which of the following is a benefit that mycorrhizal fungi confer to many plants?

(A) They protect plant roots from desiccation in extremely dry habitats.
(B) They fix nitrogen, which is particularly important for plants in nitrogen-limited habitats.
(C) They provide access to phosphorus, an essential element that is limited in many kinds of soils.
(D) They provide carbon to plants in exchange for fixed nitrogen.
(E) They produce toxins that kill the roots of neighboring plants competing for soil resources.

72. Short-term changes in plant growth rate mediated by the plant hormone auxin are hypothesized to result from

(A) loss of turgor pressure in the affected cells
(B) increased extensibility of the walls of affected cells
(C) suppression of metabolic activity in affected cells
(D) cytoskeletal rearrangements in the affected cells
(E) enlargement of the vacuoles of affected cells

73. A prokaryote that is thermophilic and methanogenic and has isoprenylglycerol ethers in its membrane instead of phospholipids is most likely

(A) a proteobacterium
(B) a spirochete
(C) a member of the genus *Chlamydia*
(D) an archaeon
(E) a rickettsia

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74. Antibiotics that affect bacterial cells interfere with all of the following EXCEPT

(A) peptidoglycan synthesis
(B) protein synthesis
(C) DNA synthesis
(D) reverse transcriptase
(E) RNA polymerase

75. Which of the following characteristics distinguishes angiosperms from gymnosperms?

(A) Perennial growth
(B) True roots
(C) Apical growth
(D) Seeds enclosed in ovaries
(E) Vascular cambium that produces phloem and xylem

76. In fungi, cell walls are reinforced by which of the following?

(A) Chitin
(B) Silica
(C) Lignin
(D) Collagen fibers
(E) Microtubules

77. Ferns undergo alternation of generations in which a

(A) dominant sporophyte alternates with an independent gametophyte
(B) dominant gametophyte alternates with a dependent sporophyte
(C) sporophyte and a gametophyte have equal life spans
(D) gametophyte produces gametes by meiosis
(E) gametophyte alternates with a haploid zygote

78. Mammals are homeostatic for all of the following EXCEPT

(A) body temperature
(B) blood glucose concentration
(C) blood pH
(D) metabolic rate
(E) blood calcium concentration

79. Which of the following statements is true of air as compared to water ?

(A) Air provides more physical support.
(B) Air has a higher O_2 concentration.
(C) Air offers more resistance to motion.
(D) Air has more thermal inertia.
(E) Air has lower rates of gas diffusion.

80. Which of the following is a reason that geneticists use mitochondrial DNA (mtDNA) to study the relatedness of animal populations?

(A) mtDNA mutates at a slower rate than nuclear DNA.
(B) mtDNA is passed from mother to child and is free from recombination that occurs between pairs of chromosomes.
(C) There are few single nucleotide polymorphisms in the hypervariable, noncoding regions.
(D) All mitochondrial proteins are coded for by mitochondrial genes.
(E) A large percentage of the mitochondrial genome codes for proteins, and thus the majority of retained mutations are neutral.

81. All of the following characteristics are typical of r-selected species EXCEPT

(A) high reproductive rate
(B) small body size
(C) occupancy of unstable environments
(D) minimal parental care
(E) high competitive ability

82. Which of the following active pools of carbon is the largest on Earth and contributes the most to carbon cycling?

(A) The atmosphere
(B) Rain-forest vegetation
(C) Recoverable fossil fuels
(D) Dead organic matter in soils
(E) The oceans

83. Which of the following characteristics is predicted for an early-successional plant community?

(A) High niche divergence among co-occurring species
(B) High ratios of primary production to standing-crop biomass
(C) High frequency of K-selected species
(D) High detrital biomass
(E) Slow nutrient cycling, with most nutrients tied up in plant biomass

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84. An aspect of the natural world that developed primarily as a result of biological processes is Earth's

(A) O_2-rich atmosphere

(B) CO_2-rich atmosphere

(C) water cycle

(D) seasonality

(E) tectonic processes
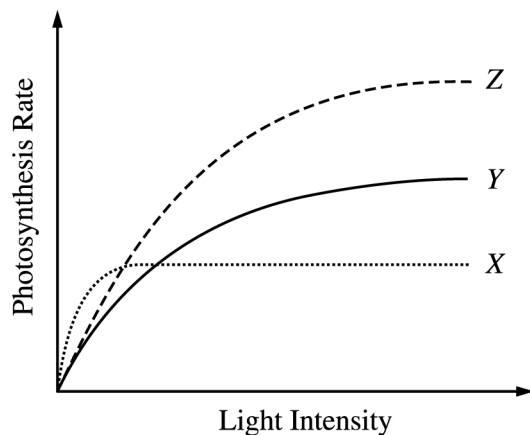
Light Intensity

85. The graph above shows the photosynthetic response of three coexisting plant species, X, Y, and Z, to a gradient of light intensity. Based on these response curves, which of the following is most likely true?

(A) Species Y is the tallest of the three.
(B) Species Y should outcompete species Z in all light environments.
(C) Species X is the superior competitor in deep shade.
(D) Species X has been artificially selected for high yield.
(E) Removal of species X should allow the population of species Z to increase greatly.

86. Hardy-Weinberg equilibrium generally assumes all of the following EXCEPT

(A) a large population
(B) genetic drift
(C) random mating
(D) absence of selection
(E) absence of migration

87. Most of the world's major deserts occur in two latitudinal bands that are centered at 30° north and 30° south latitude. This pattern is best explained by

(A) rain shadows of major mountain ranges that occur at those latitudes
(B) patterns of continental drift in the last 65 million years
(C) global climate changes that have occurred in the last century
(D) latitudinal variation in soil characteristics
(E) major patterns of atmospheric circulation above and below the equator

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Treatment (I)
A grown alone

Species A

Number of Individuals

0 — 8

Number of Weeks Elapsed

Treatment (II)
B grown alone

Species B

Number of Individuals

0 — 8

Number of Weeks Elapsed

Treatment (III)
A and B grown together

Species A

Species B

Number of Individuals

0 — 8

Number of Weeks Elapsed
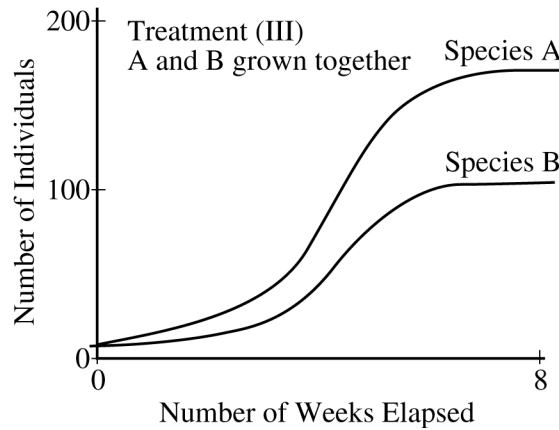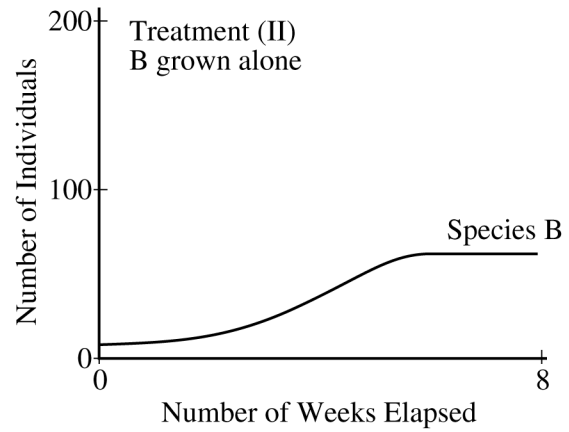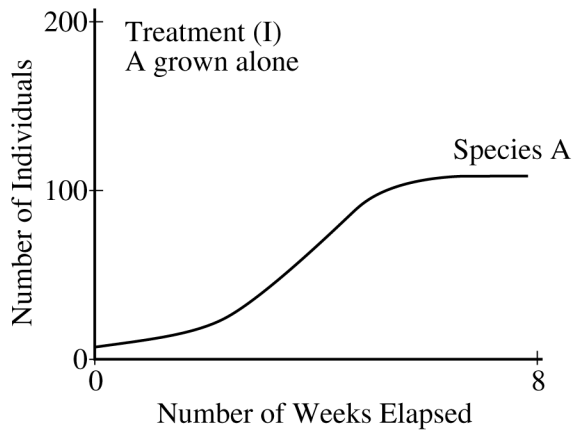
88. The figures above show the results of an experiment in which two microbial species, A and B, were grown in three treatments. In treatment I, species A was grown alone. In treatment II, species B was grown alone. In treatment III, both species were grown together at the same starting densities as in (I) and (II). The results suggest the interaction is best described as

(A) competitive
(B) commensal
(C) parasitic
(D) predatory
(E) mutualistic

89. The process in which pioneer species colonize a bare substrate such as rock, sand, or glacial till is known as

(A) weathering
(B) stabilizing succession
(C) secondary succession
(D) primary succession
(E) cyclic succession

90. Natural enemies have been implicated as a strong selective force for all of the following EXCEPT

(A) aposematic coloration
(B) chemical defenses
(C) masting (synchronous fruiting)
(D) lekking behavior
(E) immune responses

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91. Gene flow between populations results in

   (A) an increase in genetic homogeneity in the metapopulation
   (B) an increase in the rate of deleterious mutations in the metapopulation
   (C) an increased likelihood of speciation
   (D) disruption of Hardy-Weinberg equilibrium in the metapopulation
   (E) an enhancement of the effects of group selection in each population

92. Keystone species are thought to have profound effects on the structure and composition of ecological communities because they

   (A) tend to reduce diversity by eliminating food resources for other species
   (B) provide the foundation for food webs
   (C) are more abundant than most other species in their communities
   (D) have unusually narrow niche requirements
   (E) can prevent superior competitors from driving inferior competitors to local extinction

93. Among primates, a high degree of sexual dimorphism in a species usually indicates intense competition between

   (A) males in order to obtain individual food resources
   (B) males in order to obtain mates
   (C) females in order to obtain individual food resources
   (D) females in order to obtain mates
   (E) females in order to provide food for offspring

94. A species of small rodent eats seeds from only one species of pine. In normal years, a pair of these rodents will have a litter of two or three. It is unusual for small rodents to have such small litter sizes. The rodents are most likely to exhibit which other characteristic?

   (A) Moderate sexual size dimorphism
   (B) High parental investment
   (C) Precocial young
   (D) Frequent extrapair matings
   (E) Infanticide by wandering male rodents

95. In Sweden, the red fox (*Vulpes vulpes*) severely limits populations of its prey, including hares. However, red fox populations are sometimes attacked by a fatal parasite, the mange mite. As mite population sizes increase at a given site, how are hare and fox populations most likely to respond at the same site? (Assume that hares have no major predators at this site other than foxes.)

