

AP[®] Biology

Practice Exam #2 and Notes

For the
**Spring 2020
Exam**

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Contents

I. Practice Exam

Exam Content and Format	4
Administering the Practice Exam	4
Answer Sheet for Multiple-Choice Section	6
AP® Biology Practice Exam	7

II. Notes on the Practice Exam

Multiple-Choice Section	71
Answer Key and Question Alignment to Course Framework	101
Free-Response Section	103

Contact Us	111
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Practice Exam

Exam Content and Format

The AP Biology Exam is approximately 3 hours in length. There are two sections.

- Section I is 1 hour, 30 minutes and consists of 60 multiple-choice questions, accounting for 50 percent of the final score.
- Section II is 1 hour, 30 minutes and consists of 2 long free-response questions and 4 short free-response questions, accounting for 50 percent of the final score.

Administering the Practice Exam

This section contains instructions for administering the AP Biology Practice Exam. You may wish to use these instructions to create an exam situation that resembles an actual administration. If so, read the indented, boldface directions to the students; all other instructions are for administering the exam and need not be read aloud. Before beginning testing, have all exam materials ready for distribution. These include test booklets and answer sheets. (Reminder: Final instructions for every AP Exam are published in the AP Exam Instructions book.)

SECTION I: Multiple Choice

When you are ready to begin Section I, say:

Section I is the multiple-choice portion of the exam. Mark all of your responses on your answer sheet, one response per question. If you need to erase, do so carefully and completely. Your score on the multiple-choice section will be based solely on the number of questions answered correctly. You may use a four-function (with square root), scientific, or graphing calculator. Are there any questions?

You have 1 hour and 30 minutes for this section. Open your Section I booklet and begin.

Note Start Time here _____. Note Stop Time here _____. After 1 hour and 20 minutes, say:

There are 10 minutes remaining.

After 10 minutes, say:

Stop working. I will now collect your Section I booklet and multiple-choice answer sheet.

There is a 10-minute break between Sections I and II.

SECTION II: Free Response

After the break, say:

Section II is the free-response portion of the exam.

You have 1 hour and 30 minutes to answer the questions. You are responsible for pacing yourself, and may proceed freely from one question to the next. Write your answers on the lined pages provided for each question. If you need more paper during the exam, raise your hand. At the top of each extra piece of paper you use, be sure to write your name and the number of the question you are working on. Are there any questions? Open your Section II booklet and begin.

Note Start Time here _____. Note Stop Time here _____. After 1 hour and 20 minutes, say:

There are 10 minutes remaining.

After 10 minutes, say:

Stop working and close your exam booklet. Put your exam booklet on your desk, face up. Remain in your seat, without talking, while the exam materials are collected.

If any students used extra paper for the free-response section, have those students staple the extra sheet/s to the first page corresponding to that question in their exam booklets. Collect a Section II booklet from each student and check that each student wrote answers on the lined pages corresponding to each question. Then say:

The exam is over. You are now dismissed.

Name: _____

**AP[®] Biology
Answer Sheet
for Multiple-Choice Section**

No.	Answer
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No.	Answer
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AP[®] Biology Exam

SECTION I: Multiple Choice

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

At a Glance

Total Time

1 hour and 30 minutes

Number of Questions

60

Percent of Total Score

50%

Writing Instrument

Pencil required

Electronic Device

Calculator allowed

Instructions

Section I of this exam contains 60 multiple-choice questions. Indicate all of your answers to the Section I questions on the answer sheet. No credit will be given for anything written in this exam booklet, but you may use the booklet for notes or scratch work.

Use your time effectively, working as quickly as you can without losing accuracy. Do not spend too much time on any one question. Go on to other questions and come back to the ones you have not answered if you have time. It is not expected that everyone will know the answers to all of the multiple-choice questions.

Your total score on Section I is based only on the number of questions answered correctly. Points are not deducted for incorrect answers or unanswered questions.

AP® BIOLOGY EQUATIONS AND FORMULAS

Statistical Analysis and Probability

Mean

$$\bar{x} = \frac{1}{n} \sum_{i=1}^n x_i$$

Standard Deviation

$$s = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n - 1}}$$

Standard Error of the Mean

$$SE_{\bar{x}} = \frac{s}{\sqrt{n}}$$

Chi-Square

$$\chi^2 = \sum \frac{(o - e)^2}{e}$$

Chi-Square Table

p value	Degrees of Freedom							
	1	2	3	4	5	6	7	8
0.05	3.84	5.99	7.81	9.49	11.07	12.59	14.07	15.51
0.01	6.63	9.21	11.34	13.28	15.09	16.81	18.48	20.09

Laws of Probability

If A and B are mutually exclusive, then:

$$P(A \text{ or } B) = P(A) + P(B)$$

If A and B are independent, then:

$$P(A \text{ and } B) = P(A) \times P(B)$$

Hardy-Weinberg Equations

$$p^2 + 2pq + q^2 = 1 \quad p = \text{frequency of allele 1 in a population}$$

$$p + q = 1 \quad q = \text{frequency of allele 2 in a population}$$

$\bar{x}$ = sample mean

n = sample size

s = sample standard deviation (i.e., the sample-based estimate of the standard deviation of the population)

o = observed results

e = expected results

Σ = sum of all

Degrees of freedom are equal to the number of distinct possible outcomes minus one.

Metric Prefixes

Factor	Prefix	Symbol
10^9	giga	G
10^6	mega	M
10^3	kilo	k
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p

Mode = value that occurs most frequently in a data set

Median = middle value that separates the greater and lesser halves of a data set

Mean = sum of all data points divided by number of data points

Range = value obtained by subtracting the smallest observation (sample minimum) from the greatest (sample maximum)

Rate and Growth <u>Rate</u> $\frac{dY}{dt}$ dY = amount of change dt = change in time B = birth rate D = death rate N = population size K = carrying capacity $r_{\max}$ = maximum per capita growth rate of population <u>Population Growth</u> $\frac{dN}{dt} = B - D$ <u>Exponential Growth</u> $\frac{dN}{dt} = r_{\max}N$ <u>Logistic Growth</u> $\frac{dN}{dt} = r_{\max}N \left(\frac{K - N}{K} \right)$		<u>Water Potential (Ψ)</u> $\Psi = \Psi_p + \Psi_s$ Ψ_p = pressure potential Ψ_s = solute potential The water potential will be equal to the solute potential of a solution in an open container because the pressure potential of the solution in an open container is zero. <u>The Solute Potential of a Solution</u> $\Psi_s = -iCRT$ i = ionization constant (1.0 for sucrose because sucrose does not ionize in water) C = molar concentration R = pressure constant (R = 0.0831 liter bars/mole K) T = temperature in Kelvin ($^{\circ}\text{C} + 273$)
<u>Simpson's Diversity Index</u> Diversity Index = $1 - \sum \left(\frac{n}{N} \right)^2$ n = total number of organisms of a particular species N = total number of organisms of all species		<u>pH</u> = $-\log[\text{H}^+]$
Surface Area and Volume		
<u>Surface Area of a Sphere</u> $SA = 4\pi r^2$	<u>Volume of a Sphere</u> $V = \frac{4}{3}\pi r^3$	r = radius
<u>Surface Area of a Rectangular Solid</u> $SA = 2lh + 2lw + 2wh$	<u>Volume of a Rectangular Solid</u> $V = lwh$	l = length h = height w = width
<u>Surface Area of a Cylinder</u> $SA = 2\pi rh + 2\pi r^2$	<u>Volume of a Cylinder</u> $V = \pi r^2 h$	s = length of one side of a cube
<u>Surface Area of a Cube</u> $SA = 6s^2$	<u>Volume of a Cube</u> $V = s^3$	SA = surface area V = volume

BIOLOGY

SECTION I

Time—1 hour and 30 minutes

60 Questions

Directions: Each of the questions or incomplete statements below is followed by four suggested answers or completions. Select the one that is best in each case and then enter the letter in the corresponding space on the answer sheet.

1. Which of the following best describes the hydrolysis of carbohydrates?
(A) The removal of a water molecule breaks a covalent bond between sugar monomers.
(B) The removal of a water molecule forms a covalent bond between sugar monomers.
(C) The addition of a water molecule breaks a covalent bond between sugar monomers.
(D) The addition of a water molecule forms a covalent bond between sugar monomers.

2. Which of the following best describes a characteristic of DNA that makes it useful as hereditary material?
(A) There are many different types of nucleotide bases that can be incorporated into DNA.
(B) The nucleotide bases can also be used to provide the energy needed for reproduction.
(C) Nucleotide bases can be randomly replaced with different nucleotide bases to increase variation.
(D) Nucleotide bases in one strand can only be paired with specific bases in the other strand.

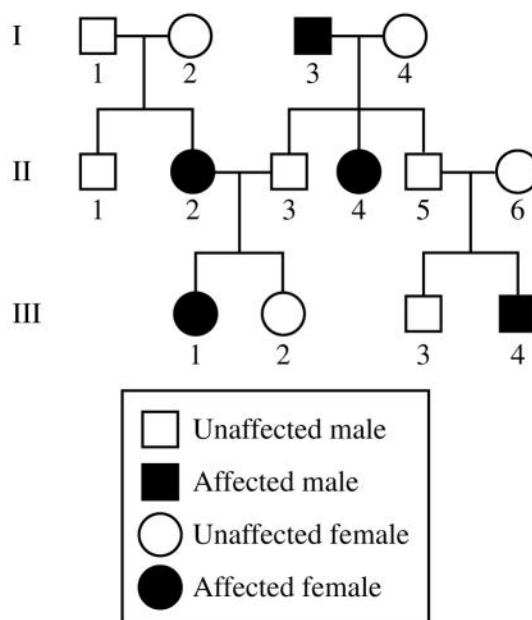


Figure 1. Pedigree of an inherited trait

3. Based on the pedigree in Figure 1, which of the following best explains the observed pattern of inheritance?
(A) The trait is autosomal dominant, because the cross between individuals I-3 and I-4 produced an affected offspring.
(B) The trait is autosomal recessive, because the cross between individuals I-1 and I-2 produced an affected offspring.
(C) The trait is sex-linked dominant, because the cross between individuals II-5 and II-6 produced an affected male.
(D) The trait is sex-linked recessive, because the cross between individuals II-2 and II-3 produced an affected female.

GO ON TO THE NEXT PAGE.

Questions 4 - 8

To investigate bacterial metabolism, a researcher divided a population (culture) of *Staphylococcus capitis* bacteria into two sets of culture tubes containing glucose. The researcher added a chemical to one set of tubes and measured the pH of the cultures at 5-minute intervals as the bacteria metabolized the glucose into lactic acid. The data are shown in Table 1.

TABLE 1. AVERAGE CHANGE IN pH IN CONTROL AND TREATMENT GROUPS OVER A 40-MINUTE PERIOD

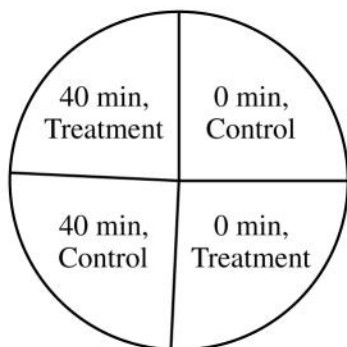
Time (min)	Average pH of Control ($\pm 2 \text{ SE}_{\bar{x}}$)	Average pH of Treatment ($\pm 2 \text{ SE}_{\bar{x}}$)
0	8.04 ± 0.05	8.04 ± 0.06
5	7.96 ± 0.03	7.91 ± 0.04
10	7.88 ± 0.02	7.85 ± 0.04
15	7.82 ± 0.02	7.79 ± 0.06
20	7.76 ± 0.03	7.70 ± 0.04
25	7.71 ± 0.04	7.67 ± 0.02
30	7.63 ± 0.03	7.63 ± 0.02
35	7.65 ± 0.02	7.60 ± 0.02
40	7.65 ± 0.01	7.59 ± 0.02

4. Which of the following best describes the process by which the bacteria are breaking down the glucose to produce lactic acid?
- (A) The bacteria are breaking down sugars in the absence of oxygen.
- (B) The bacteria are creating a H^+ gradient to synthesize more ATP.
- (C) The bacteria are using their mitochondria to break down glucose in the presence of oxygen.
- (D) The bacteria are producing CO_2 in the Krebs cycle that is then converted into lactic acid.
5. Which of the following was the dependent variable in the researcher's experiment?
- (A) Time
- (B) pH
- (C) Glucose concentration
- (D) Lactic acid concentration

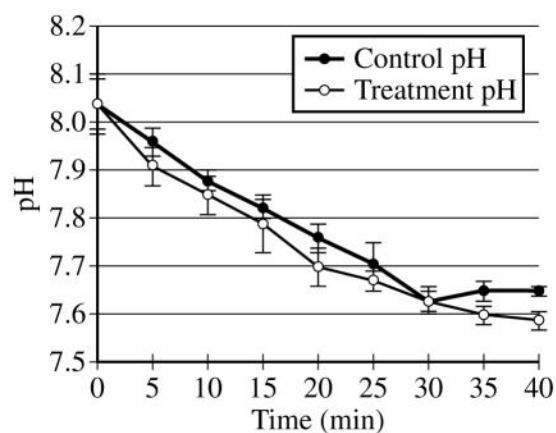
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6. Which of the following graphs best represents the data in Table 1 ?

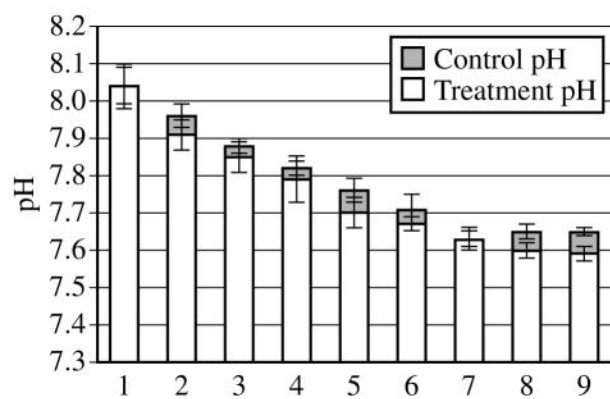
(A)



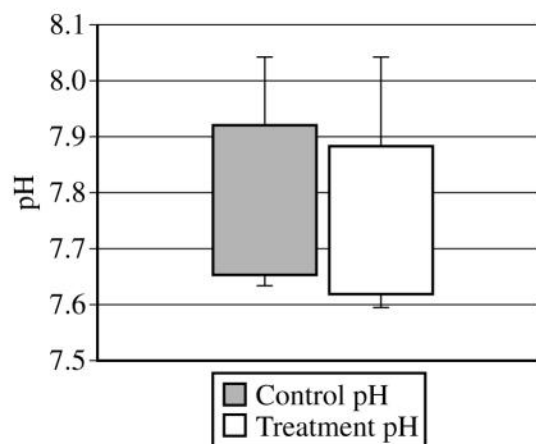
(B)



(C)



(D)



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7. Based on the data in Table 1, which of the following is the earliest time point at which there is a statistical difference in average pH between the control and treatment groups?

- (A) 5 minutes
- (B) 15 minutes
- (C) 20 minutes
- (D) 35 minutes

8. According to the data, which of the following best explains the results of the experiment?

- (A) The pH of the treatment culture was lower than the pH of the control because the chemical increased the bacterial metabolic rate.
 - (B) The pH of the treatment culture was higher than the pH of the control because the chemical denatured bacterial enzymes and decreased the metabolic rate.
 - (C) The chemical increased the metabolic rate of the bacteria because it lowered the pH.
 - (D) The chemical decreased the metabolic rate of the bacteria because it bound all available oxygen.
-

9. A mutation in the gene coding for a single-polypeptide enzyme results in the substitution of the amino acid serine, which has a polar R group, by the amino acid phenylalanine, which has a nonpolar R group. When researchers test the catalysis of the normal enzyme and the mutated enzyme, they find that the mutated enzyme has much lower activity than the normal enzyme does.

Which of the following most likely explains how the amino acid substitution has resulted in decreased catalytic activity by the mutated enzyme?

- (A) The substitution decreased the mass of the enzyme so that the mutated enzyme binds more weakly to the substrate than the normal enzyme does.
- (B) The substitution altered the secondary and tertiary structure of the enzyme so that the mutated enzyme folds into a different shape than the normal enzyme does.
- (C) The substitution caused many copies of the mutated enzyme to cluster together and compete for substrate to bind.
- (D) The substitution caused the directionality of the enzyme to change such that the amino terminus of the normal enzyme has become the carboxy terminus of the mutated enzyme.

GO ON TO THE NEXT PAGE.

10. Pitcher plants are carnivorous plants that grow in areas where the soil contains low levels of key nutrients such as nitrogen. To obtain these nutrients, most pitcher plants capture prey using traps containing a digestive fluid. The captured prey are then broken down and digested, and the pitcher plant absorbs the nutrients.

The traps of one species of pitcher plant, *Nepenthes hemsleyana*, do not contain digestive fluid. Instead they provide a suitable place for woolly bats (*Kerivoula hardwickii*) to sleep. The feces from the bat are released into the trap where nutrients in the feces are absorbed and provide the plant with the nitrogen it needs.

Which of the following best describes the relationship between the pitcher plant and the woolly bat?

- (A) The relationship is an example of parasitism because the bat is harmed while the plant benefits.
- (B) The relationship is an example of mutualism because both the plant and the bat benefit.
- (C) The relationship is an example of commensalism because the plant benefits but the bat is unaffected.
- (D) The relationship is an example of commensalism because the plant is unaffected while the bat benefits.

11. A particular genetic disorder is associated with a single gene with two alleles. Individuals with two recessive alleles are affected. The prevalence of the disorder is 1 in 6,600.

Assuming the population is in Hardy-Weinberg equilibrium, which of the following is closest to the frequency of carriers in the general population?

