ETS GRE

Measuring the Power of Learning.™

GRE® 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.

www.ets.org/gre

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

Overview

The *GRE*® Biochemistry, Cell and Molecular Biology Test consists of approximately 170 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. Testing time is 2 hours and 50 minutes; there are no separately-timed sections.

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

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

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

Test Content

The content of the test is organized into three major areas: 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.

Because of the diversity of undergraduate curricula, few test takers will have encountered all of the topics in the content outline. Consequently, no test taker 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 content 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 (e.g., nucleic acids, polysaccharides, polypeptides, complex lipids)
   - Supramolecular complexes (e.g., membranes, ribosomes, multienzyme complexes)
   - Macromolecular structure and function

C. Catalysis and Binding
   - Enzyme reaction mechanisms and kinetics
   - Ligand-protein interaction (e.g., receptors, substrates and effectors, transport proteins, antigen-antibody interactions)
   - Interplay between structure and function

D. Major Metabolic Pathways
   - Carbon, nitrogen, and sulfur assimilation
   - Anabolism
   - Catabolism
   - Synthesis and degradation of macromolecules

E. Bioenergetics
   - Energy transformations at the substrate level
   - Electron transport
   - Proton and chemical gradients
   - Energy coupling (e.g., phosphorylation, transport)

F. Regulation and Integration of Metabolism
   - Covalent modification of enzymes
   - Allosteric regulation
   - Compartmentation
   - Hormones

G. Methods
   - Biophysical approaches (e.g., spectroscopy, x-ray crystallography, mass spectroscopy)
   - Isotopes
   - Separation techniques (e.g., centrifugation, chromatography, electrophoresis)
   - Immunotechniques
   - Macromolecular structure

II. Cell Biology (28%)

Methods of importance to cellular biology, such as fluorescence probes (e.g., FRAP, FRET, GFP), imaging, cell sorting, and proteomics 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 (e.g., structure, function, transport across membranes, water regulation)
   - Nucleus (e.g., envelope, matrix, nuclear transport)
   - Mitochondria and chloroplasts (e.g. general function, biogenesis and evolution)

B. Cell Surface and Communication (in context of development and adult organisms)
   - 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
   - Muscle function
   - Cell motility

D. Protein, Processing, Targeting, and Turnover
   - Translocation across membranes
   - Posttranslational modification
   - Intracellular trafficking
   - Secretion and endocytosis
   - Protein turnover (e.g., proteosomes, lysosomes, damaged protein response)

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)
   - Stem cells (embryonic and adult, roles in development)

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 and genetic diagnostics
   - 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
   - Molecular evolution

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
   - Prokaryotic gene regulation including operon control
   - Promoter recognition by RNA polymerases
   - Prokaryotic attenuation and anti-termination
   - *Cis*-acting regulatory elements
   - *Trans*-acting regulatory factors
   - Gene rearrangements and amplifications
   - Small non-coding RNAs (e.g., siRNA, microRNA)

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
   - Proteomics and protein-protein interaction

Preparing for the Test

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

- A general review of your college courses is probably the best preparation for the test. However, the test covers a broad range of subject matter, and no one is expected to be familiar with the content of every question.
- Use the practice test to become familiar with the types of questions in the GRE Biochemistry, Cell and Molecular Biology Test, taking note of the directions. If you understand the directions before you take the test, you will have more time during the test to focus on the questions themselves.

Test-Taking Strategies

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

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

- Read the test directions carefully, and work as rapidly as you can without being careless. For each question, choose the best answer from the available options.
- All questions are of equal value; do not spend time pondering individual questions you find extremely difficult or unfamiliar.
- You may want to work through the test quite rapidly, first answering only the questions about which you feel confident, then going back and answering questions that require more thought, and concluding with the most difficult questions if there is time.
- If you decide to change an answer, make sure you completely erase it and fill in the oval corresponding to your desired answer.

- Questions for which you mark no answer or more than one answer are not counted in scoring.
- Your score will be determined by subtracting one-fourth the number of incorrect answers from the number of correct answers. It is unlikely that pure guessing will raise your score; it may lower your score. However, if you have some knowledge of a question and are able to rule out one or more of the answer choices as incorrect, your chances of selecting the correct answer are improved, and answering such questions will likely improve your score.
- Record all answers on your answer sheet. Answers recorded in your test book will not be counted.
- Do not wait until the last five minutes of a testing session to record answers on your answer sheet.

What Your Scores Mean

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

GRE Biochemistry, Cell and Molecular Biology Test scores are reported on a 200 to 990 score scale in ten-point increments. Three subscores (Biochemistry, Cell Biology, and Molecular Biology and Genetics) are also reported on a 20-99 score scale in one-point increments.

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

Taking the Practice Test

The practice test begins on page 9. The total time that you should allow for the practice test is 2 hours and 50 minutes. An answer sheet is provided for you mark your answers to the test questions.

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

To simulate how the administration will be conducted at the test center, print the answer sheet (pages 60 and 61). Then go to page 57 and follow the instructions for completing the identification areas of the answer sheet. When you are ready to begin the test, note the time and begin marking your answers on the answer sheet. Stop working on the test when 2 hours and 50 minutes have elapsed.

Scoring the Practice Test

The worksheet on page 58 lists the correct answers to the questions. Columns are provided for you to mark whether you chose the correct (C) answer or an incorrect (I) answer to each question. Draw a line across any question you omitted, because it is not counted in the scoring.

At the bottom of the page, enter the total number correct and the total number incorrect. Divide the total incorrect by 4 and subtract the resulting number from the total correct. Then round the result to the nearest whole number. This will give you your raw score. Use the score conversion table on page 59 to find the scaled score that corresponds to your raw score.

Example: Suppose you chose the correct answers to 91 questions and incorrect answers to 39. Dividing 39 by 4 yields 9.75. Subtracting 9.75 from 91 equals 81.25, which is rounded to 81. The raw score of 81 corresponds to a scaled score of 540.

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

Evaluating Your Performance

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

The data in the worksheet on page 58 are based on the performance of a sample of the test takers who took the GRE Biochemistry, Cell and Molecular Biology Test in October 2012. This sample was selected to represent the total population of GRE Biochemistry, Cell and Molecular Biology Test examinees tested between July 1, 2011, and June 30, 2014.

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

Interpretive data based on the scores earned by test takers in a recent three-year period are available in Table 2, *Subject Tests Total Score Interpretive Data Used on Score Reports*, and Table 3, *Subject Tests Interpretive Data for Subscores*, at **www.ets.org/gre/subject/scores/understand**. Each table shows selected scaled scores and the corresponding percentage of test takers who received lower scores. Note that these interpretive data are updated annually and appear on GRE score reports. To compare yourself with this population, in Table 2 look at the percentage next to the total scaled score you earned on the practice test. If a total scaled score you earned does not appear in the table, look at the scaled scores (and corresponding percentages) above and below the score you earned to assess your performance on the total test. Similarly, in Table 3, look at the percentages corresponding to the subscores you earned on the practice test. If a subscore that you earned does not appear in the table, look at the scaled scores (and corresponding percentages) above and below the score you earned to assess your performance in each subscore area.

Your three subscores show your relative strengths or weaknesses in the three subfield areas of the GRE 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 the practice test with the performance of other individuals who took the GRE Biochemistry, Cell and Molecular Biology Test, however, you will be able to determine your strengths and weaknesses and can then plan a program of study to prepare yourself for taking the GRE Biochemistry, Cell and Molecular Biology Test under standard conditions.

FORM GR1222

22

GRADUATE RECORD EXAMINATIONS®

BIOCHEMISTRY, CELL AND MOLECULAR BIOLOGY TEST

BIOCHEMISTRY, CELL AND MOLECULAR BIOLOGY TEST

Time—170 minutes

172 Questions

Directions: Each of the questions or incomplete statements below is followed by five suggested answers or completions. In each case, select the one that is best and then completely fill in the corresponding space on the answer sheet.

1. Which of the following is activated by phosphorylation?

   (A) Glycogen synthase
   (B) Acetyl CoA carboxylase
   (C) HMG CoA reductase
   (D) Mitogen-activated protein kinase (MAPK)
   (E) Hexokinase

2. When yeast produce ethanol from glucose, the reaction of acetaldehyde to form ethanol directly

   (A) generates ATP
   (B) produces NADH
   (C) regenerates NAD^+
   (D) contributes to the proton motive force
   (E) oxidizes the energy source

3. Eukaryotic cells and their organelles are disrupted by sonication. A centrifuge is used to separate soluble and insoluble components. Protein *X* is found in the insoluble fraction following centrifugation. The insoluble fraction is treated with 0.5 M NaCl and centrifugation is repeated. Protein *X* is now found in the soluble fraction. Protein *X* would be best described as

   (A) an integral plasma membrane protein
   (B) an integral membrane protein in an organelle
   (C) a peripheral membrane protein
   (D) a soluble cytoplasmic protein
   (E) a soluble nuclear protein

4. Which of the following macromolecules would yield only one type of monomer after complete hydrolysis?

   (A) DNA
   (B) Glycogen
   (C) Lipoprotein
   (D) RNA
   (E) Triacylglycerol

5. Which of the following processes is an example of posttranslational modification of protein?

   (A) Chaperonin-mediated protein folding
   (B) Enzyme activation by a protein kinase
   (C) Transit of the nuclear pore by RNA polymerase
   (D) RNA processing in the nucleolus
   (E) Enzyme inhibition due to ATP binding

6. In which of the following locations might a protein that enters the lumen of the endoplasmic reticulum also be found?

   (A) In the cytosol
   (B) In the nucleus
   (C) In peroxisomes
   (D) In the mitochondrial matrix
   (E) Outside the cell

7. A unique property of lysosomal proteins is that they

   (A) contain a stop-transfer sequence
   (B) operate only in an alkaline environment
   (C) are enclosed in clathrin-coated vesicles
   (D) are phosphorylated on mannose residues
   (E) are modified by O-linked glycosylation of asparagine residues

8. The beadlike unit of chromatin structure is the

   (A) chromatid
   (B) nucleosome
   (C) kinetochore
   (D) solenoid
   (E) scaffold

9. Inactivation of one X chromosome in female mammals is an example of which of the following phenomena?

   (A) Epigenetics
   (B) Sex-linked inheritance
   (C) Autosomal dominance
   (D) Translational control
   (E) Holandric control

GO ON TO THE NEXT PAGE.

10. Which of the following occurs during first meiotic prophase?

(A) Sister chromatids separate.
(B) Sister chromatids are replicated.
(C) Homologous chromosomes separate.
(D) Homologous chromosomes undergo exchange.
(E) DNA content becomes half of that in mitotic prophase.

11. Two *AaBb* individuals are crossed. What is the probability that a particular offspring will show one or both of the dominant traits? (*A* and *B* are dominant to *a* and *b*, respectively, and are unlinked.)

(A) 1/16
(B) 3/16
(C) 9/16
(D) 12/16
(E) 15/16

12. In which of the following regions of a eukaryotic gene will a point mutation most likely have a major negative impact on the function of the encoded protein?

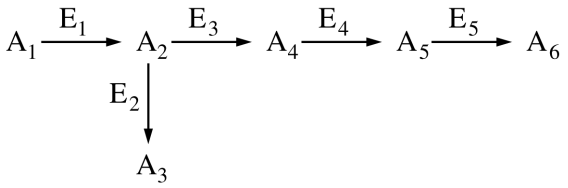
(A) The TATA box in the promoter
(B) The AAUAA sequence in the 3′ UTR
(C) The 5′ UTR
(D) The third nucleotide of a codon in the first exon
(E) The first nucleotide of a codon in the first exon

13. The migration of a protein on an SDS polyacrylamide gel is best described as inversely proportional to the

(A) negative charge
(B) isoelectric point
(C) log of carbohydrate content
(D) log of molecular weight
(E) native volume

14. The effectiveness of allosteric effectors in regulating metabolic pathways is based on their ability to

(A) change the conformation of the target enzyme(s)
(B) alter the concentration of the target enzyme(s)
(C) denature the target enzyme(s)
(D) interfere with competitive inhibitors
(E) interact with multiple substrate-binding sites on the target enzyme(s)



15. Which of the following enzymes in the anabolic pathway represented above is most likely to catalyze the rate-limiting step in the biosynthesis of A_6 ?

(A) E_1
(B) E_2
(C) E_3
(D) E_4
(E) E_5

16. Ribulose 1,5-bisphosphate carboxylase, which catalyzes the fixation of carbon dioxide during photosynthesis in plants and many algae, is located in which of the following cellular compartments?