   (A) Both fox and hare populations will decrease.
   (B) Both fox and hare populations will increase.
   (C) Fox populations will decrease and hare populations will increase.
   (D) Fox populations will increase and hare populations will decrease.
   (E) Fox populations will decrease but hare populations will be unaffected.
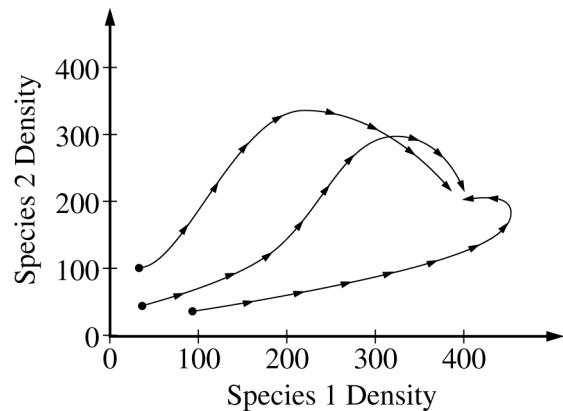
96. The figure above shows population growth trajectories over time (as indicated by the arrows) of two stored-grain beetle species when grown together under constant conditions. Three experiments were performed that differed only in the initial densities of the two species. Which of the following is the best interpretation of the experimental results?

   (A) Population growth is random (unpredictable) for each species.
   (B) No equilibrium exists in which both species can coexist.
   (C) Interspecific competition is stronger than intraspecific competition.
   (D) Density dependence within each species is stronger than interspecific competition.
   (E) No conclusion can be drawn from the information presented.

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97. Aggressive ants live in the swollen thorns of a small tropical tree and feed on oil-rich bodies that the tree produces at the tips of its leaflets. Which of the following experiments best tests the hypothesis that ants defend the plant by either killing or chasing away leaf-feeding insects?

(A) Remove ants and measure subsequent leaf damage.
(B) Remove oil-rich bodies and measure subsequent ant density.
(C) Remove the thorns and measure subsequent density of ants.
(D) Remove leaf-feeding insects and measure subsequent ant density.
(E) Remove leaf-feeding insects and measure subsequent plant growth.

98. Which of the following factors does NOT promote linkage disequilibrium?

(A) Asexual reproduction
(B) Coadapted gene complexes
(C) Epistasis
(D) Population subdivision
(E) Random mating

99. A species of goose nests on both cliffs and beaches near the ocean. Soon after hatching, all chicks must make their way to the ocean. Chicks from cliff nests must tumble down the cliff to get to the ocean, and many are killed by the fall. Which of the following is most consistent with the hypothesis that cliff nesting is adaptive in this goose species?

(A) Many more geese nest on the beaches than on the cliffs.
(B) Cliff-side nesting confers a higher fitness than does beach nesting.
(C) Chicks from cliff nests instinctively step off the cliffs at the appropriate time.
(D) More chicks survive the fall from the cliffs than are killed.
(E) Closely related goose species do not exhibit cliff nesting.

100. The A−B−O blood group locus in humans contains 3 alleles. In the Japanese population, the frequencies of these alleles, I^A, I^B, and i, are approximately 0.28, 0.17, and 0.55, respectively. If the Japanese population is in Hardy-Weinberg equilibrium at this locus, which of the following is closest to the expected frequency of heterozygotes at this locus in the Japanese population?

(A) 0.05
(B) 0.15
(C) 0.41
(D) 0.59
(E) 0.74

101. Which of the following is a biological attribute that would most likely allow a species to become cosmopolitan in distribution?

(A) Extreme habitat specialization
(B) K-selected reproductive rate
(C) Limited dispersal abilities
(D) Rarity
(E) Capacity for long-distance dispersal

102. Hybrids between some related species of plants are sterile because the parent plants had different chromosome numbers. Occasionally the chromosome number of such a hybrid plant doubles spontaneously. Which of the following best describes the descendants of those plants with the double chromosome number?

(A) The plant with the double chromosome number would be genetically defective and have no descendants.
(B) The descendants would be at a selective advantage because of the increased ability to introgress.
(C) The descendants would be reproductively successful because they could backcross with the parental species.
(D) The descendants would be at a selective disadvantage because they could not reproduce asexually.
(E) The descendants would regain the ability to reproduce sexually because chromosomes could pair normally.

103. The concept of punctuated equilibrium refers to

(A) oscillating ecological successional stages
(B) ecological succession arrested by sudden environmental changes, e.g., fire
(C) persistent predator-prey relationships in relatively stable environments
(D) bursts of speciation followed by relatively unchanging lineages
(E) erratic gene-frequency changes due to genetic drift
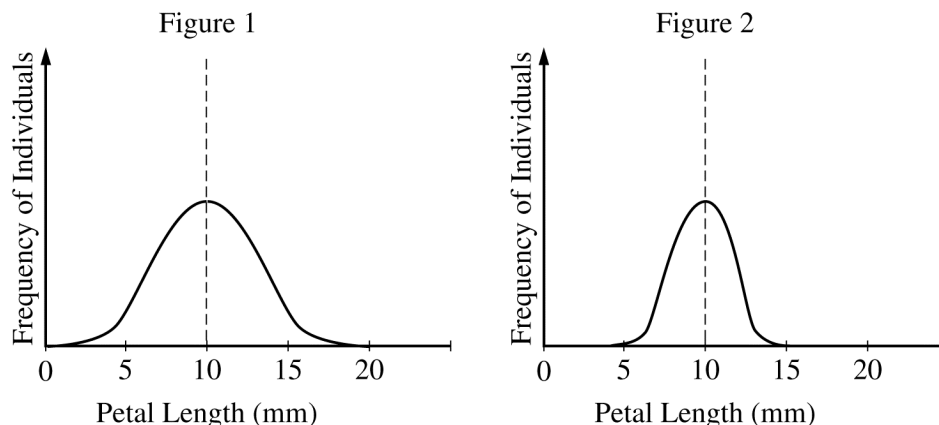
Figure 1

Figure 2

104. A plant species arrives at an island for the first time, where it is exposed to a new set of pollinators. Over the course of 20 generations, the characteristics of its flowers change. The figures above show the frequency distribution of petal length in the original colonizing population (Figure 1) and 20 generations later (Figure 2).

Which of these explanations is consistent with the observed change in petal length?

(A) Island pollinators prefer flowers with longer petals.
(B) Island pollinators avoid flowers with extremely long or extremely short petals.
(C) Island pollinators avoid flowers with average petal lengths.
(D) Island pollinators prefer flowers with shorter petals.
(E) Island pollinators do not discriminate among flowers on the basis of petal length.

105. In which of the following populations would the rate of evolution due to random genetic drift be the <u>lowest</u>? (Assume the total number of individuals is the same across populations.)

(A) There are more females than males; there is no difference in reproductive success within each sex.
(B) The numbers of males and females are equal; there is no difference in reproductive success within each sex.
(C) There are fewer females than males; there is no difference in reproductive success within each sex.
(D) The numbers of males and females are equal; a few dominant males get most matings in each generation.
(E) The numbers of males and females are equal; a few dominant females produce more progeny in each generation.

106. In one taxonomic classification, Archaea, Eukarya, and Bacteria represent the three major domains of life. Eukarya utilize the general transcription factors TBP (TATA-binding protein) and TFIIB in transcription, whereas Bacteria do not. At least one member of Archaea has a protein similar to TBP and a protein similar to TFIIB. Based on this observation, which of the following scenarios is most likely?

(A) Archaea and Eukarya diverged after their common ancestor diverged from Bacteria.
(B) Archaea and Bacteria diverged after their common ancestor diverged from Eukarya.
(C) Bacteria and Eukarya diverged after their common ancestor diverged from Archaea.
(D) Archaea, Eukarya, and Bacteria diverged simultaneously from a common ancestor.
(E) Archaea, Eukarya, and Bacteria each evolved from different ancestral organisms.

107. According to Hamilton's rule, an altruistic trait can evolve if $c < br$, where c is the fitness cost of the altruistic behavior to the donor, b is the fitness benefit to the recipient, and r is the

(A) coefficient of relatedness
(B) frequency of the altruistic allele
(C) inbreeding coefficient
(D) rate of reciprocity
(E) return on investment
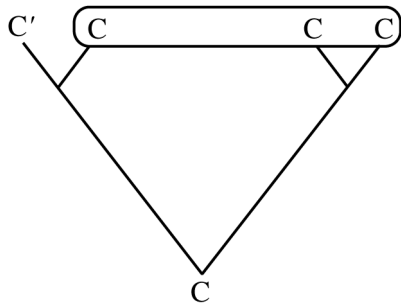
108. In the phylogenetic tree above, the grouping that is based on the presence of character C is

(A) monophyletic
(B) paraphyletic
(C) derived
(D) a deme
(E) convergent

109. RNA is thought to have played an important role in the evolution of life for which of the following reasons?

   I. It occurred in great quantities on early Earth.
  II. It can self-replicate via a complementary chain.
 III. It can catalyze some cellular functions.

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

110. In a given population, 1 out of every 400 people has a cancer caused by a completely recessive allele, b. Assuming the population is in Hardy-Weinberg equilibrium, which of the following is the expected proportion of individuals who carry the b allele but are not expected to develop the cancer?

(A) 1/400
(B) 19/400
(C) 20/400
(D) 38/400
(E) 380/400

111. Which of the following occurred first during the separation of the elements of Pangaea through continental drift?

(A) Gondwana and Laurasia were formed.
(B) Africa separated from South America.
(C) India collided with Eurasia to form the Himalayan mountain chain.
(D) Australia separated from the rest of the continental landmasses.
(E) Antarctica assumed its current position at the South Pole.

112. Which of the following facts was established prior to 1859, the year in which Charles Darwin published *On the Origin of Species* ?

(A) DNA provides the macromolecular basis of heredity.
(B) Mendelian principles explain why some traits are dominant and others are recessive.
(C) Prokaryotes include two major domains, the Bacteria and the Archaea.
(D) The age of Earth is more than 4 billion years.
(E) There exist fossilized remains of species that have become extinct.

- A terminal extracellular respiratory electron acceptor in some archaea and bacteria

- A major component of Precambrian banded rock formations that are thought to be linked to the rise of atmospheric oxygen

- A major redox component of both chloroplast and mitochondrial electron transport chains

113. Which of the following chemical elements is best characterized by the above set of statements?

   (A) Magnesium
   (B) Carbon
   (C) Sulfur
   (D) Iron
   (E) Phosphorus

114. Which of the following is the best explanation for why net primary productivity in terrestrial ecosystems tends to increase toward the tropics?

   (A) The higher species diversity in the tropics tends to increase plant growth.
   (B) There are lower metabolic costs to plant growth in the tropics.
   (C) The availability of water and warm temperatures in the tropics fosters photosynthesis.
   (D) The tropics have more predators that minimize herbivory.
   (E) The tropics have a greater availability of newly weathered inorganic nutrients.

115. Which of the following adaptations would limit pollination by bees and promote hummingbird pollination?

   (A) Patterns of ultraviolet color on the petals
   (B) Modified petals to provide a landing space
   (C) Pendant (hanging) red-colored flowers
   (D) Nectar with high sugar concentration produced in limited amounts
   (E) Upright petals fused to form a nectar cup

116. In the formation of the earliest cells, which of the following components most likely arose first?

   (A) Nucleus
   (B) Plasma membrane
   (C) Mitochondrion
   (D) Flagellum
   (E) Lysosome

117. Which of the following statements about excretory organs is true?

   (A) The kidneys of saltwater fishes produce urine hyperosmotic to their tissues.
   (B) The kidneys of desert mammals produce urine that is hypoosmotic to the urine of freshwater fishes.
   (C) Malpighian tubules allow insects to excrete waste through the exoskeleton.
   (D) Juxtamedullary nephrons in the mammalian kidney allow the organism to produce hyperosmotic urine.
   (E) Metanephridia are excretory organs that allow planaria to filter coelomic fluid.

