



**GRE**

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GRADUATE RECORD EXAMINATIONS®

# Biochemistry, Cell and Molecular Biology Test Practice Book

## **This practice book contains**

- one actual, full-length GRE® Biochemistry, Cell and Molecular 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.**

This book is provided **FREE** with test registration by the Graduate Record Examinations Board.

[www.ets.org/gre](http://www.ets.org/gre)

**Note to Test Takers:** Keep this practice book until you receive your score report.  
This book contains important information about scoring.



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## Purpose of the GRE Subject Tests

The GRE Subject Tests are designed to help graduate school admission committees and fellowship sponsors assess the qualifications of applicants in specific fields of study. The tests also provide you with an assessment of your own qualifications.

Scores on the tests are intended to indicate knowledge of the subject matter emphasized in many undergraduate programs as preparation for graduate study. Because past achievement is usually a good indicator of future performance, the scores are helpful in predicting success in graduate study. Because the tests are standardized, the test scores permit comparison of students from different institutions with different undergraduate programs. For some Subject Tests, subscores are provided in addition to the total score; these subscores indicate the strengths and weaknesses of your preparation, and they may help you plan future studies.

The GRE Board recommends that scores on the Subject Tests be considered in conjunction with other relevant information about applicants. Because numerous factors influence success in graduate school, reliance on a single measure to predict success is not advisable. Other indicators of competence typically include undergraduate transcripts showing courses taken and grades earned, letters of recommendation, and GRE General Test scores. For information about

the appropriate use of GRE scores, see the *GRE Guide to the Use of Scores* at [ets.org/gre/stupubs](http://ets.org/gre/stupubs).

## Development of the Subject Tests

Each new edition of a Subject Test is developed by a committee of examiners composed of professors in the subject who are on undergraduate and graduate faculties in different types of institutions and in different regions of the United States and Canada. In selecting members for each committee, the GRE Program seeks the advice of appropriate professional associations in the subject.

The content and scope of each test are specified and reviewed periodically by the committee of examiners. Test questions are written by committee members and by other university faculty members who are subject-matter specialists. All questions proposed for the test are reviewed and revised by the committee and subject-matter specialists at ETS. The tests are assembled in accordance with the content specifications developed by the committee to ensure adequate coverage of the various aspects of the field and, at the same time, to prevent overemphasis on any single topic. The entire test is then reviewed and approved by the committee.

Subject-matter and measurement specialists on the ETS staff assist the committee, providing information and advice about methods of test construction and helping to prepare the questions and assemble the test. In addition, each test question is reviewed to eliminate language, symbols, or content considered potentially offensive, inappropriate for major subgroups of the test-taking population, or likely to perpetuate any negative attitude that may be conveyed to these subgroups.

Because of the diversity of undergraduate curricula, it is not possible for a single test to cover all the material you may have studied. The examiners, therefore, select questions that test the basic knowledge and skills most important for successful graduate study in the particular field. The committee keeps the test up-to-date by regularly developing new editions and revising existing editions. In this way, the test content remains current. In addition, curriculum surveys are conducted periodically to ensure that the content of a test reflects what is currently being taught in the undergraduate curriculum.

After a new edition of a Subject Test is first administered, examinees' responses to each test question are analyzed in a variety of ways to determine whether each question functioned as expected. These analyses may reveal that a question is ambiguous, requires knowledge beyond the scope of the test, or is inappropriate for the total group or a particular subgroup of examinees taking the test. Such questions are not used in computing scores.

Following this analysis, the new test edition is equated to an existing test edition. In the equating process, statistical methods are used to assess the difficulty of the new test. Then scores are adjusted so that examinees who took a more difficult edition of the test are not penalized, and examinees who took an easier edition of the test do not have an advantage. Variations in the number of questions in the different editions of the test are also taken into account in this process.

Scores on the Subject Tests are reported as three-digit scaled scores with the third digit always zero. The maximum possible range for all Subject Test total scores is from 200 to 990. The actual range of scores for a particular Subject Test, however, may be smaller. For Subject Tests that report subscores, the maximum possible range is 20 to 99; however, the actual range of subscores for any test or test edition may be smaller. Subject Test score interpretive information is provided in *Interpreting Your GRE Scores*, which you will receive with your GRE score report. This publication is also available at [ets.org/gre/stupubs](http://ets.org/gre/stupubs).

## Content of the Biochemistry, Cell and Molecular Biology Test

The test consists of approximately 180 multiple-choice questions, a number of which are grouped in sets toward the end of the test and based on descriptions of laboratory situations, diagrams, or experimental results.

The content of the test is organized into three major areas: biochemistry, cell biology, and molecular biology and genetics. In addition to the total score, a subscore in each of these subfield areas is reported. Because these three disciplines are basic to the study of all organisms, test questions encompass both eukaryotes and prokaryotes. Throughout the test, there is an emphasis on questions requiring problem-solving skills (including mathematical calculations that do not require the use of a calculator) as well as content knowledge.

While only two content areas in the following outline specifically mention methodology, questions on methodology and data interpretation are included in all sections.

In developing questions for the test, the test development committee considers both the content of typical courses taken by undergraduates and the knowledge and abilities required for graduate work in the fields related to the test. Because of the diversity of undergraduate curricula, few examinees will have encountered all of the topics in the content outline. Consequently, no examinee should expect to be able to answer all questions on the edition of the test he or she takes. The three subscore areas are interrelated. Because of these interrelationships, individual questions or sets of questions may test more than one content area. Therefore, the relative emphases of the three areas in the following outline should not be considered definitive. Likewise, the topics listed are not intended to be all-inclusive but, rather, representative of the typical undergraduate experience.

### I. BIOCHEMISTRY 36%

- A. Chemical and Physical Foundations
  - Thermodynamics and kinetics
  - Redox states
  - Water, pH, acid-base reactions, and buffers
  - Solutions and equilibria
  - Solute-solvent interactions
  - Chemical interactions and bonding
  - Chemical reaction mechanisms
- B. Structural Biology: Structure, Assembly, Organization, and Dynamics
  - Small molecules
  - Macromolecules (for example, nucleic acids, polysaccharides, proteins, and complex Lipids)
  - Supramolecular complexes (for example, membranes, ribosomes, and multienzyme complexes)
- C. Catalysis and Binding
  - Enzyme reaction mechanisms and kinetics
  - Ligand-protein interaction (for example, hormone receptors, substrates and effectors, transport proteins, and antigen-antibody interactions)

- D. Major Metabolic Pathways
  - Carbon, nitrogen, and sulfur assimilation
  - Anabolism
  - Catabolism
  - Synthesis and degradation of macromolecules
- E. Bioenergetics (including respiration and photosynthesis)
  - Energy transformations at the substrate level
  - Electron transport
  - Proton and chemical gradients
  - Energy coupling (phosphorylation and transport)
- F. Regulation and Integration of Metabolism
  - Covalent modification of enzymes
  - Allosteric regulation
  - Compartmentalization
  - Hormones
- G. Methods
  - Spectroscopy
  - Isotopes
  - Separation techniques (for example, centrifugation, chromatography, and electrophoresis)
  - Immunotechniques

## II. CELL BIOLOGY 28%

Methods of importance to cellular biology, such as fluorescence probes (for example, FRAP, FRET, and GFP) and imaging, will be covered as appropriate within the context of the content below.

- A. Cellular Compartments of Prokaryotes and Eukaryotes: Organization, Dynamics, and Functions
  - Cellular membrane systems (structure and transport across membrane)
  - Nucleus (envelope and matrix)
  - Mitochondria and chloroplasts (including biogenesis and evolution)
- B. Cell Surface and Communication
  - Extracellular matrix (including cell walls)
  - Cell adhesion and junctions
  - Signal transduction
  - Receptor function
  - Excitable membrane systems
- C. Cytoskeleton, Motility, and Shape
  - Regulation of assembly and disassembly of filament systems
  - Motor function, regulation and diversity

- D. Protein, Processing, Targeting, and Turnover
  - Translocation across membranes
  - Posttranslational modification
  - Intracellular trafficking
  - Secretion and endocytosis
  - Protein turnover
- E. Cell Division, Differentiation, and Development
  - Cell cycle, mitosis, and cytokinesis
  - Meiosis and gametogenesis
  - Fertilization and early embryonic development (including positional information, homeotic genes, tissue-specific expression, nuclear and cytoplasmic interactions, growth factors and induction, environment, stem cells, and polarity)

## III. MOLECULAR BIOLOGY AND GENETICS

36%

- A. Genetic Foundations
  - Mendelian and non-Mendelian inheritance
  - Transformation, transduction, and conjugation
  - Recombination and complementation
  - Mutational analysis
  - Genetic mapping and linkage analysis
- B. Chromatin and Chromosomes
  - Karyotypes
  - Translocations, inversions, deletions, and duplications
  - Aneuploidy and polyploidy
  - Structure
  - Epigenetics
- C. Genomics
  - Genome structure
  - Physical mapping
  - Repeated DNA and gene families
  - Gene identification
  - Transposable elements
  - Bioinformatics
  - Proteomics
- D. Genome Maintenance
  - DNA replication
  - DNA damage and repair
  - DNA modification
  - DNA recombination and gene conversion

- E. Gene Expression
  - The genetic code
  - Transcription/transcriptional profiling
  - RNA processing
  - Translation
- F. Gene Regulation
  - Positive and negative control of the operon
  - Promoter recognition by RNA polymerases
  - Attenuation and antitermination
  - *Cis*-acting regulatory elements
  - *Trans*-acting regulatory factors
  - Gene rearrangements and amplifications
- G. Viruses
  - Genome replication and regulation
  - Virus assembly
  - Virus-host interactions
- H. Methods
  - Restriction maps and PCR
  - Nucleic acid blotting and hybridization
  - DNA cloning in prokaryotes and eukaryotes
  - Sequencing and analysis
  - Protein-nucleic acid interaction
  - Transgenic organisms
  - Microarrays

## Preparing for a Subject 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 this practice book to become familiar with the types of questions in the GRE Biochemistry, Cell and Molecular Biology Test, paying special attention to the directions. If you thoroughly 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. Total testing time is two hours and fifty minutes; there are no separately timed sections. 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 waste 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. 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.
- 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 Subject Test is comparable to the same scaled score earned on any other edition of the same test. Thus, equal scaled scores on a particular Subject Test indicate essentially equal levels of performance regardless of the test edition taken. Test scores should be compared only with other scores on the same Subject Test. (For example, a 680 on the Computer Science Test is not equivalent to a 680 on the Mathematics Test.)

Before taking the test, you may find it useful to know approximately what raw scores would be required to obtain a certain scaled score. Several factors influence the conversion of your raw score to your scaled score, such as the difficulty of the test edition and the number of test questions included in the computation of your raw score. Based on recent editions of the Biochemistry, Cell and Molecular Biology Test, the following table gives the range of raw scores associated with selected scaled scores for three different test editions. (Note that when the number of scored questions for a given test is greater than the range of possible scaled scores, it is likely that two or more raw scores will convert to the same scaled score.) The three test editions in the table that follows were selected to reflect varying degrees of difficulty. Examinees should note that future test editions may be somewhat more or less difficult than the test editions illustrated in the table.

### Range of Raw Scores\* Needed to Earn Selected Scaled Score on Three Biochemistry Test Editions That Differ in Difficulty

Scaled Score	Raw Scores		
	Form A	Form B	Form C
700	132-134	129-131	122-124
600	102-104	97-99	92-94
500	71-73	66-68	62-64
400	41-43	34-37	32-34
Number of Questions Used to Compute Raw Score			
	178	177	176

\*Raw Score = Number of correct answers minus one-fourth the number of incorrect answers, rounded to the nearest integer.

For a particular test edition, there are many ways to earn the same raw score. For example, on the edition listed above as “Form A,” a raw score of 71 through 73 would earn a scaled score of 500. Below are a few of the possible ways in which a scaled score of 500 could be earned on the edition:

#### Examples of Ways to Earn a Scaled Score of 500 on the Edition Labeled as “Form A”

Raw Score	Questions Answered Correctly	Questions Answered Incorrectly	Questions Not Answered	Number of Questions Used to Compute Raw Score
71	71	0	107	178
71	81	42	55	178
71	92	83	3	178
73	73	0	105	178
73	83	42	53	178
73	94	83	1	178



## **PRACTICE TEST**

To become familiar with how the administration will be conducted at the test center, first remove the answer sheet (pages 59 and 60). Then go to the back cover of the test book (page 54) 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.





**GRE**

FORM GR0522

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GRADUATE RECORD EXAMINATIONS®

**BIOCHEMISTRY, CELL  
AND MOLECULAR  
BIOLOGY TEST**

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# BIOCHEMISTRY, CELL AND MOLECULAR BIOLOGY TEST

Time—170 minutes

180 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.