- (A) 0.00015
- (B) 0.01230
- (C) 0.02430
- (D) 0.98770

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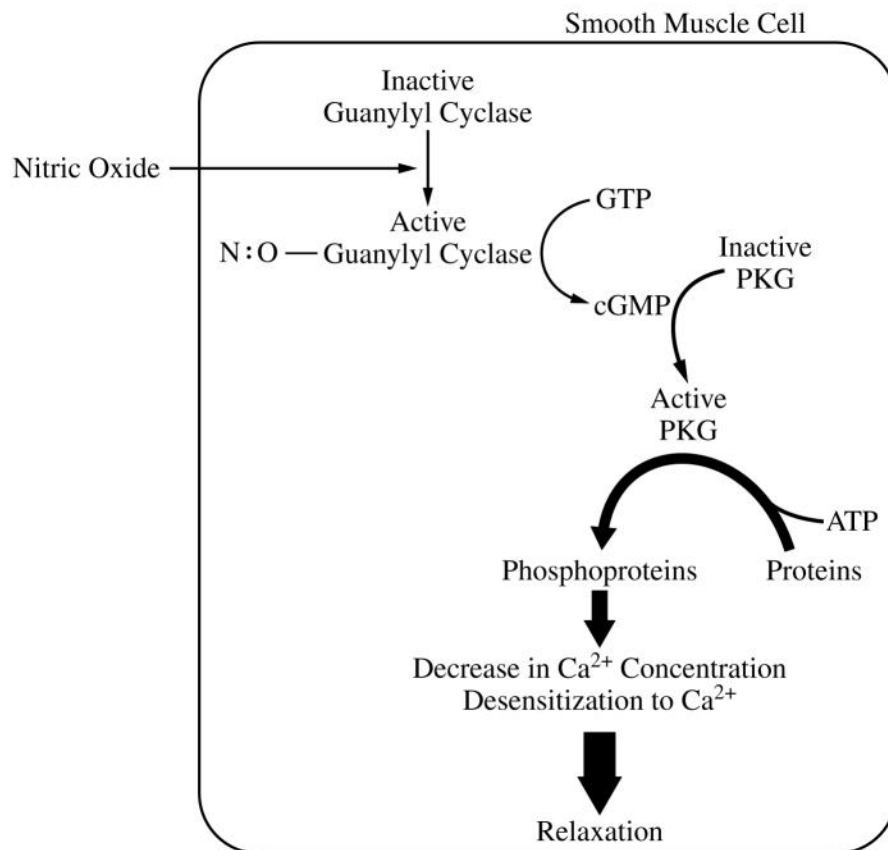


Figure 1. A signaling cascade triggers the relaxation of smooth muscle cells.

12. Blood vessels are surrounded by cells called smooth muscle cells. Nitric oxide triggers a signaling cascade in smooth muscle cells that causes the cells to relax (Figure 1).

Which of the following is represented by the gradual increase in thickness of the arrows from the top to the bottom of Figure 1 ?

- (A) The rate at which nitric oxide triggers signaling gradually increases over time.
- (B) The number of signaling molecules that are produced or activated increases with each step in the pathway.
- (C) The size of the proteins in the pathway increases as the signaling cascade moves through the cell.
- (D) The signaling pathway uses an increase in negative feedback to reduce intracellular Ca^{2+} levels and cell sensitivity to Ca^{2+} .

GO ON TO THE NEXT PAGE.

Questions 13 - 18

A student peeled the skins from grapes, exposing cells with membranes that are only permeable to water and small diffusible solutes. The student measured the mass of the peeled grapes. The student then placed each peeled grape into one of five solutions. After 24 hours, the student removed the peeled grapes from the solutions, measured their final mass, and calculated the percent change in mass (Table 1).

TABLE 1. PERCENT CHANGE IN MASS OF PEELED GRAPES IN SOLUTIONS

Solution	Concentration of Solution (weight/volume)	Percent Change in Mass
Distilled water	0%	13.48%
NaCl	20%	– 23.39%
Tap water	0.8%	9.46%
Grape juice	2.1%	2.8%
Grape soda	13%	– 15.00%

In a second experiment (Table 2), the student placed a peeled grape into a solution containing both small diffusible solutes and solutes to which the membrane is impermeable (nondiffusible solutes).

TABLE 2. CONCENTRATION OF SOLUTES IN SECOND EXPERIMENT

Location	Concentration of Small Diffusible Solutes	Concentration of Nondiffusible Solutes
Inside grape	0.4 M	1.2 M
In solution	1.6 M	0.8 M

GO ON TO THE NEXT PAGE.

13. Based on Table 1, which of the following best explains the difference in water potential between certain solutions and the grapes?
- (A) NaCl and tap water have a lower water potential because these two solutions caused the grape to gain water.
 - (B) Grape soda and NaCl have a lower water potential because these two solutions caused the grape to lose water.
 - (C) Tap water and grape juice have a lower water potential because these two solutions caused the grape to lose water.
 - (D) Grape soda and grape juice have a lower water potential because these two solutions caused the grape to gain water.
14. Based on Table 1, which of the following percentages is closest to the solute concentration of the grape?
- (A) 0.0%
 - (B) 1.3%
 - (C) 5.5%
 - (D) 10.1%
15. A student hypothesizes that the solute concentration of grape juice is higher than the solute concentration of the actual grape because the grape juice has added sugar.
- Based on the data in Table 1, which of the following best evaluates the student's hypothesis?
- (A) The hypothesis is supported because the mass of the grape decreased in the grape juice.
 - (B) The hypothesis is supported because the grape juice has a greater solute potential than the grape has.
 - (C) The hypothesis is not supported because the grape was isotonic to the grape juice.
 - (D) The hypothesis is not supported because the mass of the grape increased in the grape juice.
16. Assuming a negligible pressure potential, which of the following best predicts the net movement of the small diffusible solutes and water in the second experiment (Table 2) ?
- (A) Small diffusible solutes will diffuse into the grape cells, followed by water.
 - (B) Small diffusible solutes will diffuse out of the grape cells and water will diffuse into the cells.
 - (C) Small diffusible solutes will diffuse out of the grape cells, followed by water.
 - (D) Small diffusible solutes will diffuse into the grape cells and water will diffuse out of the cells.
17. Mercurial sulfhydryl is an inhibitor of aquaporins. Which of the following is the most likely effect of adding mercurial sulfhydryl to the distilled water solution?
- (A) The grape cells will burst because of excess water entering by active transport.
 - (B) The grape cells will gain more water because of the activation of the transport protein.
 - (C) The grape cells will shrink because active transport has been inhibited.
 - (D) The grape cells will gain water more slowly because of a lack of facilitated diffusion.

GO ON TO THE NEXT PAGE.

18. Which of the following best explains why larger grapes have a different rate of water absorption per gram of mass than smaller grapes do?

- (A) The rate is slower because smaller grapes have a larger surface-area-to-volume ratio than the larger grapes do.
 - (B) The rate is slower because larger grapes have a larger surface-area-to-volume ratio than the smaller grapes do.
 - (C) The rate is slower because smaller grapes can expand more than larger grapes to hold excess water.
 - (D) The rate is slower because larger grapes have more volume to hold excess water than smaller grapes do.
-

19. Which of the following best explains how some cells of an individual produce and secrete a specific enzyme, but other cells of the same individual do not?

- (A) The cells contain different genes and therefore do not make the same proteins.
- (B) The cells have evolved under different selective pressures, resulting in some cells making proteins that others cannot.
- (C) The cells transcribe and translate different combinations of genes, leading to the production of different sets of proteins.
- (D) The cells produce different types of ribosomes that enable the translation of different genes.

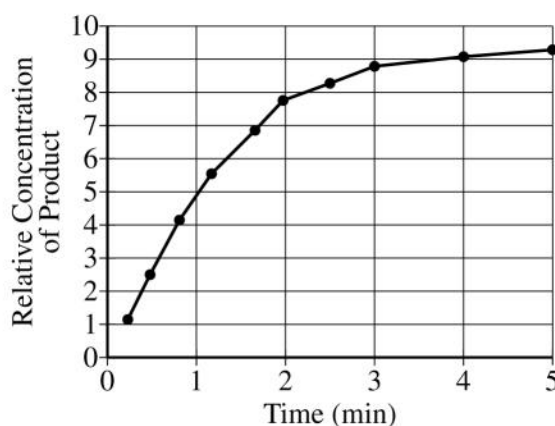


Figure 1. Change in the relative concentration of product over time

20. Figure 1 shows the amount of product produced in an enzyme-catalyzed reaction over five minutes. Which of the following best explains how the rate of the reaction changes over time?

- (A) The rate increases because more products are made over time.
- (B) The rate increases because the ratio of product to substrate increases.
- (C) The rate decreases because the ratio of product to substrate increases.
- (D) The rate decreases because the enzyme is used up as the reaction progresses.

GO ON TO THE NEXT PAGE.

21. Pyruvate kinase, a key enzyme in the glycolysis pathway, is inhibited by the amino acid alanine. The ability of alanine to inhibit the enzyme is not affected by increasing the concentration of substrate.

Which of the following best explains the mechanism by which alanine inhibits pyruvate kinase activity?

- (A) Alanine binds to an allosteric site of the enzyme, changing the shape of the enzyme's active site.
- (B) Alanine increases the enzyme-substrate binding until the enzyme becomes saturated.
- (C) Alanine is a competitive inhibitor that reversibly binds to the active site of the enzyme.
- (D) Alanine binds to the substrate, preventing the substrate from being able to bind to the active site of the enzyme.

22. Different species of bumblebee compete for flower nectar in their ecosystem. While the flowers vary in the length of their petals, bumblebees vary in the length of a mouth part called a proboscis. Bumblebees demonstrate a preference for flowers that correspond to the length of their proboscis. Species with proboscises of similar length tend to occupy different areas. Species that live in the same area tend to have proboscises of different lengths.

Which of the following best explains the relationship between the different bumblebee species living in the same area?

- (A) The bumblebees have undergone allopatric speciation due to geographic isolation.
- (B) The bumblebees have undergone niche partitioning due to competition.
- (C) The bumblebees have a mutualistic relationship with other bumblebee species due to natural selection.
- (D) The bumblebees have a commensalistic relationship due to the variety of niches that are available.

GO ON TO THE NEXT PAGE.

23. Researchers investigated whether time of day affects the rate at which certain mRNAs produced by plants are broken down. At either 1 hour after the start of the light period (morning) or 8 hours after the start of the light period (afternoon), the researchers treated identical plant seedlings with a compound that blocks transcription (time = 0 min). The researchers measured the percent remaining of two mRNAs, mRNA G and mRNA H, over the course of 120 minutes. The data are shown in Figure 1.

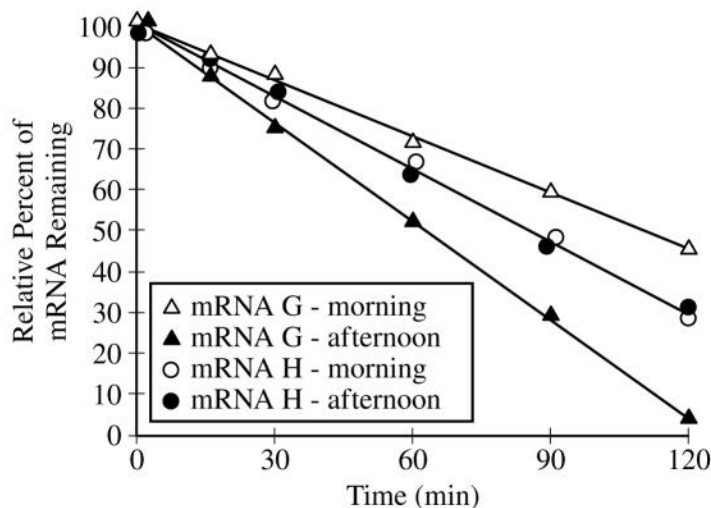


Figure 1. Degradation of mRNA G and mRNA H over time after exposure to light for 1 hour (morning) or 8 hours (afternoon)

Based on the data, which of the following best describes the relationship between light and the degradation of mRNA G and mRNA H ?

- (A) Exposure to light causes the degradation of both mRNA G and mRNA H.
 - (B) mRNA G and mRNA H degrade at the same rate during morning exposure to light.
 - (C) A longer exposure to light increases the rate of mRNA G degradation but not of mRNA H degradation.
 - (D) Exposure to more-intense afternoon light causes both mRNA G and mRNA H to degrade more rapidly in the afternoon than in the morning.
24. Which of the following observations would provide the strongest evidence that two plants belong to different biological species?
- (A) There are variations in their RNA sequences.
 - (B) The leaves and flowers show morphological differences.
 - (C) They produce viable but sterile offspring.
 - (D) They occupy unique habitats in an ecosystem.

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Questions 25 - 29

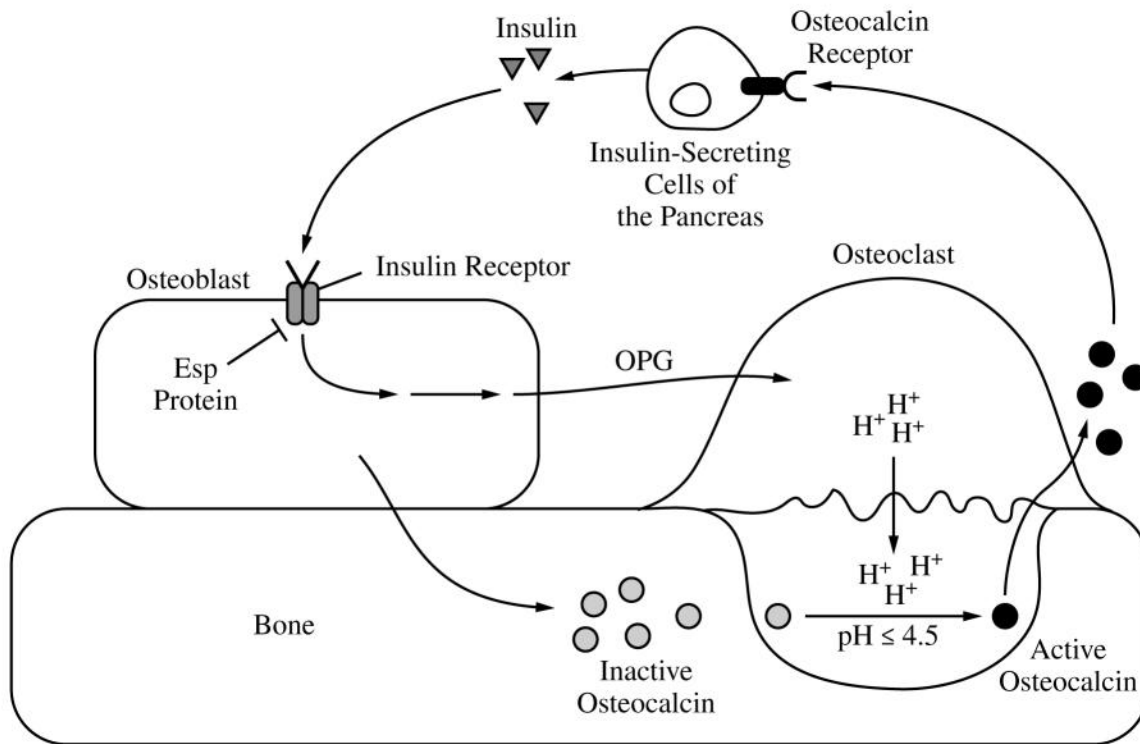


Figure 1. Pathway activated by insulin binding to the insulin receptor

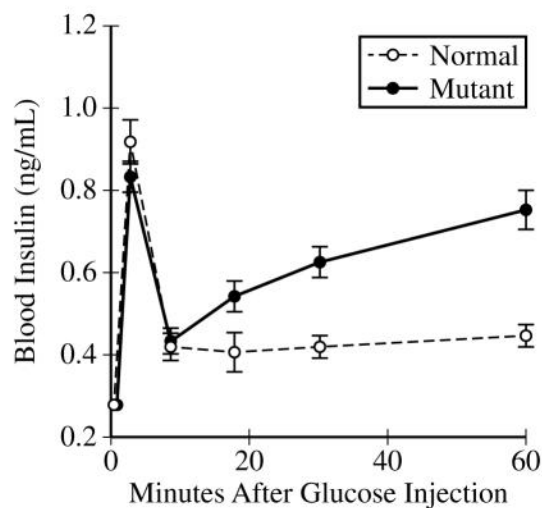


Figure 2: Blood insulin levels in normal mice and *Esp* mutant mice after exposure to glucose

Hormones are chemical signals that are released by cells in one part of the body that travel through the bloodstream to signal cells in another part of the body. Insulin is a hormone that is released by the pancreas that induces the uptake of glucose molecules from the bloodstream into cells. In this way, insulin lowers the overall blood glucose levels of the body. Osteoblasts and osteoclasts are two types of bone cells that play a role in regulating blood glucose levels (Figure 1).

Binding of insulin to the insulin receptor on osteoblasts activates a signaling pathway that results in osteoblasts releasing a molecule, OPG, that binds to neighboring osteoclasts. In response, the osteoclasts release protons (H^+) and

GO ON TO THE NEXT PAGE.

create an area of lower pH outside the cell. This low pH activates osteocalcin, a protein secreted in an inactive form by osteoblasts.

The *Esp* gene encodes a protein that alters the structure of the insulin receptor on osteoblasts and interferes with the binding of insulin to the receptor. A researcher created a group of osteoblasts with an *Esp* mutation that prevented the production of a functional *Esp* product (mutant). The researcher then exposed the mutant strain and a normal strain that expresses *Esp* to glucose and compared the levels of insulin in the blood near the osteoblasts (Figure 2).