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

Questions 118-119 refer to the following amounts of DNA found in human cell types. The amounts are indicated relative to the amount of DNA (X) found in mature neurons that are in the G_0 stage of the cell cycle.

(A) 4X
(B) 2X
(C) 1.5X
(D) 1X
(E) 0.5X

118. Amount of DNA found in a mature spermatozoan

119. Amount of DNA in a skin cell in G_2 of the cell cycle

Questions 120-122 refer to the following.

(A) Peptide hormone
(B) Prohormone
(C) Phospholipase C
(D) Steroid hormone
(E) Active G protein

120. Has relatively little biological activity

121. Binds to adenylate cyclase

122. Readily traverses cell membranes

Questions 123-125 refer to the following components of the *lac* operon in bacteria.

(A) cAMP–CAP complex
(B) Operator
(C) Promoter
(D) *lac Z*
(E) *lac I*

123. Is bound by repressor protein

124. Contains binding site for RNA polymerase

125. Encodes repressor protein

Questions 126-129 refer to the following graph.
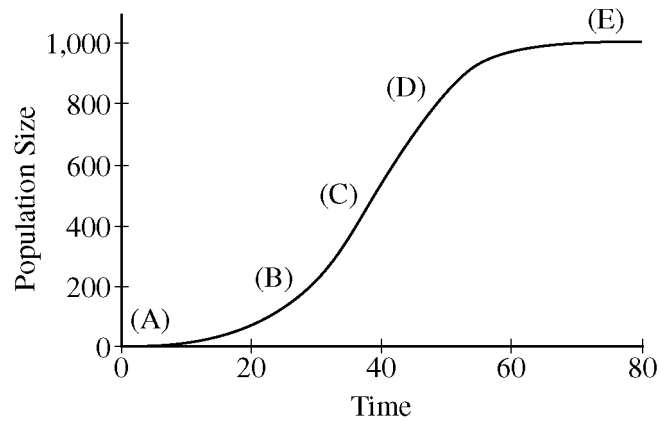
126. Rate of population growth is highest.

127. Per capita growth rate is highest.

128. Both population and per capita growth rates are positive but decelerating.

129. Population size is nearest to carrying capacity.

Questions 130-132 refer to the following.

    (A) Actin
    (B) Tubulin
    (C) Calmodulin
    (D) Fibronectin
    (E) Troponin

130. Bipolar-filament-forming protein that binds and hydrolyzes GTP

131. Major cytoskeletal protein in microvilli, filopodia, contractile rings, and growth cones

132. Calcium-binding switch protein in vertebrate skeletal muscle fibers

Questions 133-136 refer to the following functions.

    (A) Respiration
    (B) Support
    (C) Locomotion
    (D) Feeding
    (E) Excretion

133. Radula of molluscs

134. Spicules of sponges

135. Nematocysts of cnidarians

136. Tracheae of insects

Questions 137-140 refer to the following.

    (A) Biome
    (B) Community
    (C) Ecosystem
    (D) Metapopulation
    (E) Population

137. A group of potentially interbreeding individuals present at the same location

138. A group of potentially interacting species present at the same location

139. A large geographical area characterized by its dominant form of vegetation

140. All organisms and their nonliving environment present at the same location

Questions 141-143 refer to the following diagram of a replication fork.
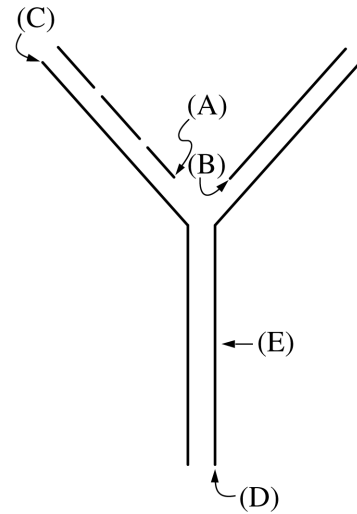
141. Location of RNA primer

142. Location of DNA polymerase

143. Location of DNA with a free 3′ OH

Directions: Each group of questions below concerns a laboratory or an experimental situation. In each case, first study the description of the situation. Then choose the one best answer to each question and fill in completely the corresponding space on the answer sheet.

Questions 144-147

TATA-binding protein (TBP) is a key transcription factor in eukaryotes. A schematic representation of the 240-amino acid TBP of yeast is shown in Figure 1 below, with the positions of two mutations indicated. The boxed area represents the evolutionarily conserved C-terminal domain of TBP, and the shaded (dark) regions of this domain represent two repeated elements involved in DNA binding. One mutation (P65S) changes proline 65 to serine, and the other (I143N) changes isoleucine 143 to asparagine.

Figure 1

P65S   I143N

1   240

Figure 2 below represents autoradiographs of gels containing RNA transcripts produced in extracts of wild-type or mutant cells. Lanes 1–2 are from wild-type yeast (WT), lanes 3–4 are from the I143N mutant, and lanes 5–6 are from the P65S mutant, as indicated. Figure 2A shows transcripts of a gene transcribed by RNA polymerase I (Pol I). Figure 2B shows transcripts of a gene transcribed by RNA polymerase II (Pol II). Figure 2C shows transcripts of a gene transcribed by RNA polymerase III (Pol III). Lanes 1, 3, and 5 show transcripts produced at 24°C, and lanes 2, 4, and 6 show transcripts produced at 37°C. Shading of the bands represents signals of different intensity.

Figure 2

                    1   2   3   4   5   6

(A) Pol I

(B) Pol II

(C) Pol III

                  24° 37° 24° 37° 24° 37°
                   WT   I143N   P65S
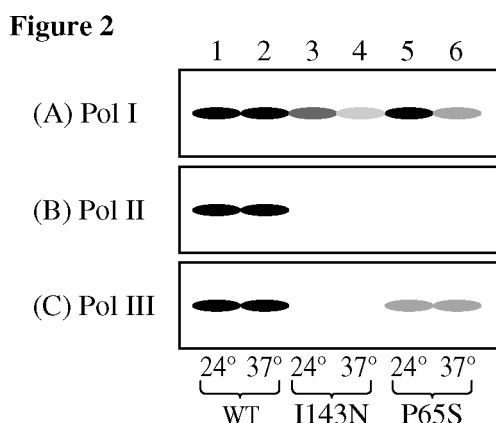
144. As a control, wild-type TBP was added to mutant extracts prior to transcription analysis. It was observed that wild-type TBP could restore transcription by all three RNA polymerases in mutant extracts. The controls were performed in order to check

(A) whether mutant transcription phenotypes are due to perturbation of TBP function
(B) for equivalent RNA levels in all lanes
(C) the specific activity of RNA polymerase
(D) for differential TBP activity in promoters of different genes
(E) whether mutant transcription phenotypes are temperature sensitive

145. Which of the following conclusions about mutations in TBP is most consistent with the data?

(A) The I143N mutation affects transcription of pol II genes in a temperature-sensitive manner.
(B) The P65S mutation affects transcription of pol II genes in a temperature-sensitive manner.
(C) The P65S mutation affects transcription of pol I genes in a temperature-sensitive manner.
(D) Transcription of pol I, pol II, and pol III genes is equally sensitive to TBP mutations.
(E) TBP function is noticeably resistant to mutation.

146. The 5S rRNA gene is transcribed by RNA polymerase III. If transcription of 5S rRNA is assayed as above, more 5S rRNA transcription would be found

(A) in extracts from the I143N mutant than in extracts from wild-type
(B) at $37°C$ than at $24°C$ in I143N mutant extracts
(C) at $37°C$ than at $24°C$ in P65S mutant extracts
(D) in both wild-type and mutant extracts, relative to a pol I transcribed gene
(E) in extracts from the P65S mutant than in extracts from the I143N mutant

147. Which of the following conclusions about TBP is most consistent with the data?

(A) TBP binds exclusively to the TATA box of eukaryotic promoters.
(B) TBP is important in regulating transcription from pol II genes exclusively.
(C) DNA binding is essential for TBP function.
(D) TBP is required for transcription of genes transcribed by pol I, pol II, and pol III.
(E) The action of wild-type TBP is temperature sensitive.

Bromodeoxyuridine (BrdU) is used to label cells in the S phase of the cell cycle. Lobsters were exposed to BrdU during six 4-hour periods during the 24-hour day. The number of labeled neurons in the brain was counted for each 4-hour labeling period, and the means of these counts were plotted as histograms relative to time of day for animals maintained on the normal light/dark cycle (Figure 1: Normal LD) and on the reversed light/dark cycle (Figure 2: Reversed LD). The shaded bars indicate the sampling period at dawn and dusk, which also are shown in the table below. The horizontal bar at the top of the graph indicates illumination conditions (white = light; black = dark; arrows = subjective dusk). The dawn/dusk data for LD and DD (dark/dark conditions) are summarized in Table 1 below.

Figure 1. Normal LD
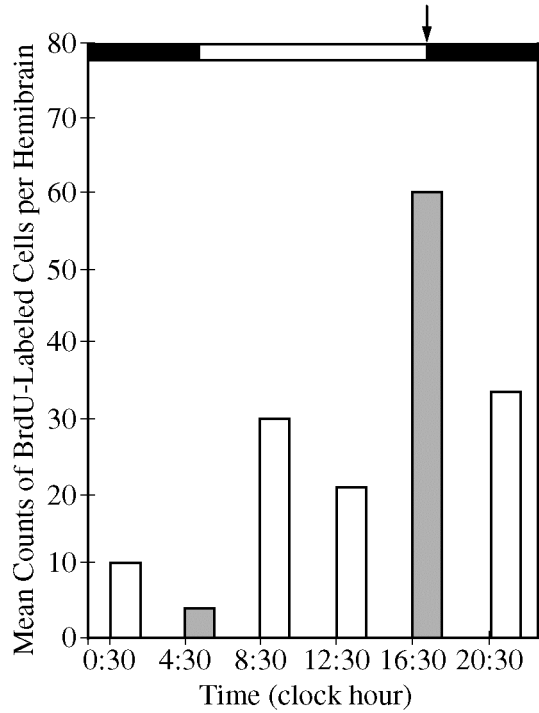
Figure 2. Reversed LD
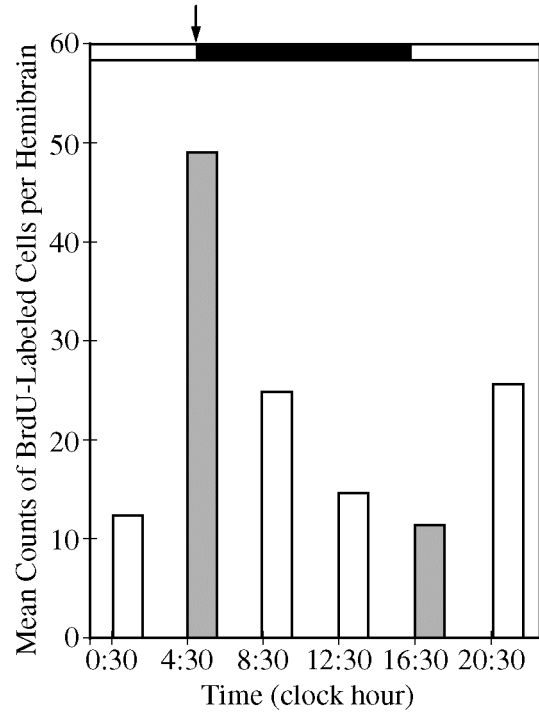
Table 1

Treatment	Light Condition 6:00 18:00	Mean Counts (4:30–7:30)	Mean Counts (16:30–19:30)
Normal LD		4.2	59.9
Normal DD		2.3	48.5
Reversed LD		49.4	11.8
Reversed DD		51.0	12.0

Normal DD: two weeks in normal LD conditions followed by three days in constant darkness.
Reversed DD: two weeks in reversed LD conditions followed by three days in constant darkness.