(A) Peroxisomes
(B) Chloroplasts
(C) Mitochondria
(D) Lysosomes
(E) Plant cell vacuoles

17. The phospholipids of plasma membranes routinely exhibit which of the following forms of movement?

I. Diffusion in the plane of the bilayer
II. Translocation from one side of the bilayer to the other side
III. Rotation of fatty-acid residues around saturated carbon atoms

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

18. Of the following, the best evidence that the interaction between a protein and a nucleic acid in a particular complex is hydrophobic is if the complex is dissociated by

(A) high salt
(B) organic solvents
(C) treatment with a nuclease
(D) treatment with a protease
(E) high pH

19. Excitation in the postsynaptic membrane is caused by which of the following?

(A) Increased sodium permeability
(B) Increased potassium permeability
(C) Decreased acetylcholine permeability
(D) Decreased calcium permeability
(E) Increased GABA permeability

20. Mutation of DNA within a single somatic cell of a multicellular organism

(A) may have no phenotypic consequence
(B) is usually inherited by individuals in future generations
(C) automatically results in cell death
(D) is generally deleterious to the organism
(E) creates hundreds of genetic alterations during DNA replication

21. DNA photolyase recognizes which of the following in order to repair pyrimidine dimers?

(A) The distortion in the double helix
(B) A specific palindromic sequence
(C) Three hydrogen bonds between affected base pairs
(D) A specific origin for repair to initiate
(E) A free 3′ end on the affected DNA strand

22. Which of the following is present in double-stranded cDNA but <u>absent</u> in the corresponding genomic DNA?

(A) A homopolymeric sequence of A:T base pairs
(B) Promoter sequences
(C) Intron sequences
(D) 5′ and 3′ untranslated sequences
(E) Exon sequences

23. Which of the following molecular genetic techniques is used to identify protein-protein interactions?

(A) Yeast two-hybrid system
(B) Southern hybridization analysis
(C) Polymerase chain reaction (PCR)
(D) Fluorescence in situ hybridization (FISH)
(E) Northern hybridization analysis

24. Which of the following enzymes would prevent religation of a restriction enzyme–digested plasmid?

(A) Klenow fragment of DNA polymerase I
(B) Calf intestine phosphatase
(C) T4 DNA ligase
(D) AMV reverse transcriptase
(E) *Taq* DNA polymerase

25. Which of the following molecules forms extracellular cross-linked fibrils of great tensile strength?

(A) Collagen
(B) Fibronectin
(C) Laminin
(D) Integrins
(E) Proteoglycans

GO ON TO THE NEXT PAGE.

26. Which of the following statements is correct concerning cell locomotion?

(A) The amount of F-actin continues to increase as the cell moves.
(B) Actin polymerizes at the leading edge.
(C) Actin is synthesized at the leading edge.
(D) Myosin contraction pushes actin filaments to the leading edge.
(E) New membrane is synthesized at the leading edge.

27. A wild-type *E. coli* strain was isolated from a local pond. After cultivation in the laboratory, cell-free culture medium from the strain was incubated with an arg^- auxotrophic lab strain. Arg^+ colonies were readily isolated following the incubation. The lab strain produced no prototrophs when incubated alone. Which of the following is most likely responsible for the arg^+ colonies obtained in the experiment?

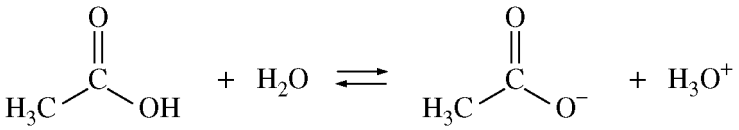
(A) An F′ plasmid
(B) Reversion of the arg^- mutation
(C) An amp^R plasmid
(D) A transducing phage
(E) A transposon

28. In humans, maturing oocytes progress to metaphase of meiosis II and then arrest their development until fertilization. Which of the following would NOT be true of meiosis II–arrested oocytes?

(A) The oocytes are haploid.
(B) Homologous chromosome pairs have separated.
(C) Sister chromatids have separated.
(D) Chromosomes are condensed.
(E) Chromosomes are aligned at the spindle midplane.

29. The rotation of the gamma subunit of the mitochondrial F_1 ATPase requires the presence of

(A) a proton motive force or ATP
(B) proton channels in the outer mitochondrial membrane
(C) O_2, ADP, and inorganic phosphate
(D) electron carriers
(E) NADH



30. For the equilibrium above, which of the following statements most accurately describes what occurs when the pH is increased (becomes more basic) ?

(A) The equilibrium constant K_{eq} increases.
(B) The equilibrium constant K_{eq} decreases.
(C) A new equilibrium is established that favors the reactants.
(D) A new equilibrium is established that favors the products.
(E) The position of the equilibrium remains the same.

31. The most definitive method for determining if actin is a component of an isolated membrane preparation would be to analyze the membrane proteins by

(A) thin-layer chromatography
(B) polyacrylamide gel electrophoresis
(C) column chromatography
(D) ultracentrifugation
(E) Western blot (immunoblot)

32. Which of the following metabolic processes occurs in the mitochondria?

(A) Cholesterol synthesis
(B) Fatty acid synthesis
(C) Glycolysis
(D) Fatty acid β-oxidation
(E) Pentose phosphate pathway

33. Which of the following sequences correctly portrays the flow of electrons during photosynthesis?

(A) NADPH $\rightarrow$ O_2 $\rightarrow$ CO_2
(B) NADPH $\rightarrow$ chlorophyll $\rightarrow$ Calvin cycle
(C) NADPH $\rightarrow$ electron transport chain $\rightarrow$ O_2
(D) H_2O $\rightarrow$ photosystem I $\rightarrow$ photosystem II
(E) H_2O $\rightarrow$ NADPH $\rightarrow$ Calvin cycle

GO ON TO THE NEXT PAGE.

34. In the reaction catalyzed by hexokinase, the two half reactions and their $\Delta G^{\circ\prime}$ values are as follows.

$ATP + H_2O \rightleftarrows ADP + P_i \qquad \Delta G^{\circ\prime} = -31 \text{ kJ} \cdot \text{mol}^{-1}$

$P_i + \text{glucose} \rightleftarrows \text{glucose-6-P} + H_2O \qquad \Delta G^{\circ\prime} = +14 \text{ kJ} \cdot \text{mol}^{-1}$

The $\Delta G^{\circ\prime}$ for the conversion of glucose to glucose-6-P with ATP as the phosphoryl donor is

(A) $-45 \text{ kJ} \cdot \text{mol}^{-1}$
(B) $-17 \text{ kJ} \cdot \text{mol}^{-1}$
(C) $0 \text{ kJ} \cdot \text{mol}^{-1}$
(D) $+17 \text{ kJ} \cdot \text{mol}^{-1}$
(E) $+45 \text{ kJ} \cdot \text{mol}^{-1}$

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35. Which of the following statements does NOT explain how viruses often produce more proteins than would be predicted from the size of their genome?

(A) Overlapping open reading frames are found on opposite strands.
(B) Some of the proteins are cleavage products of other functional proteins.
(C) Some mRNA molecules are translated in two different frames.
(D) Some primary transcripts are spliced to yield different mRNAs.
(E) Several proteins are posttranslationally fused to make a chimeric protein.

36. In *C. elegans,* the P6p cell in the lateral hypodermis is normally adjacent to the anchor cell and divides three times to form part of the vulva. The anchor cell itself is not part of the vulva and does not divide. If P6p is destroyed, the adjacent P5p cell will divide three times and form the part of the vulva that P6p normally forms. However, if the anchor cell is destroyed, no cell forms the vulva. Which of the following statements best explains these results?

(A) The anchor cell inhibits P6p from forming a vulva.
(B) The anchor cell induces P6p to form a vulva.
(C) P6p inhibits the anchor cell from forming a vulva.
(D) P6p induces the anchor cell to form a vulva.
(E) P5p induces P6p to form a vulva.

37. A high-frequency burst of action potentials causes a change in the surface of the presynaptic membrane described as ruffling. Which of the following is the cause of the change?

(A) Elevation of the osmotic pressure in the synaptic cleft
(B) Electrically induced membrane breakdown
(C) Growth-cone extensions toward new postsynaptic sites
(D) Inability of endocytosis to keep pace with exocytosis
(E) Cytosolic acidification triggered by K^+ efflux

38. Packaging of concatemeric lambda DNA into phage heads involves cleavage of the DNA at which of the following sites?

(A) *cos*
(B) *nut*^{R}
(C) *Eco*RI
(D) *attP*
(E) P_L

39. All of the following are associated with vertebrate promoters located in active chromatin EXCEPT

(A) acetylated histones
(B) DNase I–hypersensitive sites
(C) methylated cytosine bases
(D) bound TFIID
(E) chromatin-remodeling complexes

40. A human female is heterozygous for the sex-linked genetic disease glucose-6-phosphate dehydrogenase (G6PD) deficiency. Half of her cells have normal levels of the G6PD enzyme and the other half have extremely low levels. This pattern of expression is an example of which of the following?

(A) Codominance
(B) Linkage
(C) Mosaicism
(D) Polymorphism
(E) Epistasis

41. Just before sperm addition, sea urchin eggs are microinjected with a calcium chelator. What event will most likely NOT take place after fertilization?

(A) Depolarization of the plasma membrane
(B) Elevation of protein kinase C activity
(C) Elevation of phospholipase C activity
(D) Cortical granule exocytosis
(E) An increase in intracellular pH

42. When Lucifer yellow, a small dye, is injected into a neuron of the retina, neighboring neurons become rapidly labeled. If the retina is incubated in dopamine prior to Lucifer yellow injection, only the injected neuron becomes labeled. These findings suggest which of the following?

I. Neurons of the retina communicate via gap junctions.
II. Dopamine is transferred between cells via gap junctions.
III. Dopamine decreases the permeability of gap junctions.

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

43. The proton motive force generated in mitochondrial electron transport is NOT used for which of the following?

(A) Transport of ATP into the cytosol from the matrix
(B) Transport of ADP from the cytosol into the matrix
(C) Transport of phosphate ions from the cytosol into the matrix
(D) Transport of H^+ into the matrix
(E) Transport of NADH from the cytosol into the matrix

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44. In terms of energy yield, phosphorolysis is preferable to hydrolysis in the breakdown of glycogen or starch because

(A) the phosphorylase has a lower K_m value than the corresponding phosphatase
(B) the product of hydrolysis cannot be metabolized by the glycolytic pathway
(C) the debranching process requires phosphorylated glucose residues
(D) glucose 1-phosphate yields more ATP than does free glucose when subsequently catabolized to pyruvate
(E) the abundance of inorganic phosphate in the cell ensures that the reaction will proceed in both directions

45. The force between methylamine ($CH_3NH_4^+$) and acetate (CH_3COO^-) will be greater in methanol than in water because

(A) methanol, but not water, is structurally similar to methylamine
(B) methanol has a lower dielectric constant than water
(C) acetate and methylamine are more soluble in methanol than in water
(D) dipole-dipole interactions between acetate and methylamine are induced in methanol, but not in water
(E) methyl group interactions are favored in methanol

46. In glycoproteins, the carbohydrate moiety always gets attached through which of the following amino acids?

(A) Glycine or alanine
(B) Glutamine or arginine
(C) Aspartate or glutamate
(D) Tryptophan or phenylalanine
(E) Asparagine, serine, or threonine

[S] mM	V_o (μmol · min^{-1})
8×10^{-6}	80
2×10^{-5}	140
8×10^{-5}	224
4×10^{-3}	277
2×10^{-2}	280
1×10^{-1}	279

47. The data in the table above were collected for an enzyme-catalyzed reaction. The K_m for this enzyme is approximately

(A) 0.8×10^{-5} mM
(B) 2×10^{-5} mM
(C) 8×10^{-5} mM
(D) 140 μmol · min^{-1}
(E) 280 μmol · min^{-1}

---

48. Individuals with a rare genetic condition accrue abnormally high levels of DNA damage from x-ray-induced double-strand breaks. The inability to repair such breaks would be expected to result in which of the following?

(A) Accumulation of mucopolysaccharides in connective tissue
(B) Inability to remove UV-induced thymine dimers
(C) Irreversible loss of a cell cycle checkpoint and thus overproliferation
(D) Loss of apoptotic mechanisms, resulting in loss of appropriate cell death
(E) Increased frequency of sister chromatid exchange and chromosome breakage

49. Fluorescent tubulin is microinjected into the cytoplasm of a mammalian cell in interphase. Which of the following best describes where the fluorescent tubulin will first be incorporated?

(A) In the nucleus
(B) In the centromeres
(C) Throughout the length of the existing microtubules
(D) At the distal tips of microtubules
(E) At the plus ends of microfilaments

50. Which of the following chromosomal changes is NOT responsible for position-effect variegation of a gene?

(A) Transposition
(B) Translocation
(C) Inversion
(D) Polyploidization
(E) Deletion

51. Deletion of the TATA box from a eukaryotic promoter for gene *X* results in which of the following?

(A) The general transcription factors will not be able to bind to their specific DNA sequences.
(B) A gene-specific activator will not be able to bind to its regulatory DNA sequence.
(C) Transcription of the gene will be unaffected by the mutation.
(D) RNA polymerase will not transcribe genes downstream of gene *X*.
(E) The transcripts for gene *X* will lack a 5′ cap.