- Which of the following represents the most reduced form of carbon?
  - R-CH<sub>3</sub>
  - R-COOH
  - R-CHO
  - R-CH<sub>2</sub>OH
  - CO<sub>2</sub>
- The  $K_m$  (Michaelis constant) of an enzyme for a substrate is defined operationally as
  - half the substrate concentration at which the reaction rate is maximal
  - the substrate concentration at which the reaction rate is half maximal
  - the dissociation constant of the enzyme-substrate complex
  - the dissociation constant of the enzyme-product complex
  - the rate constant of the reaction at saturation
- The reversible reaction in which dihydroxyacetone phosphate and glyceraldehyde 3-phosphate combine to form fructose 1,6-bisphosphate is best characterized as
  - an aldol condensation
  - a Grignard reaction
  - a free-radical reaction
  - a hydrolytic reaction
  - a zero-order reaction
- Dinitrophenol (DNP) uncouples mitochondrial electron transport from oxidative phosphorylation by
  - dissipating the proton gradient
  - inhibiting cytochrome oxidase
  - dissociating the  $F_0$  and  $F_1$  units of the ATP synthase complex
  - binding irreversibly to ubiquinone
  - blocking the adenine nucleotide carrier (ATP/ADP exchanger)
- Most of the dry mass in the trunk of a tree was originally derived from
  - the soil
  - light energy
  - amino acids
  - CO<sub>2</sub>
  - glucose
- Which of the following cell compartments is associated with a protein skeleton composed of lamins?
  - Chloroplast
  - Basement membrane
  - Mitochondrion
  - Nucleus
  - Peroxisome
- Initiation of mitogenesis by epidermal growth factor and depolarization of the membrane of a skeletal muscle cell by acetylcholine are similar in that each
  - involves, as an essential early step, an ion flux across the plasma-membrane receptor of the responding cell
  - requires a ligand-mediated conformational change in a plasma-membrane receptor of the responding cell
  - requires activation of a G protein on the cytoplasmic face of the plasma membrane in the responding cell
  - is mediated by phosphorylation of the ligand receptor in the responding cell
  - completes its primary task by direct activation of specific regulatory DNA sequences in the nucleus of the responding cell

8. The principal site of peptide neurohormone biosynthesis is the
- (A) nucleus
  - (B) rough endoplasmic reticulum
  - (C) dendrite
  - (D) postsynaptic density
  - (E) synaptic vesicle
9. A previously unknown organism that lacks a nuclear membrane and mitochondria has just been discovered. Which of the following would this organism most likely possess?
- (A) Lysosomes
  - (B) Cilia
  - (C) Ribosomes
  - (D) Endoplasmic reticulum
  - (E) Chloroplasts
10. Drugs that either stabilize or depolymerize microtubules can be used in cancer chemotherapy. Which of the following is correct concerning such drugs?
- (A) They stimulate the immune system.
  - (B) They prevent chromatin condensation.
  - (C) They prevent movement of tumor cells into other tissues.
  - (D) They interfere with mitosis.
  - (E) They interfere with endocytosis.
11. If the genetic code consisted of four bases per codon rather than three, the maximum number of unique amino acids that could be encoded would be
- (A) 16
  - (B) 64
  - (C) 128
  - (D) 256
  - (E) 512
12. In humans, the Barr body is an
- (A) active X chromosome in females
  - (B) active X chromosome in males
  - (C) inactive Y chromosome in males
  - (D) inactive Y chromosome in females
  - (E) inactive X chromosome in females
13. Which of the following types of molecules is always found in virions?
- (A) Lipid
  - (B) Protein
  - (C) Carbohydrate
  - (D) DNA
  - (E) RNA
14. An RNA-dependent RNA polymerase is likely to be present in the virion of a
- (A) DNA virus that multiplies in the cytoplasm
  - (B) DNA virus that multiplies in the nucleus
  - (C) minus-strand RNA virus
  - (D) plus-strand RNA virus
  - (E) transforming virus
15. In *E. coli*, the inability of the *lac* repressor to bind an inducer would result in
- (A) no substantial synthesis of  $\beta$ -galactosidase
  - (B) constitutive synthesis of  $\beta$ -galactosidase
  - (C) inducible synthesis of  $\beta$ -galactosidase
  - (D) synthesis of inactive  $\beta$ -galactosidase
  - (E) synthesis of  $\beta$ -galactosidase only in the absence of lactose
16. If sucrose and monosodium glutamate (MSG) are added to a vinegar and oil salad dressing and shaken, the mixture will eventually separate into two phases of different density and polarity. Where will most of the sucrose and the MSG be located following phase separation?
- (A) Both will concentrate in the vinegar.
  - (B) Both will concentrate in the oil.
  - (C) Both will concentrate at the interface.
  - (D) Sucrose will concentrate in the oil and MSG will concentrate in the vinegar.
  - (E) Sucrose will concentrate in the vinegar and MSG will concentrate in the oil.

17. A major advantage of monoclonal antibodies compared to polyclonal antibodies is that monoclonal antibodies
- (A) have identical binding sites that recognize a specific epitope
  - (B) cross-link molecules that share antigenic sites
  - (C) are more easily coupled with probes such as fluorescent dyes
  - (D) have higher-affinity binding to antigens
  - (E) can be produced against proteins that are immunogenic in rabbits
18. The initial product of photosynthetic  $\text{CO}_2$  fixation in  $\text{C}_3$  plants is
- (A) glyceraldehyde 3-phosphate
  - (B) dihydroxyacetone phosphate
  - (C) 3-phosphoglycerate
  - (D) phosphoenolpyruvate
  - (E) 1,3-bisphosphoglycerate
19. In which of the following systems is the entropy the greatest?
- (A) Water vapor
  - (B) Liquid water at pH 7.0,  $37^\circ\text{C}$
  - (C) Water with sufficient acid added to lower the pH to 2.0
  - (D) Supercooled water (liquid water at a temperature less than  $0^\circ\text{C}$ )
  - (E) Ice
20. Which enzyme is activated by phosphorylation?
- (A) Acetyl-CoA carboxylase
  - (B) Fructose-1,6-bisphosphatase
  - (C) Glycogen synthase
  - (D) Pyruvate kinase
  - (E) Fructose-2,6-bisphosphatase
21. All of the following statements about monomeric G proteins are true EXCEPT:
- (A) They are regulated by GTP-GDP exchange proteins.
  - (B) They are regulated by GTPase activating proteins.
  - (C) They regulate enzymes that synthesize cGMP.
  - (D) They regulate vesicle formation.
  - (E) They regulate vesicle fusion.
22. All of the following are known to be part of a signal transduction cascade EXCEPT
- (A) phosphorylation of fibronectin
  - (B) dissociation of the components of a heterotrimeric G-protein
  - (C) enzymatic breakdown of phosphatidylinositol bisphosphate ( $\text{PIP}_2$ )
  - (D) elevation of intracellular  $[\text{Ca}^{2+}]$
  - (E) activation of cGMP phosphodiesterase
23. Which of the following will result if the level of potassium ions in a solution bathing a nerve cell is raised tenfold while the cell is at its resting state?
- (A) The decrease in the normal  $\text{K}^+$  gradient will cause partial depolarization.
  - (B) The amplification of the normal  $\text{K}^+$  gradient will cause partial hyperpolarization.
  - (C) The added extracellular  $\text{K}^+$  will accelerate  $\text{Na}^+/\text{K}^+$  pumping and cause partial depolarization.
  - (D) The added extracellular  $\text{K}^+$  will cause ligand-gated ion channels to open.
  - (E) The elevated  $\text{K}^+$  will promote  $\text{Ca}^{2+}$  channel opening and produce partial hyperpolarization.
24. SNARE proteins are found in the membranes of all of the following compartments EXCEPT
- (A) Mitochondria
  - (B) Golgi complex
  - (C) Early endosome
  - (D) Endoplasmic reticulum
  - (E) Synaptic plasma membrane
25. Treatment of root tip meristem cells with the microtubule inhibitor colchicine results in all of the following EXCEPT
- (A) induction of polyploidy
  - (B) prevention of cytokinesis
  - (C) inhibition of mitotic spindle assembly
  - (D) cessation of DNA replication
  - (E) prevention of chromosome segregation

26. Genes  $a$ ,  $b$ , and  $c$  are widely spaced in the bacterial genome. Transducing phage from an  $a^+ b^+ c^+$  bacterium were used to infect a culture of  $a^- b^- c^-$  cells, and  $b^+$  transductants were selected. Which of the following best describes the predicted genotypes of these transductants?
- (A) Mostly  $a^- b^+ c^-$   
 (B) Mostly  $a^- b^+ c^+$   
 (C) Mostly  $a^+ b^+ c^+$   
 (D) Mostly  $a^+ b^+ c^-$   
 (E)  $a^+ b^+ c^+$  and  $a^- b^+ c^-$  in equal frequencies
27. If a cell has one chromosome in excess of the normal number of chromosomes present in the nucleus, it is referred to as
- (A) aneuploid  
 (B) polyploid  
 (C) tetraploid  
 (D) haploid  
 (E) allotetraploid
28. Which of the following statements about retrotransposons is correct?
- (A) They transpose via an RNA intermediate.  
 (B) They contain genes for ribosomal proteins.  
 (C) They possess a gene for RNA-dependent RNA polymerase.  
 (D) They possess genes that encode proteins that integrate RNA into chromosomes.  
 (E) They are found only in bacteria.
29. When bacteria produce mammalian proteins, cDNA is used rather than genomic DNA. Which of the following is the best explanation?
- (A) It is easier to clone cDNA than genomic DNA of comparable size.  
 (B) It is easier to clone RNA than DNA.  
 (C) It is not possible to clone the entire coding region of the gene.  
 (D) Most eukaryotic genes have introns that cannot be removed in bacteria.  
 (E) Most eukaryotic gene promoters do not function in bacteria.
30. A mutation deleting an upstream activating sequence for a single gene would be expected to be
- (A) polar  
 (B) *trans*-dominant  
 (C) *cis*-dominant  
 (D) silent  
 (E) revertible
31. The difference between the molecular weight of sucrose and that of the sum of the molecular weights of its components (glucose and fructose) is
- (A) 0  
 (B) 1  
 (C) 16  
 (D) 18  
 (E) 180
32. Proline disrupts  $\alpha$ -helical structure in proteins because it is
- (A) an acidic amino acid  
 (B) an aromatic amino acid  
 (C) an imino acid  
 (D) a basic amino acid  
 (E) a sulfur-containing amino acid
33. Glycogen phosphorylase exists in two forms in skeletal muscle. The active form, phosphorylase  $a$ , is generated from phosphorylase  $b$  by
- (A) reversible dimerization of phosphorylase  $b$ , triggered by calcium ion  
 (B) proteolytic cleavage of a decapeptide from the N-terminus of phosphorylase  $b$   
 (C) protonation of the active-site histidine residue by a decrease in intracellular pH  
 (D) ATP-dependent phosphorylation of a specific serine residue on each subunit  
 (E) noncovalent binding of ATP to allosteric sites on phosphorylase  $b$

34. An alpha-helical conformation of a globular protein in solution is best determined by which of the following?
- (A) Ultraviolet-visible absorbance spectroscopy
  - (B) Fluorescence spectroscopy
  - (C) Electron microscopy
  - (D) Analytical ultracentrifugation
  - (E) Circular dichroism
35. The nucleoside adenosine exists in a protonated form with a  $pK_a$  of 3.8. The percentage of the protonated form at pH 4.8 is closest to
- (A) 1
  - (B) 9
  - (C) 50
  - (D) 91
  - (E) 99
36. Membrane carrier proteins differ from membrane channel proteins by which of the following characteristics?
- (A) Carrier proteins are glycoproteins, while channel proteins are lipoproteins.
  - (B) Carrier proteins transport molecules down their electrochemical gradient, while channel proteins transport molecules against their electrochemical gradient.
  - (C) Carrier proteins can mediate active transport, while channel proteins cannot.
  - (D) Carrier proteins do not bind to the material transported, while channel proteins do.
  - (E) Carrier proteins are synthesized on free cytoplasmic ribosomes, while channel proteins are synthesized on ribosomes bound to the endoplasmic reticulum.
37. Particular RNAs that are important for development are located in distinct regions of the *Drosophila* embryo. This is most directly demonstrated by using
- (A) western blotting
  - (B) northern blotting
  - (C) *in situ* hybridization
  - (D) *in vitro* translation
  - (E) electroporation
38. Which of the following events can induce a transient arrest in the translation of a secretory protein?
- (A) Binding of a polysome to an ER receptor
  - (B) Binding of SRP to an N-terminal signal sequence
  - (C) Binding of snRNPs to the large ribosomal subunit
  - (D) Presence of a stop-transfer sequence in the polypeptide
  - (E) Cleavage of the signal sequence by signal peptidase
39. The common pathway of entry into the endoplasmic reticulum (ER) of secretory, lysosomal, and plasma membrane proteins is best explained by which of the following?
- (A) Binding of their mRNAs to a special class of ribosomes attached to the ER
  - (B) Addition of a common sorting signal to each type of protein after completion of synthesis
  - (C) Addition of oligosaccharides to all three types of proteins
  - (D) Presence of a signal sequence that targets each type of protein to the ER during synthesis
  - (E) Presence of a zinc finger-binding domain in these three types of proteins
40. Eukaryotic cells with DNA damage often cease progression through the cell cycle until the damage is repaired. This type of control over the cell cycle is referred to as
- (A) proteasome control
  - (B) damage control
  - (C) checkpoint control
  - (D) anticyclin control
  - (E) transcriptional control

41. A microarray is a large collection of specific DNA oligonucleotides spotted in a defined pattern on a microscope slide. What is the most useful experiment that can be done with such a tool?
- (A) Predicting the presence of specific metabolites in a cell
  - (B) Comparing newly synthesized nuclear RNA with cytoplasmic RNA to locate introns
  - (C) Comparing RNA produced under two different physiological conditions to understand patterns of gene expression
  - (D) Comparing proteins produced under two different physiological conditions to understand their function
  - (E) Evaluating the linkage relationships of genes
42. In vertebrate genes, transcription regulatory regions that contain CpG islands are inactivated by which CpG modification?
- (A) Methylation
  - (B) Myristylation
  - (C) Phosphorylation
  - (D) Acetylation
  - (E) Ubiquitination
43. All of the following are proteins within the core nucleosome particle EXCEPT
- (A) H1
  - (B) H2A
  - (C) H2B
  - (D) H3
  - (E) H4
44. In a study of arginine biosynthesis in yeast, four mutant haploids requiring arginine ( $\text{Arg}^-$ ) were isolated. The  $\text{Arg}^-$  haploids were fused in pairwise combinations to form diploids, whose requirement for arginine was tested. The results of the tests were that all diploid combinations yielded arginine prototrophs. How many different Arg genes are represented among the four mutants?
- (A) One
  - (B) Two
  - (C) Three
  - (D) Four
  - (E) Five
45. A set of genes from *Bacillus subtilis* that encode the proteins required for sporulation have conserved DNA sequences  $-35$  and  $-10$  nucleotides before the site of transcript initiation, although the sequence at  $-35$  is different from that seen in most other genes from that species. Which of the following best explains this difference?
- (A) A novel sigma factor is required for transcription initiation at these genes.
  - (B) The  $-35$  sequence is the binding site for a repressor of transcription.
  - (C) The replication of these genes requires a specifically modified DNA polymerase.
  - (D) Translation of the mRNAs transcribed from these genes requires specific ribosomes that recognize a modified Shine-Dalgarno sequence.
  - (E) Transcription of these genes is induced by cAMP.
46. Acetyl CoA, the cytoplasmic substrate for fatty acid synthesis, is formed in mitochondria. The inner mitochondrial membrane is impermeable to acetyl CoA. Which of the following compounds is the form in which the carbon of acetyl CoA is transported to the cytoplasm?
- (A) Malate
  - (B) Acetate
  - (C) Citrate
  - (D) Pyruvate
  - (E) Glucose

$T(^{\circ}\text{C})$	$\text{p}K_w$
0	14.94
25	14.00
50	13.28
75	12.71

47. The ion product for liquid water,  $K_w$ , varies with temperature (T), as indicated by the change in  $\text{p}K_w$  shown in the table above. The definition of neutrality is  $[\text{H}^+] = [\text{OH}^-]$ . Which of the following is the pH of water at neutrality at  $50^{\circ}\text{C}$  ?