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148. The graphs of mean counts of BrdU-labeled neurons proliferating at different times of day in the lobster brain demonstrate that

(A) neurons proliferate at the same rate throughout a 24-hour period
(B) the greatest number of neurons proliferate at 16:30–19:30 clock hour
(C) the greatest number of neurons proliferate at 4:30–7:30 clock hour
(D) the greatest number of neurons proliferate at subjective dusk
(E) the greatest number of neurons proliferate at subjective dawn

149. The graphs demonstrate that the proliferation of new neurons is entrained by

(A) the clock hour
(B) when the animals feed
(C) the light/dark cycle
(D) temperature
(E) the relative amount of BrdU available

150. Which of the following is best supported by the data when lobsters are exposed to a normal LD cycle followed by constant darkness for three days (normal DD) ?

(A) Neuronal proliferation stops.
(B) Neuronal proliferation increases.
(C) Neuronal proliferation is greater at the time of subjective dusk.
(D) Neuronal proliferation is greater during the middle-of-the-night period.
(E) Neuronal proliferation is the same throughout the period of constant darkness.

151. These experiments demonstrate that neurogenesis in the lobster brain is controlled by

(A) the time of day
(B) diurnal hormonal variations
(C) seasonal factors, such as photoperiod and temperature
(D) BrdU, light, and the clock hour
(E) an endogenous clock that is entrained by the light/dark cycle

Questions 152-155

Plant species S is pollinated primarily by hummingbirds, whereas bees are the main pollinators of closely related species T. A study was performed to identify which floral traits influence visitation by the two pollinators. Several hundred F_2 hybrids of species S and T were produced in a greenhouse and then planted into a suitable habitat frequented by both hummingbirds and bees. For each individual F_2 plant, the investigators measured pollinator visitation rates as a function of carotenoid pigment concentration in the petals (Figure 1) and nectar volume per flower (Figure 2). In addition the investigators identified each plant's genotype at the *car* genetic locus, which influences pigmentation. The *car* genetic locus has three alleles, c^1, c^2 and c^3, as shown in Figure 3.
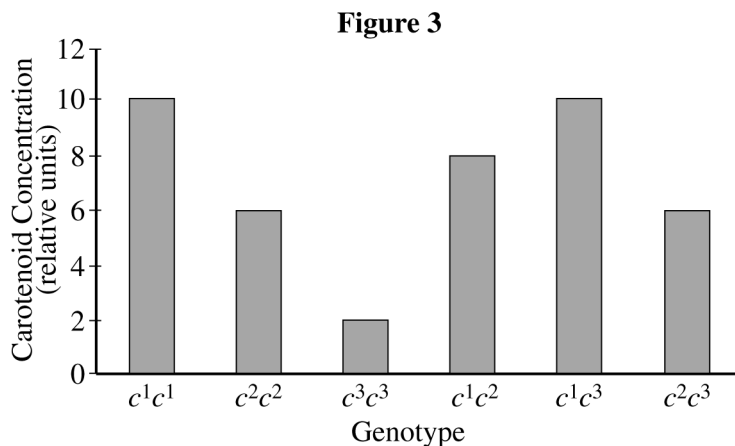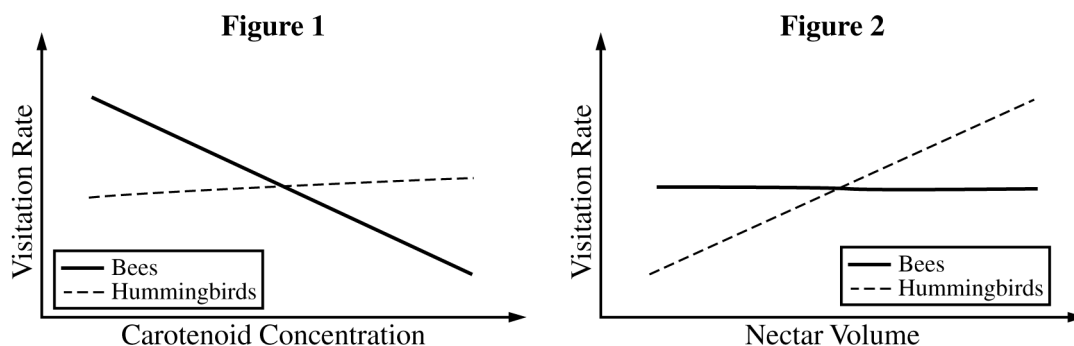
Figure 1

Figure 2

Figure 3

152. Which of the following statements agrees with the data shown in Figures 1 and 2 ?

   (A) Both bee and hummingbird visitation rates are positively correlated with carotenoid concentration.
   (B) Both bee and hummingbird visitation rates are negatively correlated with carotenoid concentration.
   (C) Only the bee visitation rate is positively correlated with carotenoid concentration.
   (D) Both bee and hummingbird visitation rates are positively correlated with nectar volume.
   (E) Only the hummingbird visitation rate is positively correlated with nectar volume.

153. Which statement accurately describes the dominance relationship between one pair of alleles at the *car* locus with respect to carotenoid concentration?

   (A) Allele c^1 is dominant to allele c^2.

   (B) Alleles c^1 and c^2 exhibit incomplete dominance.

   (C) Alleles c^1 and c^3 exhibit incomplete dominance.

   (D) Alleles c^2 and c^3 exhibit incomplete dominance.

   (E) Allele c^3 is dominant to allele c^2.

154. If plant fitness increases linearly with pollinator visitation rate and the two animal species are equally effective pollinators, which genotype at the *car* locus would be expected to be most common in plant species T ?

   (A) c^1c^1
   (B) c^2c^2
   (C) c^3c^3
   (D) c^1c^2
   (E) c^2c^3

155. An isolated population of hybrids between species S and T is discovered in an area where hummingbirds have recently gone extinct but bees remain. Assuming these conditions persist, which of the following evolutionary changes is most likely to occur during the next few hundred generations?

   (A) Average nectar volume will increase.
   (B) Average carotenoid concentration will increase.
   (C) Average carotenoid concentration will decrease.
   (D) Allele c^1 will increase in frequency.
   (E) Allele c^3 will decrease in frequency.

A comparative study of insulins from a bird (turkey), two mammals (pig and guinea pig), and a fish (bonito) was undertaken to assess the relative biological activity of the hormone. The hormone's ability to stimulate glucose oxidation (and hence, uptake and metabolism) was assayed in isolated fat cells from rats. Identical populations of fat cells were suspended in media containing radioactive glucose (^{14}C-glucose) and different concentrations of each insulin. Their production of radioactive carbon dioxide ($^{14}CO_2$) was then measured for a fixed period of time and the data were expressed as percentages of the maximum value observed for pig insulin. The percentages are plotted in the figure below as a function of the log of the insulin concentration. The resulting plot for each hormone is called a dosage-response curve.
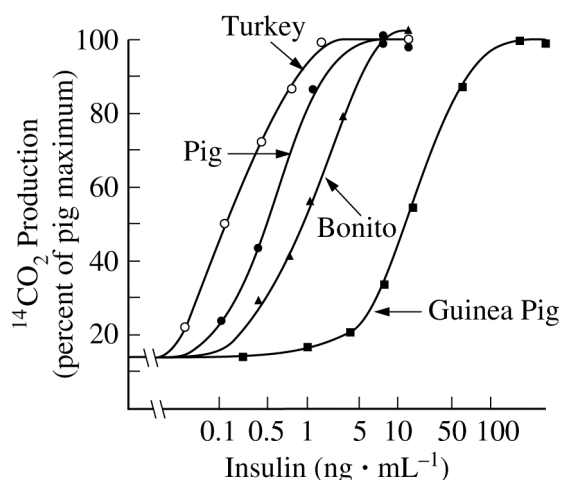
156. What concentration of pig insulin produced a half-maximal effect on glucose oxidation?

(A) 0.1 ng · mL^{-1}
(B) 0.5 ng · mL^{-1}
(C)   1 ng · mL^{-1}
(D) 10 ng · mL^{-1}
(E) The value cannot be determined from the data.

157. The four insulins differ in their ability to stimulate glucose oxidation. In spite of this difference, the hormones may be equally effective in the species from which they were obtained. Which of the following best tests this hypothesis?

(A) Repetition of the experiment to check its validity
(B) An assay of the biological activities of all four insulins on fat cells isolated from the four species
(C) Dosage-response measurements of the four insulins on rat cells from such other insulin-sensitive tissues as liver and muscle
(D) Determination of the binding affinities of the four insulins to plasma membranes isolated from rat fat cells
(E) Direct comparison of the DNA sequences of insulin genes cloned from the four species

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158. In this study, the dosage-response curve of turkey insulin lies to the left of those generated by the other vertebrate insulins. An identical result was obtained for turkey insulin in several other comparative assays of biological activity. Which of the following provides the best explanation for the relative position of the dosage-response curve of turkey insulin?

(A) Turkeys metabolize glucose less rapidly than do other vertebrates.
(B) Differences in the base sequence of the turkey insulin gene increase the hormone's ability to bind to insulin receptors at lower concentrations.
(C) Turkey insulin stimulates gene activity more effectively than does that from other species.
(D) Nonavian vertebrates metabolize glucose less rapidly than do turkeys.
(E) Turkeys have higher levels of insulin circulating in their blood than do other vertebrates.

159. Above 5 ng $\cdot$ mL^{-1}, pig insulin exerted no further effect on glucose oxidation. Which of the following best explains this result?

(A) Levels of insulin above 5 ng $\cdot$ mL^{-1} are toxic to rat fat cells.
(B) Such levels exceed the pig's capacity to synthesize and secrete insulin.
(C) At this level all insulin receptors in rat fat cells are bound to the hormone.
(D) Above this level insulin degrades itself in an autocatalytic manner.
(E) Rat fat cells show no response to insulin in concentrations greater than 5 ng $\cdot$ mL^{-1}.

Questions 160-162 refer to the following experiment.