25. Based on the information provided, which of the following best justifies the claim that osteocalcin is a hormone?
- (A) The phosphorylation of the insulin receptor causes a response in osteoblast bone cells.
 - (B) The osteoblasts in the bone secrete osteocalcin, which causes cells in the pancreas to change their activity.
 - (C) The change in expression of *Esp* changes the insulin receptor activity of the osteoblast.
 - (D) The activation of the osteocalcin by a bone cell is pH dependent.
26. Which of the following best describes the effect of insulin binding to the receptor on the osteoblast cells?
- (A) Insulin binding ultimately increases pancreatic secretion of additional insulin.
 - (B) Insulin binding blocks the release of osteocalcin from the osteoblasts.
 - (C) Insulin binding inhibits the expression of *Esp*.
 - (D) Insulin binding increases the pH of the extracellular matrix.
27. Which of the following claims is most consistent with the data shown in Figure 2 ?
- (A) *Esp* expression is necessary to prevent the overproduction of insulin.
 - (B) *Esp* protein does not regulate blood-sugar levels in normal mice.
 - (C) Normal mice require a higher blood concentration of insulin than mutant mice do.
 - (D) Mutant mice have a cyclical pattern of insulin secretion.
28. Which of the following was a positive control in the experiment?
- (A) Minutes after glucose injection
 - (B) Blood insulin
 - (C) Mutant strain
 - (D) Normal strain
29. A researcher observes that mice from the mutant strain experience low blood sugar. Which of the following best describes the feedback mechanism in the pathway (Figure 1) causing the low blood sugar in the mutant strain?
- (A) The positive feedback of insulin production
 - (B) The negative feedback of inactive osteocalcin production
 - (C) The positive feedback of the *Esp* protein
 - (D) The negative feedback of insulin-secreting pancreatic cell proliferation
-

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30. A researcher hypothesizes that, in mice, two autosomal dominant traits, trait Q and trait R, are determined by separate genes found on the same chromosome. The researcher crosses mice that are heterozygous for both traits and counts the number of offspring with each combination of phenotypes. The total number of offspring produced was 64. The researcher plans to do a chi-square analysis of the data and calculates the expected number of mice with each combination of phenotypes. Which of the following is the expected number of offspring that will display both trait Q and trait R?
- (A) 4
(B) 12
(C) 36
(D) 48
31. Researchers studying new viruses analyzed the genetic material found in four different virus samples to determine the percent nitrogen base composition of each virus. The data are shown in the table.

BASE DISTRIBUTION IN FOUR NUCLEIC ACID SAMPLES

Nitrogen Base	Percent in Sample 1	Percent in Sample 2	Percent in Sample 3	Percent in Sample 4
Adenine	27	33	21	22
Cytosine	23	17	33	28
Guanine	23	17	27	28
Thymine	0	33	0	22
Uracil	27	0	19	0

Which of the following samples most likely contains a double-stranded RNA virus?

- (A) Sample 1
(B) Sample 2
(C) Sample 3
(D) Sample 4

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32. Goats and sheep belong to the same family but different genera. While they often live together in the same pastures, the hybrid offspring that are occasionally produced between the two species rarely survive. When such a hybrid does survive, it is usually sterile.

Which of the following best explains the mechanism that maintains reproductive isolation between goats and sheep?

- (A) Gene flow is prevented because the two species belong to different trophic levels and therefore do not share a food source.
- (B) Habitat isolation creates a prezygotic barrier between the two species.
- (C) The males of one species and the females of the other species are fertile at different times.
- (D) The two species have a different number of chromosomes, resulting in a postzygotic barrier.

33. Ethylene gas is an organic molecule that serves many cell signaling roles in flowering plants. Which of the following best explains how a positive feedback mechanism involving ethylene works?

- (A) Cells of ripening fruit produce ethylene, which activates the ripening response in other fruit cells.
- (B) Low water stress causes cells to produce ethylene, which binds to root cells and initiates cell division.
- (C) Cells damaged by leaf-eating insects produce ethylene, which is released into the air, and repels insects.
- (D) Fertilized ovules produce ethylene, which initiates apoptosis in flower petal cells.

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Questions 34 - 38

A student is investigating photosynthesis in plants. The student planted grass seeds in a tray with three sections and grew the grass under artificial lights for 14 days (Figure 1). After 14 days, the student collected all of the grass from section I and recorded its mass (Table 1). The student then placed a clear cover over section II and placed an aluminum foil cover over section III (Figure 2). The student then placed the tray back under the artificial lights for seven additional days. On day 21, the student collected and measured the mass of the grass from sections II and III (Table 1).

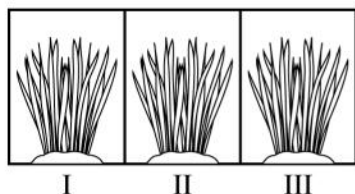


Figure 1. A tray of grass seed, grown under light for 14 days

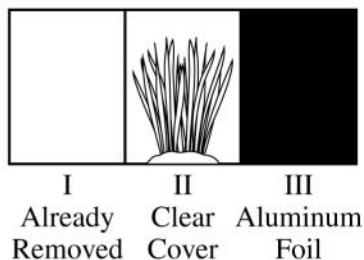


Figure 2. Modifications made to sections II and III on day 14

TABLE 1. MASS OF GRASS GROWN IN EACH SECTION

Section	Day Mass was Measured	Mass (g)
I	14	5.1
II	21	9.6
III	21	4.2

34. Based on the data, which of the following is the best approximation of the rate of growth per week in section II from day 14 to day 21 ?
- (A) 3.2 g/week
 - (B) 4.5 g/week
 - (C) 5.1 g/week
 - (D) 9.6 g/week

GO ON TO THE NEXT PAGE.

35. Which of the following best explains the observed difference in mass between the grass in section I after 14 days and the grass in section III after 21 days?
- (A) The grass in section III required more energy for metabolic processes than the grass in section I.
 - (B) The grass in section III performed more photosynthesis than the grass in section I.
 - (C) Only the grass in section III used energy from the seed for growth and development.
 - (D) Mass lost by cell respiration in section III was not replaced by photosynthesis.
36. Which of the following best explains the connection between energy, growth, and the maintenance of an ordered system in the experiment?
- (A) Energy input from light is required for the grass to grow and maintain an ordered structure.
 - (B) The grass obtains the energy for growth and maintenance of order from nutrients from the soil.
 - (C) The grass couples the release of energy from the light reactions with the production of oxygen (O_2) used to produce sugars for growth.
 - (D) Energy is required for the growth of the grass but not the maintenance of order.
37. Based on the data, which of the following is the most likely effect of a period of increased volcanic activity that significantly decreases the amount of sunlight reaching a particular ecosystem for several years?
- (A) There will be a decrease in the population sizes of most species and a decrease in the number of trophic levels.
 - (B) The population sizes of plant species will stay the same, but the average biomass of individual plants will increase.
 - (C) There will be an increase in the population sizes of omnivores because they can eat other animals instead of the plants.
 - (D) The biodiversity of the ecosystem will increase as new niches arise and become occupied by new species.
38. Which of the following is an appropriate null hypothesis for the student's experiment?
- (A) The absence of light negatively affects the mass of the grass.
 - (B) An increase in light promotes grass growth.
 - (C) A change in light intensity changes the rate of grass growth.
 - (D) The presence of light has no effect on the mass of the grass.

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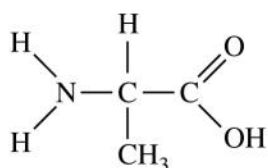


Figure 1. An amino acid

39. The amino acid in Figure 1 is found in a region of a polypeptide that folds away from water. Which part of the amino acid most likely contributes to the hydrophobic behavior of this region of the polypeptide?
- (A) Amine (NH_2) group
 - (B) Carboxyl (COOH) group
 - (C) Methyl (CH_3) group
 - (D) Hydrogen (H) atom
40. A researcher observes that when two heterozygous plants with red flowers are crossed, the resulting offspring include plants with red, white, or pink flowers. The researcher proposes the null hypothesis that flower color is the result of independent assortment and incomplete dominance. The researcher calculates a chi-square value of 7.3. Assuming two degrees of freedom, which of the following is the correct interpretation of the chi-square analysis, using a p-value of 0.05 ?
- (A) The null hypothesis should be rejected because the critical value is less than the calculated value.
 - (B) The null hypothesis should not be rejected because the critical value is less than the calculated value.
 - (C) The null hypothesis should not be rejected because the critical value is greater than the calculated value.
 - (D) The null hypothesis should be rejected because the critical value is greater than the calculated value.
41. A researcher is investigating the effects of a chemical that makes thylakoid membranes permeable to hydrogen ions (H^+). Which of the following is the most likely direct effect of adding the chemical to plant cells?
- (A) The plant cells will produce less NADPH.
 - (B) The chloroplasts will generate less ATP.
 - (C) Chlorophyll will require less light energy to excite its electrons.
 - (D) The plant cells will split fewer water molecules into hydrogen ions and oxygen.

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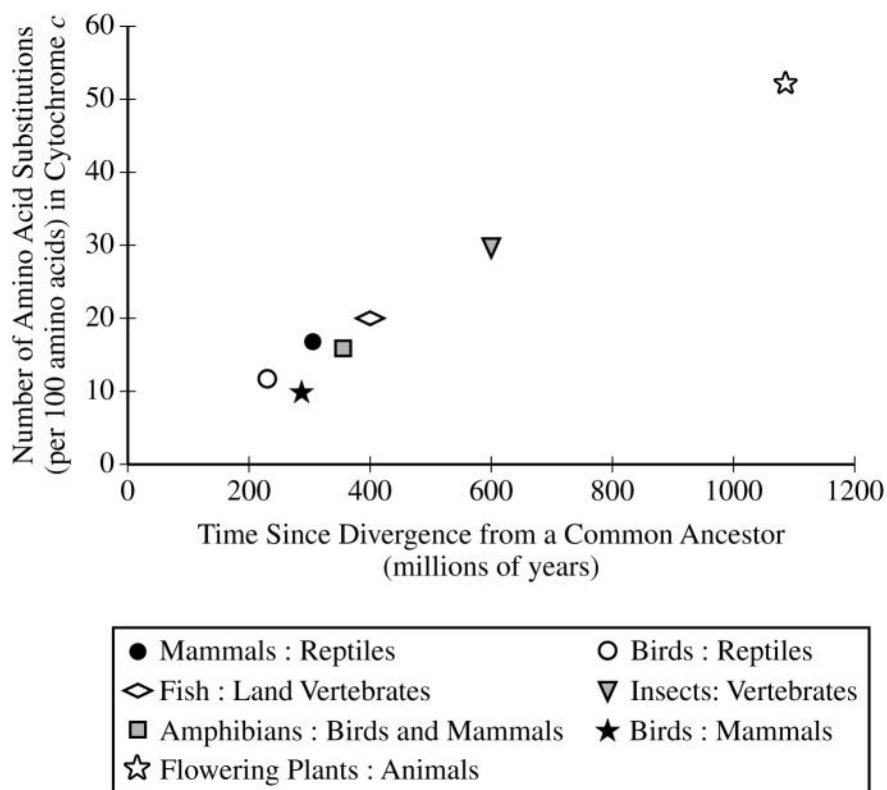


Figure 1. For paired groups of organisms, a comparison of the number of amino acid substitutions in cytochrome *c* with the time since the groups diverged from a common ancestor

42. Researchers analyzed the amino sequence of the protein cytochrome *c* in various groups of organisms and determined the number of amino substitutions that have occurred in the different groups of organisms. They plotted the data with respect to the time since divergence of the members of paired groups from a common ancestor (Figure 1). Based on the data, which of the following organisms are most distantly related?
- (A) Birds and mammals
 - (B) Mammals and reptiles
 - (C) Fish and land vertebrates
 - (D) Insects and vertebrates

GO ON TO THE NEXT PAGE.

43. Which of the following best explains how continuity of genetic information in cells is ensured across generations?
- (A) Replication uses a parental strand of DNA as a template to create a new strand of DNA.
 - (B) DNA molecules are shaped like a double helix with a constant diameter throughout.
 - (C) Transcription copies the information in DNA into an RNA transcript.
 - (D) Cells contain different polymerases for DNA replication and transcription.

44. In the spring and summer, the fur of an arctic fox contains a pigment called melanin that gives the fox's fur a dark color. In the fall and winter, the fur of the arctic fox is white.

Which of the following most likely explains how the changing seasons result in changing fur color in an arctic fox?

- (A) Environmental factors cause changes in gene expression, resulting in seasonal variations in pigment production.
- (B) Environmental factors cause different mutations in DNA during different seasons, resulting in seasonal changes in fur phenotype.
- (C) Environmental factors cause proteins to be translated using different genetic codes during different seasons, resulting in variations in pigment production.
- (D) Environmental factors cause enzymes to react with different substrates, resulting in the accumulation of different pigments.

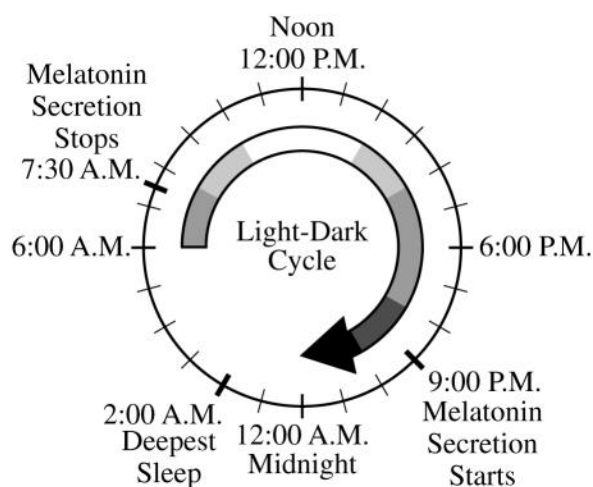


Figure 1. Key physiological points in the human sleep-wake cycle

45. The human sleep-wake cycle is regulated by melatonin. The synthesis of melatonin is regulated by light exposure (Figure 1). The human body typically develops a sleep-wake rhythm that does not respond quickly to change.

Long-term exposure to extended periods of bright light after sunset is most likely to affect a person in which of the following ways?

- (A) Melatonin synthesis will be increased, and the entire sleep-wake cycle will be shifted by several hours.
- (B) Melatonin synthesis will be increased, and the person will quickly fall asleep.
- (C) Melatonin synthesis will be inhibited, and the person will have difficulty sleeping.
- (D) Melatonin synthesis will be inhibited, and the person will quickly fall asleep.

GO ON TO THE NEXT PAGE.

46. A typical bag of fertilizer contains high levels of nitrogen, phosphorus, and potassium but trace amounts of magnesium and calcium. Which of the following best matches the fertilizer component with the molecule in which it will be incorporated by organisms in the area?

- (A) Nitrogen will be incorporated into nucleic acids.
- (B) Phosphorus will be incorporated into amino acids.
- (C) Potassium will be incorporated into lipids.
- (D) Magnesium will be incorporated into carbohydrates.

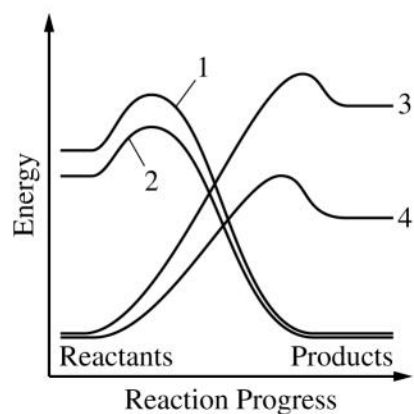


Figure 1. Change in energy over the course of four chemical reactions

47. Based on the data in Figure 1, which of the following most likely represents the change in energy that occurs when ATP hydrolysis is coupled with the phosphorylation of a substrate?

- (A) Line 4 represents ATP hydrolysis, and line 1 represents phosphorylation of a substrate.
- (B) Line 1 represents ATP hydrolysis, and line 4 represents phosphorylation of a substrate.
- (C) Line 2 represents ATP hydrolysis, and line 3 represents phosphorylation of a substrate.
- (D) Line 3 represents ATP hydrolysis, and line 2 represents phosphorylation of a substrate.

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Questions 48 - 52

The brown anole (*Anolis sagrei*) is a species of lizard native to Cuba that has been introduced into the southeastern United States. The range of brown anoles in the United States has been expanding, and they are now competing with native green anoles (*Anolis carolinensis*). Some of the characteristics of the green and brown anoles are shown in Table 1.

TABLE 1. CHARACTERISTICS OF TWO ANOLE SPECIES

Anole Species	Body Length	Limb Length Relative to Body Length	Toe Pad Size Relative to Body Length	Cold Tolerance
<i>A. sagrei</i> (brown anole)	55 – 80 mm	Long	Intermediate	30 – 35°C
<i>A. carolinensis</i> (green anole)	45 – 85 mm	Short	Very large	25 – 30°C

A cladogram showing the relationships between some anole species is shown in Figure 1.

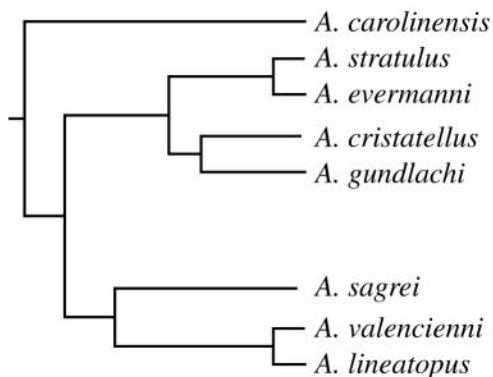


Figure 1. Cladogram of some anole species

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48. Based on the data in Table 1, which of the following best explains the observed differences in cold tolerance between brown anoles (*A. sagrei*) and green anoles (*A. carolinensis*) in the United States?
- (A) Brown anoles developed a tolerance for cold temperatures and passed on this acquired tolerance.
 - (B) Brown and green anoles produced a hybrid species that has greater tolerance to cold temperatures.
 - (C) Green anoles with greater tolerance for cold had greater reproductive success in areas with colder temperatures.
 - (D) New mutations occurred in brown anoles in response to exposure to colder temperatures.
49. In anoles, small toe pads are better for gripping irregular surfaces such as the forest floor, and large toe pads are better for gripping smooth surfaces such as leaves. Based on the data in Table 1, if brown anoles are introduced into a forest where green anoles currently live, which of the following predictions about the two species is most likely?
- (A) Brown anoles will occupy a different area of the forest from green anoles which will minimize competition.
 - (B) Brown anoles will mostly prey on flying insects, and green anoles will prey on worms and grubs.
 - (C) Brown anoles and green anoles will evolve to have the same size toe pads because they share the same niche.
 - (D) Green anoles are better adapted to the forest habitat and will chase away the introduced brown anoles.
50. Which of the following is the outgroup in the cladogram shown in Figure 1 ?
- (A) *A. evermanni*
 - (B) *A. stratulus*
 - (C) *A. gundlachi*
 - (D) *A. carolinensis*
51. Based on Figure 1, which of the following would provide the strongest evidence to support a claim that *A. valencienni* and *A. lineatopus* are the two anole species most closely related to *A. sagrei* ?
- (A) Comparing body structures, such as toe pads and limb length
 - (B) Analyzing homologous DNA sequences among the species
 - (C) Determining which species occupy a similar niche in Cuba
 - (D) Observing which species have mating behaviors most similar to those of *A. sagrei*
52. Based on the cladogram in Figure 1, which of the following conclusions about the evolution of the anole species is most reasonable?
- (A) Each species evolved in a different location, and all underwent convergent evolution.
 - (B) Each species evolved as a result of different selective pressures.
 - (C) Each species evolved as a result of a genetic bottleneck.
 - (D) Each species evolved by inheriting random mutations from the common ancestor.