- (A) 6.35
- (B) 6.64
- (C) 7.00
- (D) 7.40
- (E) 13.28

48. Which of the following groups of enzymes are unique to the Calvin cycle?

- (A) Ribulose biphosphate carboxylase, phosphoribulokinase, and sedoheptulose 1,7-biphosphatase
- (B) Ribose 5-phosphate isomerase, epimerase, and aldolase
- (C) Glyceraldehyde 3-phosphate dehydrogenase, phosphofructokinase, and phosphoenolpyruvate carboxylase
- (D) Phosphoglycolate phosphatase, glycerol kinase, and serine synthetase
- (E) Sucrose synthase, hexokinase, and glucose 6-phosphate dehydrogenase

49. Which of the following best describes the hyperchromicity of DNA?

- (A) The shift in UV absorbance to longer wavelengths upon denaturation
- (B) The shift in UV absorbance to shorter wavelengths upon hydrolysis
- (C) The shift in UV absorbance to longer wavelengths upon annealing (forming double strands)
- (D) The increase in absorbance at 260 nm upon annealing
- (E) The increase in absorbance at 260 nm upon denaturation

50. Isopentenyl pyrophosphate is a precursor of which of the following?

- I. Cholesterol
- II. Farnesyl groups on proteins
- III. Steroid hormones

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

51. Cytokinesis in animal cells is caused by

- (A) the sliding movements of a band of microtubules around the circumference of the cell
- (B) the contraction of a band of actin filaments around the circumference of the cell
- (C) the movement of the mitotic spindle fibers
- (D) endocytosis of the plasma membrane around the equator of the cell
- (E) fusion of cytoplasmic membrane vesicles at the equator of the cell

52. The synthesis of mRNA's that encode the proteins of eukaryotic ribosomes occurs in the

- (A) cytoplasm
- (B) nuclear envelope
- (C) nucleolus
- (D) euchromatin
- (E) heterochromatin

53. Which of the following is NOT a consequence of increased cellular levels of cAMP?

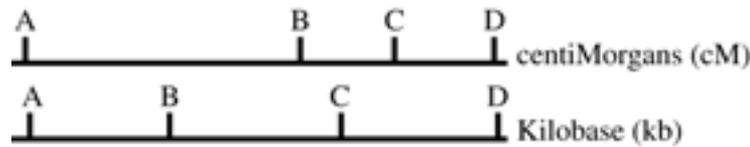
- (A) Activation of a kinase cascade
- (B) Activation of the transducin G-protein
- (C) Increased phosphorylation of glycogen phosphorylase
- (D) Inhibition of glycogen synthesis
- (E) Dissociation of the cAMP-dependent protein kinase tetramer

54. The KDEL sequence, found on luminal proteins of the ER, is responsible for

- (A) translocation of proteins into the ER lumen
- (B) insertion of proteins into the membrane of the ER
- (C) quality control in the ER
- (D) recognition by signal peptidase of the signal sequence
- (E) retrieval of ER luminal proteins from the Golgi

55. Cyclins are proteins involved in regulation of

- (A) cell-cycle protein kinases
- (B) circadian rhythms
- (C) synthesis of cAMP
- (D) membrane circulation via exocytosis and endocytosis
- (E) the cycling of tubulin subunits through microtubules



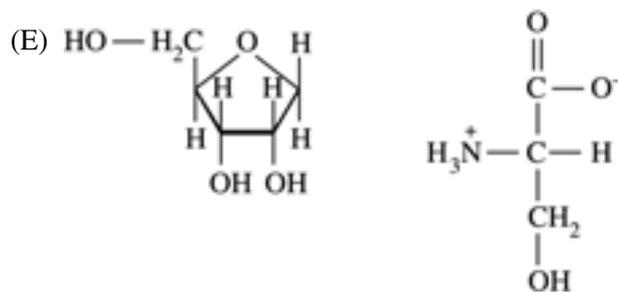
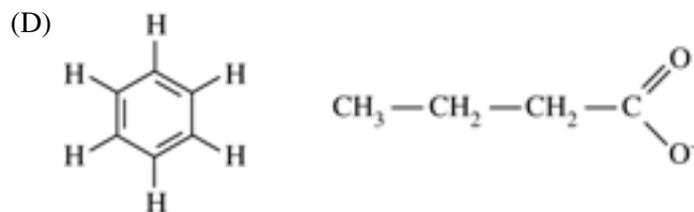
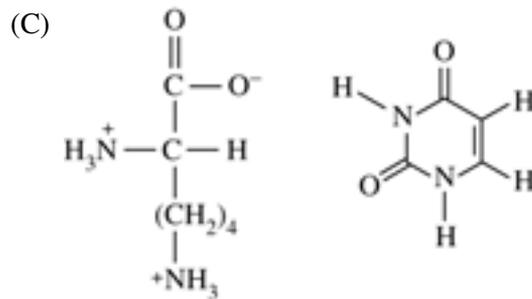
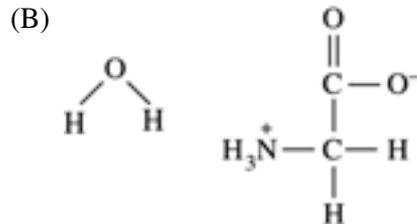
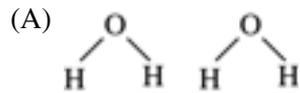
56. The uppermost figure above shows the locations of four genes on the genetic map of an organism; the lower figure shows the locations of the same four genes on a physical map derived from the nucleotide sequence of the DNA of that organism. The maps are not identical because

- (A) there is no relationship between the position of genes in a genetic map and their positions on the DNA
- (B) recombination frequencies per kb of DNA are not uniform throughout a chromosome
- (C) the farther apart two genes are, the more likely they are to recombine
- (D) the closer two genes are, the more likely they are to recombine
- (E) some genes contain introns

57. The karyotype of a triploid plant contains 72 chromosomes. How many chromosomes would the karyotype of a diploid plant of the same species contain?
- (A) 24  
(B) 48  
(C) 49  
(D) 71  
(E) 96
58. The DNA from the bacteriophage  $\phi$ X174 has a base composition of 25% A, 33% T, 24% G, and 18% C. Which of the following best explains this observation?
- (A) In viral genomes, the base pairing does not follow the standard Watson-Crick rules, and allows G-A and C-T base pairs.  
(B) In viral genomes, the base pairing does not follow the standard Watson-Crick rules, and allows G-T and C-A base pairs.  
(C) Viral genomes are linear and tolerate base-pair mismatches.  
(D) Nucleic acids from viruses are tightly complexed with nucleic acid-binding proteins and so cannot base-pair with one another.  
(E) The genome of bacteriophage  $\phi$ X174 is single-stranded.
59. The GAL4 protein activates transcription from the GAL1 promoter in yeast. To bind to DNA, the protein utilizes a
- (A) heme group  
(B) transcriptional-activating domain  
(C) zinc-finger domain  
(D) transmembrane segment  
(E) signal peptide
60. Active transposable elements have which of the following features?
- I. Repeated sequences at the ends of the transposable element  
II. Different numbers and chromosomal positions in different species of a single genus  
III. The ability to alter the phenotype of an organism
- (A) I only  
(B) II only  
(C) I and II only  
(D) I and III only  
(E) I, II, and III
61. Which of the following is NOT an anabolic product of nitrogen assimilation?
- (A) Glutamate  
(B) Glutamine  
(C) Asparagine  
(D) Aspartate  
(E) Urea

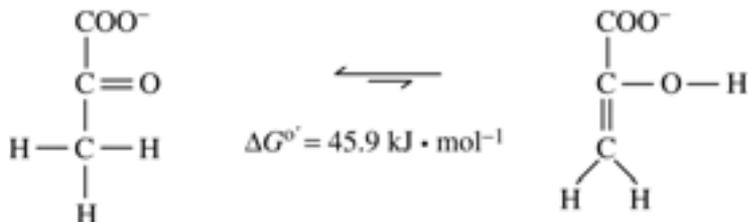
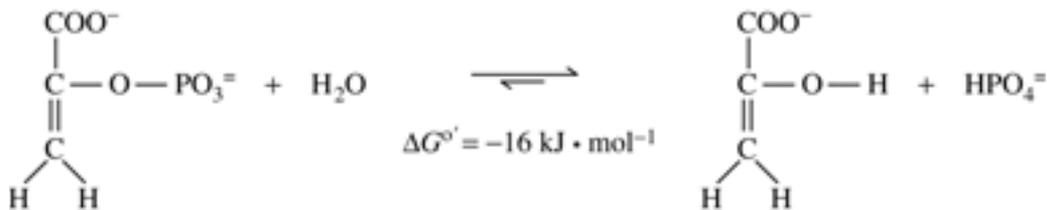
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62. Consider the average *in vivo* turnover rates for proteins, DNA, and mRNA. Which of the following orders best describes the turnover rate from fastest (shortest average lifetime) to slowest (longest average lifetime)?
- (A) mRNA > DNA > proteins  
(B) mRNA > proteins > DNA  
(C) Proteins > mRNA > DNA  
(D) Proteins > DNA > mRNA  
(E) DNA > mRNA > proteins

63. Which of the following pairs of molecules could NOT hydrogen bond with each other?

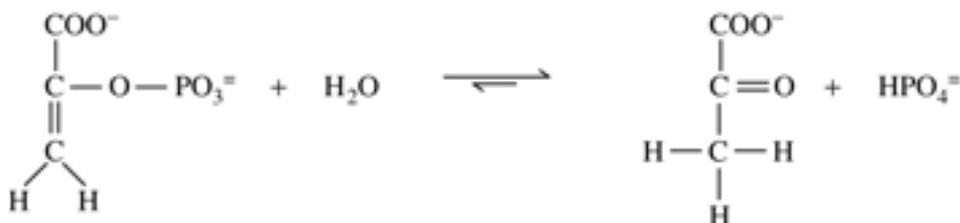


64. In glycolysis, the hydrolysis of phosphoenol pyruvate is thermodynamically driven by the highly exergonic enol-to-keto conversion of pyruvate. From the two half reactions shown below, what is the  $\Delta G^{\circ'}$  of the complete reaction?

Half Reactions

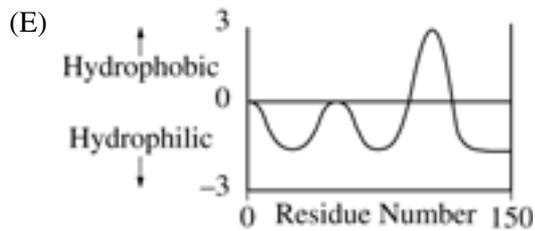
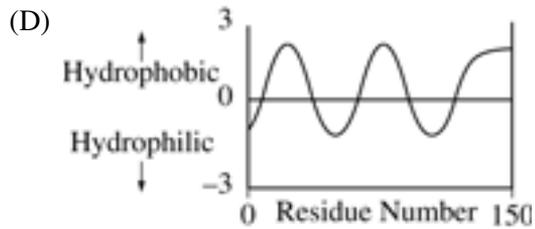
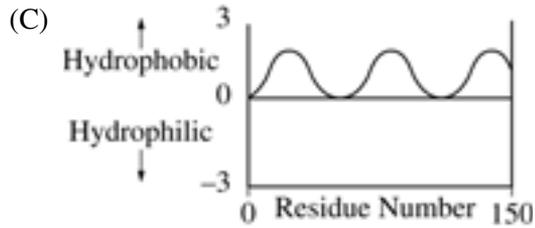
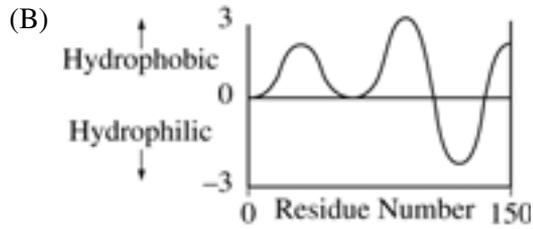
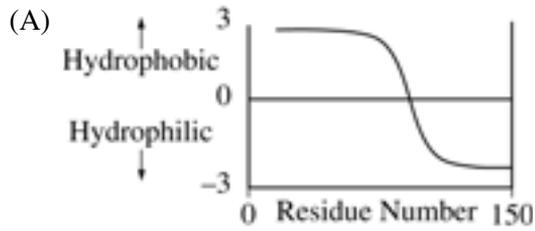


Complete Reaction



- (A)  $61.9 \text{ kJ} \cdot \text{mol}^{-1}$
- (B)  $29.9 \text{ kJ} \cdot \text{mol}^{-1}$
- (C)  $-29.9 \text{ kJ} \cdot \text{mol}^{-1}$
- (D)  $-61.9 \text{ kJ} \cdot \text{mol}^{-1}$
- (E)  $-123.8 \text{ kJ} \cdot \text{mol}^{-1}$

65. Glycophorin, an integral membrane protein, has a single transmembrane alpha helix. Which of the following idealized hydropathy plots most likely represents the transmembrane nature of glycophorin?