The graph below shows the metabolic rate of a small fish over a wide range of water temperatures while the fish is swimming at maximal sustainable speed (curve *A*) and while at rest (curve *B*).
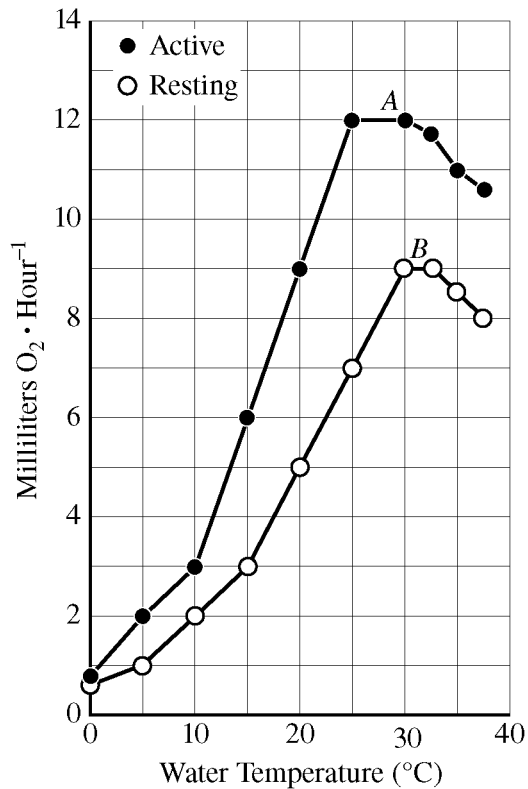
160. At which of the following water temperatures is the resting metabolism of the fish maximal?

 (A) 0°C
 (B) 10°C
 (C) 20°C
 (D) 30°C
 (E) 40°C

161. Endurance is often related to the amount by which metabolic rate can be elevated. On the basis of this assumption, at what temperature would the fish be expected to have the greatest endurance?

 (A)   5°C
 (B) 15°C
 (C) 25°C
 (D) 30°C
 (E) 35°C

162. The Q_{10} for resting metabolism between 10°C and 20°C is

 (A) 2.0
 (B) 3.0
 (C) less than for active metabolism between 10°C and 20°C
 (D) the same as for active metabolism between 10°C and 20°C
 (E) the same as for resting metabolism between 30°C and 35°C

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Biologists performed an experiment with flies to examine the effects of population size on the maintenance of genetic variation and on egg-to-adult survival. From a large source population, they randomly assigned eggs to three experimental populations of size N, equal to 20, 60, and 100. For later generations, they collected N eggs from each population and moved them into identical vials that contained fresh medium. They counted the number of adult flies that emerged and used tissue samples from the adults for genetic analyses. Genetic variation was measured by scoring alleles at several polymorphic loci and expressed as the average number of alleles at those loci. The results are summarized in Figure 1 and Figure 2 below.

Figure 1. Genetic Variation

Figure 2. Egg-to-Adult Survival
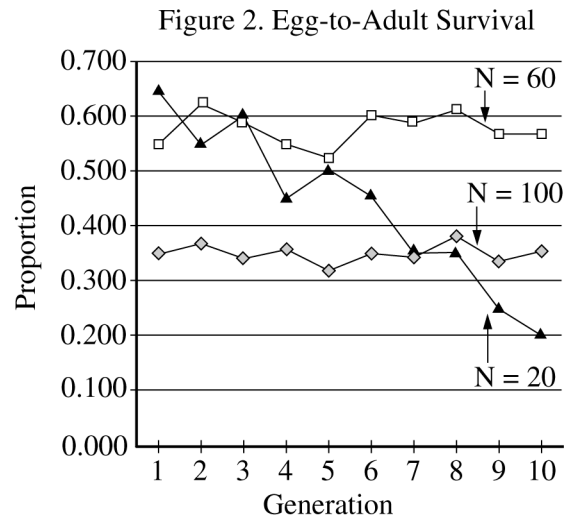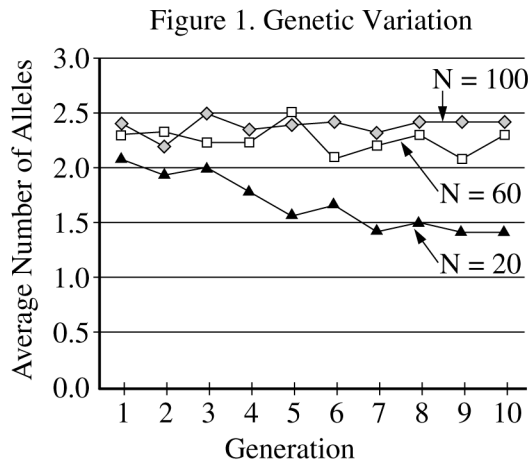
163. Based on Figure 1, which of the following best describes the change in genetic variation over time?

   (A) It increased in all three populations.
   (B) It was unchanged in the largest population and increased in the two smaller populations.
   (C) It was unchanged in all three populations.
   (D) It was unchanged in the two larger populations and declined in the smallest population.
   (E) It declined in all three populations.

164. Which process best explains the dynamics of genetic variation observed in this experiment?

   (A) Genetic drift
   (B) Linkage disequilibrium
   (C) Mutation
   (D) Segregation distortion
   (E) Selection

165. The numbers of adult flies that emerged from the three populations in the first generation are closest to which of the following?

	N = 100	N = 60	N = 20
(A)	35	33	13
(B)	35	55	20
(C)	35	60	50
(D)	65	55	35
(E)	100	60	20

166. Which other process appears to have substantially influenced the outcome of this experiment?

   (A) Density-dependent survival
   (B) Frequency-dependent fecundity
   (C) Niche partitioning
   (D) Spatial heterogeneity
   (E) Temporal variability

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Two action potentials are portrayed in the figure below. The solid line is an intracellular recording from a motor neuron (neuron A) in the spinal cord of a frog. The broken line is a recording from a sensory neuron (neuron B) in the same animal.
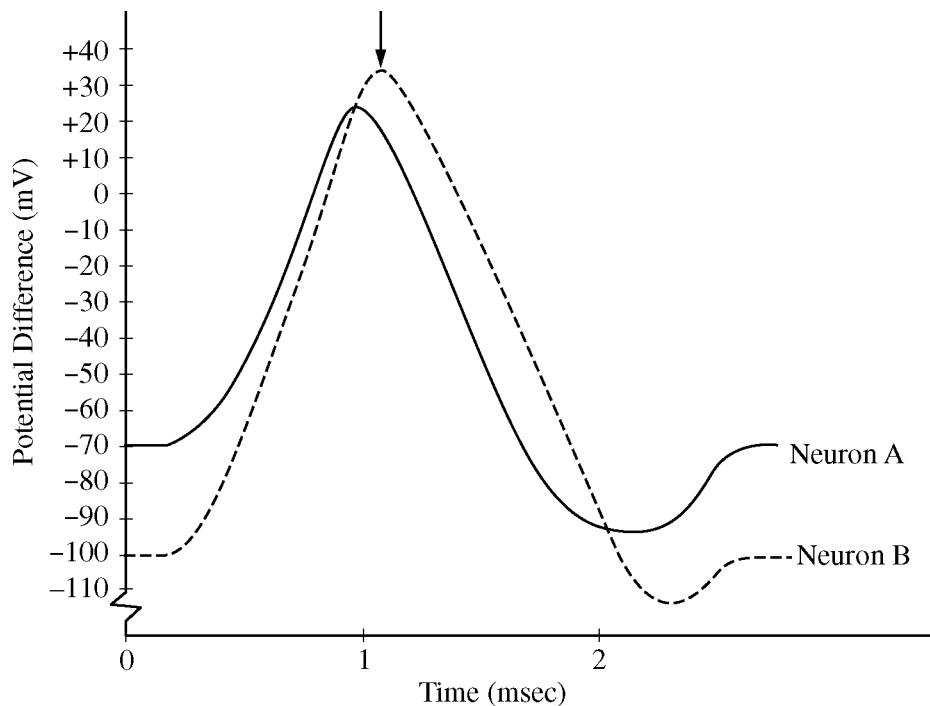
167. At time = 0, relative to neuron A, neuron B is

    (A) hypopolarized
    (B) depolarized
    (C) hyperpolarized
    (D) nonpolarized
    (E) polarizing

168. At time = 0, which of the following exerts the predominant influence on the membrane potential?

    (A) The chloride leakage current
    (B) The free diffusion of sodium
    (C) The potassium rectifier current
    (D) The potassium leakage current
    (E) The lack of ion movement

169. The change in polarization of neuron B between time = 0 and time = 1 is due to which of the following?

    (A) Only potassium leak channels are open.
    (B) Only sodium channels are closed.
    (C) Sodium channels and potassium leak channels are open.
    (D) The sodium-potassium pump is activated.
    (E) Calcium channels are closed in addition to the few sodium channels that are already closed.

170. Which of the following best describes the ionic currents at the peak (see arrow) of the action potential for neuron B?

    (A) The outward sodium current is greater than the inward potassium current.
    (B) The outward potassium current is equal to the inward sodium current.
    (C) The inward chloride current is equal to the inward sodium current.
    (D) The outward calcium current is greater than the inward sodium current.
    (E) The inward sodium current is equal to the outward chloride current.

Questions 171-173

Cardiac output, the volume of blood pumped per minute by the heart, is the product of stroke volume (SV) and heart rate (HR); that is, **CO = SV × HR.**

Heart rate can be measured directly, and cardiac output is obtained by the Fick method using the equation **CO = $\dot{Q}$/(A−V)**, where $\dot{Q}$ = the oxygen consumed (mL · min^{-1}) and A−V = the difference in oxygen content between arterial blood and venous blood. Given values for HR and CO, stroke volume is subsequently calculated.

The following data were collected before and during vigorous human exercise.

Parameter	At Rest	During Exercise
Oxygen consumption ($\dot{Q}$)	250 mL · min^{-1}	1500 mL · min^{-1}
A−V difference	50 mL O$_2$ per liter of blood	150 mL O$_2$ per liter of blood
Heart rate (HR)	60 beats · min^{-1}	120 beats · min^{-1}

171. Based on the data, during exercise cardiac output increased by a factor of approximately

   (A) 1.5
   (B) 2
   (C) 3
   (D) 6
   (E) 10

172. Based on the data, which of the following best describes how stroke volume changes during exercise?

   (A) It decreases by a factor of 4.
   (B) It decreases by a factor of 2.
   (C) It increases by a factor of 2.
   (D) It increases by a factor of 4.
   (E) It remains unchanged.

173. Based on the data, it can be concluded that increased cardiac output during exercise is primarily a function of an increase in which of the following?

   I. Heart rate
   II. Stroke volume
   III. Peripheral resistance

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

Questions 174-176

The figure below represents a temporal plot of recorded breeding activities of both allopatric and sympatric populations of three related species of *Rana* (leopard frog). *Rana* males attract females by vocalizing. The key quantifies numbers of observed breeding records for each population.