GO ON TO THE NEXT PAGE.

53. Beta thalassemia is a disorder caused by mutations in the *HBB* gene. Examination of the *HBB* protein in an individual with beta thalassemia shows that the protein is missing many amino acids at its carboxyl terminus.

Which of the following is the most likely explanation for how a mutation in the DNA could result in the loss of the carboxyl terminus of the *HBB* protein?

- (A) The mutation keeps the *HBB* gene wrapped tightly around histones, preventing transcription of the gene.
- (B) The mutation changes the promoter sequence of the gene such that different transcription factors initiate transcription of the gene.
- (C) The mutation changes a codon in the coding region of the *HBB* transcript to a stop codon such that translation terminates earlier than it should.
- (D) The mutation results in hydrogen bonds between adjacent amino acids instead of covalent bonds, resulting in the production of an unstable protein.

54. A common test for liver function involves sprinkling sulfur powder onto a sample of urine (mostly water with dissolved bodily waste). Sulfur powder sprinkled on a sample from an individual with impaired liver function will sink because the urine contains a high level of bile salts, while the sulfur powder sprinkled on normal urine samples will float.

Which of the following best explains why bile salts cause the sulfur powder to sink?

- (A) Bile salts decrease the surface tension of the urine sample.
- (B) Bile salts increase the water potential of the urine.
- (C) Bile salts increase the density of the urine sample.
- (D) Bile salts decrease the strength of the covalent bonds within a water molecule.

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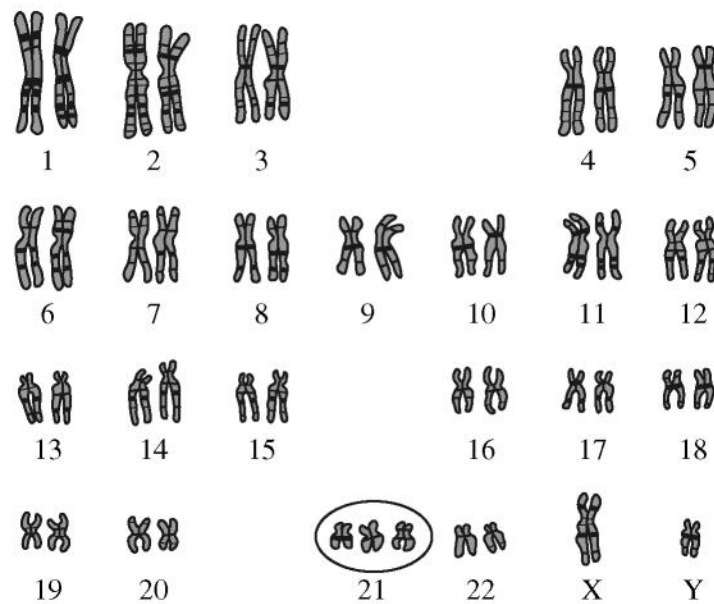


Figure 1. A karyotype obtained from a sample of human cells

55. A karyotype is a representation of all the metaphase chromosomes in a sample of cells from a particular individual (Figure 1).

Which of the following most likely explains how the chromosomes circled in Figure 1 could cause a genetic disorder in the person from whom the cells were obtained?

- (A) The extra chromosome causes crowding in the nucleus of the cells and blocks RNA polymerase from binding to and transcribing certain genes.
- (B) The extra chromosome will affect the levels of RNA transcribed from certain genes and the amount of protein produced from those genes in each cell.
- (C) The cells will not divide and enable growth, because the extra chromosome will interfere with the pairing of homologous chromosomes.
- (D) The extra chromosome will cause other chromosomes in the cell to become triploid during future rounds of cell division.

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56. Which of the following is the strongest evidence supporting the endosymbiont hypothesis?

- (A) Mitochondria have their own DNA and divide independently of the cell.
- (B) Mitochondria can carry out hydrolytic reactions on organic molecules.
- (C) Mitochondria have a highly folded membrane.
- (D) Mitochondria are found in both plants and animals.

57. Which of the following best explains how the expression of a eukaryotic gene encoding a protein will differ if the gene is expressed in a prokaryotic cell instead of in a eukaryotic cell?

- (A) No transcript will be made, because eukaryotic DNA cannot be transcribed by prokaryotic RNA polymerase.
- (B) The protein will have a different sequence of amino acids, because prokaryotes use a different genetic code.
- (C) The protein will be made but will not function, because prokaryotes cannot remove introns.
- (D) The protein will not be made, because prokaryotes lack the ribosomes necessary for translation.

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58. Low concentrations of cadmium in the water negatively affect steelhead trout. In a river community, steelhead trout are part of the trophic structure shown in Figure 1.

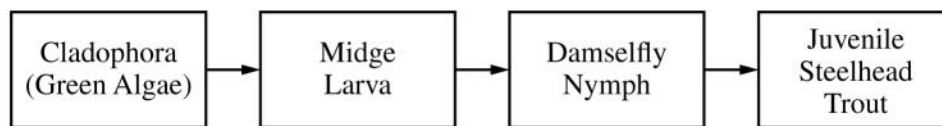


Figure 1. The trophic structure of a river community

Which of the following is the most likely immediate effect of an increase in runoff containing cadmium on the trophic structure of the river community?

- (A) The population of Cladophora will decrease, resulting in an increase in the trout population.
 - (B) There will be a large decrease in the trout population, resulting in an increase in damselfly nymphs.
 - (C) Increased stream volume will provide more area for the trout to reproduce, causing a large increase in the population of algae.
 - (D) The population of trout will decrease because the population of damselfly nymphs will decline.
59. Poaching is the illegal hunting or capturing of wild animals. Both male and female African elephants have tusks that are a significant source of ivory used for ornaments and jewelry.

Assuming that the size of the tusks is heritable, which of the following is the most likely long-term effect of poachers targeting African elephants with large tusks?

- (A) An increase in average tusk size because of the need to provide more ivory for the poaching hunters
- (B) A decrease in average tusk size because elephants with large tusks are less likely to survive to reproduce
- (C) An increase in average tusk size to provide the elephants with a defensive mechanism against poachers
- (D) A decrease in average tusk size to reduce the energy investment in the tusks

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60. A scientist adds a chemical to a culture of dividing cells in order to disrupt DNA replication. The replicated DNA produced by the cells is double-stranded, but sections of it lack covalent bonds between adjacent nucleotides (Figure 1).

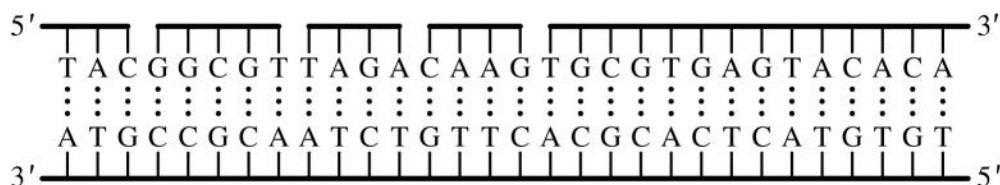


Figure 1. Replicated DNA produced after a chemical is introduced

Which of the following claims is best supported by the data?

- (A) The chemical prevents the formation of RNA primers.
- (B) The chemical inhibits DNA ligase.
- (C) The chemical blocks DNA polymerase.
- (D) The chemical disrupts hydrogen bonding.

GO ON TO THE NEXT PAGE.

END OF SECTION I

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

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

MAKE SURE YOU HAVE DONE THE FOLLOWING:

- **PLACED YOUR AP ID LABEL ON YOUR ANSWER SHEET**
- **WRITTEN AND GRIDDED YOUR AP ID CORRECTLY ON YOUR ANSWER SHEET**
- **TAKEN THE AP EXAM LABEL FROM THE FRONT OF THIS BOOKLET AND PLACED IT ON YOUR ANSWER SHEET**

AP[®] Biology Exam

SECTION II: Free Response

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

At a Glance

Total Time

1 hour and 30 minutes

Number of Questions

6

Percent of Total Score

50%

Writing Instrument

Pen with black or dark blue ink

Electronic Device

Calculator allowed

Suggested Time

Approximately
25 minutes per long question, and 10 minutes per short question.

Weight

Approximate weights:
Questions 1 and 2:
26% each
Questions 3 — 6:
12% each

Instructions

The questions for Section II are printed in this booklet. You may use the unlined pages to organize your answers and for scratch work, but you must write your answers on the labeled pages provided for each question.

Each answer should be written in paragraph form; an outline or bulleted list alone is not acceptable. Do not spend time restating the questions or providing more than the number of examples called for. For instance, if a question calls for two examples, you can earn credit only for the first two examples that you provide. Labeled diagrams may be used to supplement discussion, but unless specifically called for by the question, a diagram alone will not receive credit. Write clearly and legibly. Begin each answer on a new page. Do not skip lines. Cross out any errors you make; crossed-out work will not be scored.

Manage your time carefully. You may proceed freely from one question to the next. You may review your responses if you finish before the end of the exam is announced.

AP® BIOLOGY EQUATIONS AND FORMULAS

Statistical Analysis and Probability

Mean

$$\bar{x} = \frac{1}{n} \sum_{i=1}^n x_i$$

Standard Deviation

$$s = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n - 1}}$$

Standard Error of the Mean

$$SE_{\bar{x}} = \frac{s}{\sqrt{n}}$$

Chi-Square

$$\chi^2 = \sum \frac{(o - e)^2}{e}$$

Chi-Square Table

p value	Degrees of Freedom							
	1	2	3	4	5	6	7	8
0.05	3.84	5.99	7.81	9.49	11.07	12.59	14.07	15.51
0.01	6.63	9.21	11.34	13.28	15.09	16.81	18.48	20.09

Laws of Probability

If A and B are mutually exclusive, then:

$$P(A \text{ or } B) = P(A) + P(B)$$

If A and B are independent, then:

$$P(A \text{ and } B) = P(A) \times P(B)$$

Hardy-Weinberg Equations

$$p^2 + 2pq + q^2 = 1 \quad p = \text{frequency of allele 1 in a population}$$

$$p + q = 1 \quad q = \text{frequency of allele 2 in a population}$$

$\bar{x}$ = sample mean

n = sample size

s = sample standard deviation (i.e., the sample-based estimate of the standard deviation of the population)

o = observed results

e = expected results

Σ = sum of all

Degrees of freedom are equal to the number of distinct possible outcomes minus one.

Metric Prefixes

Factor	Prefix	Symbol
10^9	giga	G
10^6	mega	M
10^3	kilo	k
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p

Mode = value that occurs most frequently in a data set

Median = middle value that separates the greater and lesser halves of a data set

Mean = sum of all data points divided by number of data points

Range = value obtained by subtracting the smallest observation (sample minimum) from the greatest (sample maximum)

Rate and Growth <u>Rate</u> $\frac{dY}{dt}$ dY = amount of change dt = change in time B = birth rate D = death rate N = population size K = carrying capacity $r_{\max}$ = maximum per capita growth rate of population <u>Population Growth</u> $\frac{dN}{dt} = B - D$ <u>Exponential Growth</u> $\frac{dN}{dt} = r_{\max}N$ <u>Logistic Growth</u> $\frac{dN}{dt} = r_{\max}N\left(\frac{K - N}{K}\right)$		<u>Water Potential (Ψ)</u> $\Psi = \Psi_p + \Psi_s$ Ψ_p = pressure potential Ψ_s = solute potential The water potential will be equal to the solute potential of a solution in an open container because the pressure potential of the solution in an open container is zero. <u>The Solute Potential of a Solution</u> $\Psi_s = -iCRT$ i = ionization constant (1.0 for sucrose because sucrose does not ionize in water) C = molar concentration R = pressure constant (R = 0.0831 liter bars/mole K) T = temperature in Kelvin ($^{\circ}\text{C} + 273$)
<u>Simpson's Diversity Index</u> Diversity Index = $1 - \sum\left(\frac{n}{N}\right)^2$ n = total number of organisms of a particular species N = total number of organisms of all species		<u>pH</u> = $-\log[\text{H}^+]$
Surface Area and Volume		
<u>Surface Area of a Sphere</u> $SA = 4\pi r^2$	<u>Volume of a Sphere</u> $V = \frac{4}{3}\pi r^3$	r = radius
<u>Surface Area of a Rectangular Solid</u> $SA = 2lh + 2lw + 2wh$	<u>Volume of a Rectangular Solid</u> $V = lwh$	l = length h = height w = width
<u>Surface Area of a Cylinder</u> $SA = 2\pi rh + 2\pi r^2$	<u>Volume of a Cylinder</u> $V = \pi r^2 h$	s = length of one side of a cube
<u>Surface Area of a Cube</u> $SA = 6s^2$	<u>Volume of a Cube</u> $V = s^3$	SA = surface area V = volume

BIOLOGY
SECTION II

Time—1 hour and 30 minutes

6 Questions

Directions: Questions 1 and 2 are long free-response questions that require about 25 minutes each to answer. Questions 3 through 6 are short free-response questions that require about 10 minutes each to answer.

Read each question carefully and completely. Write your response in the space provided for each question. Only material written in the space provided will be scored. Answers must be written out in paragraph form. Outlines, bulleted lists, or diagrams alone are not acceptable.

Question 1 is on the following page.

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1. Electrons from the oxidation of glucose and other nutrients by glycolysis and the Krebs cycle are added to the electron-carrying compound NAD^+ to form NADH . To meet the continuous requirement for NAD^+ by cells, NADH is reduced back to NAD^+ through the electron transport chain, in the presence (+) of oxygen, or through fermentation, in the absence (–) of oxygen (Figure 1).

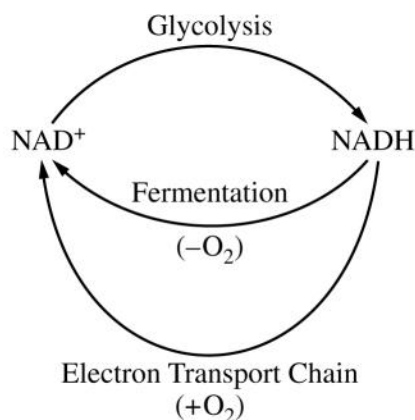


Figure 1. A simplified model of metabolism and the recycling of NAD^+

MT-ND5 is a mitochondrial gene that encodes a subunit of NADH dehydrogenase, the enzyme that catalyzes the initial oxidation of its substrate NADH to NAD^+ and H^+ in the electron transport chain of mitochondria. A mutation in *MT-ND5* is associated with a rare genetic disorder that results in a buildup of lactic acid in the body. A researcher hypothesizes that the mutated NADH dehydrogenase has decreased activity but is not completely nonfunctioning and that, by increasing the pool of NADH in cells, the activity of NADH dehydrogenase will increase.

To test this idea, the researcher treated a group of individuals with this disorder with a vitamin that is similar to NADH and measured the concentration of NAD^+ and lactic acid in the blood over the course of 20 weeks. The results from a representative individual are shown in Figure 2.

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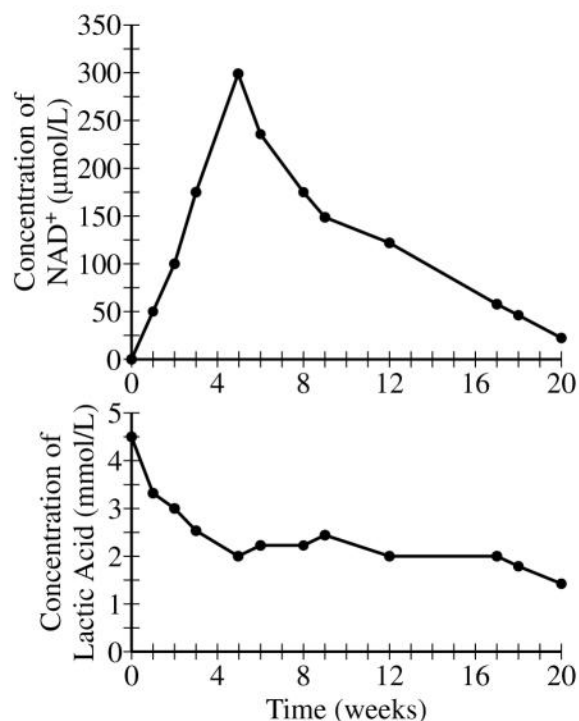


Figure 2. The concentration of NAD⁺ (top) and lactic acid (bottom) in the blood of a representative treated individual

- (a) **Describe** the pattern of inheritance that is most likely associated with a mutation in the *MT-ND5* gene. **Explain** why individuals are not typically heterozygous with respect to mitochondrial genes.
- (b) **Identify** a dependent variable measured in the researcher's experiment. **Identify** one control that the researcher could use to improve the validity of the experiment. **Justify** the researcher analyzing blood samples at many intermediate time points instead of at only the beginning and the end of the 20-week period.
- (c) **Describe** the relationship between the concentration of NAD⁺ in the blood and the concentration of lactic acid in the blood during the first 5 weeks of treatment with the vitamin. Based on Figure 2, **calculate** the average rate of change in blood NAD⁺ concentrations from week 5 to week 17.
- (d) The researcher performed a follow-up experiment to measure the rate of oxygen consumption by muscle and brain cells. **Predict** the effect of the *MT-ND5* mutation on the rate of oxygen consumption in muscle and brain cells. **Justify** your prediction. The researcher had hypothesized that the addition of the vitamin that is similar in structure to NADH would increase the activity of the mutated NADH dehydrogenase enzyme in individuals with the disorder. **Explain** how the vitamin most likely increased the activity of the enzyme.

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WRITE ALL YOUR RESPONSES ON THE LINED PAGES.

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2. Atherosclerosis is a disease that results when certain cells and proteins of an individual's body adhere to and damage blood vessels, especially those around the heart. Researchers continue to look for improved ways to treat individuals with the disease. Data obtained from earlier experiments suggested that it might be possible to reduce damage to the blood vessels by increasing the expression of FXR1, an RNA-binding protein in the muscle cells that form the outer surface of the blood vessels. Additional data suggested that IL-19, a protein secreted by certain white blood cells, might regulate expression of the *FXR1* gene.