66. Rhodopsin,  $\beta$ -adrenergic receptors, and muscarinic acetylcholine receptors share which of the following features?
- Each causes an inhibitory intracellular response.
  - Each activates a tyrosine kinase cascade.
  - Each is composed of an  $\alpha\beta$  dimer.
  - Each functions through a heterotrimeric G-protein.
  - Each gates a cation channel.
67. Retroviral oncogenes are probably aberrant forms of normal cellular genes that regulate cell proliferation. Which of the following gene products are LEAST likely to be encoded by an oncogene?
- GTP-binding proteins
  - DNA-binding proteins
  - Transmembrane proteins
  - Capsid proteins
  - Tyrosine kinases
68. Which of the following best supports the endosymbiotic theory of the evolutionary origin of mitochondria?
- Mitochondria, chloroplasts, and prokaryotes contain electron carriers.
  - Genes for mitochondrial pyruvate dehydrogenase subunits are found in the nuclear DNA.
  - Mitochondrial and bacterial ribosomal functions are inhibited by the same antibiotics.
  - The outer mitochondrial membrane contains the protein porin.
  - Many mitochondrial proteins are imported across both inner and outer membranes after translation on cytoplasmic ribosomes is completed.
69. When the nucleus of a frog red blood cell, which does not replicate DNA, is transplanted into an enucleated frog egg, the egg goes through several cell divisions. Which of the following is the best interpretation for this phenomenon?
- Isolated red-blood-cell nuclei synthesize DNA.
  - The nucleus plays no role in cell division.
  - An enucleated frog egg can divide.
  - Genes do not function during early cleavage.
  - The cytoplasm controls nuclear DNA synthesis.
70. The nuclear-synthesized poly-A sequence at the 3' end of eukaryotic messenger RNA is
- attached at random sequences within the 3' non-translated region of a pre-mRNA
  - found also as a common feature in rRNA and tRNA
  - transcribed from poly-T sequences in template DNA
  - transcribed by RNA polymerase II
  - added after 3' end cleavage of the pre-mRNA transcript
71. A silent mutation in a gene results in
- no change in the nucleotide sequence of the mRNA encoded by the gene
  - no change in the amino acid sequence of the protein encoded by the gene
  - no expression of the protein encoded by the gene
  - an amino acid substitution that has a significant effect on the functional activity of the protein encoded by the gene
  - a shift of the translational reading frame

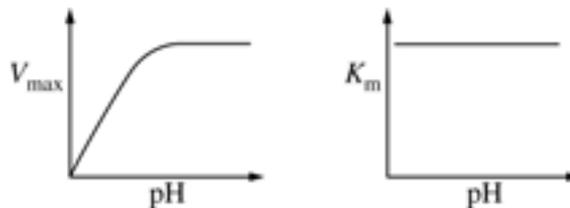
72. Which of the following most accurately explains the cause for the abnormal numbers of chromosomes during human reproduction that can result in Down syndrome, Turner's syndrome, or Klinefelter's syndrome?
- (A) The occurrence of nondisjunction of homologous chromosomes during meiosis
  - (B) The duplicative production of extra chromosomes during DNA replication
  - (C) The abnormal pairing of nonhomologous chromosomes during prophase of meiosis I
  - (D) The selective loss of particular chromosomes from the sex cells after formation of the mature gamete
  - (E) The fusion of two sperm with one egg to provide an extra set of paternal chromosomes
73. THIS ITEM WAS NOT SCORED.
74. The enzyme reverse transcriptase is useful in the generation of cDNA libraries for which of the following reasons?
- (A) It is sensitive to high temperatures and so can be readily "killed" by heat treatment when the reaction is completed.
  - (B) It does not require a primer to initiate polymerization as do most DNA polymerases.
  - (C) It is insensitive to high temperatures and so can survive the many cycles of heating required to perform the polymerase chain reaction.
  - (D) It is an RNA-dependent DNA polymerase.
  - (E) It lacks the proofreading function of most DNA polymerases and so is able to utilize mRNA from mutated genes as a template.
75. Gene rearrangements play a role in which of the following processes?
- (A) Adaptation to carbon source by bacteria
  - (B) Surface antigen changes in trypanosomes
  - (C) Sex determination in nematodes
  - (D) Host range modification in bacteriophage T4
  - (E) Segmentation during arthropod development
76. A mutant of *E. coli* with a heat-sensitive DNA ligase (25°C permissive, 37°C nonpermissive) has been used to show that DNA synthesis is discontinuous. Examination of DNA replication in the presence of [<sup>3</sup>H]-thymidine in the mutant would demonstrate which of following?
- (A) The accumulation of short segments of unlabeled DNA at 25°C and at 37°C
  - (B) The accumulation of short segments of unlabeled DNA at 25°C but not at 37°C
  - (C) The accumulation of short segments of radioactive DNA at 37°C but not at 25°C
  - (D) The accumulation of short segments of radioactive DNA at 25°C but not at 37°C
  - (E) The incorporation of short fragments of radioactive DNA into longer ones at 25°C and at 37°C
77. All of the following statements are true about damage by ultraviolet light to DNA in living cells EXCEPT:
- (A) The damage blocks normal DNA replication.
  - (B) The most damaging wavelength is about 260 nm.
  - (C) Covalent bonds are formed that join neighboring pyrimidines.
  - (D) Neighboring phosphodiester bonds are cleaved.
  - (E) Most cells can synthesize proteins capable of repairing UV damage.

78. Which of the following best predicts the direction of a chemical reaction?

- (A)  $\Delta S$  (entropy change)
- (B)  $\Delta H$  (enthalpy change)
- (C)  $\Delta E$  (internal energy change)
- (D)  $\Delta G$  (Gibbs free energy change)
- (E)  $E_{\text{act}}$  (energy of activation)

79. Thyroxine labeled with  $^{131}\text{I}$  is administered to a patient for the purpose of imaging the thyroid gland. The radioactive half-life of the isotope is 8 days. The biological half-life (the time required for half of the compound to be eliminated from the body) is 2 days. The time at which 3/4 of the original radioactivity will no longer be detectable in the body is closest to

- (A) 2.0 days
- (B) 3.2 days
- (C) 4.0 days
- (D) 4.8 days
- (E) 16.0 days



80. The pH dependencies of  $V_{\text{max}}$  and  $K_m$  for an enzyme are shown above. These data are most consistent with the requirement for

- (A) a general base in catalysis
- (B) a general acid in catalysis
- (C) a dissociable cofactor in catalysis
- (D) a basic residue in substrate binding
- (E) an acidic residue in substrate binding

81. A coenzyme required by some enzymes that transfer one-carbon groups is

- (A) pyridoxal phosphate
- (B) tetrahydrofolate
- (C) thiamine pyrophosphate
- (D) flavin adenine dinucleotide
- (E) nicotinamide adenine dinucleotide

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82. Which of the following represents the sequence of electron flow in the light reactions of photosynthesis in higher plants?

- (A)  $\text{H}_2\text{O} \rightarrow \text{photosystem I} \rightarrow \text{photosystem II} \rightarrow \text{NADP}$
- (B)  $\text{H}_2\text{O} \rightarrow \text{photosystem II} \rightarrow \text{photosystem I} \rightarrow \text{NADP}$
- (C)  $\text{H}_2\text{O} \rightarrow \text{photosystem II} \rightarrow \text{photosystem I} \rightarrow \text{ATP}$
- (D)  $\text{NADPH} \rightarrow \text{photosystem I} \rightarrow \text{photosystem II} \rightarrow \text{O}_2$
- (E)  $\text{Photosystem I} \rightarrow \text{photosystem II} \rightarrow \text{NADPH} \rightarrow \text{O}_2$

83. Allosteric inhibition of an enzyme involves which of the following?
- (A) Binding of an inhibitor to a site other than the substrate binding site
  - (B) Binding of an inhibitor competitively to the substrate binding site
  - (C) Binding of an inhibitor noncompetitively to the substrate binding site
  - (D) Cooperative binding of substrate to an enzyme with four or more subunits
  - (E) Cooperative binding of substrate to an enzyme that does not deviate from normal Michaelis-Menten kinetics
84. The ability of a cell to migrate on a substrate involves all of the following EXCEPT
- (A) formation and breakage of focal adhesions
  - (B) assembly of an actin meshwork at the leading edge
  - (C) WASp proteins
  - (D) Arp2/3 complex proteins
  - (E) connexin proteins
85. Correct statements concerning different members of the myosin family include which of the following?
- I. Some are actin plus (barbed)-end motors
  - II. Some are actin minus (pointed)-end motors
  - III. Some are actin-depolymerizing proteins
- (A) I only
  - (B) II only
  - (C) III only
  - (D) I and II only
  - (E) I, II, and III
86. Which of the following cell junctions is responsible for metabolic coupling?
- (A) Tight junction
  - (B) Gap junction
  - (C) Adherens junction
  - (D) Desmosome
  - (E) Hemidesmosome
87. A dicentric chromosome is unstable because
- (A) it cannot resynthesize its telomeres during replication
  - (B) it pairs with nonhomologous chromosomes in meiosis
  - (C) it pairs with nonhomologous chromosomes in mitosis
  - (D) it is often simultaneously drawn to opposing spindle poles in mitosis
  - (E) many of its genes are silenced
88. Which of the following statements about repetitive DNA is NOT true?
- (A) Repetitive DNA is associated with the centromeres and telomeres in higher eukaryotes.
  - (B) Repetitive DNA is restricted to nontranscribed regions of the genome.
  - (C) Repetitive DNA sequences are often found in tandem clusters throughout the genome.
  - (D) Repetitive DNA was first detected because of its rapid reassociation kinetics.
  - (E) Transposable elements can contribute to the repetitive DNA fraction.
89. Which of the following is NOT characteristic of a eukaryotic enhancer element?
- (A) Its activity is independent of its orientation (i.e., the sequence can be inverted without effect).
  - (B) Its activity is dependent on its distance from the start site of transcription.
  - (C) It may be found as far as 1 to 2 kilobases from the promoter.
  - (D) It may be positioned at the 5' end or the 3' end of the gene.
  - (E) It increases the level of transcription of genes under its control.

90. THIS ITEM WAS NOT SCORED.

91. The glyoxylate cycle is found in plants and bacteria but not in animals. The lack of this cycle in animals results in the inability to

- (A) synthesize oxaloacetate from isocitrate
- (B) synthesize glutamate from malate
- (C) perform gluconeogenesis from amino acids
- (D) perform gluconeogenesis from fatty acids
- (E) perform  $\text{CO}_2$  fixation via the reverse citric acid cycle

92. The urea cycle occurs in the

- (A) mitochondrion and cytoplasm
- (B) mitochondrion and lysosome
- (C) endoplasmic reticulum
- (D) Golgi complex
- (E) peroxisome

93. The units of the molar extinction coefficient are

- (A)  $\text{L} \cdot \text{mole}^{-1} \cdot \text{cm}^{-1}$
- (B)  $\text{L} \cdot \text{mole} \cdot \text{cm}^{-1}$
- (C)  $\text{mole}^{-1} \cdot \text{cm}^{-1}$
- (D)  $\text{cm} \cdot \text{L}^{-1} \cdot \text{cm}^{-1}$
- (E)  $\text{mL} \cdot \text{mg}^{-1} \cdot \text{cm}^{-1}$

94. The Pasteur effect, a decrease in the rate of glucose consumption when anaerobically grown yeast cells are exposed to  $\text{O}_2$ , can be attributed to

- (A) uncoupling of oxidative phosphorylation from electron transport
- (B) stimulation of glycogen breakdown
- (C) an increase in ADP and AMP concentrations due to ATP hydrolysis
- (D) a decreased ATP yield per glucose molecule
- (E) an inhibition of phosphofructokinase by ATP and citrate

95. The equilibrium constant for the reaction catalyzed by malate dehydrogenase (malate to oxaloacetate) is about  $5.9 \times 10^{-6}$ . Which of the following best describes the situation in which malate is converted to oxaloacetate during the citric acid (Krebs) cycle?

- (A) The reaction is exergonic under standard conditions in the direction of the citric acid cycle and this drives the reaction.
- (B) The next reaction of the cycle, citrate synthase, is highly exergonic and it pulls the malate dehydrogenase reaction forward by removing oxaloacetate.
- (C) Malate dehydrogenase catalyzes an irreversible reaction in the citric acid cycle.
- (D) Malate dehydrogenase changes the equilibrium constant for the reaction, allowing it to proceed rapidly.
- (E) Malate accumulates in the cell to such a high concentration that it pushes the reaction forward.

96. Which of the following reactions is anaplerotic (replenishes intermediate pools) for the citric acid cycle?

- (A) Oxaloacetate + GTP  $\rightarrow$  phosphoenolpyruvate + CO<sub>2</sub> + GDP
  - (B) Malate + NAD<sup>+</sup>  $\rightarrow$  oxaloacetate + NADH + H<sup>+</sup>
  - (C) Citrate + ATP + CoA  $\rightarrow$  oxaloacetate + ADP + acetyl-CoA + P<sub>i</sub>
  - (D) Oxaloacetate + acetyl-CoA  $\rightarrow$  citrate + CoA
  - (E) Pyruvate + HCO<sub>3</sub><sup>-</sup> + ATP  $\rightarrow$  oxaloacetate + ADP + P<sub>i</sub> + H<sup>+</sup>
- 

97. Propagation of a regenerative action potential along an axon can be accelerated by which of the following?

- (A) A decrease in the transmembrane resistance
- (B) A decrease in the axoplasmic resistance
- (C) Reduced myelin wrapping
- (D) Shortened internodal lengths
- (E) Narrowing of the axon diameter

98. All of the following processes occur in the pathway leading to regulated protein secretion in animal cells EXCEPT

- (A) formation of transport vesicles from the rough endoplasmic reticulum
- (B) an increase in the concentration of cytosolic calcium ions prior to secretion
- (C) synthesis of an amino-terminal signal sequence
- (D) phosphorylation of a mannose residue in a glycoprotein
- (E) trimming of N-linked oligosaccharides

99. Which of the following events occurs first as a result of EGF binding to its receptor?

- (A) Activation of a serine/threonine kinase
- (B) Activation of a tyrosine phosphatase
- (C) Activation of a tyrosine kinase
- (D) Activation of a phospholipase
- (E) Activation of a GTPase

100. Mitosis and meiosis accomplish segregation of the replicated DNA to two or more daughter cells. Which of the following is characteristic of both mitosis and meiosis?