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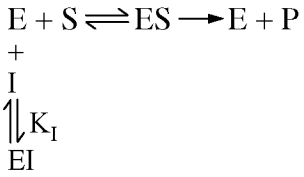


52. The enzyme reaction scheme above most closely depicts

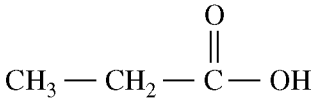
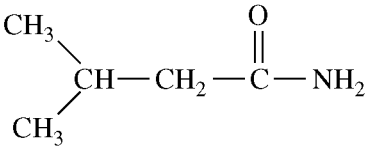
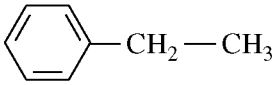
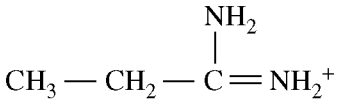
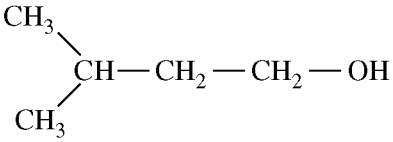
(A) noncompetitive inhibition
(B) mixed inhibition
(C) uncompetitive inhibition
(D) competitive inhibition
(E) concerted feedback inhibition

53. An enzyme has a V_{max} of 50 μmol product formed $(\text{minute} \times \text{mg protein})^{-1}$ and a K_m of 10 μM for the substrate. When a reaction mixture contains the enzyme and 5 μM substrate, which of the following percentages of the maximum velocity will be closest to the initial reaction rate?

(A) 5%
(B) 15%
(C) 33%
(D) 50%
(E) 66%

54. What properties of glucokinase allow it to phosphorylate glucose in the liver when the blood glucose concentration is higher than normal—for example, 15 mM instead of the usual 5 mM?

(A) High molecular weight and high V_{max}
(B) High K_m for glucose and its lack of inhibition by glucose 6-phosphate
(C) High V_{max} and location in the mitochondrial matrix
(D) Allosteric inhibition by glucose 6-phosphate and its high V_{max}
(E) Ability to act equally well on D-glucose and L-glucose

Inhibitor	K_I (μM)
	1492
	803
	187
	876
	495

55. An amino acid transporter protein is responsible for the transport of a specific amino acid across a membrane. The K_I values of several competitive inhibitors of the amino acid transporter are shown above. Based on these data, which of the following is most likely the amino acid transported by this protein?

(A) Arginine
(B) Glutamic acid
(C) Leucine
(D) Serine
(E) Tyrosine

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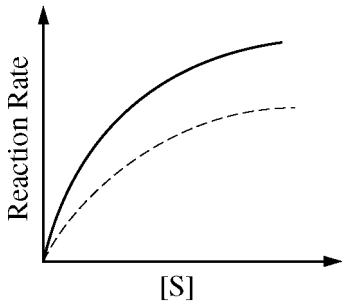
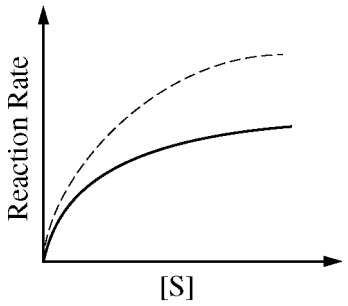
56. Which of the following graphs best shows the results of reaction rate versus substrate concentration for a cooperative enzyme in the absence (solid lines) and presence (dashed lines) of an allosteric inhibitor?

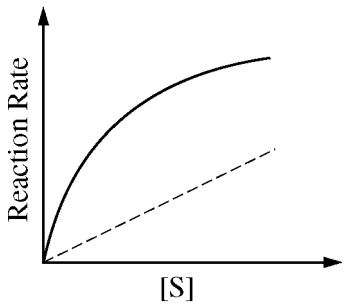
(A)



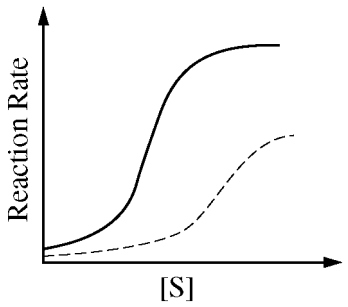
(B)



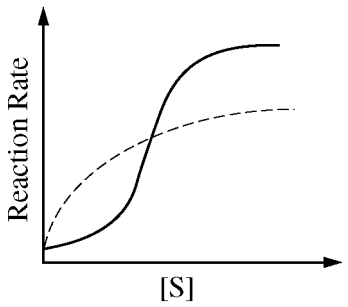
(C)



(D)



(E)



57. Which of the following best explains why the plasma membranes of all cells exhibit a negative resting potential?

(A) The membrane is mostly permeable to Cl^-, and the Cl^- gradient favors its diffusion out of the cell.
(B) The membrane is mostly permeable to K^+, and the K^+ gradient favors its diffusion into the cell.
(C) The membrane is mostly permeable to K^+, and the K^+ gradient favors its diffusion out of the cell.
(D) The membrane is mostly permeable to Na^+, and the Na^+ gradient favors its diffusion into the cell.
(E) The membrane is mostly permeable to Na^+, and the Na^+ gradient favors its diffusion out of the cell.

58. Extracellular matrices are LEAST likely to play a major role in which of the following?

(A) Enabling tissues to resist compression and tension
(B) Giving tissues elasticity
(C) Keeping cell layers separated from each other
(D) Promoting the diffusion of oxygen within tissues
(E) Giving rise to intracellular signals

59. G-protein linked receptors exhibit which of the following?

(A) Tyrosine kinase activity
(B) ATPase activity
(C) Seven transmembrane domains
(D) Nuclear localization
(E) Dimerization

60. Which is LEAST likely to be involved in the expression of mammalian immunoglobulin genes?

(A) Gene amplification
(B) DNA rearrangements to produce new antibody variable regions
(C) Transcription factors expressed only in antibody-producing cells
(D) Deletion of some chromosomal DNA sequences
(E) Enhancers bound by tissue-specific transcription factors

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61. Which of the following is true regarding the acetylation of histones during transcription?

(A) Histone acetyltransferases are part of the general transcription factor complex.
(B) Histones are acetylated immediately after translation in the Golgi apparatus.
(C) Acetylation of local histones further increases the overall positive charge in that region.
(D) H1 acetylation results in transcriptional silencing.
(E) Deposition of acetylated histones is regulated by histone phosphorylation.

62. In the prototype bacterial two-component regulatory system, which of the following are true?

I. Induced gene expression requires cell-to-cell contact.
II. The sensor molecule is often a surface receptor.
III. The activator protein is transcriptionally induced.
IV. The activator protein undergoes a conformational change.

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

63. The *pha*-4 gene encodes a developmental transcription factor involved in pharynx development. Early in development, low levels of PHA-4 protein are observed, while later in development, high levels of PHA-4 protein are present. Early targets of PHA-4 regulation encode regional specifiers, while later targets are required for the structure and function of the pharynx. Which of the following is the most likely explanation for this observation?

(A) The PHA-4 protein must have a different primary structure early in development as compared to later development.
(B) The early target genes activate the expression of the late target genes.
(C) The early target genes repress the expression of the late target genes.
(D) The PHA-4 binding sites of the early targets have a low affinity for the PHA-4 protein, while the late targets have a higher affinity.
(E) The PHA-4 binding sites of the early targets have a high affinity for the PHA-4 protein, while the late targets have a lower affinity.

64. In *E. coli*, deleting the ribosome binding site and region 1 of the *trp* attenuator and leaving the remainder of the attenuator intact has which of the following effects?

(A) The attenuator structure will not form, and the structural genes will be transcribed.
(B) The attenuator structure will always form, and transcription will terminate.
(C) The frequency of attenuation will still be controlled by the concentration of trp-$tRNA_{trp}$.
(D) Attenuation will occur randomly.
(E) Translation of the structural genes will not occur.

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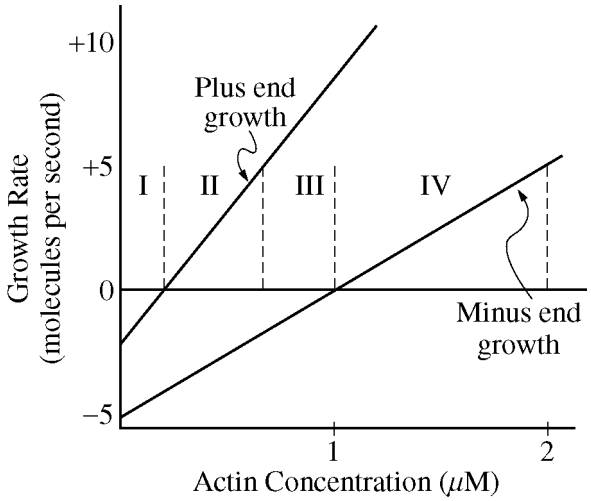
65. The end result of the kinase cascade activated by epidermal growth factor (EGF) is

(A) activation of transcription factors
(B) transphosphorylation of the EGF receptor
(C) receptor internalization
(D) activation of Ras
(E) dissociation of the alpha and beta-gamma subunits of its G protein

66. During protein synthesis, which of the following proteins interacts via its N-terminal sequence with the signal recognition particle (SRP) ?

(A) Nuclear matrix protein
(B) Lysosomal protein
(C) Peroxisomal protein
(D) Mitochondrial protein
(E) Chloroplast protein

67. Which of the following best indicates the concentration range of actin where treadmilling takes place?



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

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isocitrate + NAD^+ → α-ketoglutarate + CO_2 + NADH

68. For the above redox reaction, which is the reducing agent?

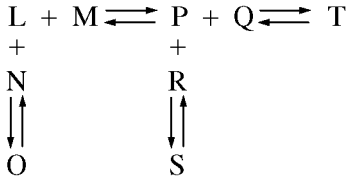
(A) Isocitrate
(B) NAD^+
(C) α-ketoglutarate
(D) CO_2
(E) NADH

69. Which of the following is LEAST soluble in aqueous solution?

(A) Sucrose
(B) KCl
(C) Ethanol
(D) Palmitic acid
(E) Oxaloacetic acid

70. Within the aqueous environment of an animal cell, sugars are stored as polymers rather than as monomers. If the sugars were stored as monomers instead of polymers, which of the following properties would be LEAST affected?

(A) Freezing point
(B) Boiling point
(C) Osmotic pressure
(D) Viscosity
(E) pH



71. The series of reactions given above are at equilibrium. The formation of T can be increased by an increase in the concentration of all of the following EXCEPT

(A) M
(B) N
(C) O
(D) Q
(E) S

72. If the reaction $A + B \rightarrow C$ is first order with respect to A and first order with respect to B, then the rate equation for the forward reaction would be

(A) rate = k[A]
(B) rate = k[B]
(C) rate = k[A][B]
(D) rate = $k_A + k_B$
(E) rate = $k_A[A] + k_B[B]$

73. In a series of two-factor crosses, 30 percent recombination occurs between gene *A* and gene *B*, and 26 percent recombination between gene *B* and gene *C*. If the order of genes on the chromosome is *A-B-C*, how much recombination will be seen between *A* and *C* in a two-factor cross?

(A) 4%
(B) 8%
(C) 28%
(D) 50%
(E) 56%

74. A LOD score is used to do which of the following?

(A) Evaluate the linkage of a phenotypic character to a particular region on a chromosome
(B) Determine the order of markers in a linkage group
(C) Estimate the penetrance of an allele
(D) Evaluate the extent of epistatic interaction between two genetic loci
(E) Estimate the frequency of double crossovers

75. A phenotypically wild-type fruit fly (*Drosophila melanogaster*) was crossed with a fly of unknown genotype. Of the progeny, 3/8 were wild-type; 3/8 had vestigial wings and wild-type bodies; 1/8 had wild-type wings and black bodies; and 1/8 had vestigial wings and black bodies. The allele for vestigial wings is *vg*, and the allele for black body is *b*. What were the genotypes of the two parent flies?

(A) *vg*/*vg* ; *b*/*b* and *vg*/+ ; *b*/+
(B) *vg*/+ ; +/+ and *vg*/+ ; *b*/*b*
(C) *vg*/*vg* ; +/+ and *vg*/+ ; *b*/+
(D) *vg*/*vg* ; *b*/+ and *vg*/+ ; *b*/+
(E) *vg*/+ ; *b*/+ and *vg*/+ ; *b*/+

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	Wild-type	Mutant 1	Mutant 2	Mutant 3	Mutant 4	Mutant 5
Wild-type	+	+	+	+	+	+
Mutant 1		–	+	+	+	+
Mutant 2			–	+	–	+
Mutant 3				–	+	–
Mutant 4					–	+
Mutant 5						–

76. Five mutants of a fungus that are auxotrophs for compound X have been isolated. A complementation test is performed on these mutants by mating them in all possible pairwise combinations and testing the progeny for prototrophy. Based on the results above, which of the following is correct? (A plus sign [+] indicates that the progeny of the cross are prototrophs, while a minus sign [–] indicates they are auxotrophs.)