Month

J F M A M J J A S O N D

Allopatric populations
  Rana berlandieri
  Rana blairi
  Rana sphenocephala

Sympatric populations
  Rana berlandieri
  Rana blairi
  Rana sphenocephala

Key:
—— Scattered breeding records
━━ 3–5 breeding records
━━ 6–10 breeding records
▬▬ >10 breeding records
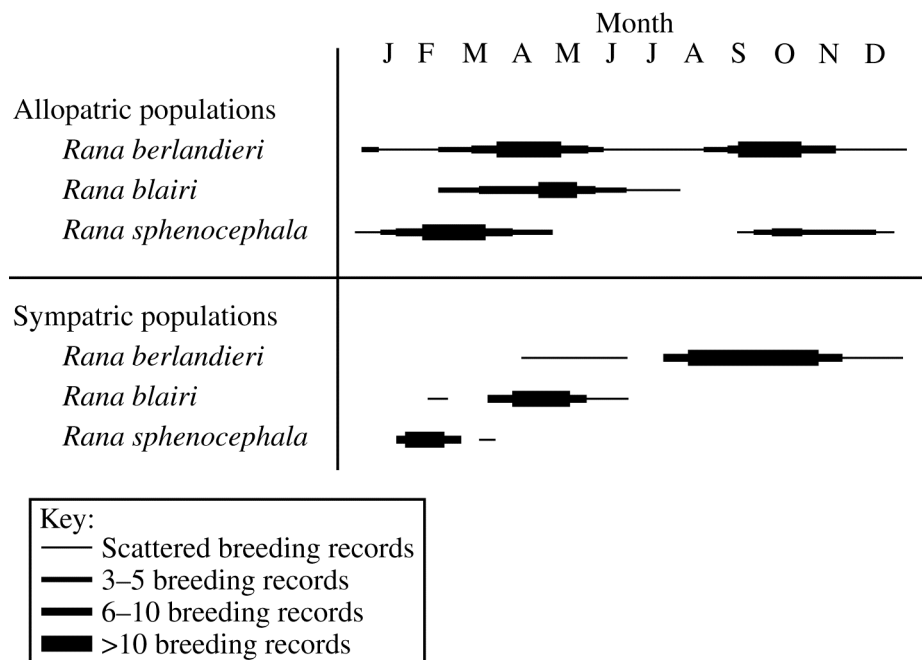
174. Which of the following is correct based on the data?

(A) Sympatric populations of *R. berlandieri* have expanded their breeding seasons compared with allopatric populations.
(B) Sympatric populations of *R. sphenocephala* have expanded their breeding seasons compared with allopatric populations.
(C) Sympatric populations of all three species have reduced the overlap of their breeding seasons compared with allopatric populations.
(D) Allopatric populations of all three species have largely nonoverlapping breeding seasons.
(E) The breeding seasons of allopatric and sympatric populations of all three species are similar.

175. Based on the data, which of the following inferences is most likely correct?

(A) Interspecific hybrids are fertile only in areas of sympatry.
(B) The mating calls of the three species are very similar.
(C) The sympatric populations of the three species are more morphologically divergent than the allopatric populations.
(D) The sympatric populations of the three species are more genetically divergent than the allopatric populations.
(E) The allopatric populations of *Rana* are parthenogenetic.

176. The data suggest that when the three *Rana* species occur sympatrically they exhibit which of the following?

(A) Prezygotic reproductive isolation
(B) Cytogenetic incompatibility
(C) Convergent evolution
(D) Postzygotic reproductive isolation
(E) Sympatric hybridization

Questions 177-179

The graph above represents the relationship among serum concentrations of human immunodeficiency virus (HIV) RNA, anti-HIV antibody, and CD4$^+$ and CD8$^+$ T cells over a 10-year period following infection of an individual by the virus, with resulting disease.

177. What is the primary explanation for the drop in HIV concentration during the 6- to 12-week period following infection?

   (A) The virus undergoes rapid mutation.
   (B) The immune system eliminates most of the virus.
   (C) The rate of viral replication accelerates.
   (D) Cells encapsulate the viruses, thus protecting them from the immune system.
   (E) The viruses enter cells and therefore are not measurable.

178. Based on the data, during which time period is an individual infectious?

   (A) Only during the initial increase in HIV concentration
   (B) Only when the concentration of CD8$^+$ T cells is in decline
   (C) Only when the concentration of anti-HIV antibody peaks
   (D) Starting at year 1 after infection
   (E) Throughout the entire period of infection

179. Which of the following is the best explanation for the gradual rise in HIV concentration after year 1 of infection?

   (A) The host's lymphoid organs have been destroyed by HIV.
   (B) HIV is released from lymphocytes, and CD4$^+$ T cells decrease in number.
   (C) Anti-HIV antibodies no longer recognize the virus.
   (D) HIV has infected brain cells.
   (E) The size of the CD8$^+$ T cell population is decreasing.

GO ON TO THE NEXT PAGE.

Questions 180-181

The following experiment is designed to study the role of several hormones in the regulation of metamorphosis in frogs.

Group #	Treatment	Days to Metamorphosis
1	Saline	30
2	Prolactin	> 100
3	TSH	15
4	Thyroxine	10
5	Corticosterone	30
6	Thyroxine + Corticosterone	5
7	Prolactin + TSH	30
8	Thyroid gland removed	> 100

Groups consisting of 10 frog tadpoles (all in the same developmental stage) were injected with one of several solutions or else had their thyroid glands removed (treatments) and the time until final tail reabsorption was measured. The experiment was terminated at 100 days. The hormones used were from one of three glands: the pituitary gland (prolactin and TSH— thyroid stimulating hormone), the thyroid gland (thyroxine), or the adrenal glands (corticosterone). The only known endogenous action of TSH is to stimulate thyroid gland secretions.

180. If the thyroid gland were removed from the tadpoles in Group 3, metamorphosis would

    (A) occur at 10 days
    (B) occur at 15 days
    (C) occur at 30 days
    (D) occur immediately
    (E) not occur over the course of the experiment

181. These results suggest which of the following about prolactin at the dose tested?

    (A) It promotes metamorphosis.
    (B) It opposes the action of the thyroid gland.
    (C) It has the opposite effect from that of corticosterone.
    (D) It can reverse the effects of thyroid removal in Group 8.
    (E) It can completely block the action of thyroxine and TSH.

Questions 182-185

The MacArthur-Wilson equilibrium model of island biogeography predicts the number of species found on islands. The figure below depicts two volcanic islands located off a section of mainland coast.
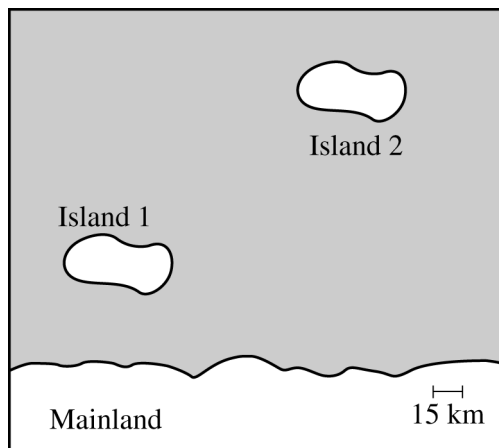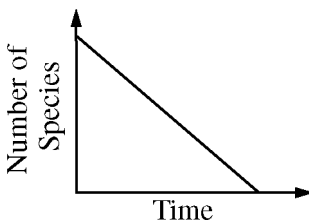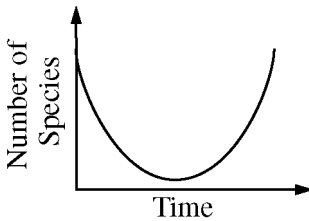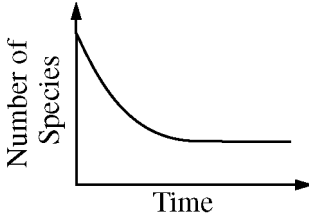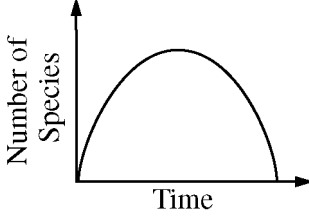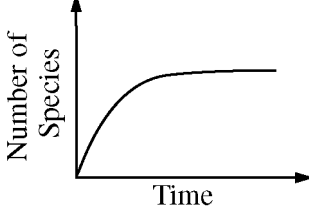
182. The MacArthur-Wilson model predicts that the relative numbers of bird species on the mainland and two islands would be

   (A) Mainland > Island 1 = Island 2
   (B) Mainland > Island 1 > Island 2
   (C) Mainland > Island 2 > Island 1
   (D) Mainland = Island 1 = Island 2
   (E) Island 2 > Island 1 > Mainland

183. According to the MacArthur-Wilson model, how would the number of bird species change from the time of an island's formation (assuming it remains constant in size and isolation) ?

   (A)

   Number of Species / Time

   (B)

   Number of Species / Time

   (C)

   Number of Species / Time

   (D)

   Number of Species / Time

   (E)

   Number of Species / Time

184. According to the MacArthur-Wilson model, the number of bird species present on Island 2 at any one time is a function of the relative rates of

   (A) speciation and extinction
   (B) immigration and local extinction
   (C) competition and predation
   (D) island growth and shrinkage
   (E) stability and disturbance

185. If a drop in sea level led Island 1 to double in area, the MacArthur-Wilson model predicts that the number of bird species found there would

   (A) remain unchanged
   (B) experience an initial sharp increase, then decrease and equilibrate at the previous number of species
   (C) experience an initial sharp decrease, then increase and equilibrate at the previous number of species
   (D) increase and equilibrate at a new, higher number of species
   (E) decrease and equilibrate at a new, lower number of species

Questions 186-188 refer to the following pedigree for the inheritance of a very rare human disease over three generations.

Generation I

Generation II

Generation III

Legend:

○ Unaffected female

● Affected female

□ Unaffected male
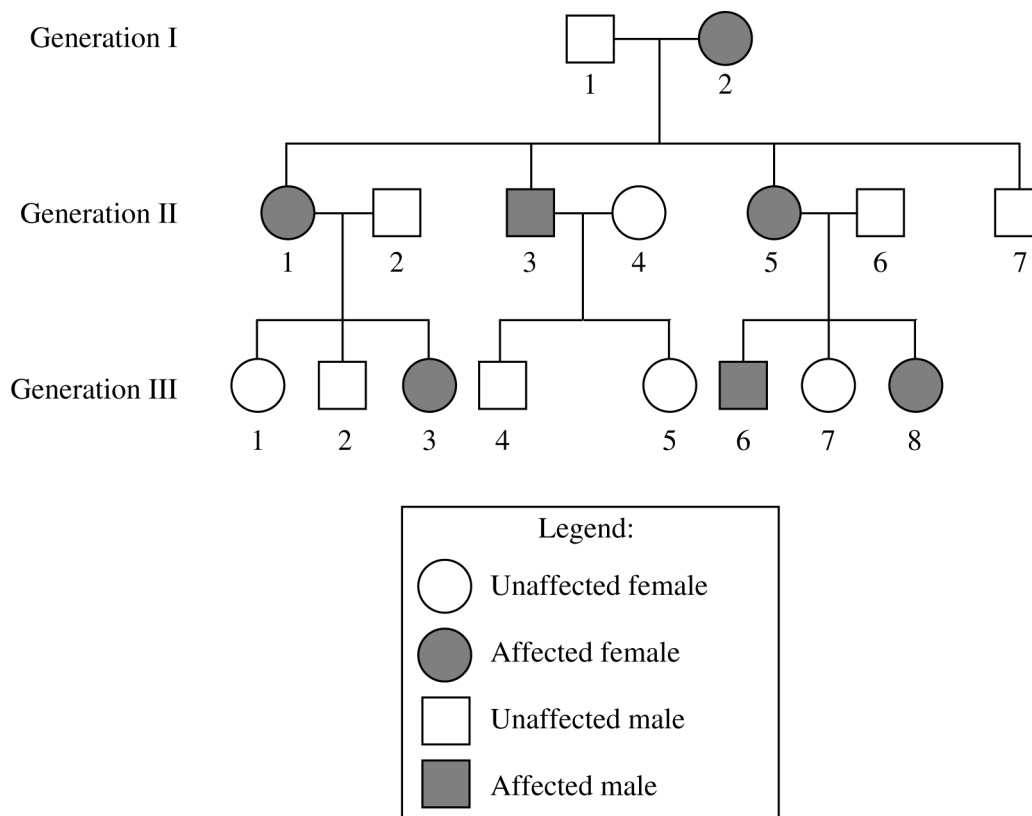
■ Affected male

186. Which of the following is the most likely mode of inheritance for the disease trait?

(A) Cytoplasmic
(B) X-linked recessive
(C) Y-linked dominant
(D) Autosomal dominant
(E) Genetic imprinting

187. If individual III-3 were to have a daughter, what is the probability that the daughter would receive the disease trait from her mother (III-3) ?