- (A) Chromosomes attach to spindle fibers composed of actin.
- (B) The resulting cells are diploid (2n).
- (C) The resulting cells are haploid (1n).
- (D) Spindle fibers attach to chromosomes at their kinetochores.
- (E) Chiasmata form between chromosome arms.

101. The increase in the number of nucleoli during oocyte development in the frog *Xenopus laevis* is the result of

- (A) accelerated cell division
- (B) rapid chromosome replication
- (C) rapid synthesis of transfer RNA
- (D) amplification of the ribosomal RNA genes
- (E) accumulation of yolk protein

102. In meiosis, an inversion in one member of a pair of homologous chromosomes will most likely lead to which of the following?

- (A) Nondisjunction of the affected chromosome
- (B) Chromosomes with duplications and deficiencies
- (C) Increased recombination frequency in the inverted region
- (D) Mispairing of the affected chromosome with a nonhomologous chromosome
- (E) Cellular arrest in meiotic prophase

103. One important mechanism for maintaining sequence identity among the many copies of a gene within a tandem array is
- unequal crossing-over
  - gene conversion
  - retrotransposition
  - deletion
  - inversion
104. Which of the following mRNA molecules would form the most stable stem-loop structure?
- 5'...GGCUU.....UUCGG.....3'
  - 5'...GGCUU.....AAGCC.....3'
  - 5'...GGCUU.....GGCUU.....3'
  - 5'...GGCUU.....CCGAA.....3'
  - 5'...AAGCC.....AAGCC.....3'
105. Which of the following conditions is likely to interfere with the transfer of genetic material by conjugation in bacteria?
- Pretreatment of the recipient cells with DNase
  - Pretreatment of the recipient cells by application of strong shearing forces
  - Treatment of the recipient cells with cycloheximide
  - Treatment of the mating cell pairs by application of strong shearing forces
  - Treatment of the mating cell pairs with RNase
106. The zymogen chymotrypsinogen is converted to active chymotrypsin by
- binding of a necessary metal ion
  - reduction of a disulfide bond
  - proteolytic cleavage
  - phosphorylation of an amino acid side chain
  - the action of a signal peptide peptidase
107. How many grams of  $\text{MgCl}_2$  are required to prepare one liter of a 10-millimolar  $\text{MgCl}_2$  solution? (Atomic weight of  $\text{Mg} = 24.3 \text{ g}$ ; atomic weight of  $\text{Cl} = 35.5 \text{ g}$ .)
- 0.59 g
  - 0.95 g
  - 59 g
  - 95 g
  - 950 g
108. Which of the following statements is true regarding the polysaccharides starch, glycogen, cellulose, and chitin?
- All have  $\alpha 1 \rightarrow 4$  linkages.
  - Starch is built from a different monomer than are the others.
  - Each is built from a single type of monomer.
  - Only chitin has a core protein.
  - Chitin and cellulose differ from each other only in the extent of their branching.
109. All of the following statements about the fluid mosaic model of biological membranes are true EXCEPT:
- Lipid molecules in the membrane readily undergo lateral diffusion.
  - Lipid molecules in the membrane readily undergo transverse (flip-flop) diffusion.
  - Integral membrane proteins can undergo lateral diffusion.
  - The saturated hydrocarbon chains of lipid molecules in the membrane undergo carbon-carbon bond rotation.
  - The transition temperature of a membrane is sensitive to the composition of the lipid molecules in the membrane.

110. The primary action of steroid hormones is at the level of
- RNA export from the nucleus
  - transcription
  - pre-mRNA splicing
  - mRNA degradation
  - gene rearrangement
111. The first metabolic intermediate that is common to the aerobic metabolism of glucose and fatty acids is
- acetyl CoA
  - beta-hydroxybutyrate
  - pyruvate
  - citrate
  - glyceraldehyde 3-phosphate
112. In an operon regulated only by attenuation, a mutation causing oversynthesis of the gene products is most likely to be in the part of the DNA corresponding to the
- operator
  - 3' terminal sequence of the RNA
  - 5' terminal sequence of the RNA
  - introns of the RNA
  - coding sequence for the *trans* activator
113. Two protein sequences are compared by BLAST and produce an  $e$  value of  $e^{-100}$ . This  $e$  value most likely signifies which of the following about the genes encoding these two proteins?
- They function in the same tissue.
  - They have unrelated functions.
  - They are descended from a common ancestor.
  - They are derived from related species.
  - They encode proteins that form a dimeric complex.
114. The processes that lead to the synthesis of the functional light chain of an antibody molecule include
- DNA rearrangement but no RNA splicing
  - DNA rearrangement but no gene duplication
  - DNA rearrangement but no protein processing
  - RNA splicing but no DNA rearrangement
  - gene duplication but no protein processing
115. A second mutation in the same gene restores the wild-type phenotype. This phenomenon is referred to as
- intergenic complementation
  - gene conversion
  - synthetic enhancement
  - intragenic suppression
  - epistasis
116. During the gluconeogenic conversion of pyruvate into glucose in the liver, all of the following are involved EXCEPT
- pyruvate carboxylase
  - phosphoenolpyruvate carboxylase
  - phosphoenolpyruvate carboxykinase
  - glucose 6-phosphatase
  - fructose 1,6-bisphosphatase
117. Water is generally a good solvent for polar molecules and a poor solvent for nonpolar molecules. These solvent properties are best explained by
- the high density of liquid water relative to polar solvents
  - the ability to form intermolecular hydrogen bonds
  - the density of solid water being less than the density of liquid water
  - high surface tension
  - high heat of vaporization

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

**Questions 118-121 refer to the following cellular processes.**

- (A) Phagocytosis
- (B) Exocytosis
- (C) Endocytosis
- (D) Transcytosis
- (E) Apoptosis

- 118. Movement of plasma membrane receptors from the basolateral surface to the apical surface of polarized epithelial cells
- 119. Up-regulation of glucose transporters at the plasma membrane
- 120. Selective retrieval of cell-surface proteins for recycling or degradation
- 121. Neurotransmitter release

**Questions 122-123**

- (A) Transition
  - (B) Transversion
  - (C) Translocation
  - (D) Tautomerization
  - (E) Reversion
- 122. The exchange of material between nonhomologous chromosomes
  - 123. The change from a mutant allele to a wild-type allele

**Questions 124-126 refer to the following protein-modifying reagents.**

- (A) Chymotrypsin
- (B) Cyanogen bromide
- (C) Iodoacetamide
- (D) Phenylglyoxal
- (E) Pyridoxal 5'-phosphate

- 124. Forms a Schiff-base linkage with the  $\epsilon$ -amino group of lysine residues
- 125. Specifically cleaves polypeptides on the carboxyl side of methionine residues
- 126. Generally used as a sulfhydryl-modifying reagent

**Questions 127-129 refer to the following cell structures.**

- (A) Thylakoid membrane
- (B) Nuclear lamina
- (C) Eubacterial cell wall
- (D) Plant cell wall
- (E) Endoplasmic reticulum

- 127. Its assembly is inhibited by penicillin.
- 128. It is formed from polymeric fibrils composed of cellulose cross-linked by pectin and hemicellulose.
- 129. It is the site of dolichol phosphate function.

**Questions 130-134**

- (A) Photoreactivation
- (B) Excision repair
- (C) Recombination repair
- (D) SOS repair
- (E) Mismatch repair

130. Produces oligonucleotides that contain damaged bases
131. Acts only on pyrimidine dimers
132. Uses methyl groups to distinguish parental and daughter strands
133. Is often mutagenic
134. Involves exchange of sister strands

**Questions 135-137 refer to the following.**

- (A) Cytochrome *c*
- (B) Cytochrome *b*
- (C) Plastocyanin
- (D) Ubiquinone
- (E) Plastoquinone

135. Donates electrons to mitochondrial cytochrome oxidase
136. Donates electrons to P<sub>700</sub> of Photosystem I
137. Accepts electrons from mitochondrial NADH dehydrogenase

**Questions 138-140 refer to the following classes of enzymes.**

- (A) Isomerase
- (B) Kinase
- (C) Ligase
- (D) Phosphatase
- (E) Oxidoreductase

138. Catalyzes the hydrolytic removal of one phosphate group from a monosaccharide bisphosphate
139. Catalyzes the transfer of a phosphoryl group to a nucleoside diphosphate
140. Catalyzes the conversion of a ketosugar phosphate to the corresponding aldose phosphate

**Questions 141-142 refer to the following organisms.**

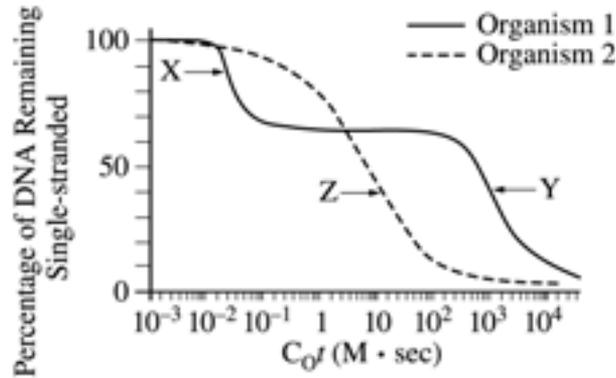
- (A) *E. coli*
- (B) Yeast
- (C) Bacteriophage T4
- (D) Bacteriophage lambda
- (E) Adenovirus

141. Possesses genes that may be integrated into the genome of an infected eukaryotic cell
142. Can lysogenize bacteria

**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 143-144**

The figure below is a graph of the reannealing (reforming of double-stranded molecules) of total genomic DNA from two different organisms. DNA was extracted from each organism, sheared to a uniform size, and then denatured by heating. An identical amount of each preparation of sheared, single-stranded DNA was allowed to reanneal under identical conditions of pH, buffer, ionic strength, and temperature. The reannealing curves shown were obtained by plotting the percentage of DNA remaining single-stranded *versus* the product of the total DNA concentration ( $C_0$ ), in moles of nucleotide per liter, times the renaturation time ( $t$ ), in seconds.



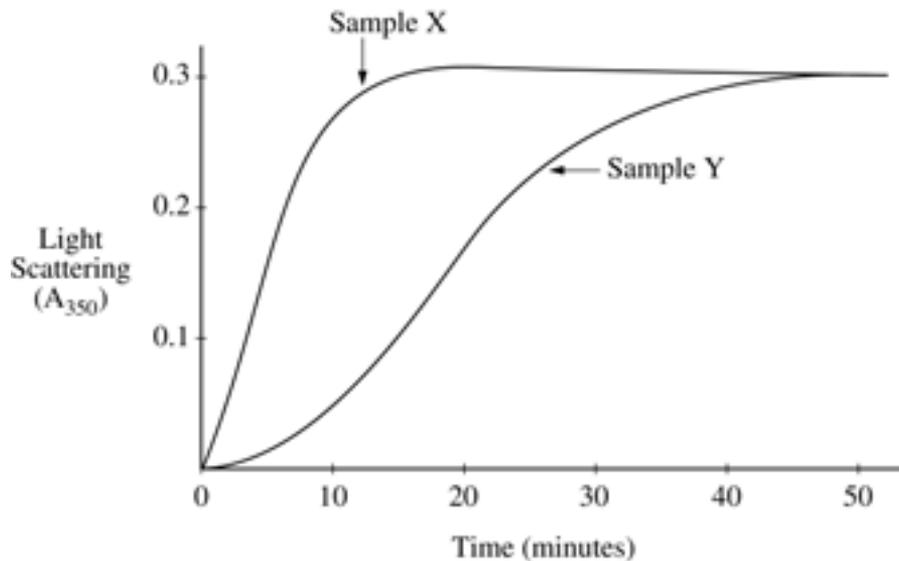
143. In the samples of sheared DNA, which of the following is true about the sequence complexity of the populations indicated by X, Y, and Z in the figure?
- (A) Y is more complex than either X or Z.
  - (B) X is more complex than either Y or Z.
  - (C) X and Y are of equivalent complexity and more complex than Z.
  - (D) X and Y are of equivalent complexity and less complex than Z.
  - (E) X, Y, and Z are of equivalent complexity.

144. Proteins are most likely encoded by which of the populations of DNA fragments indicated by X, Y and Z in the figure?
- (A) X only
  - (B) Y only
  - (C) X and Y
  - (D) X and Z
  - (E) Y and Z

## Questions 145-148

The assembly of pure brain tubulin into microtubules *in vitro* can be followed by using a spectrophotometer to measure light scattering (absorbance at 350 nanometers). The total mass of microtubule polymer is proportional to the amount of light scattered. Polymerization is initiated by warming the sample buffer, containing tubulin and an excess of GTP, to 37°C.

In the experiment whose results are shown below, soluble tubulin at 1.6 milligrams per milliliter was used for both sample X and sample Y. A small volume of eukaryotic basal bodies was added to sample X only. Assume that the basal body sample did not significantly affect the volume or the initial tubulin concentration of sample X.