(A) All of the mutants belong to one complementation group.
(B) Mutant 1 forms one complementation group, while mutants 2, 3, 4, and 5 form another.
(C) Mutant 1 forms one complementation group; mutants 2 and 4 form a second complementation group; and mutants 3 and 5 form a third group.
(D) Mutant 1 forms one complementation group; mutants 2 and 4 form a second; mutant 3 forms a third; and mutant 5 forms the fourth complementation group.
(E) Each of the mutants belongs to a different complementation group.

77. During DNA replication in bacteria, the mismatch repair system differentiates the daughter strand from the parent strand by

(A) methylated adenine in the sequence GATC in the parent strand but not the daughter strand
(B) methylated adenine in the sequence GATC in the daughter strand but not the parent strand
(C) DNA polymerase bound to the parent strand but not the daughter strand
(D) a stretch of single-stranded DNA on the parent strand but not the daughter strand
(E) a DNA helicase bound to the parent strand but not the daughter strand

78. Tetanus toxin is taken up by receptor-mediated endocytosis at the termini of axons and is moved by retrograde transport to the neuronal cell body. Treating neurons with microtubule depolymerizing drugs blocks the transport. Which of the following treatments would also be likely to block the transport?

(A) Injecting the neurons with RNAi directed against dynein
(B) Injecting the neurons with kinesin I
(C) Injecting the neurons with an antibody directed against myosin V
(D) Overexpressing a dominant negative rho in the neurons
(E) Treating the neurons with cytochalasin D

79. Protein modifications occurring in the Golgi include which of the following?

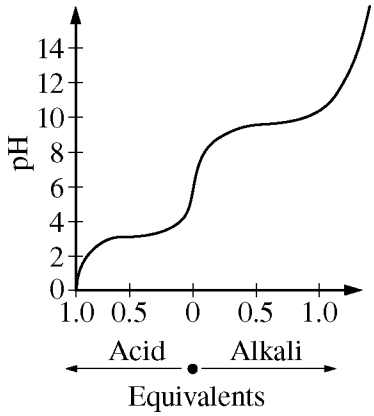
(A) Removal of sialic acid
(B) BiP-mediated protein folding
(C) Removal of the signal peptide
(D) Attachment of core N-linked oligosaccharides
(E) Modification of high-mannose and complex N-linked oligosaccharides

80. Translocation of most proteins into the ER requires all of the following EXCEPT

(A) a signal sequence
(B) a signal receptor protein
(C) ribosomes
(D) GTP
(E) signal peptidase

81. A genetic analysis of an unknown infectious agent reveals that it contains only the nucleotides G, A, U, and C in the proportion 30 percent, 35 percent, 15 percent, and 20 percent, respectively. Based on this information, this infectious agent is most likely a

(A) double-stranded DNA virus
(B) double-stranded RNA virus
(C) single-stranded DNA virus
(D) single-stranded RNA virus
(E) virus containing a DNA/RNA hybrid



82. The most likely amino acid that would yield the above titration curve would be

(A) Arginine
(B) Glutamic acid
(C) Glycine
(D) Histidine
(E) Tyrosine

83. Pyruvate is LEAST likely to be used to synthesize which of the following?

(A) acetyl CoA
(B) ethanol
(C) lactate
(D) branched-chain amino acids
(E) purine nucleotides

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84. The technique of chromosome painting in the analysis of human karyotypes relies on which of the following?

(A) Inherent fluorescence due to G-C base pairs
(B) Inherent fluorescence due to A-T base pairs
(C) Specific hybridization with fluorescent probe molecules
(D) Restriction digestion followed by nick translation with fluorescent nucleotides
(E) Fluorescence resonance energy transfer

85. Which of the following is the origin of the majority of the ATP used in the pathway of gluconeogenesis?

(A) β-oxidation of fatty acids
(B) Breakdown of amino acids
(C) Degradation of glycogen
(D) Oxidation of fructose-6-phosphate
(E) Fructose-2,6-bisphosphate

86. Which of the following enzymes would be most useful as a marker for chloroplasts during isolation of plant cell organelles?

(A) Malate dehydrogenase
(B) Phosphoribulokinase
(C) DNA polymerase
(D) Hexokinase
(E) Isocitrate lyase

87. Which of the following best indicates that a segment of DNA is a gene?

(A) Multiple expressed sequence tags (ESTs) of the DNA sequence
(B) Multiple short overlapping reading frames
(C) A 50% sequence identity with a known promoter sequence
(D) A DNA sequence that is predicted to be able to form a large hairpin loop
(E) A DNA sequence that is similar to introns

88. Which of the following events, occurring within a tandem repeat sequence, will cause an expansion or contraction of the array?

(A) Endoreduplication
(B) Homologous recombination
(C) Unequal crossing-over
(D) Error-prone DNA repair
(E) Inversion

89. Each repeat unit within the nuclear ribosomal gene cluster of eukaryotes (rDNA) contains

(A) a promoter for RNA pol I
(B) a terminator for RNA pol II
(C) an ATG start codon
(D) polyadenylation signals
(E) at least one tRNA gene

90. Which is NOT a characteristic typical of retrotransposons?

(A) Encoding a reverse transcriptase
(B) Constituting a significant proportion of animal genomes
(C) Random integration in genome
(D) Flanking by direct repeats
(E) Alternative splicing

91. The unfolded protein response involves all of the following EXCEPT

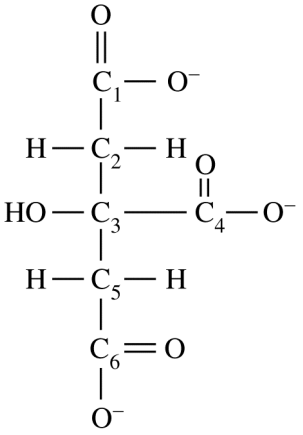
(A) the chaperonin BiP
(B) the proteasome
(C) the sec61p translocon
(D) attenuation of protein synthesis
(E) attenuation of mRNA synthesis

92. Proteasomes are responsible for the degradation of all of the following EXCEPT

(A) cyclin B during anaphase
(B) securin at anaphase
(C) proteins targeted to lysosomes
(D) foreign protein for antigen presentation
(E) misfolded proteins from the ER

93. All of the following are possible fates of fatty acids that enter the liver EXCEPT

(A) use by the liver as an energy source
(B) conversion to ketone bodies
(C) conversion to glucose
(D) conversion to triacylglycerols
(E) conversion to acetyl-CoA for cholesterol synthesis

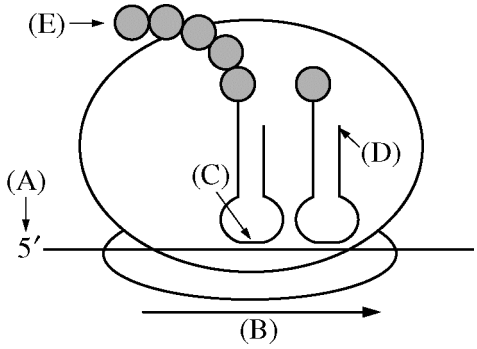


94. In the TCA cycle, citrate loses two of its six carbons as CO_2 as it is converted to oxaloacetate. From the citrate structure shown above where all six carbons are numbered, which two carbons are lost as CO_2 ?

(A) C_1 and C_2
(B) C_1 and C_4
(C) C_1 and C_6
(D) C_4 and C_6
(E) C_5 and C_6

95. The coding region of a gene is 102 nucleotides long, including both start and stop codons. Which of the following would be the most likely effect of a single nucleotide deletion at position 76 in the coding region?

(A) There would be no effect on the polypeptide.
(B) Only the active site would be affected.
(C) The entire amino acid sequence of the polypeptide would change.
(D) There would be changes in only the first 25 amino acids.
(E) There would be changes in only the last 8 amino acids.



96. A eukaryotic translation complex during the elongation stage is represented by the diagram above. Which of the following labels on the diagram is NOT correct?

(A) Location of the mRNA cap structure
(B) Direction of ribosome movement
(C) Anticodon of a tRNA molecule
(D) 5′ end of a tRNA molecule
(E) Carboxyl-terminus of the growing peptide chain

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97. An altered form of a replicative DNA polymerase lacks $3' \rightarrow 5'$ exonuclease activity. This alteration would most likely result in which of the following?

(A) A decrease in processivity
(B) An increased mutation rate
(C) An ability to replicate DNA without a primer
(D) An inability to replicate DNA
(E) An inability to remove RNA primers

98. Glycine can be formed from another amino acid in a single step. This reaction is catalyzed by

(A) cystathionase
(B) glycine cleavage enzyme
(C) glycine aminotransferase
(D) serine dehydratase
(E) serine hydroxymethyl transferase

99. When 50 μL of a ^{14}C sample is added into 10 mL of scintillation cocktail, a liquid scintillation counter reports 15,200 counts per minute (cpm), with an efficiency of 0.92. Which of the following is closest to the number of disintegrations per minute (dpm) in the 50 μL sample?

(A) 1,520 dpm
(B) 13,984 dpm
(C) 16,522 dpm
(D) 21,000 dpm
(E) 210,000 dpm

100. Glucagon stimulates release of fatty acids from adipocytes because it

(A) activates a transporter of fatty acids
(B) activates lipoprotein lipase
(C) activates hormone-sensitive lipase
(D) inhibits export of glycerol
(E) inhibits uptake of glucose

101. When a polymerase chain reaction (PCR) amplification was performed on human genomic DNA, multiple products of varying sizes were obtained, including one of the expected size. Which of the following modifications to the protocol is the most likely to eliminate the extra PCR products?

(A) Raising the denaturation temperature from 94°C to 96°C
(B) Raising the annealing temperature from 52°C to 56°C
(C) Raising the elongation temperature from 70°C to 74°C
(D) Increasing the elongation time from 3 minutes to 4 minutes
(E) Decreasing the number of cycles from 30 to 24

102. A cell-free translation system contains microsomes but lacks signal recognition particles (SRP). The mRNA encoding a secretory protein is translated in this system. Which of the following outcomes is most likely?

(A) No protein synthesis will occur.
(B) Protein synthesis will begin but the protein will not be fully synthesized.
(C) The protein will be fully synthesized and its signal sequence will be removed.
(D) The protein will be fully synthesized and incorporated into microsomes.
(E) The protein will be fully synthesized but not incorporated into microsomes.

103. Substrate-level phosphorylation is catalyzed by which of the following enzymes?

(A) Hexokinase
(B) Glycerol kinase
(C) Pyruvate kinase
(D) Galactokinase
(E) Phosphofructokinase-1

104. A mixture of soluble proteins containing proteins X and Y is immunoprecipitated using anti–protein X antibody. Both protein X and protein Y are immunoprecipitated. Which of the following does NOT explain this observation?

(A) Protein X and protein Y are part of the same multimeric complex.
(B) Protein X and protein Y are covalently bound.
(C) Protein Y is a truncated version of protein X.
(D) Protein X and protein Y are present in the same organelle.
(E) Anti–protein X antibodies cross-react with protein Y.

105. The addition of malonate ($^{-}OOC - CH_2 - COO^{-}$) to the citric acid cycle would most directly inhibit which of the following enzymes?

(A) Isocitrate dehydrogenase
(B) α-ketoglutarate dehydrogenase
(C) Malate dehydrogenase
(D) Fumarase
(E) Succinate dehydrogenase

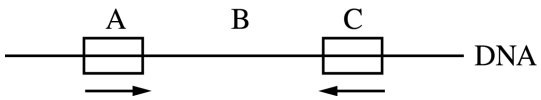
106. In contrast to chemical-induced mutations, mutations induced by transposons are more likely to

(A) be lethal
(B) be dominant
(C) be stable
(D) revert to wild type
(E) be a gain of function

GO ON TO THE NEXT PAGE.

107. Matrix-assisted laser desorption ionization time of flight (MALDI-TOF) spectrometry is most useful for predicting which of the following?

(A) Molecular mass
(B) Isoelectric point
(C) Bonding patterns
(D) Secondary structure
(E) Three-dimensional structure



108. In the diagram shown above, segments A and C are copies of a repeated DNA sequence, flanking a unique stretch shown as B. A and C are in an inverted orientation relative to each other, as indicated by the arrows. Intramolecular recombination between segments A and C would most likely lead to

(A) duplication of segment B only
(B) duplication of segments A, B, and C
(C) inversion of segment B
(D) deletion of segment B only
(E) deletion of segments A, B, and C

109. Elongation of telomeres by the enzyme telomerase and the processing of pre-mRNA to mRNA by the spliceosome share which of the following characteristics?