(A) 1.00
(B) 0.50
(C) 0.33
(D) 0.25
(E) 0.00

188. If individuals III-3 and III-6 were to produce a son, what is the probability that the son would be affected with the disease?

(A) 1.00
(B) 0.75
(C) 0.50
(D) 0.25
(E) 0.00

According to the ABC model of flower development in *Arabidopsis*, three classes of organ identity genes—designated A, B, and C—are required to specify the identity of floral organs in each whorl of a flower. As shown in the figure below, expression of A class genes alone in the first (outermost) whorl specifies sepals; expression of A and B class genes in the second whorl specifies petals; expression of B and C class genes in the third whorl specifies stamens; and expression of C class genes alone specifies carpels.

A and C class genes restrict each other's expression. Null mutations in A class genes lead to expression of C class genes in all four whorls, whereas null C class mutations result in expression of A class genes in all whorls.

Sepal (Se) Whorl 1   Petal (Pe) Whorl 2   Stamen (St) Whorl 3   Carpel (Ca) Whorl 4

B

A

C
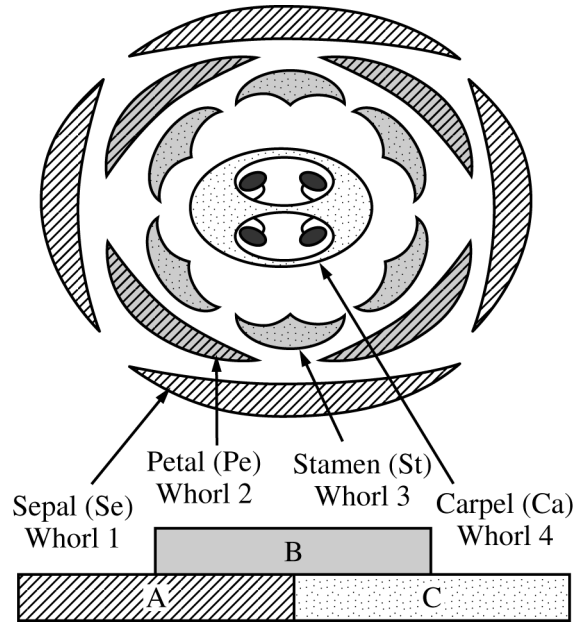
189. If wild type *Arabidopsis* were transformed with a chimeric gene composed of a C class promoter fused to a B class coding sequence, which of the following arrangements (outer to inner) would be predicted?

(A) Se Pe St St
(B) Se Pe Ca Ca
(C) Pe Pe St Ca
(D) Se Se St Ca
(E) Se Pe Pe Ca

190. An *Arabidopsis* line that produced flowers with carpel identity in all four whorls would most likely have mutation(s) in

(A) A class genes only
(B) B class genes only
(C) C class genes only
(D) A and B class genes
(E) A and C class genes

191. According to the ABC model, which of the following arrangements of floral organs (from outermost to innermost whorl) would be predicted for a null mutation in a B class gene?

(A) Se Pe St Ca
(B) Se Se Ca Ca
(C) Pe Pe St St
(D) Se Pe Pe Se
(E) St St Ca Ca

57

Questions 192-194

The following figure is a model of seedling establishment as a function of distance from a parent tree. Initial seed density measures the number of seeds falling to the ground. Seed survivorship measures the proportion of seeds that survive to the adult stage at each distance.
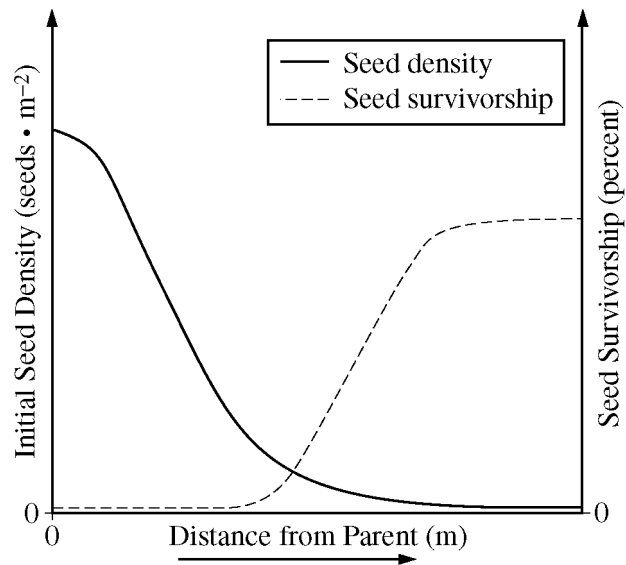
192. This model predicts that recruitment of new individuals into the population should be

(A) highest directly under the parent tree
(B) highest at an intermediate distance from the parent tree
(C) highest far from the parent tree
(D) high directly under the parent tree and far from it, but low at intermediate distances from it
(E) independent of the distance from the parent tree

193. Which of the following factors is most likely to generate the seed density curve shown?

(A) There are no effective seed dispersers of this tree species.
(B) Most seeds fall directly under the parent tree, but some are dispersed away from it.
(C) The seeds are randomly dispersed by wind.
(D) Seed predation is lowest under the parent tree.
(E) The microhabitat is most favorable directly under the parent tree.

194. Which of the following factors is most likely to generate the seed survivorship curve shown?

(A) Seed predation is lowest far from the parent tree.
(B) The best microhabitat for mutualistic seed dispersers is directly under the parent tree.
(C) The best microhabitat for seedling growth is directly under the parent tree.
(D) Many seeds reach the locations where they would have the highest probability of surviving to adulthood.
(E) Seedling competition is most intense at intermediate distances from the parent tree.

If you finish before time is called, you may check your work on this test.

I NOTE: To ensure prompt processing of test results, it is important that you fill in the blanks <u>exactly</u> as directed.

SUBJECT TEST

A. Print and sign your full name in this box:

PRINT: _____

                (LAST)   (FIRST)   (MIDDLE)

SIGN: _____

Copy this code in box 6 on your answer sheet. Then fill in the corresponding ovals exactly as shown.

6. TITLE CODE

| 2 | 4 | 2 | 3 | 6 |

Copy the Test Name and Form Code in box 7 on your answer sheet.

TEST NAME   *Biology*

FORM CODE   *GR1224*

GRADUATE RECORD EXAMINATIONS SUBJECT TEST

B. The Subject Tests are intended to measure your achievement in a specialized field of study. Most of the questions are concerned with subject matter that is probably familiar to you, but some of the questions may refer to areas that you have not studied.

Your score will be determined by subtracting one-fourth the number of incorrect answers from the number of correct answers. Questions for which you mark no answer or more than one answer are not counted in scoring. If you have some knowledge of a question and are able to rule out one or more of the answer choices as incorrect, your chances of selecting the correct answer are improved, and answering such questions will likely improve your score. It is unlikely that pure guessing will raise your score; it may lower your score.

You are advised to use your time effectively and to work as rapidly as you can without losing accuracy. Do not spend too much time on questions that are too difficult for you. Go on to the other questions and come back to the difficult ones later if you can.

YOU MUST INDICATE ALL YOUR ANSWERS ON THE SEPARATE ANSWER SHEET. No credit will be given for anything written in this examination book, but you may write in the book as much as you wish to work out your answers. After you have decided on your response to a question, fill in the corresponding oval on the answer sheet. BE SURE THAT EACH MARK IS DARK AND COMPLETELY FILLS THE OVAL. Mark <u>only one</u> answer to each question. No credit will be given for multiple answers. Erase all stray marks. If you change an answer, be sure that all previous marks are erased completely. Incomplete erasures may be read as intended answers. Do not be concerned that the answer sheet provides spaces for more answers than there are questions in the test.

<u>Example:</u>

What city is the capital of France?

(A) Rome
(B) Paris
(C) London
(D) Cairo
(E) Oslo

<u>Sample Answer</u>

Ⓐ ● Ⓒ Ⓓ Ⓔ   CORRECT ANSWER PROPERLY MARKED

Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ   IMPROPER MARKS
Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ

DO NOT OPEN YOUR TEST BOOK UNTIL YOU ARE TOLD TO DO SO.

ETS Educational Testing Service

Educational Testing Service
Princeton, New Jersey 08541

Worksheet for the GRE Biology Test, Form GR1224
Answer Key and Percentages* of Examinees Answering Each Question Correctly

Question Number	Answer	P+	C	I	1	2	3
1	E	58			•		
2	B	61			•		
3	A	79			•		
4	D	70			•		
5	E	78			•		
6	A	94			•		
7	D	17			•		
8	D	54			•		
9	D	87			•		
10	D	91			•		
11	D	7			•		
12	A	48			•		
13	B	75			•		
14	D	51			•		
15	A	36			•		
16	A	90			•		
17	C	52			•		
18	B	85			•		
19	C	32			•		
20	C	32			•		
21	E	67			•		
22	B	38			•		
23	C	65			•		
24	D	62			•		
25	A	75			•		
26	B	78			•		
27	C	58			•		
28	A	63			•		
29	C	50			•		
30	D	51			•		
31	B	48			•		
32	C	44			•		
33	C	38			•		
34	E	15			•		
35	B	77			•		
36	D	64			•		
37	D	59				•	
38	B	50				•	
39	D	72				•	
40	C	46				•	
41	C	64				•	
42	C	50				•	
43	C	77				•	
44	B	66				•	
45	C	92				•	
46	C	53				•	
47	B	27				•	
48	B	21				•	
49	D	68				•	
50	B	56				•	
51	B	21				•	
52	C	85				•	
53	E	63				•	
54	C	74				•	
55	D	43				•	
56	A	39				•	
57	C	52				•	
58	E	20				•	
59	D	36				•	
60	B	78				•	
61	A	57				•	
62	B	56				•	
63	D	33				•	
64	C	72				•	
65	B	40				•	

Question Number	Answer	P+	C	I	1	2	3
66	C	10			•		
67	D	49			•		
68	D	56			•		
69	C	42			•		
70	B	75			•		
71	C	17			•		
72	B	26			•		
73	D	61			•		
74	D	72			•		
75	D	79			•		
76	A	67			•		
77	A	40			•		
78	D	54			•		
79	B	70				•	
80	B	84				•	
81	E	65				•	
82	E	32				•	
83	B	28				•	
84	A	90				•	
85	C	93				•	
86	B	87				•	
87	E	81				•	
88	E	89				•	
89	D	88				•	
90	D	46				•	
91	A	44				•	
92	E	43				•	
93	B	84				•	
94	B	88				•	
95	C	98				•	
96	D	45				•	
97	A	94				•	
98	E	29				•	
99	B	60				•	
100	D	24				•	
101	E	51				•	
102	E	52				•	
103	D	60				•	
104	B	86				•	
105	B	53				•	
106	A	87				•	
107	A	57				•	
108	B	66				•	
109	E	54				•	
110	D	37				•	
111	A	54				•	
112	E	64				•	
113	D	30				•	
114	C	76				•	
115	C	39				•	
116	B	78				•	
117	D	18					•
118	E	64			•		
119	B	71			•		
120	B	52				•	
121	E	48				•	
122	D	65				•	
123	B	47			•		
124	C	74			•		
125	E	40			•		
126	C	89					•
127	A	8					•
128	D	82					•
129	E	95					•
130	B	33					•