145. Which of the following statements best describes the situation at 50 minutes in both sample X and sample Y?
- (A) All tubulin is in the polymeric form.
  - (B) The rate of tubulin subunit addition to microtubules equals the rate of tubulin loss from microtubules.
  - (C) Tubulin subunit addition to microtubules has been limited by the hydrolysis of all the GTP.
  - (D) The number of microtubules is continuing to increase.
  - (E) The average length of the microtubules is continuing to increase.
146. The ratio of the mass of polymerized tubulin in sample X to that in sample Y at 15 minutes is approximately
- (A) 0.2
  - (B) 0.3
  - (C) 1
  - (D) 2
  - (E) 3
147. Unlike sample X, sample Y exhibits a lag time before polymerization begins. This lag time in Y is most likely due to which of the following?
- (A) Time necessary for GTP hydrolysis
  - (B) Time needed for GTP/GDP exchange by the tubulin subunits
  - (C) Time needed for a nucleation step
  - (D) Inability to detect microtubules when they are short
  - (E) Dynamic instability of the microtubules
148. Which of the following is the best explanation for the fact that the maximum rate of polymerization exhibited by sample X is faster than that exhibited by sample Y?
- (A) There is more tubulin in sample X.
  - (B) Each microtubule elongates at a faster rate in sample X.
  - (C) The microtubules in sample X are longer.
  - (D) There are more microtubules elongating in sample X.
  - (E) The microtubules formed in sample Y are more stable.

**Questions 149-152**

In *Drosophila melanogaster*, cinnabar eye (*cn*) and vestigial wing (*vg*) are simple recessive traits. A female, heterozygous for both genes, was crossed with a male with cinnabar eyes and vestigial wings. The offspring resulting from this cross are listed in the table below.

Class	Phenotype	Number
I	Wild type	445
II	Cinnabar eye, wild-type wing	51
III	Wild-type eye, vestigial wing	49
IV	Cinnabar eye, vestigial wing	455

149. Recombinant phenotypes include which of the following classes?

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

150. From the data shown, the distance between the *cn* and *vg* genes is approximately

- (A) 500 map units
- (B) 100 map units
- (C) 50 map units
- (D) 10 map units
- (E) 5 map units

151. If crossing-over were to occur in the male parent, the anticipated effect on phenotypic numbers would be

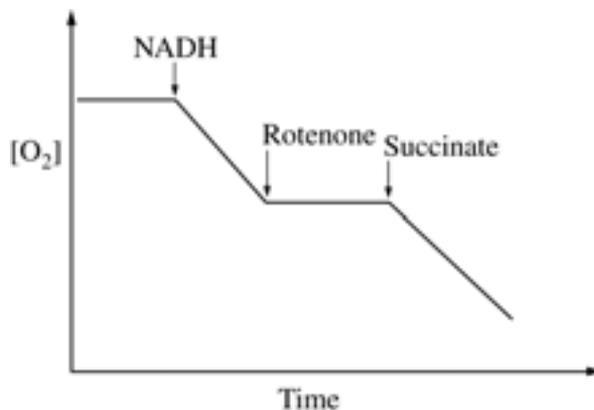
- (A) a decrease in class I
- (B) a decrease in class II
- (C) a decrease in class III
- (D) a decrease in class IV
- (E) no significant difference

152. If *cn* and *vg* were unlinked, what percent of the offspring would be expected to have either cinnabar eyes or vestigial wings or both?

- (A) 100%
- (B) 75%
- (C) 50%
- (D) 25%
- (E) 6%

### Questions 153-155

A suspension of vesicles derived from mitochondria was freshly prepared in buffer containing ADP and inorganic phosphate. The suspension was placed in a stirred reaction chamber with no gas phase. The  $O_2$  concentration in the reaction chamber was continuously monitored by means of an  $O_2$  electrode. The recording shown below was obtained. At the times indicated by each arrow, the specific reagent was added to the reaction chamber. Note that after each addition of reagent, previously added reagents were still present. Reagent concentrations did not significantly decrease over the course of the experiment.



153. The rate of  $O_2$  consumption increased upon addition of NADH because
- (A) NADH is an allosteric activator of NADH ubiquinone oxidoreductase
  - (B) NADH uncouples oxidation from phosphorylation
  - (C) NADH displaces  $O_2$  from the reaction mixture
  - (D) cytochrome oxidase binds NADH and transfers electrons from NADH to  $O_2$
  - (E) electrons from the oxidation of NADH are transferred through the electron transport chain to  $O_2$
154. The results of the experiment indicate that the mechanism by which rotenone inhibits  $O_2$  consumption can be most accurately described by which of the following?
- (A) Rotenone uncouples oxidation from phosphorylation.
  - (B) Rotenone is an analog of NADH.
  - (C) Rotenone blocks  $CF_o$  of the ATP synthase.
  - (D) Rotenone inhibits cytochrome oxidase.
  - (E) Rotenone inhibits NADH dehydrogenase (Complex I).
155. The rate of ATP production should be
- (A) highest after addition of succinate, less high after addition of NADH, and lowest after addition of rotenone
  - (B) highest after addition of NADH, less high after addition of succinate, and lowest after addition of rotenone
  - (C) highest after addition of rotenone, less high after addition of succinate, and lowest after addition of NADH
  - (D) high at all times and unaffected by the additions of NADH, succinate, and rotenone
  - (E) very low at all times and unaffected by the additions of NADH, rotenone, and succinate

## Questions 156-158

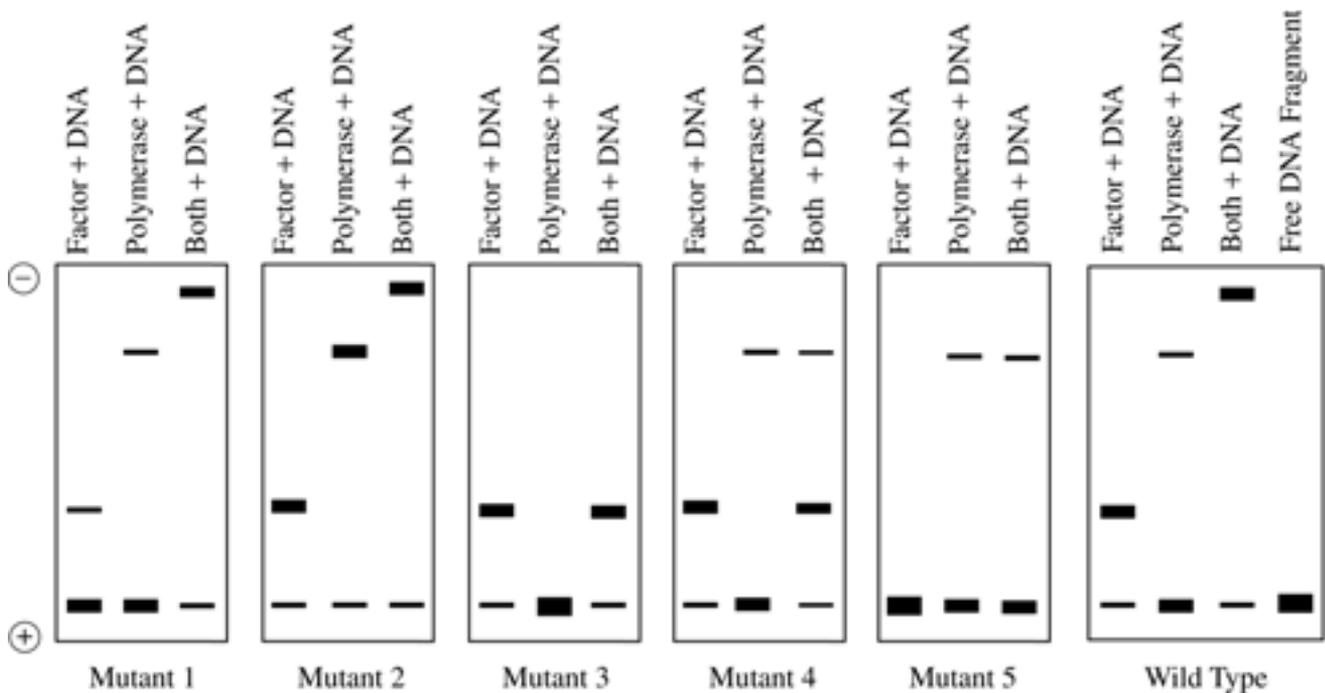
The ability of a population of fibroblasts to migrate along the surface of a tissue culture dish depends on adhesion between the cell surface and the extracellular matrix molecules coating the dish. The dish is coated with laminin, and the only cell-surface protein capable of binding laminin is a cell-adhesion protein called an integrin. Integrins are integral plasma-membrane proteins that function as  $\alpha\beta$  heterodimers. Under these conditions the rate at which a fibroblast can migrate along the laminin-coated culture dish is proportional to the strength of adhesion between the cell and the laminin substrate. The table below lists the rate of cell migration observed for fibroblasts genetically engineered to generate the indicated phenotypes.

<u>Fibroblast Phenotype</u>	<u>Level of Integrin Heterodimer at the Cell Surface (percent of wild type)</u>	<u>Rate of Cell Migration (<math>\mu\text{m}/\text{min}</math>)</u>
1. Wild type	100	2
2. Overexpression of the wild-type integrin $\alpha$ subunit	104	2
3. Overexpression of an integrin $\beta$ subunit lacking the cytoplasmic domain	96	0.6
4. Overexpression of the soluble cytoplasmic domain of an integrin $\beta$ subunit	98	0.6
5. Absence of the integrin $\alpha$ subunit	Less than 1	0.05

156. Which of the following is the most likely explanation for failure of overexpression of the integrin  $\alpha$  subunit to alter the rate of fibroblast migration?
- (A) The integrin  $\alpha$  subunit is not required for integrin function.
  - (B) The integrin  $\alpha$  subunit cannot function without a  $\beta$  subunit.
  - (C) The integrin  $\alpha$  subunit binds a cytoplasmic protein factor necessary for integrin function.
  - (D) The integrin  $\alpha$  subunit alone is functional, but the cell proteolytically destroys the excess integrin  $\alpha$  subunits.
  - (E) Excess integrin  $\alpha$  subunit induces loss of  $\alpha\beta$  heterodimer from the cell surface.
157. One explanation for the effect of overexpression of the cytoplasmic domain of the integrin  $\beta$  subunit is that this domain normally functions to bind a cytoplasmic factor necessary for integrin function. Which of the following would be the most informative experiment to identify the cytoplasmic factor?
- (A) Fractionate a fibroblast cell extract using an affinity column prepared with the cytoplasmic domain of the integrin  $\beta$  subunit.
  - (B) Fractionate a fibroblast cell extract using an affinity column prepared with the integrin  $\beta$  subunit lacking the cytoplasmic domain.
  - (C) Inject live fibroblasts with the cytoplasmic domain of the integrin  $\beta$  subunit.
  - (D) Inject live fibroblasts with an antibody to the cytoplasmic domain of the integrin  $\beta$  subunit.
  - (E) Inject cells with a cytoplasmic extract obtained from cells lacking the cytoplasmic domain of the integrin  $\beta$  subunit.
158. Microinjection into the cytoplasm of a wild-type cell of a solution of a synthetic peptide possessing the same sequence as the integrin  $\beta$  subunit cytoplasmic domain would be expected to yield an average fibroblast-cell migration rate of
- (A)  $4 \mu\text{m}/\text{min}$
  - (B)  $2 \mu\text{m}/\text{min}$
  - (C)  $0.6 \mu\text{m}/\text{min}$
  - (D)  $0.05 \mu\text{m}/\text{min}$
  - (E)  $0.01 \mu\text{m}/\text{min}$

## Questions 159-161

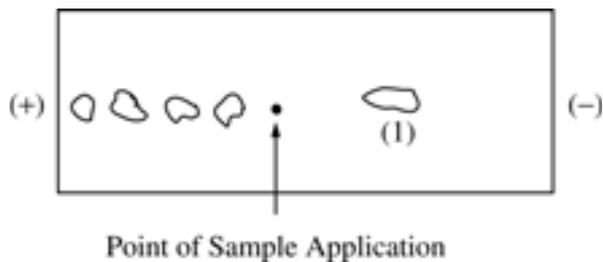
Five *E. coli* strains have been identified, each of which has a different mutation that disrupts the normal regulation of a particular operon. For each mutant strain, the mutation has been mapped to the promoter or the operator region; however, the exact sequence changes are not known for these mutations. It is known that the normal promoter/operator consists of a single binding site for a positively acting transcription factor located just upstream of the promoter itself. Short DNA fragments containing the promoter and the operator were subcloned from each of the five mutant strains and from the wild type, purified, and radiolabeled. These fragments were then incubated under conditions of DNA excess with either purified regulatory factor or RNA polymerase or with both polymerase and regulatory factor. The resulting protein-DNA complexes were separated by electrophoresis, and the radioactive DNA fragments were detected by exposure to x-ray film, giving the results shown below. Electrophoresis is from top to bottom; the largest complexes run slowest.



159. One of the mutations increases the affinity of the polymerase for the promoter. Transcription of the operon is not stimulated by the regulatory factor in this mutant. Which mutant is most likely to show this effect?
- (A) Mutant 1
  - (B) Mutant 2
  - (C) Mutant 3
  - (D) Mutant 4
  - (E) Mutant 5
160. One of the mutations maps to the operator. Transcription of the operon is not stimulated by the regulatory factor in this mutant. Which mutant is most likely to show this effect?
- (A) Mutant 1
  - (B) Mutant 2
  - (C) Mutant 3
  - (D) Mutant 4
  - (E) Mutant 5
161. One of the mutations is known to result from a small deletion between the operator and the promoter. The polymerase and the regulatory factor are each able to bind to the mutated DNA sequence, but are unable to form the three-component complex. Transcription of the operon is not stimulated by the regulatory factor in this mutant. Which mutant shows the properties that might be expected for such a change?
- (A) Mutant 1
  - (B) Mutant 2
  - (C) Mutant 3
  - (D) Mutant 4
  - (E) Mutant 5

Questions 162-163 refer to the following laboratory situation.