(A) Both processes require double-stranded DNA for enzyme function.
(B) Both processes occur primarily in the cytoplasm.
(C) Both processes require G-proteins and downstream effectors.
(D) Both processes require protease activity and are processive.
(E) Both processes require an RNA component for enzyme function.

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 110-112 refer to the following.

(A) Klenow fragment
(B) β clamp
(C) DnaG
(D) SSB protein
(E) RNase H

110. Proofreads as part of its catalytic activity

111. Maintains the parental strands as single strands of DNA

112. Increases the processivity of DNA polymerase

Questions 113-116 refer to the following.

(A) Diacylglycerol (DAG)
(B) Heteromeric G protein (hetG)
(C) Phosphatidyl 1,4,5-triphosphate (IP_3)
(D) Adenylate cyclase (AC)
(E) Phospholipase C (PLC)

113. Active when bound with GTP

114. Produces cAMP when activated

115. Inactivated by GTPase-activating proteins (GAPs)

116. Directly stimulates the release of calcium from intracellular stores

Questions 117-119 refer to the following.

(A) Reduction
(B) Hydrolysis
(C) Group transfer
(D) Isomerization
(E) Oxidation

117. Cleavage of a peptide bond

118. Phosphorylation of a serine residue on a protein

119. Formation of a disulfide bond between cysteines

Questions 120-122 refer to the following stages of the cell cycle.

(A) Interphase
(B) Prophase
(C) Metaphase
(D) Anaphase
(E) Cytokinesis

120. Actin interaction with myosin is essential.

121. Kinetochores are paired and possess microtubules of equal length.

122. Microtubule depolymerization is essential.

GO ON TO THE NEXT PAGE.

Questions 123-126 refer to the following.

(A) Ribulose 1,5-bisphosphate carboxylase
(B) Arginase
(C) Nitrogenase
(D) Malate dehydrogenase
(E) 5-phosphoribosyl l-pyrophosphate synthase

123. A metallo-enzyme that catalyzes the conversion of molecular nitrogen to two molecules of ammonia

124. A key regulatory enzyme in the Calvin cycle

125. An enzyme whose product serves as a precursor for the biosynthesis of both purine and pyrimidine nucleotides

126. An enzyme in the urea cycle whose product is urea

Questions 127-128 refer to the following.

(A) ChIP (chromatin immunoprecipitation)
(B) RNAi
(C) snRNP
(D) hnRNA
(E) MALDI-TOF

127. Used to analyze proteins associated with specific DNA sequences

128. Used to alter the expression of specific genes in eukaryotic cells

Questions 129-131 refer to the following amino acids.

(A) Proline
(B) Tyrosine
(C) Histidine
(D) Lysine
(E) Isoleucine

129. The amino acid that would contribute most to protein absorption at 280 nm

130. The amino acid that would be expected to be located within the interior of a folded protein suspended in an aqueous buffer

131. The amino acid that would disrupt the ordered structure of a folded α-helix

Questions 132-135 refer to the following.

(A) Zinc finger
(B) Acidic domain
(C) Triple helix
(D) Long terminal repeat (LTR)
(E) Stem-loop

132. A common structural motif found in the DNA binding domains of transcriptional activators

133. A retroviral sequence element

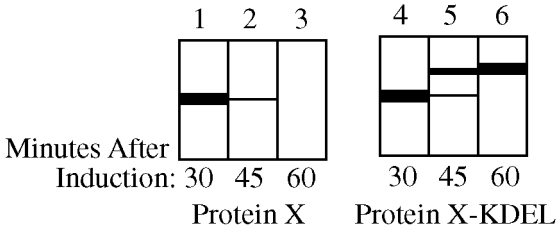
134. A structural motif in transcriptional activator proteins that interacts with proteins in the general transcription apparatus

135. The structure of a transcriptional attenuator

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 136-138

A cell line is transfected with a plasmid encoding either a secreted glycoprotein, X, or a variant of X that contains the amino acids KDEL at its C terminus, both of them under control of an inducible promoter. KDEL motifs are normally found on proteins located in the lumen of the ER. At 30 minutes after induction, cycloheximide, an inhibitor of protein synthesis, is added to the culture medium. At 30, 45, and 60 minutes after induction (that is, 0, 15, or 30 min in cycloheximide), the cells are lysed, rough microsomes are isolated and solubilized, and X or X-KDEL is immunoprecipitated from the solubilized material and run on SDS-PAGE gels. The following gels are obtained.



136. The most likely reason why there is less material in lanes 2 and 3 than there is in lane 1 is that protein X

(A) is digested in cycloheximide
(B) is less stable than protein X-KDEL
(C) is translocated into the lumen of the endoplasmic reticulum within 15 minutes of its synthesis
(D) exits the endoplasmic reticulum within 15 minutes of its synthesis
(E) is incorporated into COPI vesicles within 15 minutes of its synthesis

137. The most likely explanation for the additional bands seen in lanes 5 and 6 is that

(A) the signal sequence is not removed from some of the X-KDEL molecules
(B) X-KDEL oligomerizes after protein synthesis is completed
(C) X-KDEL becomes modified in the endoplasmic reticulum after protein synthesis is completed
(D) some of the X-KDEL molecules are modified in the Golgi and then returned to the endoplasmic reticulum
(E) the quality control mechanism in the endoplasmic reticulum recognizes X-KDEL as being aberrant and has targeted it for degradation

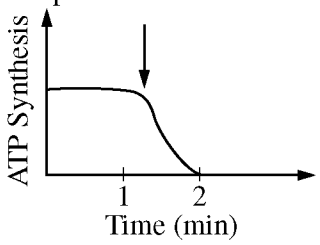
138. If cycloheximide had been omitted from the experiment, then

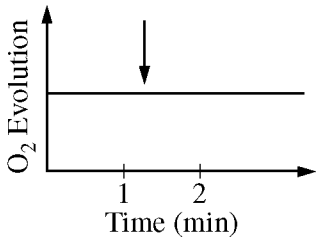
(A) no protein band would be observed in lane 2
(B) bands at higher molecular weight equivalent to those observed in lanes 5 and 6 would be observed in lanes 2 and 3
(C) only the lower-molecular-weight bands would be observed in lanes 5 and 6
(D) the total amount of protein observed in each gel lane would increase
(E) the total amount of protein observed in lanes 2 and 3 and 5 and 6 would increase

Questions 139-141

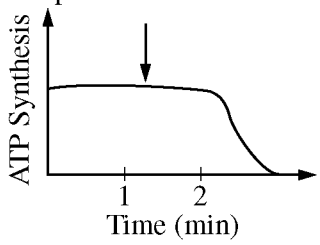
A series of chemical compounds have properties that suggest they would interfere with chloroplast function. The effects of the compounds have been tested using illuminated suspensions of isolated chloroplasts and measuring the rates of ATP synthesis and O_2 production. The results are shown below with the arrow indicating time of addition of the compound.

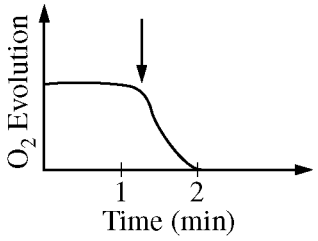
Compound A



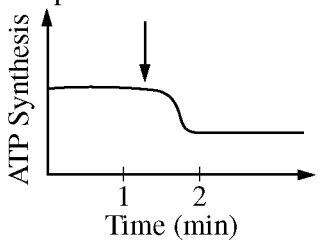


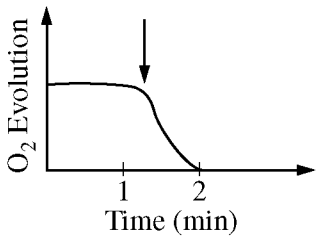
Compound B





Compound C





139. Which of the following statements is true for the chloroplasts treated with compound A?

(A) No proton gradient exists across the thylakoid membrane, and the reduction of $NADP^+$ drops to zero.
(B) No proton gradient exists across the thylakoid membrane, but the reduction of $NADP^+$ continues at the initial rate.
(C) The proton gradient across the thylakoid membrane is unaffected, but the reduction of $NADP^+$ drops to zero.
(D) No proton gradient exists across the thylakoid membrane, but the reduction of $NADP^+$ increases to a new, higher steady-state level.
(E) Neither the proton gradient across the thylakoid membrane nor the reduction of $NADP^+$ is affected.

140. Which of the following compounds appear(s) to act by blocking noncyclic photophosphorylation while leaving cyclic photophosphorylation unaffected?

(A) Compound A only
(B) Compound B only
(C) Compound C only
(D) Compounds A and B
(E) Compounds B and C

141. Isolated chloroplast suspensions can be induced to make ATP in the dark for a short period by incubating them in a low-pH solution and then rapidly transferring them to a high-pH solution. If subjected to such a procedure, chloroplasts would be expected to make ATP if they were first treated with which of the following compounds?

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

Questions 142-145

To understand the signaling pathway leading from sperm-egg fusion to calcium increase, various substances were injected into sea urchin eggs. The effects of these substances on calcium increase are shown in the table below.

Definitions of terms used in the table are as follows.

PLCγ – hydrolyzes a phospholipid to produce IP_3 and is regulated by tyrosine phosphorylation
PP2 – an inhibitor of tyrosine kinase
SHP2 – tyrosine phosphatase
Dominant-negative protein – inhibits the function of the wild-type version of the protein in the same cell

Injected Substance(s)	Sperm Added	Calcium Increase
1. Buffer control	Yes	Yes
2. IP_3	No	Yes
3. PP2	Yes	No
4. PP2 inactive analog	Yes	Yes
5. PP2 followed by IP_3	No	Yes
6. Dominant-negative PLCγ protein	Yes	No
7. Dominant-negative SHP2 protein	No	Yes

GO ON TO THE NEXT PAGE.

142. Calcium increase at fertilization requires which of the following?

I. PP2
II. Tyrosine kinase
III. PLCγ

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

143. A reasonable explanation for the calcium increase shown in line 7 of the table is that

(A) IP_3 must be dephosphorylated
(B) phosphatase activity is required
(C) wild-type SHP2 phosphorylates PLCγ
(D) PLCγ cannot be dephosphorylated
(E) tyrosine phosphorylation is not required

144. An informative experiment to determine the position of PLCγ in the signaling pathway would be to inject eggs with which of the following?

(A) Dominant-negative PLCγ protein and IP_3
(B) Wild-type PLCγ only
(C) Wild-type PLCγ and IP_3
(D) A calcium chelator only
(E) A calcium chelator and IP_3

145. Based on the information provided, which of the following pairs is in the correct order to lead to calcium increase in the normal signal transduction pathway induced by fertilization?

	Upstream	Downstream
(A)	IP_3	Tyrosine kinase
(B)	IP_3	PLCγ
(C)	PLCγ	IP_3
(D)	SHP2	PLCγ
(E)	PP2	IP_3

Questions 146-148

Wild-type flies of the species *Drosophila melanogaster* have red eyes and wings with normal cross veins. Recessive mutant alleles of the sex-linked genes *w* (white) and *cv* (crossveinless) lead, respectively, to the formation of white eyes and crossveinless wings.

A virgin female fly who was heterozygous for the mutant *w* and *cv* alleles was crossed to a wild-type male. The male progeny of this cross were primarily of two types. One type had white eyes and normal wings and the other had red eyes and crossveinless wings. Smaller numbers of wild-type males and males with white eyes and crossveinless wings were also obtained.

146. The occurrence of the wild-type male progeny was most likely the result of

(A) dominance of the wild-type alleles of the *w* and *cv* genes
(B) independent assortment of the *w* and *cv* genes during meiosis
(C) crossing over in the female parent
(D) crossing over in both parents
(E) loss of the recessive alleles during gametogenesis

147. Approximately 6 percent of the male progeny were mutant for both phenotypes. Thus, the *w* and *cv* genes are separated by approximately how many map units?