Question Number	Answer	P+	C	I	1	2	3
131	A	59			•		
132	E	67			•		
133	D	42				•	
134	B	42				•	
135	D	43				•	
136	A	84				•	
137	E	88					•
138	B	88					•
139	A	83					•
140	C	81					•
141	A	63			•		
142	B	66			•		
143	B	31			•		
144	A	51			•		
145	C	76			•		
146	E	71			•		
147	D	53			•		
148	D	80				•	
149	C	88				•	
150	C	58				•	
151	E	80				•	
152	E	95					•
153	B	75					•
154	C	72					•
155	C	83					•
156	B	73			•		
157	B	76			•		
158	B	41			•		
159	C	67			•		
160	D	96				•	
161	C	55				•	
162	C	38				•	
163	D	91					•
164	A	62					•
165	A	62					•
166	A	57					•
167	C	57			•		
168	D	31			•		
169	C	52			•		
170	B	40			•		
171	B	73				•	
172	E	65				•	
173	A	61				•	
174	C	85					•
175	B	30					•
176	A	58					•
177	B	49			•		
178	E	73			•		
179	B	69			•		
180	E	71				•	
181	B	55				•	
182	B	77					•
183	E	75					•
184	B	61					•
185	D	73					•
186	D	67			•		
187	B	75			•		
188	B	44			•		
189	A	28				•	
190	D	37				•	
191	B	62				•	
192	B	34					•
193	B	89					•
194	A	74					•

Total Correct (C): _____

Total Incorrect (I): _____

Total Raw: (C-I/4): _____

Scaled Score: _____

Sub 1 Correct (C): _____

Sub 1 Incorrect (I): _____

Sub 1 Raw: (C-I/4): _____

Scaled Score: _____

Sub 2 Correct (C): _____

Sub 2 Incorrect (I): _____

Sub 2 Raw: (C-I/4): _____

Scaled Score: _____

Sub 3 Correct (C): _____

Sub 3 Incorrect (I): _____

Sub 3 Raw: (C-I/4): _____

Scaled Score: _____

*The P+ column indicates the percent of GRE Biology Test examinees who answered each question correct. It is based on a sample of October 2012 examinees selected to represent all GRE Biology Test examinees tested between July 1, 2011, and June 30, 2014.

Score Conversions for the GRE Biology Test, Form GR1224

TOTAL SCORE

Raw Score	Scaled Score	Raw Score	Scaled Score
175-194	990	84-85	640
173-174	980	81-83	630
170-172	970	78-80	620
168-169	960	76-77	610
165-167	950	73-75	600
162-164	940	70-72	590
160-161	930	68-69	580
157-159	920	65-67	570
154-156	910	63-64	560
152-153	900	60-62	550
149-151	890	57-59	540
147-148	880	55-56	530
144-146	870	52-54	520
141-143	860	49-51	510
139-140	850	47-48	500
136-138	840	44-46	490
133-135	830	42-43	480
131-132	820	39-41	470
128-130	810	36-38	460
126-127	800	34-35	450
123-125	790	31-33	440
120-122	780	28-30	430
118-119	770	26-27	420
115-117	760	23-25	410
112-114	750	21-22	400
110-111	740	18-20	390
107-109	730	15-17	380
105-106	720	13-14	370
102-104	710	10-12	360
99-101	700	7-9	350
97-98	690	5-6	340
94-96	680	2-4	330
91-93	670	0-1	320
89-90	660		
86-88	650		

SUBSCORES

Raw Scores			Scaled Score	Raw Scores			Scaled Score
Sub 1	Sub 2	Sub 3		Sub 1	Sub 2	Sub 3	
62-65	58-65		99	26	25	32	64
61	57	64	98	25	24	31	63
60	56	63	97	24	23	30	62
59	55	62	96	23	22	29	61
58	54	61	95	22	21	28	60
57	53	60	94	21	20		59
56	52	59	93	20	19	27	58
55	51	58	92	19	18	26	57
54	50		91	18	17	25	56
53	49	57	90	17	16	24	55
51-52		56	89	16	15	23	54
50	48	55	88	15	14	22	53
49	47	54	87	14	13	21	52
48	46	53	86	13	12	20	51
47	45	52	85	12	11	19	50
46	44	51	84	11	10	18	49
45	43	50	83	10	9	17	48
44	42	49	82	9	8	16	47
43	41	48	81	7-8	7	15	46
42	40	47	80	6	6	14	45
41	39	46	79	5	5	13	44
40	38	45	78	4			43
39	37	44	77	3	4	12	42
38	36	43	76	2	3	11	41
37	35		75	1	2	10	40
36	34	42	74	0	1	9	39
35	33	41	73		0	8	38
34	32	40	72			7	37
33	31	39	71			6	36
32	30	38	70			5	35
31	29	37	69			4	34
30	28	36	68			3	33
29	27	35	67			2	32
28		34	66			1	31
27	26	33	65			0	30

DO NOT USE INK

Use only a pencil with soft, black lead (No. 2 or HB) to complete this answer sheet.
Be sure to fill in completely the space that corresponds to your answer choice.
Completely erase any errors or stray marks.

GRADUATE RECORD EXAMINATIONS® - GRE® - SUBJECT TEST

SIDE 1

1. NAME Enter your last name, first name initial (given name), and middle initial if you have one.
Omit spaces, apostrophes, Jr., II., etc.

Last Name only (Family Name or Surname) - First 15 Letters

First Name Initial | Middle Initial

BE SURE EACH MARK IS DARK AND COMPLETELY FILLS THE INTENDED SPACE AS ILLUSTRATED HERE. ●
YOU MAY FIND MORE RESPONSE SPACES THAN YOU NEED. IF SO, PLEASE LEAVE THEM BLANK.

3. DATE OF BIRTH

Month	Day	Year
Jan.		
Feb.		
Mar.		
April		
May		
June		
July		
Aug.		
Sept.		
Oct.		
Nov.		
Dec.		

4. SOCIAL SECURITY NUMBER (U.S.A. only)

5. REGISTRATION NUMBER (from your admission ticket)

6. TITLE CODE (on back cover of your test book)

7. TEST NAME (on back cover of your test book)

FORM CODE (on back cover of your test book)

8. TEST BOOK SERIAL NUMBER (number in upper right corner of front cover of your test book)

SHADED AREA FOR ETS USE ONLY

742862

2.

YOUR NAME: (Print)
Last Name (Family or Surname)   First Name (Given)   M.I.

MAILING ADDRESS: (Print)
P.O. Box or Street Address
City   State or Province
Country   Zip or Postal Code

CENTER:
City   State or Province
Country   Center Number   Room Number

SIGNATURE:

Q3117-06,07/1   00101-02954 • TF77E70   MH/wan07190

SUBJECT TEST

**COMPLETE THE
CERTIFICATION STATEMENT,
THEN TURN ANSWER SHEET
OVER TO SIDE 1.**

CERTIFICATION STATEMENT

Please write the following statement below, DO NOT PRINT.
"I certify that I am the person whose name appears on this answer sheet. I also agree not to disclose the contents of the test I am taking today to anyone."
Sign and date where indicated.

SIGNATURE: _____   DATE: ____ / ____ / ____
Month Day Year

BE SURE EACH MARK IS DARK AND COMPLETELY FILLS THE INTENDED SPACE AS ILLUSTRATED HERE: ●.
YOU MAY FIND MORE RESPONSE SPACES THAN YOU NEED. IF SO, PLEASE LEAVE THEM BLANK.

115	A B C D E	147	A B C D E	179	A B C D E	211	A B C D E
116	A B C D E	148	A B C D E	180	A B C D E	212	A B C D E
117	A B C D E	149	A B C D E	181	A B C D E	213	A B C D E
118	A B C D E	150	A B C D E	182	A B C D E	214	A B C D E
119	A B C D E	151	A B C D E	183	A B C D E	215	A B C D E
120	A B C D E	152	A B C D E	184	A B C D E	216	A B C D E
121	A B C D E	153	A B C D E	185	A B C D E	217	A B C D E
122	A B C D E	154	A B C D E	186	A B C D E	218	A B C D E
123	A B C D E	155	A B C D E	187	A B C D E	219	A B C D E
124	A B C D E	156	A B C D E	188	A B C D E	220	A B C D E
125	A B C D E	157	A B C D E	189	A B C D E	221	A B C D E
126	A B C D E	158	A B C D E	190	A B C D E	222	A B C D E
127	A B C D E	159	A B C D E	191	A B C D E	223	A B C D E
128	A B C D E	160	A B C D E	192	A B C D E	224	A B C D E
129	A B C D E	161	A B C D E	193	A B C D E	225	A B C D E
130	A B C D E	162	A B C D E	194	A B C D E	226	A B C D E
131	A B C D E	163	A B C D E	195	A B C D E	227	A B C D E
132	A B C D E	164	A B C D E	196	A B C D E	228	A B C D E
133	A B C D E	165	A B C D E	197	A B C D E	229	A B C D E
134	A B C D E	166	A B C D E	198	A B C D E	230	A B C D E
135	A B C D E	167	A B C D E	199	A B C D E	231	A B C D E
136	A B C D E	168	A B C D E	200	A B C D E	232	A B C D E
137	A B C D E	169	A B C D E	201	A B C D E	233	A B C D E
138	A B C D E	170	A B C D E	202	A B C D E	234	A B C D E
139	A B C D E	171	A B C D E	203	A B C D E	235	A B C D E
140	A B C D E	172	A B C D E	204	A B C D E	236	A B C D E
141	A B C D E	173	A B C D E	205	A B C D E	237	A B C D E
142	A B C D E	174	A B C D E	206	A B C D E	238	A B C D E
143	A B C D E	175	A B C D E	207	A B C D E	239	A B C D E
144	A B C D E	176	A B C D E	208	A B C D E	240	A B C D E
145	A B C D E	177	A B C D E	209	A B C D E	241	A B C D E
146	A B C D E	178	A B C D E	210	A B C D E	242	A B C D E

IF YOU DO NOT WANT THIS ANSWER SHEET TO BE SCORED

If you want to cancel your scores from this test administration, complete A and B below. You will not receive scores for this test. No record of this test or the cancellation will be sent to the recipients you indicated, and there will be no scores for this test on your GRE file.

To cancel your scores from this test administration, you must:

A. Fill in both ovals here . . .   —   B. sign your full name here: _____

TR	TW	TFS	TCS	1R	1W	1FS	1CS	2R	2W	2FS	2CS
	FOR ETS USE ONLY			3R	3W	3FS	3CS	4R	4W	4FS	4CS
				5R	5W	5FS	5CS	6R	6W	6FS	6CS