A student was given a task of identifying the contents of five bottles of amino acids from which the labels had fallen off. Each of the original bottles contained one of the following: arginine, histidine, cysteine, proline, and tryptophan.



162. Which of the following methods could be most readily employed to identify tryptophan?

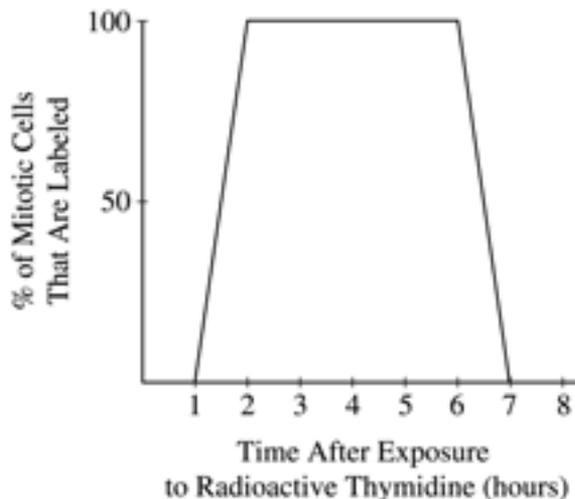
- (A) Electrophoresis
- (B) Ultraviolet spectroscopy
- (C) Gel filtration
- (D) Analytical ultracentrifugation
- (E) Optical rotation

163. Each amino acid was subjected to paper electrophoresis in a pH 9.5 buffer, and then the amino acids were visualized by spraying the paper with ninhydrin. Which amino acid is at the point labeled (1) in the figure above?

- (A) Arginine
- (B) Histidine
- (C) Cysteine
- (D) Proline
- (E) Tryptophan

## Questions 164-166

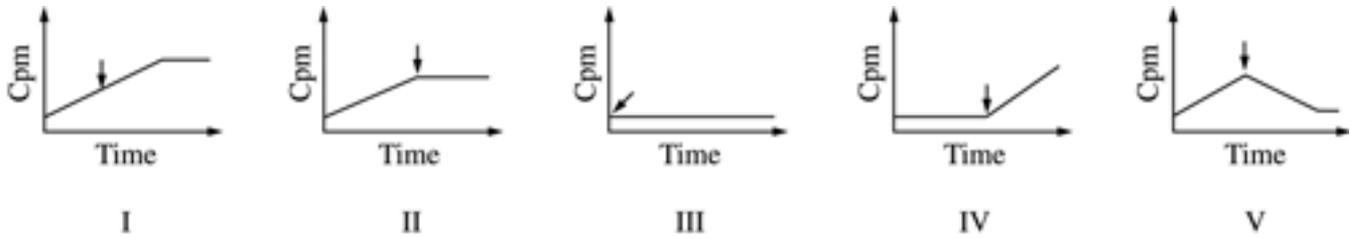
The stages of the cell cycle for a cultured mammalian cell line require the following periods of time:  $G_1 = 8$  hr,  $S = 5$  hr,  $G_2 = 1$  hr,  $M = 1$  hr. An asynchronous culture of these cells is exposed to radioactive thymidine for five minutes and then allowed to continue to grow in nonradioactive medium. The figure below shows the percent of mitotic cells that are radioactively labeled as a function of time after exposure to the radioactive thymidine.



164. The reason it takes approximately one hour before the first radioactively labeled mitotic cells are observed is that
- (A) cells must repair thymidine-induced DNA damage before entering  $G_2$
  - (B) the cells get out of synchrony as they proceed through the cell cycle
  - (C) the period of thymidine labeling is 5 minutes
  - (D)  $G_2$  lasts 1 hr
  - (E) M phase lasts 1 hr
165. What percent of labeled cells are in M phase at 2 hours after exposure to labeled thymidine?
- (A) 100
  - (B) 33
  - (C) 20
  - (D) 6
  - (E) 0
166. If the length of  $G_2$  were increased by one hour, which of the following statements would be true regarding the slope of the line from the point of the first appearance of labeled mitotic cells to the first point at which all the mitotic cells were labeled?
- (A) It would increase.
  - (B) It would decrease.
  - (C) It would stay the same.
  - (D) It would switch from a positive to a negative slope.
  - (E) No conclusion regarding the slope of the line can be drawn.

**Questions 167-170 refer to the following experiment.**

The graphs below represent various curves obtained in different *in vitro* bacterial translation experiments. The peptide product was assayed as acid-precipitable counts per minute (cpm) that resulted from incorporation of a mixture of radiolabeled amino acids. The arrows represent the times at which various substances were added to the systems.



167. The addition of an antibiotic at the start of the assay results in the curve shown in graph III, while addition at a later time yields the curve shown in graph I. This antibiotic most likely blocks

- (A) elongation only
- (B) initiation only
- (C) termination only
- (D) both initiation and elongation
- (E) both elongation and termination

168. Addition of *fmet-tRNA<sub>f</sub>* to a system lacking only this component is most likely to give the curve shown in graph

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

169. Addition of a peptide that binds irreversibly to the A site of the ribosome will most likely give which of the following graphs?

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

170. Addition of which of the following would most likely give the curve seen in graph V?

- (A) Ribonuclease
- (B) Exopeptidase
- (C) Deoxyribonuclease
- (D) Chloramphenicol
- (E) Cycloheximide

**Questions 171-175**

The effects of a newly discovered human virus on host cell metabolism were studied by infecting HeLa cells with the virus at a multiplicity of infection of 10 virus particles per cell. Before infection (0 hour) and at various times after infection (6, 12, 18, and 24 hours), samples from the cultures were labeled with <sup>35</sup>S-methionine for 30 minutes. At the end of each 30-minute labeling, cell extracts were prepared and analyzed by SDS-polyacrylamide gel electrophoresis. The gels were dried and exposed to x-ray film to detect radioactive proteins. The results of this experiment are shown in Figure 1. The numbers to the right of the figure show the positions of molecular weight standards.

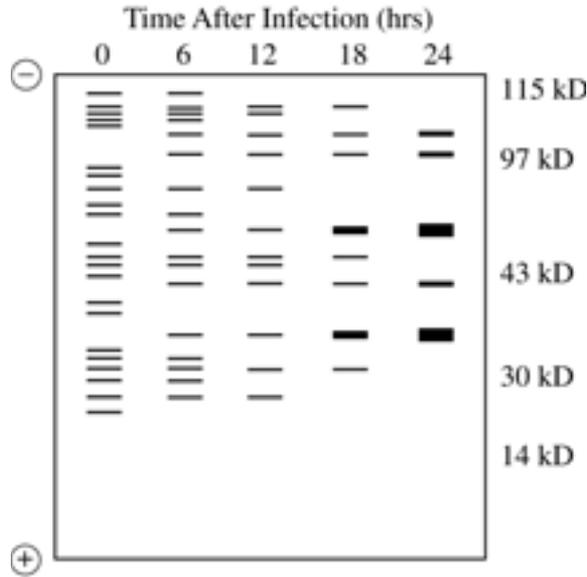


Figure 1

In a second set of experiments, mRNA-free cytosolic extracts were prepared from the cells at 0 hours and at 24 hours after infection and used for *in vitro* translation assays. In addition to <sup>35</sup>S-methionine, either actin mRNA or the intact viral genome was added to each reaction. The products were examined by gel electrophoresis and autoradiography, and the results are shown in Figure 2. Also shown in Figure 2 are the results of a similar *in vitro* translation reaction carried out using the viral template and the 24-hour extract with the addition of microsomes. Note that in the presence of microsomes, the band labeled X disappears and a new band, Y, appears. Bands X and Y were excised from the gel and digested with trypsin, and the tryptic peptides obtained were compared by gel electrophoresis. Most of the peptides obtained from the two proteins were identical, but each protein gave rise to one unique peptide.

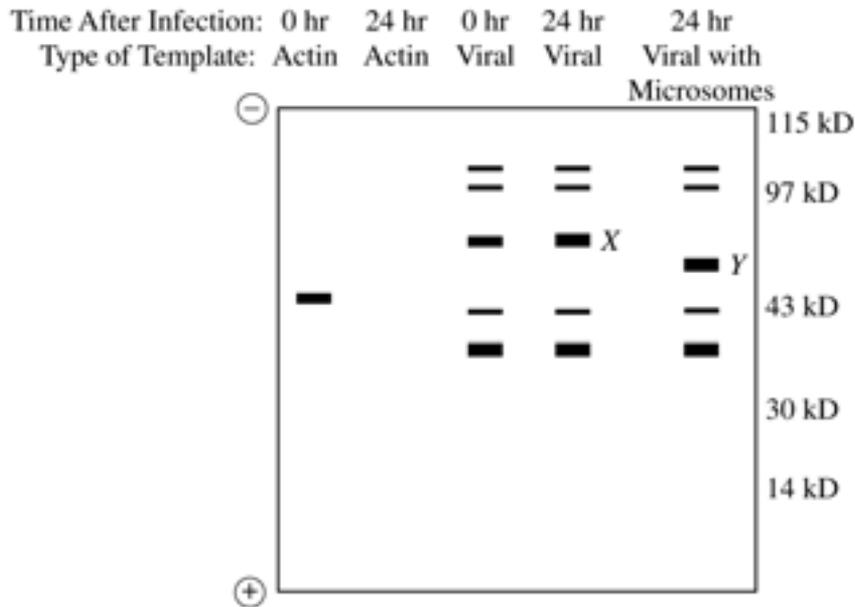


Figure 2

171. The bands in Figure 1 represent which of the following?
- Total viral and cellular proteins present in cells at the time the extracts were prepared
  - Total viral proteins present in cells at the time the extracts were prepared
  - Only viral proteins that were synthesized during the 30-minute labeling period
  - Only cellular proteins that were synthesized during the 30-minute labeling period
  - Both viral and cellular proteins that were synthesized during the 30-minute labeling periods
172. According to the data in Figure 2, the genome of this virus is
- plus-strand RNA
  - plus-strand DNA
  - double-stranded RNA
  - double-stranded DNA
  - minus-strand RNA
173. The most likely explanation for the data in Figures 1 and 2 is that the virus shuts off
- host-cell DNA synthesis
  - transcription of cellular but not viral mRNAs
  - translation of cellular but not viral mRNAs
  - transcription of viral and cellular mRNAs
  - translation of viral and cellular mRNAs
174. The most likely explanation for the appearance of protein *Y* in Figure 2 is which of the following?
- Protein *Y* is translated from the same mRNA as protein *X*, but in a different reading frame.
  - Protein *Y* is translated in the same reading frame as protein *X*, but uses a different AUG initiation codon.
  - Protein *X* and *Y* are encoded by differentially spliced mRNAs.
  - Protein *X* is a proteolytic product of protein *Y*.
  - Protein *Y* is a proteolytic product of protein *X*.
175. According to the information in Figure 2, protein *Y* most likely represents which of the following viral proteins?
- RNA polymerase
  - DNA polymerase
  - Capsid protein
  - Protease
  - Envelope protein

**Questions 176-180**

The antibiotic fluconazole is used against pathogenic fungi. After long-term treatment, resistant organisms can arise. One yeast strain was resistant to  $10 \mu\text{g} \cdot \text{mL}^{-1}$  fluconazole, whereas the growth of the wild type was prevented by  $5 \mu\text{g} \cdot \text{mL}^{-1}$ . The kinetics of the enzyme that is the target of fluconazole, lanosterol 14-demethylase (14-DM), were determined in the wild type and the resistant yeast, and the curves shown in Figures 1a and 1b were obtained. In order to determine whether resistance was caused by a mutation in 14-DM, the sequences of the genes from the wild type and the resistant strain were determined. Figure 2 shows a comparison of the part of these sequences where differences were found.

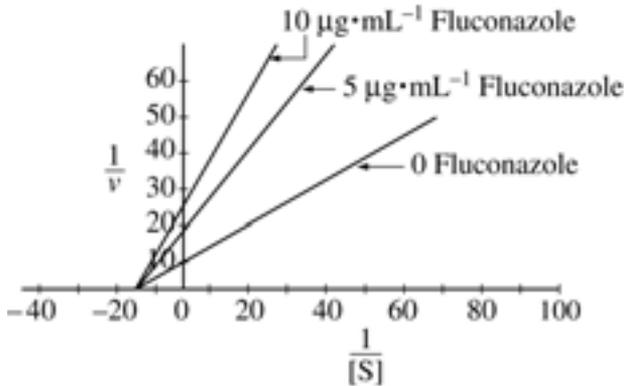


Figure 1a. WILD-TYPE STRAIN

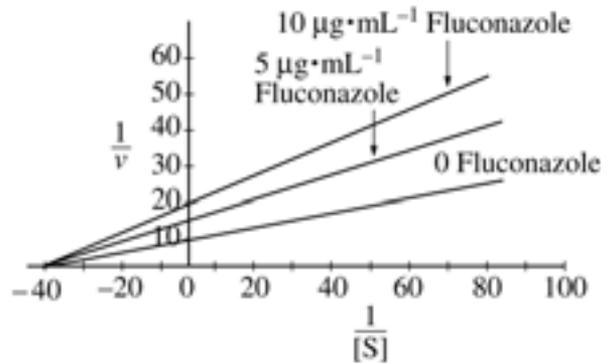


Figure 1b. RESISTANT STRAIN

Wild Type

	300									330
Codon:	...UUU	UUA	AAG	GCA	CAC	AAC	GAG	UUA	UGG	UUU ...
	51									60
Protein:	... phe	leu	lys	ala	his	asn	glu	leu	trp	phe

Resistant Strain

	300									330
Codon:	...UUU	AUU	AAA	GGC	ACA	CAA	CGA	GUU	UGG	UUU ...
	51									60
Protein:	... phe	ile	lys	gly	thr	gln	arg	val	trp	phe ...