To investigate the regulation of the *FXR1* gene by IL-19, a researcher added IL-19 to vessel-lining muscle cells growing in the lab. The researcher measured the amount of FXR1 protein produced by the cells over a period of 48 hours in the presence of IL-19. The researcher then calculated the relative amount of FXR1 present at each time point compared with the amount of FXR1 at Time 0, when IL-19 was first added to the cells. Data from three replicate experiments are shown in Table 1.

TABLE 1. RELATIVE AMOUNT OF FXR1 PRODUCED BY CELLS
IN RESPONSE TO IL-19

Time in the Presence of IL-19 (h)	Relative Amount of FXR1 Protein $\pm 2SE_{\bar{x}}$
0	0.98 ± 0.070
4	1.70 ± 0.220
8	1.60 ± 0.275
16	3.10 ± 0.800
24	2.15 ± 0.405
48	1.60 ± 0.520

- (a) **Describe** how amino acids are categorized by their chemical properties. **Explain** how a change in the amino acid sequence of the FXR1 protein could decrease the ability of the protein to bind to RNA.
- (b) Using the template in the space provided for your response, **construct** an appropriately labeled graph that represents the data shown in Table 1. **Determine** whether there is a statistical difference in the amount of FXR1 protein produced by the cells after 16 and 24 hours in the presence of IL-19.

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- (c) Based on the data for the 48-hour period, **describe** the effect of IL-19 on *FXR1* gene expression.
- (d) The researcher hypothesizes that the *FXR1* gene codes for a protein that binds to mRNAs that encode some of the proteins that damage arteries. Individuals with a particular mutation of the *FXR1* gene tend to have high levels of these proteins. Based on this information, **predict** how the FXR1 protein most likely interacts with the mRNAs.

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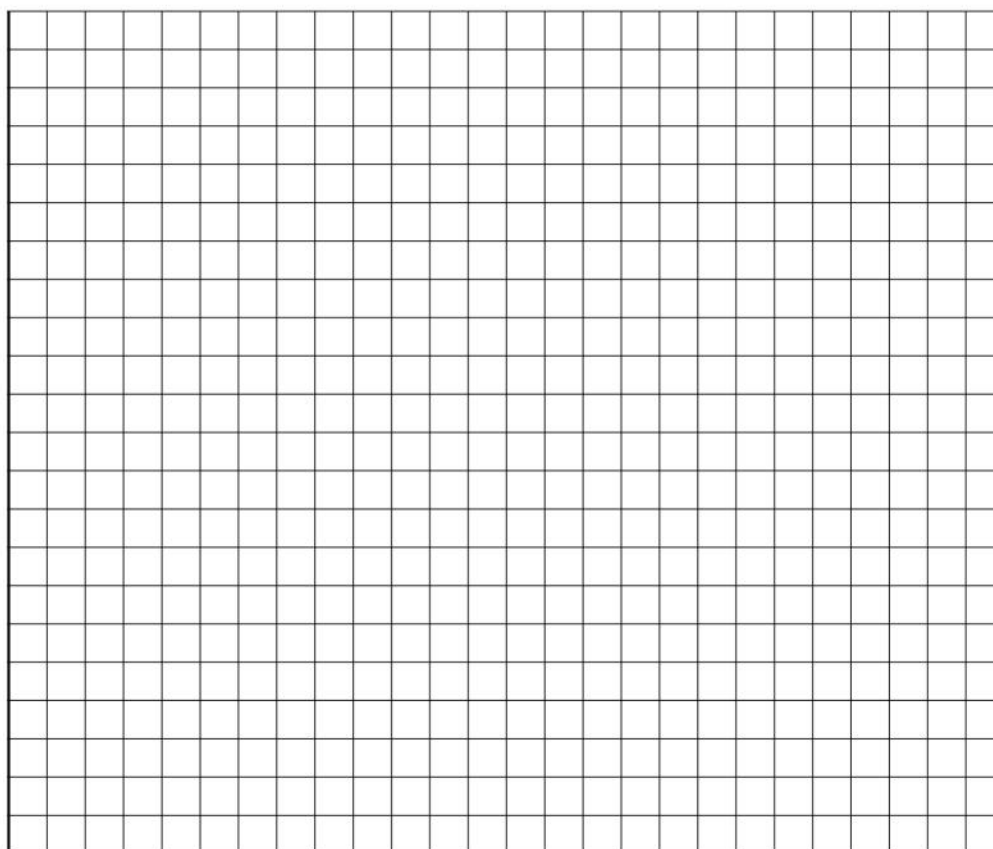
WRITE ALL YOUR RESPONSES ON THE LINED PAGES.

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(data table reprinted for reference)

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3. Researchers grew populations of identical *Escherichia coli* (*E. coli*) bacteria in a growth medium that contained a low concentration of glucose and a high concentration of citrate, a substance that is not typically consumed by *E. coli*. For thousands of generations, the bacteria used only glucose as an energy source and grew relatively slowly and to a low density because of the low concentration of glucose. After about 30,000 generations, one population emerged that began to rapidly grow to a much higher density. The researchers hypothesized that the bacteria evolved the ability to use citrate as an energy source and referred to them as Cit^+ . To test the hypothesis, the researchers grew separate populations of the Cit^+ bacteria and bacteria from the original population (Cit^-) in a growth medium that contained only citrate.

- Describe** one outcome that would demonstrate that a given population has evolved.
- Identify** the dependent variable measured in the experiments.
- Predict** the results obtained by the researchers when they grew the Cit^+ and Cit^- bacteria in the medium that contained only citrate.
- The researchers claim that the Cit^+ mutation increases the fitness of the bacteria. **Provide reasoning** to support the claim.

PAGE FOR ANSWERING QUESTION 3

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4. The Tasmanian devil (*Sarcophilus harrisii*) is a species of mammal whose only wild population is native to the isolated island of Tasmania, off the coast of Australia. Tasmanian devils have a very low level of genetic diversity across the entire species. Researchers hypothesize this lack of diversity is the result of several genetic bottlenecks in the species' history.

In 1996 a new disease called devil facial tumor disease (DFTD) appeared in the wild Tasmanian devil population. DFTD can spread from one animal to another and causes the death of most affected animals. The impact of DFTD on the Tasmanian devil population has resulted in a decrease in the total population of more than 85% over the last two decades.

- (a) **Describe** the process that maintained a stable Tasmanian devil population size before the appearance of DFTD in 1996.
- (b) **Explain** how the huge reduction of the Tasmanian devil population since 1996 affects the susceptibility of the current population to new diseases in comparison with the susceptibility of the population before 1996.
- (c) Tasmanian devils are top predators and are considered a keystone species in their community. **Predict** the effect of the rapid reduction of the Tasmanian devil population on the rest of the community.
- (d) **Justify** the prediction of part (c).

PAGE FOR ANSWERING QUESTION 4

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This image shows a single sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

5. The p53 protein is a transcription factor that regulates a cell's progression through the cell cycle after DNA is damaged by ultraviolet (UV) radiation. The p53 pathway is shown in Figure 1.

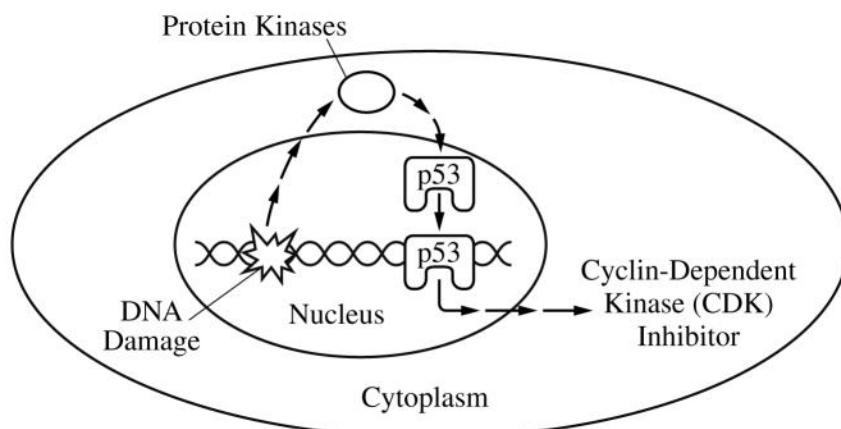
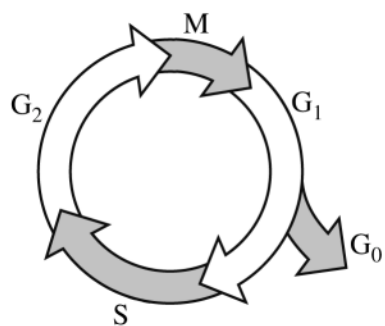


Figure 1. The role of p53 in regulating cell cycle progression in response to DNA damage

- (a) A skin cell completes one round of the cell cycle. **Describe** the products.
- (b) Based on Figure 1, **explain** how p53 regulates the cell cycle in the presence of damaged DNA.
- (c) **Draw** an X on the template in the space provided for your response to indicate the phase during which the replication of damaged DNA would occur.
- (d) Based on Figure 1, **explain** how a mutation to p53 may lead to an increased risk of cancer.

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6. The human kidney filters the blood to retain useful substances and remove waste products and excess water as urine. *SLC3A1* and *SLC7A9* are two different genes that each encode one part of a transporter protein complex typically found in the plasma membrane of human kidney cells. This transporter complex moves certain amino acids across the plasma membrane of the cells. Mutations in both the *SLC3A1* and *SLC7A9* genes are associated with increased levels of the polar amino acid cysteine in the urine, a condition called cystinuria. A researcher identified seven individuals with a family history of cystinuria. The researcher measured the concentration of cysteine in the urine of the seven individuals and sequenced their *SLC3A1* and *SLC7A9* genes to determine whether they carry functional (+) or mutant (–) alleles of genes. The results are shown in Table 1.

TABLE 1. CHARACTERISTICS OF SEVEN INDIVIDUALS WHO CARRY AT LEAST ONE MUTANT ALLELE

Individual	Concentration of Cysteine in Urine Relative to Normal Values	<i>SLC3A1</i> Alleles	<i>SLC7A9</i> Alleles
1	32.2	–/–	+/–
2	29.8	+/–	–/–
3	11.0	–/–	+/+
4	8.8	+/+	–/–
5	7.7	–/–	+/+
6	2.3	+/+	+/–
7	0.5	+/–	+/+

+ indicates the presence of a functional allele and – indicates the presence of a mutant allele.

- (a) **Identify** the individual who most likely exhibits symptoms of cystinuria.
- (b) **Describe** the relationship between the total number of mutant alleles in an individual and the concentration of cysteine in the urine.
- (c) **Evaluate** the hypothesis that mutations in *SLC7A9* have a greater effect on the transport of cysteine across the plasma membrane of kidney cells than do mutations in *SLC3A1*.
- (d) **Explain** how the data support the claim that cysteine is a large polar molecule.

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END OF EXAM

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

**THE FOLLOWING INSTRUCTIONS APPLY TO THE COVERS OF THE SECTION II BOOKLET.
MAKE SURE YOU HAVE DONE THE FOLLOWING:**

- **COMPLETED THE IDENTIFICATION INFORMATION AS REQUESTED ON THE FRONT AND BACK COVERS OF THE SECTION II BOOKLET**
- **CHECKED THAT YOUR AP ID LABEL IS IN THE BOX ON THE FRONT COVER**

Notes on the AP Biology Practice Exam

Multiple-Choice Section

Course Framework Alignment and Rationales

Question 1

Skill	Learning Objective	Topic
1.A: Describe biological concepts and/or processes.	SYI-1.B: Describe the properties of the monomers and the type of bonds that connect the monomers in biological macromolecules.	Introduction to Biological Macromolecules
(A)	Incorrect. The removal of water is not involved in breaking the bond between sugar monomers.	
(B)	Incorrect. Hydrolysis of carbohydrates does not result in the formation of bonds between sugar molecules. Additionally, it does not involve the removal of a water molecule.	
(C)	Correct. The hydrolysis of carbohydrates involves the addition of a water molecule, which breaks the covalent bond between monomers.	
(D)	Incorrect. Although hydrolysis does involve the addition of a water molecule, hydrolysis does not result in the formation of bonds between sugar molecules.	

Question 2

Skill	Learning Objective	Topic
1.A: Describe biological concepts and/or processes.	IST-1.L: Describe the characteristics of DNA that allow it to be used as the hereditary material.	DNA and RNA Structure
(A)	Incorrect. There are only four different types of nucleotide bases that can be incorporated and the number of types doesn't contribute to its usefulness as hereditary material.	
(B)	Incorrect. Although nucleotide bases could be metabolized to provide energy, this would not help maintain the sequence of bases making it useful as hereditary material.	
(C)	Incorrect. The random replacement of nucleotide bases in a DNA molecule would destroy the information contained in the sequence.	
(D)	Correct. The pairing of specific bases allows one strand to be used as a template for replicating the other strand, ensuring that DNA can be replicated with a relatively high accuracy.	

Question 3

Skill	Learning Objective	Topic
2.B: Explain relationships between different characteristics of biological concepts or processes represented visually- a. In theoretical contexts. b. In applied contexts.	SYI-3.C: Explain how chromosomal inheritance generates genetic variation in sexual reproduction.	Chromosomal Inheritance
(A)	Incorrect. Although autosomal dominance pattern of inheritance can explain individuals I-3 and I-4 producing an affected offspring, it cannot explain individuals I-1 and I-2 producing an affected offspring.	
(B)	Correct. Only an autosomal recessive pattern of inheritance can explain individuals I-1 and I-2, who are unaffected, producing an affected offspring. The autosomal recessive pattern is also consistent with the complete pedigree.	
(C)	Incorrect. If the trait was a sex-linked dominant trait, then either individual II-5 or II-6 would have to be affected.	
(D)	Incorrect. If the trait was a sex-linked recessive trait, then individual II-3 would have to be affected.	

Question 4

Skill	Learning Objective	Topic
1.A: Describe biological concepts and/or processes.	ENE-1.L: Explain how cells obtain energy from biological macromolecules in order to power cellular functions.	Cellular Respiration
(A)	Correct. Lactic acid is one of the end products of anaerobic metabolism of sucrose.	
(B)	Incorrect. The creation of a H^+ gradient to synthesize ATP is not associated with glycolysis or fermentation.	
(C)	Incorrect. While mitochondria do produce ATP in the presence of oxygen, bacteria do not have mitochondria.	
(D)	Incorrect. While CO_2 is produced in the Krebs cycle during aerobic respiration, CO_2 is not converted to lactic acid.	

Question 5

Skill	Learning Objective	Topic
3.C: Identify experimental procedures that are aligned to the question, including- a. Identifying dependent and independent variables. b. Identifying appropriate controls. c. Justifying appropriate controls.	ENE-1.L: Explain how cells obtain energy from biological macromolecules in order to power cellular functions.	Cellular Respiration
(A)	Incorrect. Time is an independent variable in this experiment because time is controlled.	
(B)	Correct. The pH is being measured in this experiment and is therefore the dependent variable.	
(C)	Incorrect. While pH decreases as glucose is metabolized, glucose concentration was not measured in this experiment and cannot be a dependent variable.	
(D)	Incorrect. While pH decreases as lactic acid is produced, lactic acid concentration was not measured in this experiment and cannot be a dependent variable.	

Question 6

Skill	Learning Objective	Topic
4.B: Describe data from a table or graph, including- a. Identifying specific data points. b. Describing trends and/or patterns in the data. c. Describing relationships between variables.	ENE-1.L: Explain how cells obtain energy from biological macromolecules in order to power cellular functions.	Cellular Respiration
(A)	Incorrect. While the pie chart does indicate two time periods used in the experiment, it provides no indication of pH.	
(B)	Correct. This graph shows the decreasing pH values and error bars over time for both the control and treatment cultures.	
(C)	Incorrect. While the stacked bar chart does indicate pH values consistent with the data from the treatment group, the control data are hard to interpret because only the difference between the treatment and control values are shown. Also, time is not shown.	
(D)	Incorrect. While the range of pH values for the control and treatment groups may be represented by this graph, it does not show the change in pH over time.	

Question 7

Skill	Learning Objective	Topic
4.B: Describe data from a table or graph, including- a. Identifying specific data points. b. Describing trends and/or patterns in the data. c. Describing relationships between variables.	ENE-1.L: Explain how cells obtain energy from biological macromolecules in order to power cellular functions.	Cellular Respiration
(A)	Incorrect. The pH values $\pm 2SE_{\bar{x}}$ of the control and treatment at 5 minutes overlap, so the values are statistically indistinguishable.	
(B)	Incorrect. The pH values $\pm 2SE_{\bar{x}}$ of the control and treatment at 15 minutes overlap, so the values are statistically indistinguishable.	
(C)	Incorrect. The pH values $\pm 2SE_{\bar{x}}$ of the control and treatment at 20 minutes overlap, so the values are statistically indistinguishable.	
(D)	Correct. The first time the pH values $\pm 2SE_{\bar{x}}$ of the control and treatment do not overlap is at 35 minutes.	

Question 8

Skill	Learning Objective	Topic
2.B: Explain relationships between different characteristics of biological concepts or processes represented visually- a. In theoretical contexts. b. In applied contexts.	ENE-1.L: Explain how cells obtain energy from biological macromolecules in order to power cellular functions.	Cellular Respiration
(A)	Correct. An increased bacterial metabolic rate results in the production of more lactic acid, which lowers the pH of the cultures.	
(B)	Incorrect. The pH of the treatment culture was never higher than that of the control culture.	
(C)	Incorrect. Because the initial pH of both cultures was the same, there is no indication that the compound directly affected the pH.	
(D)	Incorrect. The bacteria in both cultures were using anaerobic metabolism to break down the glucose. Oxygen is not required for this process, so binding all available oxygen to another molecule should not impact the rate of metabolism.	

Question 9

Skill	Learning Objective	Topic
1.C: Explain biological concepts, processes, and/or models in applied contexts.	SYI-1.B: Describe the properties of the monomers and the type of bonds that connect the monomers in biological macromolecules.	Properties of Biological Macromolecules
(A)	Incorrect. The mass of the enzyme should not impact the affinity of the enzyme for its substrate.	
(B)	Correct. The replacement of a polar amino acid with a nonpolar amino acid will affect the folding of the enzyme because there will be different interactions between the R groups.	
(C)	Incorrect. The replacement of the amino acid should not result in competitive inhibition between enzymes.	
(D)	Incorrect. The replacement of the amino acid will not change the directionality of the chain of amino acids.	