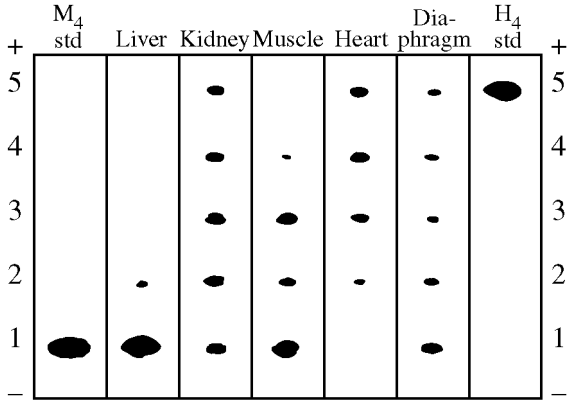
(A) 3
(B) 6
(C) 12
(D) 24
(E) 44

148. The percent of phenotypically wild-type females from this cross is predicted to be approximately

(A) 100%
(B) 50%
(C) 25%
(D) 12%
(E) 6%

Questions 149-150

Lactate dehydrogenase (LDH) can exist as various tetrameric isozymes. Extracts from different rat tissues were run on a nondenaturing polyacrylamide gel and stained for LDH activity, as shown below. Standard tetramers of M subunits (M_4) and H subunits (H_4) were run alongside the tissue extracts.



149. Which of the following is the subunit composition of the isozyme running at position 2 ?

(A) M_4
(B) M_3H
(C) M_2H_2
(D) MH_3
(E) H_4

150. Which of the following conclusions can be drawn from the experiment regarding the heart isozymes?

(A) All of the enzyme exists in the H_4 isozyme form.
(B) Only heart tissue contains the H_4 form.
(C) Heart tissue contains all five isozymes.
(D) The M_4 form is lacking in heart tissue.
(E) Heart tissue is the only tissue that does not contain all possible combinations.

Questions 151-153

Cholesterol is an essential component of some membrane microdomains. FRET (fluorescence resonance energy transfer) is a process by which the energy absorbed by a fluorescent molecule can be transferred to an adjacent fluorescent molecule. When FRET occurs, the neighboring molecule, rather than the excited molecule, fluoresces. To determine if two membrane proteins, X and Y, are near neighbors present in a microdomain of the plasma membrane, the proteins were tagged with CFP or YFP (CFP = cyan fluorescent protein; YFP = yellow fluorescent protein). CFP is excited by 435 nm light and emits fluorescent light at 480 nm. YFP is excited by 488 nm light and emits light at 535 nm. The following data were obtained.

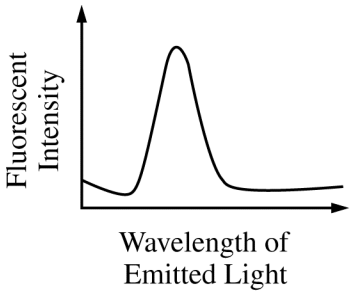


Figure 1.
Cells Expressing X-CFP and Irradiated with 435 nm Light

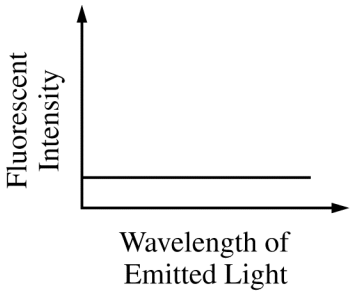


Figure 2.
Cells Expressing X-YFP and Irradiated with 435 nm Light

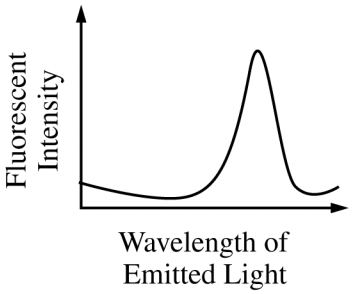


Figure 3.
Cells Expressing X-YFP and Irradiated with 488 nm Light

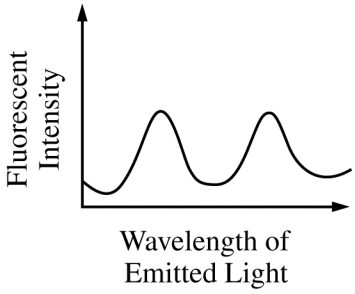


Figure 4.
Cells Expressing X-CFP and Y-YFP Irradiated with 435 nm Light

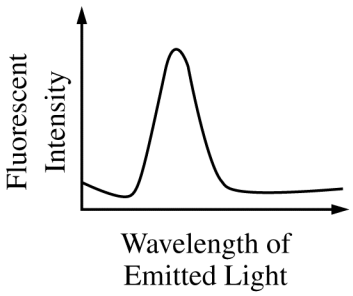


Figure 5.
Cells Expressing X-CFP and Y-YFP Incubated in Fillipin, a Drug that Removes Cholesterol from the Membrane, and Irradiated with 435 nm Light

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151. The reason that the curve in Figure 2 is flat is

(A) there are no fluorescent proteins present in the cells used in the trial
(B) the fluorescent proteins present are quenched by irradiation at 435 nm
(C) the fluorescent proteins present have transferred their energy to neighboring fluorescent proteins
(D) the fluorescent proteins present are not excited by irradiation at 435 nm
(E) none of the fluorescent proteins are present in membrane microdomain

152. The reason that there are two peaks of emitted fluorescent light in Figure 4 is

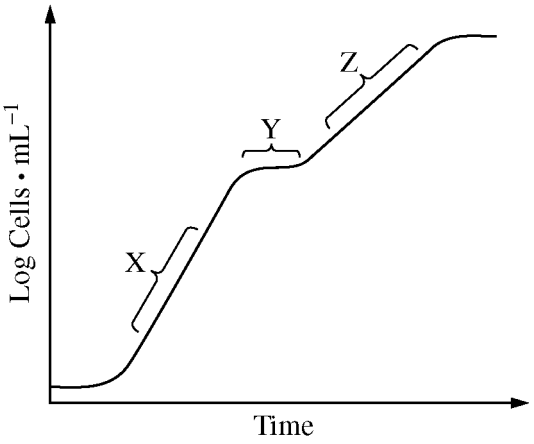
(A) emission from CFP results in excitation of YFP
(B) emission from YFP results in excitation of CFP
(C) excitation of YFP results in excitation of CFP
(D) excitation of YFP results in quenching of CFP
(E) excitation of CFP results in quenching of YFP

153. These data suggest which of the following?

(A) The cells used in the study do not have membrane microdomains.
(B) Fillipin induces the formation of membrane microdomains.
(C) X-CFP and Y-YFP are near neighbors only when membrane microdomains are present.
(D) Cholesterol is required for X-CFP and Y-YFP to fluoresce.
(E) Cholesterol allows membrane proteins to diffuse away from membrane microdomains.

Questions 154-157

An *E. coli* culture is grown on a mixture of glucose and lactose as carbon sources. The growth curve for the culture is shown in the figure below.



154. Which region(s) of the curve correspond(s) to exponential growth of the culture?

(A) X only
(B) Y only
(C) X and Y only
(D) Y and Z only
(E) X and Z only

155. Which of the following statements is true regarding region Y of the growth curve?

(A) New enzymes required for the metabolism of lactose are being synthesized.
(B) New enzymes required for the metabolism of glucose are being synthesized.
(C) New enzymes required for the maintenance of the stationary phase of the growth curve are being synthesized.
(D) New enzymes required for the maintenance of the decline phase of the growth curve are being synthesized.
(E) No new enzyme synthesis is likely to occur in the *E. coli* culture.

156. The growth experiment described above is repeated using an *E. coli* strain with a deletion of the *lacZ* gene. Which of the following statements is correct about the strain?

(A) It cannot utilize glucose as a carbon source.
(B) It cannot utilize lactose as a carbon source.
(C) It demonstrates growth kinetics that are identical to those shown in the figure.
(D) It cannot synthesize DNA.
(E) It cannot synthesize messenger RNA.

157. The growth curve is the result of

(A) attenuation
(B) catabolite repression
(C) antisense regulation
(D) feedback inhibition
(E) reversible covalent modification

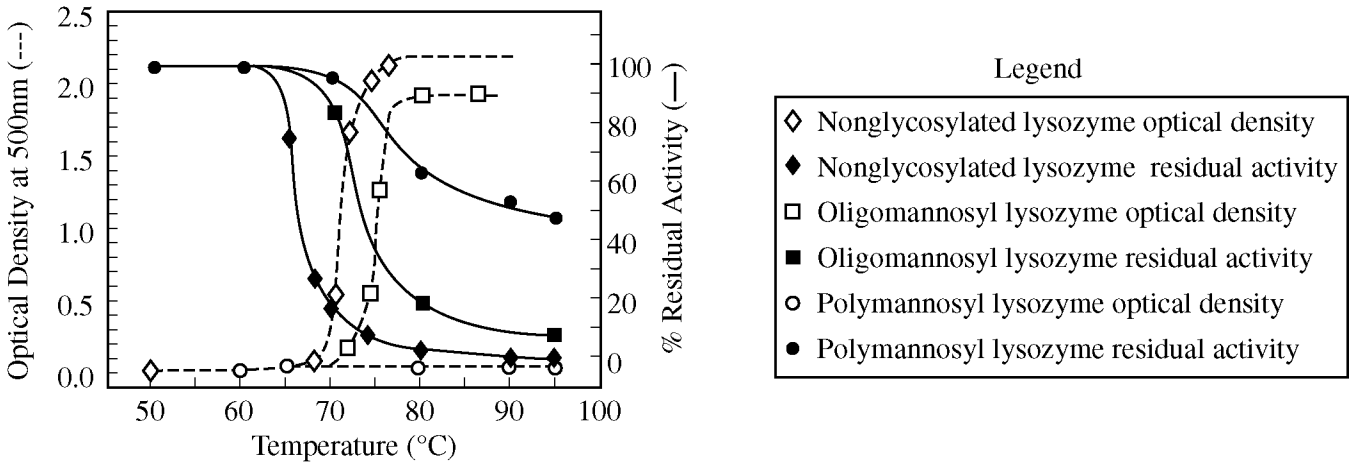
Questions 158-160

In a series of experiments designed to test the effect of glycosylation on proteins, the hen egg white enzyme lysozyme (MW ~14 kD) was genetically modified so as to introduce a site for N-glycosylation. When the protein was expressed in yeast, two forms of the enzyme were isolated: one with a short oligomannose chain, and one with a long polymannose chain. These proteins were examined for enzymatic activity with two different substrates: a soluble substrate, glycol chitin, and an insoluble substrate, a cell wall suspension from the bacterium *M. luteus,* as shown in the table below. Further experiments were carried out in order to determine the thermal stability of the proteins, as shown in the figure below. Thermal stability was estimated by measuring the developed turbidity (precipitation) and residual enzymatic activity when samples were heated from 30°C to 95°C. Turbidity was measured as optical density at 500 nm. Residual enzyme activity was measured by hydrolysis of glycol chitin.

ENZYMATIC ACTIVITY OF GLYCOSYLATED LYSOZYMES

	Enzymatic activity (% of nonglycosylated enzyme)	
Lysozyme	**Glycol chitin**	***M. luteus* cell wall**
Nonglycosylated	100	100
Oligomannosyl	100	73
Polymannosyl	81	11

THERMAL STABILITY OF GLYCOSYLATED LYSOZYMES



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158. What is the primary effect of glycosylation on enzymatic activity assayed with the soluble or insoluble substrates?

(A) Glycosylation has no effect on either activity.
(B) Glycosylation, irrespective of chain length, increases activities with both substrates.
(C) Glycosylation, irrespective of chain length, decreases activities with both substrates.
(D) Glycosylation with long chains decreases the activities with both substrates.
(E) Glycosylation with short chains decreases the activities with both substrates.

159. Which of the following most accurately describes the observed effects of glycosylation on thermal stability of the enzyme?