Figure 2 PARTIAL CODING SEQUENCES AND DEDUCED AMINO ACIDS FROM THE 14-DM GENES OF RESISTANT AND WILD-TYPE YEAST

176. Which of the following is the effect of fluconazole on the lanosterol 14-DM?
- (A) Competitive inhibition
  - (B) Uncompetitive inhibition
  - (C) Noncompetitive inhibition
  - (D) Irreversible inactivation
  - (E) Activation
177. Which of the following kinds of mutation is found in the gene for the resistant enzyme shown in Figure 2 ?
- (A) Missense
  - (B) Nonsense
  - (C) Frameshift
  - (D) Silent
  - (E) Null
178. Which of the following amino acid changes shown in Figure 2 is most likely to alter sensitivity to fluconazole?
- (A) Leu → Ile
  - (B) Ala → Gly
  - (C) Asn → Gln
  - (D) Glu → Arg
  - (E) Leu → Val
179. A diploid was made by mating the resistant yeast and the wild type. Of 20 diploids picked, all were resistant to  $10 \mu\text{g} \cdot \text{mL}^{-1}$  of fluconazole. This is most likely due to which of the following?
- (A) Gene conversion
  - (B) Dominance of the mutation
  - (C) Suppression of the mutation
  - (D) Complementation
  - (E) Mitotic crossing-over
180. The mutation alters which of the following kinetic or thermodynamic properties of the reaction catalyzed by 14-DM?
- (A)  $K_m$  only
  - (B)  $K_{eq}$  only
  - (C)  $V_{max}$  only
  - (D)  $K_m$  and  $V_{max}$  only
  - (E)  $K_m$ ,  $K_{eq}$ , and  $V_{max}$

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

**NO TEST MATERIAL ON THIS PAGE**



## Scoring Your Subject Test

Biochemistry, Cell and Molecular Biology Test scores are reported on a 200 to 990 score scale in ten-point increments. The actual range of scores is smaller, and it varies from edition to edition because different editions are not of precisely the same difficulty. However, this variation in score range is usually small and should be taken into account mainly when comparing two very high scores. In general, differences between scores at the 99th percentile should be ignored. **The score conversion table on page 57 shows the score range for this edition of the test only.**

Subscores are reported as two-digit scaled scores. The maximum possible range of Subject Test subscores is 20 to 99. Like total scores, the actual range of subscores for any test or test edition may be smaller than 20 to 99.

The worksheet on page 56 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 total score. Use the total score conversion table to find the scaled total score that corresponds to your raw total score.

Example: Suppose you chose the correct answers to 91 questions and incorrect answers to 39. Dividing 39 by 4 yields 9.8. Subtracting 9.8 from 91 equals 81.2, which is rounded to 81. The raw score of 81 corresponds to a scaled score of 530.

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.

## Worksheet for the Biochemistry, Cell and Molecular Biology Test, Form GR0522 Answer Key and Percentages\* of Examinees Answering Each Question Correctly

QUESTION		P+	RESPONSE		SUBSCORE		
Number	Answer		C	I	1	2	3
1	A	72			•		
2	B	68			•		
3	A	71			•		
4	A	43			•		
5	D	62			•		
6	D	49				•	
7	B	32				•	
8	B	68				•	
9	C	56				•	
10	D	84				•	
11	D	74					•
12	E	74					•
13	B	58					•
14	C	32					•
15	A	36					•
16	A	60			•		
17	A	60			•		
18	C	23			•		
19	A	84			•		
20	E	12			•		
21	C	24				•	
22	A	48				•	
23	A	17				•	
24	A	41				•	
25	D	56				•	
26	A	42					•
27	A	66					•
28	A	62					•
29	D	81					•
30	C	43					•
31	D	55			•		
32	C	50			•		
33	D	40			•		
34	E	33			•		
35	B	29			•		
36	C	61				•	
37	C	62				•	
38	B	33				•	
39	D	61				•	
40	C	82				•	
41	C	74					•
42	A	59					•
43	A	47					•
44	D	40					•
45	A	48					•
46	C	21			•		
47	B	60			•		
48	A	50			•		
49	E	23			•		
50	E	16			•		
51	B	57				•	
52	D	20				•	
53	B	31				•	
54	E	28				•	
55	A	73				•	
56	B	49					•
57	B	92					•
58	E	80					•
59	C	64					•
60	E	60					•

QUESTION		P+	RESPONSE		SUBSCORE		
Number	Answer		C	I	1	2	3
61	E	41			•		
62	B	73			•		
63	D	81			•		
64	D	72			•		
65	E	57			•		
66	D	41				•	
67	D	56				•	
68	C	59				•	
69	E	48				•	
70	E	67					•
71	B	88					•
72	A	85					•
73	**						
74	D	70					•
75	B	35					•
76	C	49					•
77	D	45					•
78	D	85			•		
79	B	42			•		
80	A	32			•		
81	B	27			•		
82	B	56			•		
83	A	82			•		
84	E	17				•	
85	D	38				•	
86	B	40				•	
87	D	60					•
88	B	56					•
89	B	44					•
90	**						
91	D	18			•		
92	A	45			•		
93	A	56			•		
94	E	33			•		
95	B	50			•		
96	E	28			•		
97	B	13				•	
98	D	22				•	
99	C	38				•	
100	D	70				•	
101	D	25					•
102	B	29					•
103	B	19					•
104	B	82					•
105	D	46					•
106	C	63			•		
107	B	80			•		
108	C	41			•		
109	B	61			•		
110	B	70			•		
111	A	59			•		
112	C	14					•
113	C	29					•
114	B	28					•
115	D	49					•
116	B	26			•		
117	B	96			•		
118	D	76				•	
119	B	30				•	
120	C	72				•	

QUESTION		P+	RESPONSE		SUBSCORE		
Number	Answer		C	I	1	2	3
121	B	85			•		
122	C	72					•
123	E	83					•
124	E	23			•		
125	B	25			•		
126	C	18			•		
127	C	85				•	
128	D	85				•	
129	E	23				•	
130	B	27					•
131	A	36					•
132	E	52					•
133	D	33					•
134	C	82					•
135	A	35			•		
136	C	15			•		
137	D	35			•		
138	D	84			•		
139	B	72			•		
140	A	79			•		
141	E	67					•
142	D	50					•
143	A	50			•		
144	E	48			•		
145	B	60				•	
146	E	83				•	
147	C	44				•	
148	D	33				•	
149	C	70					•
150	D	42					•
151	E	64					•
152	B	48					•
153	E	69			•		
154	E	40			•		
155	B	58			•		
156	B	61				•	
157	A	51				•	
158	C	61				•	
159	B	53					•
160	E	42					•
161	D	48					•
162	B	57			•		
163	A	45			•		
164	D	51				•	
165	C	11				•	
166	C	34				•	
167	B	75					•
168	D	74					•
169	E	55					•
170	B	44					•
171	E	62			•		
172	A	27					•
173	C	48					•
174	E	33				•	
175	E	15				•	
176	C	29			•		
177	C	73					•
178	D	63			•		
179	B	78					•
180	A	17			•		

Total Correct (C) \_\_\_\_\_

Total Incorrect (I) \_\_\_\_\_

Total Score:  
C - I/4 = \_\_\_\_\_

Scaled Score (SS) = \_\_\_\_\_

Subscores

1) C - I/4 = \_\_\_\_\_ SS = \_\_\_\_\_

2) C - I/4 = \_\_\_\_\_ SS = \_\_\_\_\_

3) C - I/4 = \_\_\_\_\_ SS = \_\_\_\_\_

\* The P+ column indicates the percent of BIOCHEMISTRY Test examinees who answered each question correctly; it is based on a sample of November 2005 examinees selected to represent all BIOCHEMISTRY Test examinees tested between July 1, 2004, and June 30, 2007.

\*\* Items 73 and 90 were not scored when this form of the test was originally administered.

## Score Conversions and Percents Below\* for the Biochemistry, Cell and Molecular Biology Test, Form GR0522

TOTAL SCORE					
Raw Score	Scaled Score	%	Raw Score	Scaled Score	%
176-178	840	99	85-87	550	60
173-175	830	99	82-84	540	57
170-172	820	99	79-81	530	53
166-169	810	99	76-78	520	49
163-165	800	99	73-75	510	45
			69-72	500	41
160-162	790	99			
157-159	780	99	66-68	490	37
154-156	770	99	63-65	480	33
151-153	760	99	60-62	470	30
148-150	750	99	57-59	460	26
145-147	740	99	54-56	450	23
141-144	730	98	51-53	440	20
138-140	720	97	47-50	430	17
135-137	710	97	44-46	420	15
132-134	700	96	41-43	410	12
			38-40	400	10
129-131	690	95			
126-128	680	93	35-37	390	8
123-125	670	92	32-34	380	6
119-122	660	90	29-31	370	5
116-118	650	89	26-28	360	3
113-115	640	87	22-25	350	3
110-112	630	85	19-21	340	2
107-109	620	82	16-18	330	1
104-106	610	80	13-15	320	1
101-103	600	77	10-12	310	1
			7-9	300	1
98-100	590	74			
94-97	580	70	4-6	290	1
91-93	570	67	1-3	280	1
88-90	560	64	0	270	1

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

\*Percent scoring below the scaled score is based on the performance of 6,252 examinees who took the BIOCHEMISTRY Test between July 1, 2004, and June 30, 2007. This percent below information was used for score reports during the 2008-09 testing year.

## 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. Both the worksheet on page 56 and the table on page 57 use performance data from GRE Biochemistry, Cell and Molecular Biology Test examinees.

The data in the worksheet on page 56 are based on the performance of a sample of the examinees who took this test in November 2005. This sample was selected to represent the total population of GRE Biochemistry, Cell and Molecular Biology Test examinees tested between July 2004 and June 2007. 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.

The first table on page 57 contains, for each scaled score, the percentage of examinees tested between July 2004 and June 2007 who received lower scores. Interpretive data based on the scores earned by examinees tested in this three-year period will be used by admissions officers in the 2008-09 testing year. These percentages appear in the score conversion table in a column to the right of the scaled scores. For example, in the percentage column opposite the scaled score of 530 is the number 53. This means that 53 percent of the GRE Biochemistry, Cell and Molecular Biology Test examinees tested between July 2004 and June 2007 scored lower than 530. To compare yourself with this population, look at the percentage next to the scaled score you earned on the practice test.

Your three subscores show your relative strengths or weaknesses in the three subfield areas of the Biochemistry, Cell and Molecular 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 biochemistry, cell and molecular 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 this practice test with the performance of other GRE Biochemistry, Cell and Molecular Biology Test examinees, 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 Biochemistry, Cell and Molecular Biology Test under standard conditions.

**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.

**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																																																											
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z

**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:** \_\_\_\_\_

**ETS GRADUATE RECORD EXAMINATIONS® - GRE® - SUBJECT TEST SIDE 1**

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.

39	A	B	C	D	E	77	A	B	C	D	E	107	A	B	C	D	E	114	A	B	C	D	E
40	A	B	C	D	E	78	A	B	C	D	E	108	A	B	C	D	E	111	A	B	C	D	E
41	A	B	C	D	E	79	A	B	C	D	E	109	A	B	C	D	E	112	A	B	C	D	E
42	A	B	C	D	E	80	A	B	C	D	E	110	A	B	C	D	E	113	A	B	C	D	E
43	A	B	C	D	E	81	A	B	C	D	E	111	A	B	C	D	E	114	A	B	C	D	E
44	A	B	C	D	E	82	A	B	C	D	E	112	A	B	C	D	E						
45	A	B	C	D	E	83	A	B	C	D	E	113	A	B	C	D	E						
46	A	B	C	D	E	84	A	B	C	D	E	114	A	B	C	D	E						
47	A	B	C	D	E	85	A	B	C	D	E												
48	A	B	C	D	E	86	A	B	C	D	E												
49	A	B	C	D	E	87	A	B	C	D	E												
50	A	B	C	D	E	88	A	B	C	D	E												
51	A	B	C	D	E	89	A	B	C	D	E												
52	A	B	C	D	E	90	A	B	C	D	E												
53	A	B	C	D	E	91	A	B	C	D	E												
54	A	B	C	D	E	92	A	B	C	D	E												
55	A	B	C	D	E	93	A	B	C	D	E												
56	A	B	C	D	E	94	A	B	C	D	E												
57	A	B	C	D	E	95	A	B	C	D	E												
58	A	B	C	D	E	96	A	B	C	D	E												
59	A	B	C	D	E	97	A	B	C	D	E												
60	A	B	C	D	E	98	A	B	C	D	E												
61	A	B	C	D	E	99	A	B	C	D	E												
62	A	B	C	D	E	100	A	B	C	D	E												
63	A	B	C	D	E	101	A	B	C	D	E												
64	A	B	C	D	E	102	A	B	C	D	E												
65	A	B	C	D	E	103	A	B	C	D	E												
66	A	B	C	D	E	104	A	B	C	D	E												
67	A	B	C	D	E	105	A	B	C	D	E												
68	A	B	C	D	E	106	A	B	C	D	E												
69	A	B	C	D	E	107	A	B	C	D	E												
70	A	B	C	D	E	108	A	B	C	D	E												
71	A	B	C	D	E	109	A	B	C	D	E												
72	A	B	C	D	E	110	A	B	C	D	E												
73	A	B	C	D	E	111	A	B	C	D	E												
74	A	B	C	D	E	112	A	B	C	D	E												
75	A	B	C	D	E	113	A	B	C	D	E												
76	A	B	C	D	E	114	A	B	C	D	E												

Item responses continued on reverse side.

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

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

**FORM CODE** (on back cover of your test book)

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

**SHADED AREA FOR ETS USE ONLY**

**5. REGISTRATION NUMBER** (from your admission ticket)

0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

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

0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

**3. DATE OF BIRTH**

Month	Day	Year						
0	0	0	0	0	0	0	0	0

SIDE 2

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)

TR	TW	TFS	TCS	1R	1W	1FS	1CS	2R	2W	2FS	2CS
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