Question 10

Skill	Learning Objective	Topic
1.C: Explain biological concepts, processes, and/or models in applied contexts.	ENE-4.B: Explain how interactions within and among populations influence community structure.	Community Ecology
(A)	Incorrect. There is nothing to suggest that the bat is harmed by this relationship.	
(B)	Correct. The pitcher plant benefits from the nitrogen from the bat, and the bat benefits from the safe place to sleep.	
(C)	Incorrect. The bat benefits from the safe place to sleep provided by the plant.	
(D)	Incorrect. The plant is affected by this relationship in that it benefits from the nitrogen received from the bat feces.	

Question 11

Skill	Learning Objective	Topic
5.A: Perform mathematical calculations, including- a. Mathematical equations in the curriculum. b. Means. c. Rates. d. Ratios. e. Percentages.	EVO-1.K: Describe the conditions under which allele and genotype frequencies will change in populations.	Hardy-Weinberg Equilibrium
(A)	Incorrect. This is the value for q^2 , which is the frequency of individuals with the disorder.	
(B)	Incorrect. This is the value for q , which is the frequency of the recessive allele.	
(C)	Correct. This is the value for $2pq$, which is the frequency of individuals who are heterozygous for the disorder.	
(D)	Incorrect. This is the value for p , which is the frequency of the dominant allele.	

Question 12

Skill	Learning Objective	Topic
2.A: Describe characteristics of a biological concept, process, or model represented visually.	IST-3.D: Describe the role of components of a signal transduction pathway in producing a cellular response.	Introduction to Signal Transduction
(A)	Incorrect. Nitric oxide is only involved in the first step of the signaling cascade and there is no indication that the nitric oxide triggered signaling increases over time.	
(B)	Correct. One of the benefits of a signaling cascade is that a relatively few initial signaling molecules can result in a large change, because at each step, a signaling molecule activates many other signaling molecules.	
(C)	Incorrect. The thickness of the arrows represents the increase in the number of signaling molecules. Just increasing the size of the proteins in the pathway would not create a signaling cascade.	
(D)	Incorrect. There is no indication of any negative feedback in this pathway.	

Question 13

Skill	Learning Objective	Topic
6.D: Explain the relationship between experimental results and larger biological concepts, processes, or theories.	ENE-2.H: Explain how concentration gradients affect the movement of molecules across membranes.	Tonicity and Osmoregulation
(A)	Incorrect. The mass of the grape decreased in NaCl solution, indicating that the grape lost water.	
(B)	Correct. The mass of the grape decreased in both the grape soda and the NaCl solutions, indicating that water left. Since water moves from higher water potential to lower water potential, the grape has a higher water potential than either solution has.	
(C)	Incorrect. The mass of the grape increased in both the tap water and the grape juice, indicating the grape gained water.	
(D)	Incorrect. The mass of the grape decreased in the grape soda, indicating that the grape lost water.	

Question 14

Skill	Learning Objective	Topic
4.B: Describe data from a table or graph, including- a. Identifying specific data points. b. Describing trends and/or patterns in the data. c. Describing relationships between variables.	ENE-2.H: Explain how concentration gradients affect the movement of molecules across membranes.	Tonicity and Osmoregulation
(A)	Incorrect. The distilled water had a concentration of 0.0%, and the mass of the grape increased by 13.48% indicating the concentration of the grape and solution were not equal.	
(B)	Incorrect. The grape gained mass in the grape juice which has a concentration of 2.1%, suggesting that the concentration of the grape is higher than 2.1% not lower.	
(C)	Correct. The grape had a small positive change in mass in the 2.1% solution and a large negative change in mass in the 13% solution, suggesting the concentration of the grape is somewhere between those two percentages but closer to 2.1%.	
(D)	Incorrect. Although 10.1% is between the concentration of the solution with the smallest decrease in mass (13%) and the concentration of the solution with the smallest increase in mass (2.1%), 10.1% is closer to 13% than 2.1%, indicating the change in mass would be closer to -15% than 0.0%.	

Question 15

Skill	Learning Objective	Topic
5.D: Use data to evaluate a hypothesis (or prediction), including- a. Rejecting or failing to reject the null hypothesis. b. Supporting or refuting the alternative hypothesis.	ENE-2.H: Explain how concentration gradients affect the movement of molecules across membranes.	Tonicity and Osmoregulation
(A)	Incorrect. According to the data provided, the mass of the grape increased in the grape juice.	
(B)	Incorrect. The mass of the grape increased in the grape juice, suggesting the solute potential of the grape was higher than that of the grape juice.	
(C)	Incorrect. The mass of the grape increased while in grape juice. The mass would have stayed the same if the grape and the grape juice were isotonic.	
(D)	Correct. The mass of the grape increased in the grape juice, suggesting the grape juice is hypotonic compared with the grape and thus allowed water to move into the grape. Extra sugar would have likely made the grape juice hypertonic.	

Question 16

Skill	Learning Objective	Topic
3.B: State the null and alternative hypotheses or predict the results of an experiment.	ENE-2.E: Describe the mechanisms that organisms use to maintain solute and water balance.	Membrane Transport
(A)	Correct. Small diffusible solutes would diffuse into the cell because there is a lower concentration inside the grape. Combined with the concentration of nondiffusible solutes, the interior of the grape will now be hypertonic to the exterior and water would move in.	
(B)	Incorrect. There is a higher concentration of small diffusible solutes outside the grape than inside the grape. Solutes move from high concentration to low concentration.	
(C)	Incorrect. There is a higher concentration of small diffusible solutes outside the grape than inside the grape. Solutes move from high concentration to low concentration.	
(D)	Incorrect. While small diffusible solutes will move into the grape increasing the osmolarity of the grape, water will not move out of the grape.	

Question 17

Skill	Learning Objective	Topic
6.E: Predict the causes or effects of a change in, or disruption to, one or more components in a biological system based on- a. Biological concepts or processes. b. A visual representation of a biological concept, process, or model. c. Data.	ENE-2.G: Explain how the structure of a molecule affects its ability to pass through the plasma membrane.	Facilitated Diffusion
(A)	Incorrect. Active transport is not used to move water through the membrane.	
(B)	Incorrect. Mercurial sulfhydryl inhibits the transport protein. It does not activate the transport protein.	
(C)	Incorrect. Although mercurial sulfhydryl inhibits aquaporins, water is not transported actively.	
(D)	Correct. While small amounts of water can pass through the membrane by simple diffusion, aquaporins are channel proteins that allow larger amounts of water to move over a shorter period of time.	

Question 18

Skill	Learning Objective	Topic
1.B: Explain biological concepts and/or processes.	ENE-1.B: Explain the effect of surface area-to-volume ratios on the exchange of materials between cells or organisms and the environment.	Cell Size
(A)	Correct. A grape with a smaller surface-area-to-volume ratio will have a slower rate of water absorption per gram.	
(B)	Incorrect. A grape with a larger surface-area-to-volume ratio would have a higher rate of water absorption per gram, not a lower one.	
(C)	Incorrect. The ability to expand is not related to the rate of water absorption per gram. Additionally, there is nothing to suggest that smaller grapes would be able to expand more than larger grapes can.	
(D)	Incorrect. Larger grapes may have a larger volume, but the rate of water absorption per gram is more dependent on the surface area.	

Question 19

Skill	Learning Objective	Topic
1.C: Explain biological concepts, processes, and/or models in applied contexts.	IST-2.D: Explain the connection between the regulation of gene expression and phenotypic differences in cells and organisms.	Gene Expression and Cell Specialization
(A)	Incorrect. The majority of the cells in an organism have the same genes.	
(B)	Incorrect. Cells do not evolve. They may develop and specialize for different functions, but this is not an evolutionary process.	
(C)	Correct. The process by which cells specialize for certain functions involves activating different sets of genes.	
(D)	Incorrect. Eukaryotic organisms have only two types of ribosomes, a larger ribosome in the cytosol and a small ribosome in the mitochondria. These two types of ribosomes do not account for the diverse sets of genes that are activated in different types of cells.	

Question 20

Skill	Learning Objective	Topic
2.B: Explain relationships between different characteristics of biological concepts or processes represented visually- a. In theoretical contexts. b. In applied contexts.	ENE-1.G: Explain how the cellular environment affects enzyme activity.	Environmental Impacts on Enzyme Function
(A)	Incorrect. Although the total amount of product increases over time, the decreasing slope of the line indicates that the reaction rate is decreasing over time not increasing.	
(B)	Incorrect. The decreasing slope of the line indicates that the reaction rate is decreasing. Additionally, an increase in the ratio of products to substrate should result in a decrease in the rate of the reaction not an increase.	
(C)	Correct. The decreasing slope of the line indicates that the reaction rate is decreasing over time. As the reaction proceeds and the ratio of product to substrate increases, the reaction rate decreases.	
(D)	Incorrect. Although the decreasing slope of the line indicates that the reaction rate is decreasing over time, enzymes are not used up by the reaction.	

Question 21

Skill	Learning Objective	Topic
1.C: Explain biological concepts, processes, and/or models in applied contexts.	ENE-1.G: Explain how the cellular environment affects enzyme activity.	Environmental Impacts on Enzyme Function
(A)	Correct. Changing the shape of the enzyme's active site will prevent it from catalyzing the reaction regardless of the concentration of the substrate.	
(B)	Incorrect. Increasing substrate-enzyme binding would increase the activity of the enzyme, not inhibit the enzyme.	
(C)	Incorrect. If alanine were competing with the substrate for the active site, then increasing the concentration of the substrate would increase the chances of the substrate binding and decrease the effect of the inhibitor.	
(D)	Incorrect. Alanine binds to and affects the enzyme, not the substrate.	

Question 22

Skill	Learning Objective	Topic
1.C: Explain biological concepts, processes, and/or models in applied contexts.	ENE-4.B: Explain how interactions within and among populations influence community structure.	Community Ecology
(A)	Incorrect. The bumblebee species are not geographically isolated from one another.	
(B)	Correct. The bumblebee species rely on different flowers depending on the length of their proboscis. This allows multiple species to occupy the same area while decreasing competition.	
(C)	Incorrect. There may be a mutualistic relationship between bumblebees and the plants they pollinate, but not between different bumblebee species.	
(D)	Incorrect. No bumblebee species appears to benefit from the presence of the other species.	

Question 23

Skill	Learning Objective	Topic
4.B: Describe data from a table or graph, including- a. Identifying specific data points. b. Describing trends and/or patterns in the data. c. Describing relationships between variables.	SYI-3.B: Explain how the same genotype can result in multiple phenotypes under different environmental conditions.	Environmental Effects on Phenotype
(A)	Incorrect. The rate of mRNA H degradation is independent of the length of light exposure, which suggests that light does not cause its degradation.	
(B)	Incorrect. mRNA H degrades more rapidly than mRNA G during morning exposure to light.	
(C)	Correct. The rate of degradation of mRNA G after the plant has been exposed to light for 8 hours is greater than the rate of degradation of mRNA G after the plant has been exposed to light for only 1 hour. The rate of mRNA H degradation is unaffected by the length of time the plant has been exposed to light.	
(D)	Incorrect. The rate of degradation of mRNA H is not affected by the time of day.	

Question 24

Skill	Learning Objective	Topic
1.A: Describe biological concepts and/or processes.	EVO-3.D: Describe the conditions under which new species may arise.	Speciation
(A)	Incorrect. Individuals of the same species can have differences between their RNA sequences.	
(B)	Incorrect. Individuals of the same species can be morphologically distinct.	
(C)	Correct. Based on the biological species concept, organisms of different species cannot produce hybrid offspring that are capable of reproducing.	
(D)	Incorrect. A single species can occupy multiple habitats.	

Question 25

Skill	Learning Objective	Topic
6.C: Provide reasoning to justify a claim by connecting evidence to biological theories.	IST-3.B: Explain how cells communicate with one another over short and long distances.	Cell Communication
(A)	Incorrect. Phosphorylation of the insulin receptor does not provide evidence that osteocalcin is a hormone.	
(B)	Correct. Hormones are signaling molecules that can be secreted from one part of the body and act on another part of the body.	
(C)	Incorrect. Activation of intracellular pathways is not necessarily dependent on hormone signaling.	
(D)	Incorrect. The pH dependency of osteocalcin activation does not provide evidence that osteocalcin is a hormone.	

Question 26

Skill	Learning Objective	Topic
2.A: Describe characteristics of a biological concept, process, or model represented visually.	IST-3.C: Describe the components of a signal transduction pathway.	Introduction to Signal Transduction
(A)	Correct. Insulin binding increases the secretion of additional insulin via osteocalcin signaling.	
(B)	Incorrect. Insulin binding stimulates the production of osteocalcin.	
(C)	Incorrect. Insulin binding is inhibited by Esp protein.	
(D)	Incorrect. Insulin binding causes osteoclasts to release protons and create an area of lower pH outside the cell.	

Question 27

Skill	Learning Objective	Topic
6.A: Make a scientific claim	IST-3.F: Describe the different types of cellular responses elicited by a signal transduction pathway.	Signal Transduction
(A)	Correct. Mutant mice that do not express Esp have a higher blood insulin level twenty minutes after injection and beyond.	
(B)	Incorrect. Normal mice that produce Esp protein maintain a regulated blood insulin level after injection.	
(C)	Incorrect. Insulin levels in normal mice are never statistically greater than insulin levels in mutant mice.	
(D)	Incorrect. The data do not show a cyclical pattern of insulin secretion for the mutant mice.	

Question 28

Skill	Learning Objective	Topic
3.C: Identify experimental procedures that are aligned to the question, including- a. Identifying dependent and independent variables. b. Identifying appropriate controls. c. Justifying appropriate controls.	IST-3.E: Describe the role of the environment in eliciting a cellular response.	Signal Transduction
(A)	Incorrect. Minutes after glucose injection is an independent variable that is controlled by the researcher.	
(B)	Incorrect. Blood insulin is the dependent variable in the experiment that is measured.	
(C)	Incorrect. The response of the mutant strain of mice to glucose was unknown.	
(D)	Correct. Treatment of the normal strain of mouse has a known, expected result to ensure the experiment is functioning and is therefore the positive control.	

Question 29

Skill	Learning Objective	Topic
2.A: Describe characteristics of a biological concept, process, or model represented visually.	ENE-3.C: Explain how positive feedback affects homeostasis.	Feedback
(A)	Correct. The release of insulin from the pancreas ultimately leads to more insulin being released. The excess insulin production results in too much sugar being removed from the bloodstream and the low blood sugar seen in the mutant mice.	
(B)	Incorrect. Inactive osteocalcin does not affect insulin production and removal of sugar from the bloodstream.	
(C)	Incorrect. The Esp protein is not part of a positive feedback loop.	
(D)	Incorrect. Insulin-secreting pancreatic cell proliferation is not dependent on a negative feedback pathway.	

Question 30

Skill	Learning Objective	Topic
5.C: Perform chi-square hypothesis testing.	IST-1.I: Explain the inheritance of genes and traits as described by Mendel's laws.	Mendelian Genetics
(A)	Incorrect. Four is the number of offspring expected to have the recessive trait for both genes.	
(B)	Incorrect. Twelve is the number of offspring expected to have the dominant trait for one gene and the recessive trait for the other gene.	
(C)	Correct. In a dihybrid cross of mice that are heterozygous for both traits, nine out of sixteen offspring are expected to have the dominant phenotype for both traits. $\frac{9}{16} \times 64 = 36$	
(D)	Incorrect. 48 is the number of offspring expected to have the dominant phenotype in a monohybrid cross of heterozygotes.	

Question 31

Skill	Learning Objective	Topic
4.B: Describe data from a table or graph, including- a. Identifying specific data points. b. Describing trends and/or patterns in the data. c. Describing relationships between variables.	IST-1.L: Describe the characteristics of DNA that allow it to be used as the hereditary material.	DNA and RNA Structure
(A)	Correct. A double-stranded nucleic acid will contain equal amounts of complementary bases. Sample one contains 23 percent of both cytosine and guanine and 27 percent of both adenine and uracil, consistent with Chargaff's rule. The presence of uracil instead of thymine indicates that the nucleic acid is an RNA molecule, not a DNA molecule.	
(B)	Incorrect. While Sample 2 shows base percentages consistent with a double-stranded nucleic acid, with a 17 percent frequency of both cytosine and guanine and 33 percent frequency of both adenine and thymine, the presence of thymine instead of uracil indicates the molecule is DNA, not RNA.	
(C)	Incorrect. While the presence of uracil and absence of thymine indicates that Sample 3 is RNA not DNA, the uneven distribution of the four bases indicates that this is a single-stranded nucleic acid.	
(D)	Incorrect. While the relative frequencies of the four bases in Sample 4 suggest that this is a double-stranded molecule, the presence of thymine instead of uracil indicates that this is DNA, not RNA.	

Question 32

Skill	Learning Objective	Topic
1.C: Explain biological concepts, processes, and/or models in applied contexts.	EVO-3.F: Explain the processes and mechanisms that drive speciation.	Speciation
(A)	Incorrect. Using different food sources does not necessarily prevent gene flow between two species.	
(B)	Incorrect. The information indicates that goats and sheep often share a habitat, so they are not isolated. Additionally, while hybrids are sterile or do not survive, some are produced, indicating that the barrier is postzygotic.	
(C)	Incorrect. Different times of fertility would be a prezygotic barrier, and the information indicates that zygotes, and sometimes viable offspring, are formed.	
(D)	Correct. Closely related species might be able to mate and even produce a viable offspring, but if the chromosome numbers of the two species are not the same, the offspring will not have homologous pairs of chromosomes and will not be able to produce functional gametes.	

Question 33

Skill	Learning Objective	Topic
1.C: Explain biological concepts, processes, and/or models in applied contexts.	ENE-3.C: Explain how positive feedback affects homeostasis.	Feedback
(A)	Correct. This is an explanation of positive feedback. The production of ethylene by some cells results in other cells producing ethylene, causing a rapid increase in the ripening process and increasing the overall level of ethylene present.	
(B)	Incorrect. This is an explanation of negative feedback. The production of ethylene in response to low water stress results in root growth, increasing the opportunity to find water and decrease low water stress.	
(C)	Incorrect. This is an explanation of negative feedback. The production of ethylene in response to insect damage repels insects, decreasing the insect damage. A decrease in the insect population would lead to a decrease in ethylene production.	
(D)	Incorrect. This is an explanation of negative feedback. The production of ethylene by fertilized ovules in a flower results in controlled death of the flower petals.	