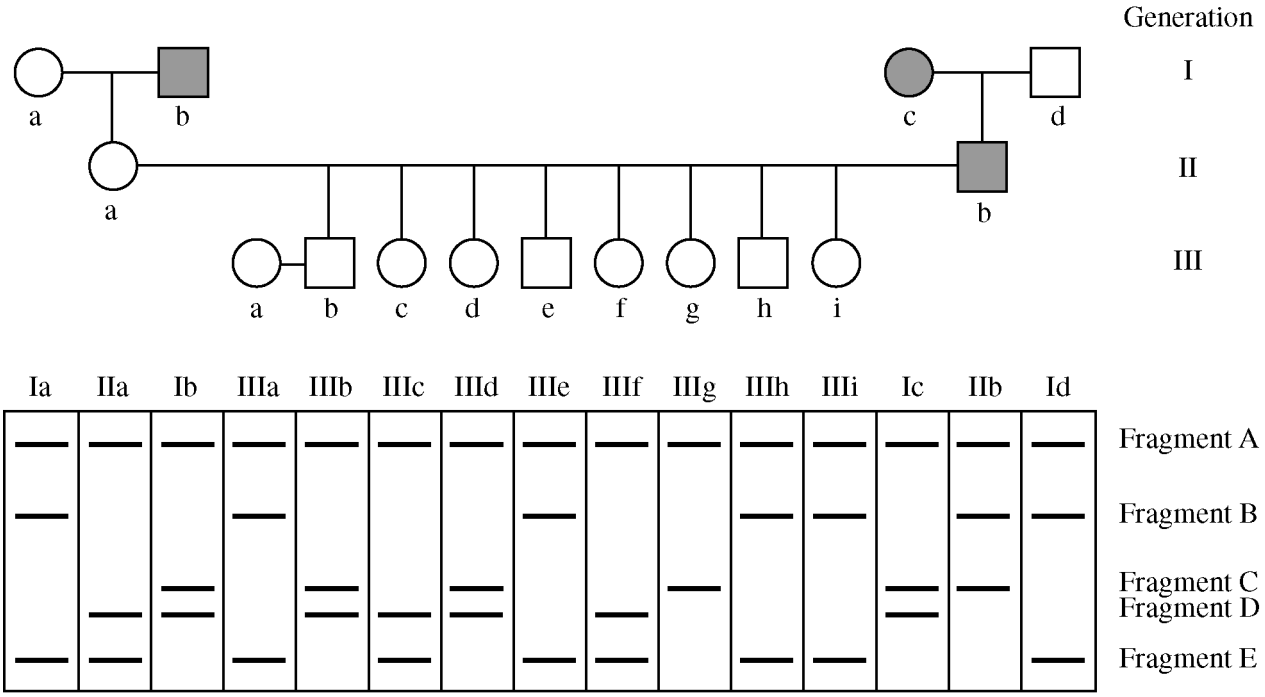
(A) Glycosylation has no effect on the thermal stability.
(B) Glycosylation decreases the thermal stability.
(C) Glycosylation with long chains decreases the thermal stability, but short chains have no effect.
(D) Glycosylation increases the thermal stability; the greater increase occurs with short chains.
(E) Glycosylation increases the thermal stability; the greater increase occurs with long chains.

160. A second glycosylation site is engineered into the lysozyme gene, and protein expression in yeast results in additional polymannosylation at this second site. Which of the following is the most likely result of this additional glycosylation relative to polymannosylation at the single site?

(A) Enzyme activity assayed with the insoluble substrate increases.
(B) Enzyme activity assayed with the soluble substrate decreases.
(C) Upon heating, enzyme activity decreases further.
(D) Upon heating, optical density increases.
(E) Polymannosylation at this second site has no effect on enzyme activity or thermal stability.

Questions 161-163

The pedigree below follows the inheritance pattern of a late-onset (after age thirty) genetic disease that is 100 percent penetrant; affected individuals are represented as a shaded circle (female) or square (male). A restriction fragment length polymorphism (RFLP) analysis of each individual's DNA is shown below the pedigree. Individuals IIIa through IIIi are under the age of thirty.



161. Which grandchildren (IIIb–IIIi) will eventually be affected by the disease?

(A) IIIc, IIIe, IIIf, IIIh, IIIi
(B) IIId, IIIe, IIIh, IIIi
(C) IIIc, IIId, IIIg, IIIh
(D) IIIb, IIIc, IIIf
(E) IIIb, IIId, IIIg

162. Individual IIIb and the indicated woman (IIIa), whose family has no history of the disease, have a child. What is the probability that the child will be affected?

(A) 0%
(B) 25%
(C) 33%
(D) 50%
(E) 100%

163. What is the most likely explanation for the inheritance of fragment A?

(A) It is derived from the Y chromosome.
(B) It is a duplicate locus that is not polymorphic.
(C) It contains the gene sequence.
(D) It is one of three alleles for the RFLP locus.
(E) It is derived from mitochondrial DNA.

Questions 164-166

Chlamydomonas is a unicellular green alga containing two flagella per haploid cell. Under certain conditions, two haploid cells can be induced to mate, producing a single cell containing a mixture of the cytoplasm from both haploid cells. This state is called a dikaryon, and the single cell now contains four flagella instead of two.

In addition to dikaryon formation, two other characteristics of this research organism allow investigators to study flagellar assembly: First, the flagella on individual cells can be easily removed, and the cell will regenerate new flagella as shown by the kinetics in Figure 1 below. Second, new protein synthesis is required to produce full-length flagella, as shown in Figure 2, by using the drug cycloheximide (whose effects can be rapidly reversed simply by removal of the drug from the medium).

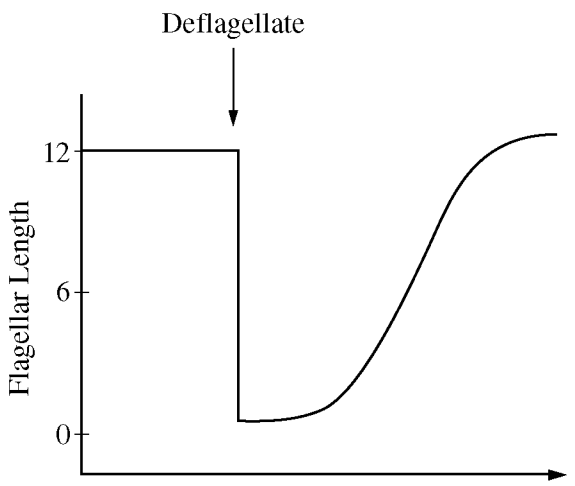


Figure 1

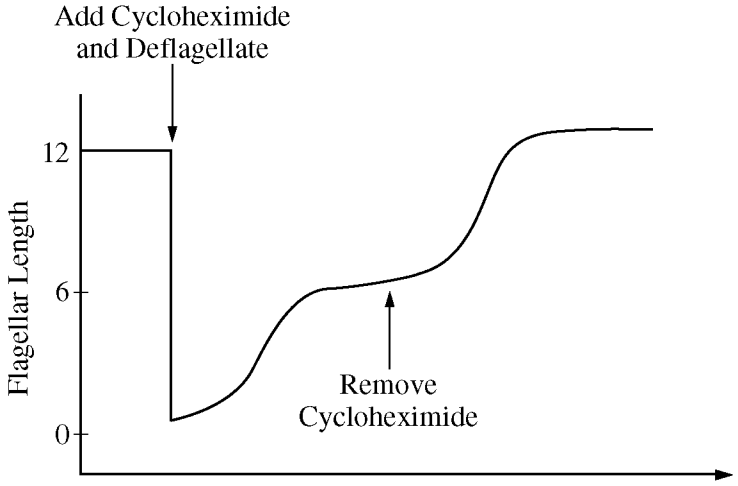


Figure 2

In an experiment to observe the response of cells to dikaryon formation (Figure 3), cell A has been deflagellated and allowed to reassemble its flagella in the presence of cycloheximide. Cell B, which carries a myc-tagged tubulin gene, had intact flagella. Cell A and cell B are then induced to form a dikaryon in medium lacking cycloheximide. After time sufficient to allow full-length flagellar regeneration, fluorescently tagged antibodies to tubulin were used to identify all four flagella of the dikaryon (Figure 4a), while anti-myc antibodies were used to identify tubulin carrying the myc epitope tag (Figure 4b).

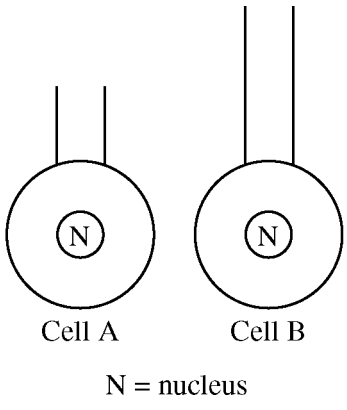


Figure 3. Light Microscopy Images Showing Two Cells (A and B)

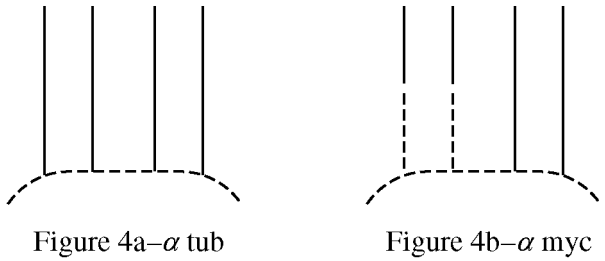


Figure 4a–α tub

Figure 4b–α myc

Dotted line shows outline of dikaryon cell, not visible by fluorescence.

Figure 4. Immunofluorescence Image Showing Flagellar Portion of Dikaryon Cell Bodies

GO ON TO THE NEXT PAGE.

164. The most likely explanation for the effect of cycloheximide on flagellar assembly (Figure 2) in the cells is that it

(A) prevents assembly of tubulin required for outer doublet formation
(B) prevents the synthesis of carbohydrates that are part of the elongating flagellar membrane
(C) prevents the synthesis of a protein that is present in a quantity sufficient to sustain assembly of flagella to half the normal length
(D) prevents the synthesis of a key flagellar protein that is absent in the cell but is essential for assembly and is induced by the process of deflagellation
(E) blocks the synthesis of an enzyme required to initiate the flagellar assembly reaction

165. Which of the following statements best summarizes the results of the experiment as represented in Figures 3 and 4 ?

(A) Cell B induces gene transcription in the nucleus of cell A after dikaryon formation, and the resulting new polypeptides, encoded by the genome of cell A, contribute to flagellar elongation.
(B) Tubulin subunits synthesized by cell B are used after dikaryon formation to elongate the flagella from cell A to normal length.
(C) Both cell A and cell B disassemble and then reassemble their flagella to normal length in response to dikaryon formation.
(D) In the absence of cycloheximide, cell A can once again synthesize tubulin subunits, which are used exclusively to elongate the flagella from cell A to normal length.
(E) An enzyme in the cytoplasm of the dikaryon removes the myc epitope tag from the tubulin subunits of cell B.

166. The data shown in Figures 3 and 4 indicate that during flagellar assembly, new tubulin subunits are incorporated

(A) at the base of the flagella
(B) along the entire flagellar length
(C) at the base of the central pair and at the tip of the outer doublets
(D) at the distal end of the flagellum
(E) at the tip of the central pair and at the base of the outer doublets

Questions 167-169

Cell cycle–specific protein kinases are believed to be involved in the activation of the phosphatase Cdc25. To monitor phosphorylation of Cdc25, different kinases were mixed with Cdc25 and ^{32}P-labeled ATP. Following incubation under the experimental conditions described below, the reaction mixtures were subjected to SDS-PAGE and autoradiography (Figure 1). The appearance of a band on the autoradiogram represents newly phosphorylated Cdc25. In parallel, Cdc25 activity was measured and the results graphed directly below the corresponding gel lane (Figure 2).

EXPERIMENTAL CONDITIONS

Lane 1: Control (no kinase added)
Lane 2: Polo kinase added
Lane 3: p38 MAP kinase added
Lane 4: p38 MAP kinase added for a specified time, then replaced with Polo kinase
Lane 5: Polo kinase added for a specified time, then replaced with p38 MAP kinase

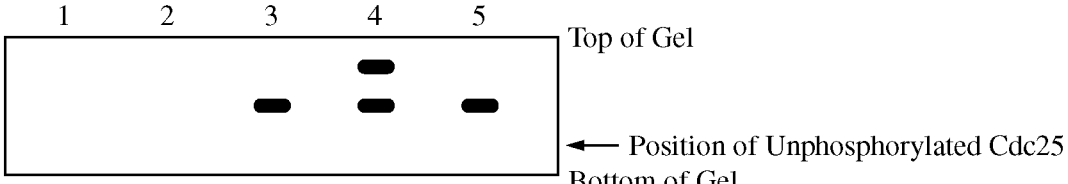


Figure 1. Autoradiogram of SDS-PAGE

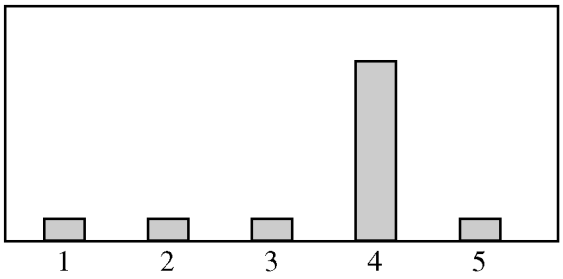


Figure 2. Histogram of Cdc25 Activity

167. According to the data, which of the following is correct?

(A) Kinases are not able to phosphorylate and activate Cdc25.
(B) p38 MAP kinase can phosphorylate Cdc25 in the absence of other kinases.
(C) Polo kinase alone can dephosphorylate Cdc25.
(D) Phosphorylation by p38 MAP kinase alone can activate Cdc25.
(E) Polo kinase and p38 MAP kinase phosphorylate the same amino-acid residue of Cdc25.

168. Which of the following is supported by the data?

(A) Phosphorylation is not required for Cdc25 activity.
(B) Addition of one phosphate to Cdc25 is sufficient to activate Cdc25.
(C) Addition of two phosphates to Cdc25 is needed to activate Cdc25.
(D) Addition of a minimum of three phosphates to Cdc25 is needed to activate Cdc25.
(E) Removal of a phosphate from Cdc25 is required for Cdc25 activity.

169. The data support which of the following statements concerning the phosphorylation and activation of Cdc25 ?

(A) p38 MAP kinase alone is sufficient to activate Cdc25.
(B) Polo kinase alone is sufficient to activate Cdc25.
(C) p38 MAP kinase can phosphorylate Cdc25 only after Polo kinase first places a phosphate on Cdc25.
(D) Polo kinase can phosphorylate Cdc25 only after p38 MAP kinase first places a phosphate on Cdc25.
(E) p38 MAP kinase phosphorylates Polo kinase, and then Polo kinase can phosphorylate and activate Cdc25.

Questions 170-172

The effects of an RNA polymerase inhibitor were determined using HeLa cells in culture. Before the addition of inhibitor, ^{3}H-uridine and ^{35}S-methionine were added to separate cultures, and the accumulation of labeled RNA (Figure 1) and labeled protein (Figure 2) was determined over time. After 10 hours of labeling, the cultures were split and the RNA polymerase inhibitor was added to one culture of each type, as indicated by the arrows in the graphs below. In control cultures, incubation was continued in the absence of the inhibitor as shown.

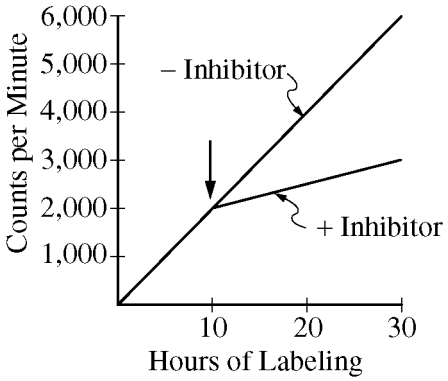


Figure 1. Labeled RNA (^{3}H-uridine) accumulation

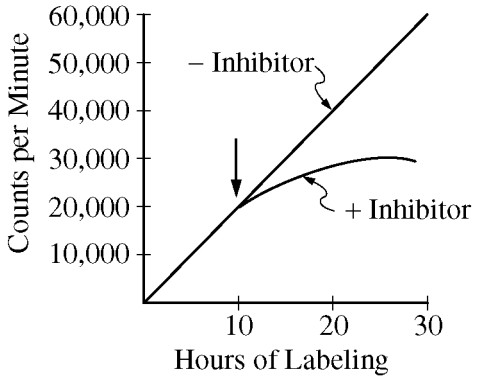


Figure 2. Labeled protein (^{35}S-methionine) accumulation

To further characterize the effects of the inhibitor on HeLa cells, a nuclear extract was made and fractionated by anion exchange chromatography using a DEAE Sephadex column. After the column was washed, bound proteins were eluted using a gradient of increasing $(NH_4)_2\ SO_4$ concentration. The individual fractions were examined for RNA polymerase activity in the absence (solid lines) or presence (dotted lines) of the RNA polymerase inhibitor (Figure 3).

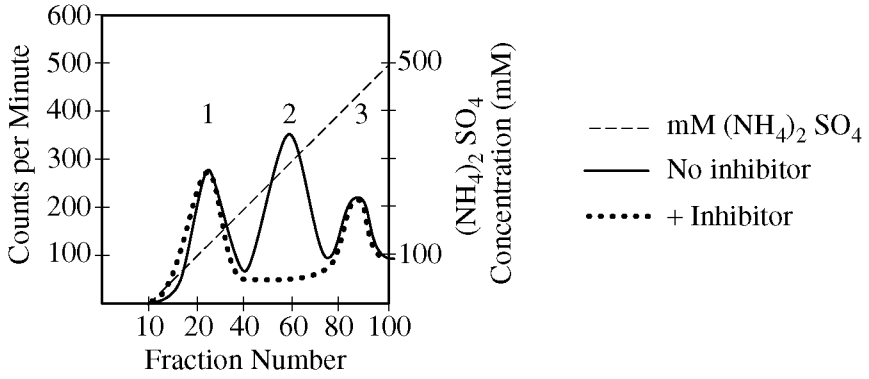


Figure 3. RNA polymerase activity (^{3}H-uridine incorporation)

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170. In the cell culture experiments, the incorporation of ^{35}S into newly synthesized protein continued for several hours in the presence of the inhibitor. In these experiments, continuation of protein synthesis occurred mostly because of the time it takes for

(A) preexisting mRNAs to decay
(B) disassembly of 80S ribosomes
(C) the inhibitor to enter the nucleus
(D) newly synthesized RNA to exit the nucleus
(E) RNA polymerase I to finish transcription once started

171. As determined by the *in vivo* cell labeling experiments in Figure 1, the percent of the total RNA synthesis that is sensitive to the inhibitor is closest to

(A) 95%
(B) 75%
(C) 50%
(D) 20%
(E) 5%

172. The material eluting from the column in peak 1 (Figure 3) localized to the nucleolus. This RNA polymerase is most likely directly involved in the production of

(A) rRNA only
(B) tRNA only
(C) mRNA only
(D) rRNA and tRNA
(E) mRNA and tRNA

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

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SUBJECT TEST

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

PRINT: _____
(LAST) (FIRST) (MIDDLE)

SIGN: _____

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

6. TITLE CODE				
2	2	5	3	5
0	0	0	0	0
1	1	1	1	1
●	●	2	2	2
3	3	3	●	3
4	4	4	4	4
5	5	●	5	●
6	6	6	6	6
7	7	7	7	7
8	8	8	8	8
9	9	9	9	9

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

TEST NAME Biochemistry

FORM CODE GR1222

GRADUATE RECORD EXAMINATIONS SUBJECT TEST

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

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

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

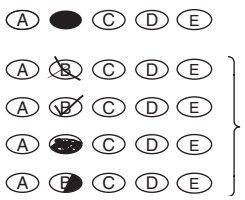
YOU MUST INDICATE ALL YOUR ANSWERS ON THE SEPARATE ANSWER SHEET. No credit will be given for anything written in this examination book, but you may write in the book as much as you wish to work out your answers. After you have decided on your response to a question, fill in the corresponding oval on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

Example:

What city is the capital of France?

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

Sample Answer



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Worksheet for the GRE Biochemistry, Cell and Molecular Biology Test, Form GR1222
Answer Key and Percentages* of Test Takers Answering Each Question Correctly

Question			Response		Subscore		
Number	Answer	P+	C	I	1	2	3
1	D	45			•		
2	C	53			•		
3	C	36			•		
4	B	86			•		
5	B	44				•	
6	E	48				•	
7	D	20				•	
8	B	79					•
9	A	49					•
10	D	53				•	
11	E	69					•
12	E	69					•
13	D	88			•		
14	A	85			•		
15	C	61			•		
16	B	82				•	
17	D	53				•	
18	B	74			•		
19	A	46				•	
20	A	90					•
21	A	78					•
22	A	55					•
23	A	53					•
24	B	46					•
25	A	64				•	
26	B	60				•	
27	D	22					•
28	C	51				•	
29	A	70				•	
30	D	44			•		
31	E	74			•		
32	D	52			•		
33	E	54			•		
34	B	90			•		
35	E	44					•
36	B	83				•	
37	D	23				•	
38	A	12					•
39	C	46					•
40	C	56					•
41	D	14				•	
42	E	78				•	
43	E	33			•		
44	D	46			•		
45	B	37			•		
46	E	42			•		
47	B	71			•		
48	E	52					•
49	D	50				•	
50	D	56					•
51	A	67					•
52	D	82			•		
53	C	39			•		
54	B	63			•		
55	E	31			•		
56	D	51			•		
57	C	36				•	
58	D	37				•	
59	C	64				•	
60	A	16					•

Question			Response		Subscore		
Number	Answer	P+	C	I	1	2	3
61	A	31					•
62	C	26					•
63	E	29					•
64	A	23					•
65	A	70				•	
66	B	32				•	
67	C	41				•	
68	A	72			•		
69	D	70			•		
70	E	71			•		
71	B	84			•		
72	C	76			•		
73	D	16					•
74	A	15					•
75	D	46					•
76	C	56					•
77	A	71					•
78	A	42				•	
79	E	35				•	
80	E	25				•	
81	D	94					•
82	C	25			•		
83	E	50			•		
84	C	59					•
85	A	37			•		
86	B	63			•		
87	A	46					•
88	C	41					•
89	A	36					•
90	E	43					•
91	E	32				•	
92	C	44				•	
93	C	54			•		
94	D	23			•		
95	E	92					•
96	E	65					•
97	B	71					•
98	E	40			•		
99	C	27			•		
100	C	35			•		
101	B	49					•
102	E	63				•	
103	C	31			•		
104	D	85			•		
105	E	7			•		
106	D	17					•
107	A	40			•		
108	C	31					•
109	E	72					•
110	A	29					•
111	D	70					•
112	B	61					•
113	B	74				•	
114	D	84				•	
115	B	49				•	
116	C	64				•	
117	B	90			•		
118	C	78			•		
119	E	65			•		
120	E	63				•	

Question			Response		Subscore		
Number	Answer	P+	C	I	1	2	3
121	C	79				•	
122	D	64				•	
123	C	83			•		
124	A	68			•		
125	E	51			•		
126	B	54			•		
127	A	65					•
128	B	82					•
129	B	61			•		
130	E	70			•		
131	A	81			•		
132	A	82					•
133	D	71					•
134	B	33					•
135	E	72					•
136	D	49				•	
137	D	31				•	
138	E	67				•	
139	B	61			•		
140	C	37			•		
141	E	27			•		
142	E	66				•	
143	D	43				•	
144	A	52				•	
145	C	62				•	
146	C	39					•
147	C	16					•
148	A	44					•
149	B	79			•		
150	D	86			•		
151	D	86				•	
152	A	82				•	
153	C	65				•	
154	E	80					•
155	A	83					•
156	B	93					•
157	B	50					•
158	D	66			•		
159	E	57			•		
160	B	56			•		
161	E	89					•
162	D	46					•
163	B	35					•
164	C	58				•	
165	B	48				•	
166	D	42				•	
167	B	79			•		
168	C	83			•		
169	D	85			•		
170	A	65					•
171	B	33					•
172	A	48					•

Total Correct (**C**): _____ Sub 1 Correct (**C**): _____ Sub 2 Correct (**C**): _____ Sub 3 Correct (**C**): _____

Total Incorrect (**I**): _____ Sub 1 Incorrect (**I**): _____ Sub 2 Incorrect (**I**): _____ Sub 3 Incorrect (**I**): _____

Total Raw: (**C** – **I**/4): _____ Sub 1 Raw: (**C** – **I**/4): _____ Sub 2 Raw: (**C** – **I**/4): _____ Sub 3 Raw: (**C** – **I**/4): _____

Scaled Score: _____ Scaled Score: _____ Scaled Score: _____ Scaled Score: _____

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

Score Conversions for the GRE Biochemistry, Cell and Molecular Biology Test, Form GR1222

Total Score

Raw Score	Scaled Score	Raw Score	Scaled Score
170-172	840	79-81	540
167-169	830	76-78	530
164-166	820	73-75	520
161-163	810	70-72	510
158-160	800	67-69	500
155-157	790	64-66	490
152-154	780	61-63	480
149-151	770	58-60	470
145-148	760	54-57	460
142-144	750	51-53	450
139-141	740	48-50	440
136-138	730	45-47	430
133-135	720	42-44	420
130-132	710	39-41	410
127-129	700	36-38	400
124-126	690	33-35	390
121-123	680	30-32	380
118-120	670	27-29	370
115-117	660	24-26	360
112-114	650	21-23	350
109-111	640	18-20	340
106-108	630	15-17	330
103-105	620	12-14	320
100-102	610	9-11	310
97-99	600	6-8	300
94-96	590	3-5	290
91-93	580	0-2	280
88-90	570		
85-87	560		
82-84	550		

Subscores

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

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

2.

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

MAILING ADDRESS: (Print) _____
P.O. Box or Street Address

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City State or Province

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Country Zip or Postal Code

CENTER: _____
City State or Province

_____
Country Center Number Room Number

SIGNATURE: _____

GRADUATE RECORD EXAMINATIONS® - ETS 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.

Item responses continued on reverse side.

3. DATE OF BIRTH

Month	Day	Year
Jan.		
Feb.		
Mar.	0 0	0 0
April	1 1	1 1
May	2 2	2 2
June	3 3	3 3
July	4 4	4 4
Aug.	5 5	5 5
Sept.	6 6	6 6
Oct.	7 7	7 7
Nov.	8 8	8 8
Dec.	9 9	9 9

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

5. REGISTRATION NUMBER (from your admission ticket)

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

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

FORM CODE (on back cover of your test book)

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

SHADED AREA FOR ETS USE ONLY

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

1 2 3 4

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

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

IF YOU DO NOT WANT THIS ANSWER SHEET TO BE SCORED

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

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

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

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