Question 34

Skill	Learning Objective	Topic
5.A: Perform mathematical calculations, including- a. Mathematical equations in the curriculum. b. Means. c. Rates. d. Ratios. e. Percentages.	ENE-1.O: Explain how the activities of autotrophs and heterotrophs enable the flow of energy within an ecosystem.	Energy Flow through Ecosystems
(A)	Incorrect. The average weekly growth rate for the whole three-week period is 3.2 g/week (total growth rate divided by three weeks).	
(B)	Correct. The approximate growth rate of section II is 4.5 g/week for days 14 to 21. Assuming the mass at day 14 of section II is the same as that of section I, then the rate for days 14 through 21 is $9.6 - 5.1$ g/week.	
(C)	Incorrect. The mass of section I on day 14 is 5.1g.	
(D)	Incorrect. The total mass of grass in section II on day 21 is 9.6g.	

Question 35

Skill	Learning Objective	Topic
6.D: Explain the relationship between experimental results and larger biological concepts, processes, or theories.	ENE-1.M: Describe the strategies organisms use to acquire and use energy.	Energy Flow through Ecosystems
(A)	Incorrect. The grass in section III did not require more energy than the grass in section I, but the grass in section III did not store any energy from photosynthesis during days 14 through 21.	
(B)	Incorrect. The grass in section III performed no photosynthesis after day 14 since the grass did not receive any light. This is also supported by the decrease in biomass relative to section I at two weeks.	
(C)	Incorrect. The grass in all three sections used up the energy stored in the seeds during germination before the grass was able to perform photosynthesis.	
(D)	Correct. Grass in all sections used stored mass for cellular respiration, but during days 14 through 21 the grass in section III was not able to produce biomass through photosynthesis.	

Question 36

Skill	Learning Objective	Topic
1.C: Explain biological concepts, processes, and/or models in applied contexts.	ENE-1.H: Describe the role of energy in living organisms.	Cellular Energy
(A)	Correct. The plant is considered an ordered system, and without the input of new energy by photosynthesis, the plant draws on its stored energy reserves for maintenance at the cost of growth.	
(B)	Incorrect. Nutrients from the soil are incorporated into plant matter synthesized for growth, but the energy source is light and the material for growth is primarily water and carbon dioxide.	
(C)	Incorrect. The oxygen released during the light-dependent reactions is a byproduct of photosynthesis and is not incorporated into the synthesis of sugars but is instead released into the atmosphere.	
(D)	Incorrect. The loss of mass in section II reflects the plant's use of stored energy for maintenance.	

Question 37

Skill	Learning Objective	Topic
6.E: Predict the causes or effects of a change in, or disruption to, one or more components in a biological system based on- a. Biological concepts or processes. b. A visual representation of a biological concept, process, or model. c. Data.	ENE-1.N: Explain how changes in energy availability affect populations and ecosystems.	Energy Flow through Ecosystems
(A)	Correct. The data establish that a lack of adequate light leads to a loss of biomass. This loss would narrow the base of the energy pyramid, with less energy available throughout the ecosystem, leading to a decrease in population sizes of most species and possible extinction of some species and the loss of one or more of the top trophic levels.	
(B)	Incorrect. The data establish that without light, biomass decreases rather than increases.	
(C)	Incorrect. About 90 percent of the energy obtained by an omnivore is lost to heat and maintenance. The consumer trophic levels would rapidly use up energy stores without an influx of new energy from producers.	
(D)	Incorrect. Niche availability due to loss of energy-starved consumers does not help other consumers, who would also suffer from the lack of energy.	

Question 38

Skill	Learning Objective	Topic
3.B: State the null and alternative hypotheses or predict the results of an experiment.	ENE-1.M: Describe the strategies organisms use to acquire and use energy.	Energy Flow through Ecosystems
(A)	Incorrect. Predicting a negative effect is still an alternate hypothesis as it is stating that changing the independent variable will affect the dependent variable.	
(B)	Incorrect. This would be an alternate hypothesis that can be tested by modifying the protocol of the experiment. It predicts a change in the dependent variable based on a change in the independent variable.	
(C)	Incorrect. This would be an alternate hypothesis that can be tested by modifying the protocol of the experiment. It predicts a change in the dependent variable based on a change in the independent variable.	
(D)	Correct. A null hypothesis states that a change in the designated independent variable would have no effect on the dependent variable. In this experiment, light is the independent variable and the mass of grass is the dependent variable.	

Question 39

Skill	Learning Objective	Topic
2.A: Describe characteristics of a biological concept, process, or model represented visually.	SYI-1.B: Describe the properties of the monomers and the type of bonds that connect the monomers in biological macromolecules.	Properties of Biological Macromolecules
(A)	Incorrect. All amino acids have an amine group in this position. This amine group forms a covalent peptide bond with the carboxyl group of another amino acid and does not contribute significantly to hydrophobic behavior.	
(B)	Incorrect. All amino acids have a carboxyl group in this position. This carboxyl group forms a covalent peptide bond with an amine group of another amino acid and does not contribute significantly to hydrophobic behavior.	
(C)	Correct. The methyl group is one of the functional groups that differentiate the twenty amino acids found in proteins. Since the methyl group is nonpolar, it is likely to make this region of the polypeptide more hydrophobic.	
(D)	Incorrect. Hydrogen atoms, especially those bonded to carbon atoms, do not on their own add either hydrophobic or hydrophilic characteristics to their molecule.	

Question 40

Skill	Learning Objective	Topic
5.C: Perform chi-square hypothesis testing.	IST-1.J: Explain deviations from Mendel's model of the inheritance of traits.	Non-Mendelian Genetics
(A)	Correct. The critical value for two degrees of freedom and a p-value of 0.05 is 5.99, which is less than the calculated value of 7.3.	
(B)	Incorrect. The null hypothesis is rejected if the critical value is less than the calculated value.	
(C)	Incorrect. The critical value for two degrees of freedom and a p-value of 0.05 is 5.99, which is less than the calculated value of 7.3.	
(D)	Incorrect. The critical value for two degrees of freedom and a p-value of 0.05 is 5.99, which is less than the calculated value of 7.3.	

Question 41

Skill	Learning Objective	Topic
3.B: State the null and alternative hypotheses or predict the results of an experiment.	ENE-1.J: Explain how cells capture energy from light and transfer it to biological molecules for storage and use.	Photosynthesis
(A)	Incorrect. The production of NADPH is not directly tied to the proton gradient across the thylakoid membrane.	
(B)	Correct. The phosphorylation of ADP to form ATP is dependent on the flow of hydrogen ions through ATP synthase. Making the membrane permeable to hydrogen ions would disrupt the proton gradient and fewer protons would be available to flow through ATP synthase.	
(C)	Incorrect. The amount of light energy required to excite the electrons in chlorophyll is not related to a proton gradient.	
(D)	Incorrect. While the splitting of a water molecule creates protons, this reaction does not depend on a proton gradient to occur.	

Question 42

Skill	Learning Objective	Topic
4.B: Describe data from a table or graph, including- a. Identifying specific data points. b. Describing trends and/or patterns in the data. c. Describing relationships between variables.	EVO-1.N: Explain how morphological, biochemical, and geologic data provide evidence that organisms have changed over time.	Evidence for Evolution
(A)	Incorrect. The data indicate that birds and mammals diverged approximately 270 million years ago.	
(B)	Incorrect. The data indicate that reptiles and mammals diverged approximately 325 million years ago.	
(C)	Incorrect: The data indicate that fish and land vertebrates diverged approximately 400 million years ago.	
(D)	Correct. The data indicate that insects and vertebrates diverged approximately 600 million years ago.	

Question 43

Skill	Learning Objective	Topic
1.B: Explain biological concepts and/or processes.	IST-1.M: Describe the mechanisms by which genetic information is copied for transmission between generations.	Replication
(A)	Correct. The use of a parental DNA template strand ensures the new DNA double helix produced will have the same sequence of bases as the parental strand.	
(B)	Incorrect. Although DNA molecules are shaped like a double helix, this information does not best explain the continuity of genetic information across generations.	
(C)	Incorrect. Although the formation of an RNA transcript is important to cellular functions such as protein synthesis, this does not help explain the continuity of genetic information across generations.	
(D)	Incorrect. Although cells do contain different polymerases, this does not help explain the continuity of genetic information across generations.	

Question 44

Skill	Learning Objective	Topic
1.C: Explain biological concepts, processes, and/or models in applied contexts.	SYI-3.B: Explain how the same genotype can result in multiple phenotypes under different environmental conditions.	Environmental Effects on Phenotype
(A)	Correct. Environmental factors can influence gene expression, in this case resulting in a reduction of melanin during the fall and winter.	
(B)	Incorrect. While environmental factors can cause mutations, these mutations are random and do not result in specific changes from season to season.	
(C)	Incorrect. There is only one universal genetic code used for the translation of all proteins.	
(D)	Incorrect. Enzymes are specific to their substrate because of their structure. Environmental factors associated with a change in the seasons will not affect the substrates that can bind to an enzyme.	

Question 45

Skill	Learning Objective	Topic
6.E: Predict the causes or effects of a change in, or disruption to, one or more components in a biological system based on- a. Biological concepts or processes. b. A visual representation of a biological concept, process, or model. c. Data.	ENE-3.D: Explain how the behavioral and/or physiological response of an organism is related to changes in internal or external environment.	Responses to the Environment
(A)	Incorrect. Bright light inhibits melatonin production rather than stimulating it.	
(B)	Incorrect. Bright light inhibits melatonin production rather than stimulating it.	
(C)	Correct. Melatonin promotes sleep, and its production is inhibited by light. Exposure to light after sunset will likely prevent melatonin secretion and negatively impact sleep.	
(D)	Incorrect. While light does inhibit melatonin synthesis, the lack of melatonin would likely prevent the person from falling asleep.	

Question 46

Skill	Learning Objective	Topic
1.A: Describe biological concepts and/or processes.	ENE-1.A: Describe the composition of macromolecules required by living organisms.	Elements of Life
(A)	Correct. All the bases in the nucleotides that compose nucleic acids contain nitrogen.	
(B)	Incorrect. All amino acids contain carbon, oxygen, nitrogen, and hydrogen. A few amino acids contain sulfur. No unmodified amino acids contain phosphorus.	
(C)	Incorrect. All lipids contain carbon, hydrogen, and oxygen. Some lipids contain nitrogen and phosphorus. Lipids generally do not contain potassium.	
(D)	Incorrect. All carbohydrates have carbon, hydrogen, and oxygen. Carbohydrates generally do not contain magnesium.	

Question 47

Skill	Learning Objective	Topic
2.A: Describe characteristics of a biological concept, process, or model represented visually.	ENE-1.H: Describe the role of energy in living organisms.	Cellular Energy
(A)	Incorrect. The hydrolysis of ATP is exergonic (releases energy) and line 4 represents an endergonic (requires energy) reaction. Additionally, the phosphorylation of a substrate is endergonic and Line 1 represents an exergonic reaction.	
(B)	Correct. Line 4, an endergonic (requires energy) reaction that could represent the phosphorylation reaction, is coupled to Line 1, an exergonic reaction (releases energy) that could represent the hydrolysis reaction. Additionally, the total energy of the reactants represented by lines 1 and 4 is less than that of the products, because some energy is converted to heat.	
(C)	Incorrect. Although line 2 could represent the hydrolysis of ATP, an exergonic reaction (releases energy), it cannot be coupled to the reaction represented by line 3. Since no reactions are 100% efficient, some energy is converted to heat. The total energy of the products must be less than the total energy of the reactants.	
(D)	Incorrect. The hydrolysis of ATP is exergonic (releases energy) and line 3 represents an endergonic reaction (requires energy). Additionally, the phosphorylation of a substrate is endergonic and Line 2 represents an exergonic reaction.	

Question 48

Skill	Learning Objective	Topic
6.D: Explain the relationship between experimental results and larger biological concepts, processes, or theories.	EVO-1.E: Describe the importance of phenotypic variation in a population.	Natural Selection
(A)	Incorrect. Although an individual organism may develop a tolerance for cold temperatures, this adaptation does not involve a change in the nucleotide base sequence in DNA. Acquired characteristics cannot be passed on to new generations based on different sequences of base pairs.	
(B)	Incorrect. There is no information in Table 1 to suggest that a hybrid species has formed.	
(C)	Correct. In a population of anoles that showed variation for cold tolerance, individuals with an increased tolerance for colder temperatures would have had an advantage over others in a colder environment. This advantage would have led to increased reproductive success and an increase in the frequency of those alleles permitting increased cold tolerance in future generations.	
(D)	Incorrect. Mutations are random and do not occur in response to colder temperatures. Existing mutations in individual organisms could affect the phenotype of the organisms and result in these organisms having a greater reproductive success.	

Question 49

Skill	Learning Objective	Topic
6.E: Predict the causes or effects of a change in, or disruption to, one or more components in a biological system based on- a. Biological concepts or processes. b. A visual representation of a biological concept, process, or model. c. Data.	ENE-4.B: Explain how interactions within and among populations influence community structure.	Community Ecology
(A)	Correct. Since green anoles have large toe pads, they are likely to occupy a niche on plants. The brown anoles have smaller toe pads than green anoles do, suggesting that they would be less successful on plants.	
(B)	Incorrect. There is no direct information about the feeding habits of the two lizards in the table. If brown anoles feed mainly at the ground level and green anoles feed mainly while on plants, then it is more likely that brown anoles will prey on worms and grubs and green anoles will prey on flying insects.	
(C)	Incorrect. Based on toe pad size, they do not share the same niche and competition is likely to help maintain this niche separation.	
(D)	Incorrect. There is no information in the table to indicate that one of the two lizards will be better adapted to the forest habitat.	

Question 50

Skill	Learning Objective	Topic
2.A: Describe characteristics of a biological concept, process, or model represented visually.	EVO-3.B: Describe the types of evidence that can be used to infer an evolutionary relationship.	Phylogeny
(A)	Incorrect. <i>A. evermanni</i> is more closely related to certain species than to others. It is not the outgroup.	
(B)	Incorrect. <i>A. stratulus</i> is more closely related to certain species than to others. It is not the outgroup.	
(C)	Incorrect. <i>A. gundlachi</i> is more closely related to certain species than to others. It is not the outgroup.	
(D)	Correct. Based on the cladogram, <i>A. carolinensis</i> is more distantly related to all of the other species in the cladogram than the other species are related to each other.	

Question 51

Skill	Learning Objective	Topic
6.B: Support a claim with evidence from biological principles, concepts, processes, and/or data.	EVO-3.B: Describe the types of evidence that can be used to infer an evolutionary relationship.	Phylogeny
(A)	Incorrect. Dimensions of body parts, which may be under strong selective pressures, are not reliable indicators of relatedness. Additionally, small changes in DNA can result in large morphological changes.	
(B)	Correct. The rate that mutations appear in the genomes of species is relatively constant, and therefore the number of differences between two species can serve as a molecular clock to measure how long ago species diverged.	
(C)	Incorrect. Many unrelated species can occupy similar niches.	
(D)	Incorrect. Similar mating behaviors may have evolved by convergent evolution and do not indicate a close evolutionary relationship.	

Question 52

Skill	Learning Objective	Topic
6.A: Make a scientific claim	EVO-3.B: Describe the types of evidence that can be used to infer an evolutionary relationship.	Phylogeny
(A)	Incorrect. Convergent evolution increases the similarities between species rather than the differences suggested by the cladogram.	
(B)	Correct. Different populations of anoles likely experienced different selective pressures, which selected for different traits.	
(C)	Incorrect. There is nothing in the information provided to suggest that the anole species experienced a genetic bottleneck.	
(D)	Incorrect. While species do inherit DNA from their common ancestor, it is the selective pressures that each species experiences that cause divergence.	

Question 53

Skill	Learning Objective	Topic
1.C: Explain biological concepts, processes, and/or models in applied contexts.	IST-1.O: Describe how the phenotype of an organism is determined by its genotype.	Translation
(A)	Incorrect. If the mutation kept the gene wrapped around the histones, no transcription would occur and, instead of a shortened protein, no protein would be produced.	
(B)	Incorrect. Transcription by different transcription factors might affect when and in which cells the protein would be produced, but it would not affect the length of the protein.	
(C)	Correct. Changing a codon in the coding region to a stop codon would cause the ribosome to stop translating before the polypeptide was fully formed.	
(D)	Incorrect. Mutations could affect which amino acids are introduced into the protein, but they would not affect the type of bond that forms between adjacent amino acids.	

Question 54

Skill	Learning Objective	Topic
1.C: Explain biological concepts, processes, and/or models in applied contexts.	SYI-1.A: Explain how the properties of water that result from its polarity and hydrogen bonding affect its biological function.	Structure of Water and Hydrogen Bonding
(A)	Correct. If bile salts interfere with the hydrogen bonds between surface water molecules, then the surface tension will be reduced and the sulfur powder will sink.	
(B)	Incorrect. Although water molecules will move from an area of higher water potential to an area of lower water potential, this does not explain the floating or sinking of the sulfur powder.	
(C)	Incorrect. If bile salts increased the density of the urine sample, then materials such as sulfur powder would have a greater tendency to float and not sink.	
(D)	Incorrect. Although bile salts may affect the hydrogen bonds between water molecules, bile salts are not likely to affect the covalent bonds of the water molecules.	

Question 55

Skill	Learning Objective	Topic
2.B: Explain relationships between different characteristics of biological concepts or processes represented visually- a. In theoretical contexts. b. In applied contexts.	IST-4.A: Explain how changes in genotype may result in changes in phenotype.	Mutations
(A)	Incorrect. While there are many chromosomes, an extra chromosome would not cause the chromosomes to be so crowded that RNA polymerase could not access the genes.	
(B)	Correct. Having an additional copy of all genes on chromosome 21 would result in an increase in the amount of RNA transcribed from those genes. The protein levels for these genes would be higher than is typical.	
(C)	Incorrect. Homologous chromosomes only pair during meiosis, not mitosis which is necessary for cell division and growth.	
(D)	Incorrect. The presence of an extra chromosome would not affect the number of copies of other chromosomes.	

Question 56

Skill	Learning Objective	Topic
6.B: Support a claim with evidence from biological principles, concepts, processes, and/or data.	EVO-1.B: Describe the relationship between the functions of endosymbiotic organelles and their free-living ancestral counterparts.	Origins of Cell Compartmentalization
(A)	Correct. Existing bacteria all have a DNA genome and the ability to divide. In order for mitochondria to have been free-living bacteria, as suggested by the endosymbiont hypothesis, they would need these traits.	
(B)	Incorrect. The ability to carry out hydrolytic reactions on organic molecules does not suggest that mitochondria were once free-living bacteria, as suggested by the endosymbiont hypothesis.	
(C)	Incorrect. A highly folded membrane does not suggest that mitochondria were once free-living bacteria, as suggested by the endosymbiont hypothesis.	
(D)	Incorrect. Plants and animals are both eukaryotes. The presence of mitochondria in these organisms does not support that mitochondria were once free-living bacteria, as suggested by the endosymbiont hypothesis.	

Question 57

Skill	Learning Objective	Topic
1.C: Explain biological concepts, processes, and/or models in applied contexts.	IST-1.N: Describe the mechanisms by which genetic information flows from DNA to RNA to protein.	Transcription and RNA Processing
(A)	Incorrect. There are no structural differences between eukaryotic DNA and prokaryotic DNA that would prevent prokaryotic RNA polymerase from transcribing a eukaryotic gene.	
(B)	Incorrect. Although DNA sequences can be unique to a species, the genetic code used to translate an mRNA transcript into a protein is universal to all species.	
(C)	Correct. The prokaryotic cell will be able to produce a protein from the transcript, but it will have a different amino acid sequence and therefore a different function, because only eukaryotes remove introns from mRNA transcripts.	
(D)	Incorrect. While there are structural differences between the ribosomes of prokaryotes and eukaryotes, prokaryotes contain ribosomes for translation.	

Question 58

Skill	Learning Objective	Topic
6.E: Predict the causes or effects of a change in, or disruption to, one or more components in a biological system based on- a. Biological concepts or processes. b. A visual representation of a biological concept, process, or model. c. Data.	ENE-4.B: Explain how interactions within and among populations influence community structure.	Community Ecology
(A)	Incorrect. Cladophora are the producers of this trophic structure. If the Cladophora population decreases, there would be less food available to the entire trophic structure resulting in a decrease in the populations at all levels.	
(B)	Correct. Increased cadmium in the river will negatively impact the steelhead trout. With fewer trout feeding on the damselfly nymphs, the nymph population will increase.	
(C)	Incorrect. An increase in the steelhead trout population would result in fewer damselfly nymphs to consume the midge larvae. Then there would be more midge larvae to consume the Cladophora. The Cladophora population would decrease, not increase.	
(D)	Incorrect. The information provided does not suggest the cadmium has any direct impact on the damselflies. While the steelhead trout population is expected to decrease, it is not because of a decrease in damselflies.	

Question 59

Skill	Learning Objective	Topic
6.E: Predict the causes or effects of a change in, or disruption to, one or more components in a biological system based on- a. Biological concepts or processes. b. A visual representation of a biological concept, process, or model. c. Data.	EVO-1.F: Explain how humans can affect diversity within a population.	Artificial Selection
(A)	Incorrect. Tusk size would not increase due to the need of poachers. If poachers targeted the elephants with the largest tusks, fewer of these elephants would survive to reproduce and future generations would have fewer elephants with large tusks.	
(B)	Correct. If poachers targeted the elephants with the largest tusks, then more elephants with small tusks would survive to reproduce and future generations would see an increase in the number of small-tusked elephants.	
(C)	Incorrect. Natural selection is the result of selective pressures and is not goal directed. Elephants cannot change the size of their tusks just because it would be beneficial.	
(D)	Incorrect. Although a decrease in average tusk size is expected, this would be due to the alleles of the elephants that survive to reproduce, not the need to reduce energy investment in the tusks.	

Question 60

Skill	Learning Objective	Topic
6.B: Support a claim with evidence from biological principles, concepts, processes, and/or data.	IST-1.M: Describe the mechanisms by which genetic information is copied for transmission between generations.	Replication
(A)	Incorrect. Because DNA replication has occurred and DNA polymerase requires an RNA primer to initiate DNA replication, RNA primers must have formed.	
(B)	Correct. The missing bonds in the backbone of the lagging strand of DNA indicate that DNA ligase was not able to join the fragments.	
(C)	Incorrect. The double-stranded DNA indicates that DNA polymerase was able to complete the replication of the DNA.	
(D)	Incorrect. Because complementary bases are held in place by hydrogen bonding, disruption of hydrogen bonding would have resulted in the dissociation of the two strands.	

Answer Key and Question Alignment to Course Framework

Multiple-Choice Questions	Answer	Skill	Learning Objective	Topic
1	C	1.A	SYI-1.B	Introduction to Biological Macromolecules
2	D	1.A	IST-1.L	DNA and RNA Structure
3	B	2.B	SYI-3.C	Chromosomal Inheritance
4	A	1.A	ENE-1.L	Cellular Respiration
5	B	3.C	ENE-1.L	Cellular Respiration
6	B	4.B	ENE-1.L	Cellular Respiration
7	D	4.B	ENE-1.L	Cellular Respiration
8	A	2.B	ENE-1.L	Cellular Respiration
9	B	1.C	SYI-1.B	Properties of Biological Macromolecules
10	B	1.C	ENE-4.B	Community Ecology
11	C	5.A	EVO-1.K	Hardy-Weinberg Equilibrium
12	B	2.A	IST-3.D	Introduction to Signal Transduction
13	B	6.D	ENE-2.H	Tonicity and Osmoregulation
14	C	4.B	ENE-2.H	Tonicity and Osmoregulation
15	D	5.D	ENE-2.H	Tonicity and Osmoregulation
16	A	3.B	ENE-2.E	Membrane Transport
17	D	6.E	ENE-2.G	Facilitated Diffusion
18	A	1.B	ENE-1.B	Cell Size
19	C	1.C	IST-2.D	Gene Expression and Cell Specialization
20	C	2.B	ENE-1.G	Environmental Impacts on Enzyme Function
21	A	1.C	ENE-1.G	Environmental Impacts on Enzyme Function
22	B	1.C	ENE-4.B	Community Ecology
23	C	4.B	SYI-3.B	Environmental Effects on Phenotype
24	C	1.A	EVO-3.D	Speciation
25	B	6.C	IST-3.B	Cell Communication
26	A	2.A	IST-3.C	Introduction to Signal Transduction
27	A	6.A	IST-3.F	Signal Transduction
28	D	3.C	IST-3.E	Signal Transduction
29	A	2.A	ENE-3.C	Feedback
30	C	5.C	IST-1.I	Mendelian Genetics

Multiple-Choice Questions	Answer	Skill	Learning Objective	Topic
31	A	4.B	IST-1.L	DNA and RNA Structure
32	D	1.C	EVO-3.F	Speciation
33	A	1.C	ENE-3.C	Feedback
34	B	5.A	ENE-1.O	Energy Flow through Ecosystems
35	D	6.D	ENE-1.M	Energy Flow through Ecosystems
36	A	1.C	ENE-1.H	Cellular Energy
37	A	6.E	ENE-1.N	Energy Flow through Ecosystems
38	D	3.B	ENE-1.M	Energy Flow through Ecosystems
39	C	2.A	SYI-1.B	Properties of Biological Macromolecules
40	A	5.C	IST-1.J	Non-Mendelian Genetics
41	B	3.B	ENE-1.J	Photosynthesis
42	D	4.B	EVO-1.N	Evidence for Evolution
43	A	1.B	IST-1.M	Replication
44	A	1.C	SYI-3.B	Environmental Effects on Phenotype
45	C	6.E	ENE-3.D	Responses to the Environment
46	A	1.A	ENE-1.A	Elements of Life
47	B	2.A	ENE-1.H	Cellular Energy
48	C	6.D	EVO-1.E	Natural Selection
49	A	6.E	ENE-4.B	Community Ecology
50	D	2.A	EVO-3.B	Phylogeny
51	B	6.B	EVO-3.B	Phylogeny
52	B	6.A	EVO-3.B	Phylogeny
53	C	1.C	IST-1.O	Translation
54	A	1.C	SYI-1.A	Structure of Water and Hydrogen Bonding
55	B	2.B	IST-4.A	Mutations
56	A	6.B	EVO-1.B	Origins of Cell Compartmentalization
57	C	1.C	IST-1.N	Transcription and RNA Processing
58	B	6.E	ENE-4.B	Community Ecology
59	B	6.E	EVO-1.F	Artificial Selection
60	B	6.B	IST-1.M	Replication

Free-Response Section

Scoring Guidelines

Question 1: Interpreting and Evaluating Experimental Results		10 points
Learning Objectives: IST-1.J ENE-1.K ENE-1.L		
(A)	Describe the pattern of inheritance that is most likely associated with a mutation in the <i>MT-ND5</i> gene.	1 point 1.A
	The mutant allele is only inherited from the maternal parent.	
	Explain why individuals are not typically heterozygous with respect to mitochondrial genes.	1 point 1.C
	<i>MT-ND5</i> is a mitochondrial gene and mitochondria only carry a single, unpaired chromosome.	
Total for part (A)		2 points
(B)	Identify a dependent variable measured in the researcher's experiment.	1 point 3.C
	Accept one of the following: - Concentration of lactic acid in the blood - Concentration of NAD⁺ in the blood	
	Identify one control that the researcher could use to improve the validity of the experiment.	1 point 3.C
	Measure NAD⁺ and lactic acid levels in a group of other affected individuals treated with placebo for comparison.	
	Justify the researcher analyzing blood samples at many intermediate time points instead of at only the beginning and the end of the 20-week period.	1 point 3.C
	By collecting more data, the researcher will see a more accurate trend.	
Total for part (B)		3 points

(C)	Describe the relationship between the concentration of NAD⁺ in the blood and the concentration of lactic acid in the blood during the first 5 weeks of treatment with the vitamin. The concentration of NAD⁺ increased and the concentration of lactic acid decreased.	1 point 4.B
	Based on Figure 2, calculate the average rate of change in blood NAD⁺ concentrations from week 5 to week 17. Accept one of the following: 20 μmol/1/week based on the calculation $[(60 - 300) / (17 - 5)]$ -20 μmol/1/week based on the calculation $[(60 - 300) / (17 - 5)]$	1 point 5.A
		Total for part (C) 2 points
(D)	The researcher performed a follow-up experiment to measure the rate of oxygen consumption by muscle and brain cells. Predict the effect of the <i>MT-ND5</i> mutation on the rate of oxygen consumption in muscle and brain cells. The mutation will decrease the rate of oxygen consumption by the electron transport chain.	1 point 3.B
	Justify your prediction. The mutation likely inhibits the rate of oxygen consumption because the electron transport chain will be less efficient, so less oxygen will be required as a terminal electron acceptor.	1 point 6.B
	The researcher had hypothesized that the addition of the vitamin that is similar in structure to NADH would increase the activity of the mutated NADH dehydrogenase enzyme in individuals with the disorder. Explain how the vitamin most likely increased the activity of the enzyme. The enzyme had decreased activity but still functioned. Increasing the amount of substrate should increase the amount of product produced. Because the vitamin was similar to NADH, it could bind to the active site of the enzyme and effectively increase the substrate concentration.	1 point 6.D
		Total for part (D) 3 points
		Total for question 1 10 points

Question 2: Interpreting and Evaluating Experimental Results with Graphing

8 points

Learning Objectives: SYI-1.B SYI-1.C IST-2.A IST-2.D IST-2.A

- (A) Describe how amino acids are categorized by their chemical properties. **1 point** **1.A**
- Based on their R groups, amino acids are categorized as hydrophobic, hydrophilic, or ionic (acidic or basic).

Explain how a change in the amino acid sequence of the FXR1 protein could decrease the ability of the protein to bind to RNA. **1 point** **1.C**

- A change in amino acid sequence changes the shape of a protein, so that RNA-binding sites formed by the interactions of certain amino acids may change or be lost entirely.

Total for part (A) 2 point

- (B) Using the template in the space provided for your response, construct an appropriately labeled graph that represents the data shown in Table 1. **3 points** **4.A**

One point for each of the following:

- Correct axes and labeling
- Correctly plotted means
- Correctly plotted error bars

Determine whether there is a statistical difference in the amount of FXR1 protein produced by the cells after 16 and 24 hours in the presence of IL-19. **1 point** **5.B**

- No statistical difference

Total for part (B) 4 points

- (C) Based on the data for the 48-hour period, describe the effect of IL-19 on *FXR1* gene expression. **1 point** **4.B**
- IL-19 causes a small increase in expression of the *FXR1* gene.

Total for part (C) 1 point

-
- (D)** The researcher hypothesizes that the *FXR1* gene codes for a protein that binds to mRNAs that encode some of the proteins that damage arteries. Individuals with a loss-of-function mutation of the *FXR1* gene tend to have high levels of these proteins. Based on this information, predict how the FXR1 protein most likely interacts with the mRNAs. **1 point** 

Accept one of the following:

- The FXR1 protein must inhibit translation of the mRNAs.
- The FXR1 protein must degrade the mRNAs.

Total for part (D) 1 point

Total for question 2 8 points

Question 3: Scientific Investigation**4 points****Learning Objectives:** EVO-1.1 EVO-1.E EVO-1.D

- | | | |
|------------|---|-----------------------|
| (A) | Describe one outcome that would demonstrate that a given population has evolved.

• There is a change in allele frequency. | 1 point
1.A |
| <hr/> | | |
| (B) | Identify the dependent variable measured in the experiments.

Accept one of the following:
• Growth rate of the bacteria
• Density of the bacteria | 1 point
3.C |
| <hr/> | | |
| (C) | Predict the results obtained by the researchers when they grew the Cit ⁺ and Cit ⁻ bacteria in the medium that contained only citrate.

• Only the Cit ⁺ bacteria grew. | 1 point
3.B |
| <hr/> | | |
| (D) | The researcher claims that the Cit ⁺ mutation increases the fitness of the bacteria. Provide reasoning to support the claim.

• The Cit ⁺ bacteria have an energy source unavailable to other strains and could grow and reproduce at a more rapid rate due to reduced competition for resources. | 1 point
6.C |
-

Total for question 3 4 points

Question 4: Conceptual Analysis**4 points****Learning Objectives:** SYI-1.H SYI-3.F SYI-3.G

- (A) Describe the process that maintained a stable Tasmanian devil population size before the appearance of DFTD in 1996. **1 point**
1.A
- The Tasmanian devil population would have been maintained at a stable population size by density-dependent factors (e.g., birth rate equaling death rate, the populations reaching carrying capacity).
- (B) Explain how the huge reduction of the Tasmanian devil population since 1996 affects the susceptibility of the current population to new diseases in comparison with the susceptibility of the population before 1996. **1 point**
1.C
- The population underwent a genetic bottleneck and thus has reduced genetic diversity. The current population is more likely to be susceptible to a new disease (less likely to harbor natural resistance) than it would have been in the past.
- (C) Tasmanian devils are top predators and are considered a keystone species in their community. Predict the effect of the rapid reduction of the Tasmanian devil population on the rest of the community. **1 point**
6.E
- Accept one of the following:**
- The community will collapse or be destabilized.
 - The population sizes of some species will increase and others will decrease.
 - Species diversity of the community will decrease.
- (D) Justify the prediction of part (c). **1 point**
6.C
- The prey species of the Tasmanian devil would have increased in number as the Tasmanian devil population decreased. This in turn would have likely led to population decreases of the food sources for these prey species.

Total for question 4 4 points

**Question 5: Analyze Model
or Visual Representation of a Biological Concept or Process**

4 points

Learning Objectives: IST-1.C IST-1.D IST-1.B IST-1.E

- | | | |
|------------|--|---|
| (A) | A skin cell completes one round of the cell cycle. Describe the products. <ul style="list-style-type: none">• Two diploid cells with identical sets of DNA | 1 point
1.A |
| <hr/> | | |
| (B) | Based on Figure 1, explain how p53 regulates the cell cycle in the presence of damaged DNA. <ul style="list-style-type: none">• p53 stimulates expression of the CDK inhibitor, preventing progression of the cell cycle. (The CDK inhibitor blocks the interaction between the CDK and cyclins.) | 1 point
2.B |
| <hr/> | | |
| (C) | Draw an X on the template in the space provided for your response to indicate the phase during which the replication of damaged DNA would occur. <ul style="list-style-type: none">• Must place an X on any portion of S | 1 point
2.D |
| <hr/> | | |
| (D) | Based on Figure 1, explain how a mutation to p53 may lead to an increased risk of cancer. <ul style="list-style-type: none">• A mutation may prevent activation of p53, which will then not stimulate the CDK inhibitor, allowing the cell cycle to progress through the cell cycle with damaged or mutated DNA. | 1 point
2.C |
-

Total for question 5 4 points

Question 6: Analyze Data**4 points****Learning Objectives:** ENE-2.G ENE-2.C

- | | | |
|------------|--|------------------------------|
| (A) | Identify the individual who most likely exhibits symptoms of cystinuria.
<ul style="list-style-type: none">• Individual 1 | 1 point
4.B |
| <hr/> | | |
| (B) | Describe the relationship between the total number of mutant alleles in an individual and the concentration of cysteine in the urine.
<ul style="list-style-type: none">• The more mutant alleles an individual has, the higher the concentration of cysteine in the urine. | 1 point
4.B |
| <hr/> | | |
| (C) | Evaluate the hypothesis that mutations in <i>SLC7 A9</i> have a greater effect on the transport of cysteine than do mutations in <i>SLC3 A1</i> .
<ul style="list-style-type: none">• The hypothesis is not supported by the data. While the individual with a single mutant allele for <i>SLC7 A9</i> has a higher concentration than the individual with a single mutant allele for <i>SLC3 A1</i>, the individual with two mutated <i>SLC7 A9</i> alleles does not have a higher concentration than one of the individuals with two mutant <i>SLC3 A1</i> alleles. | 1 point
5.D |
| <hr/> | | |
| (D) | Explain how the data support the claim that cysteine is a large polar molecule.
<ul style="list-style-type: none">• Cysteine builds up in the urine when the transporter proteins are mutated, which suggests that cysteine requires specific channel proteins through which to move, as do most large polar molecules. | 1 point
6.D |
-

Total for question 6 4 points

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