

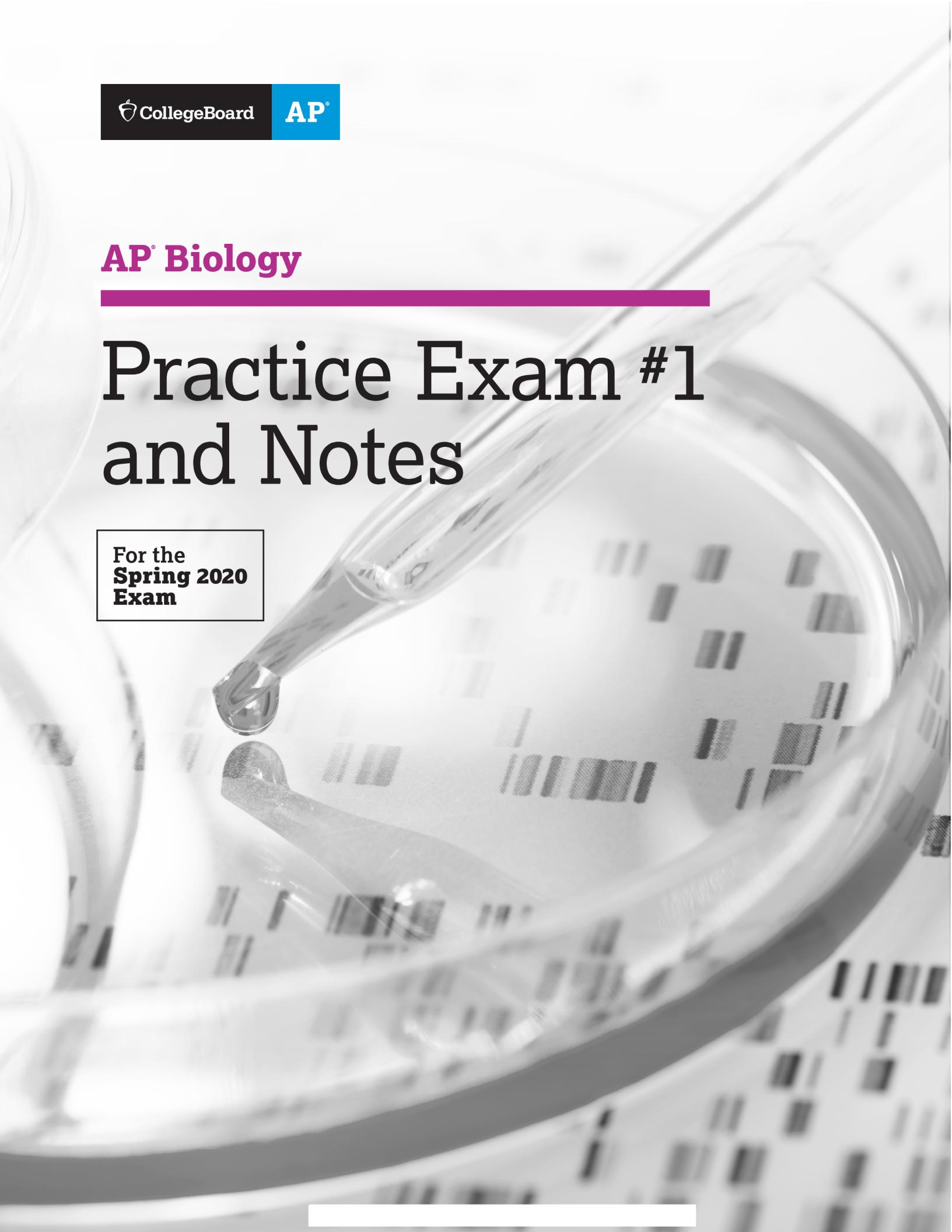


AP[®]

AP[®] Biology

Practice Exam #1 and Notes

For the
Spring 2020
Exam



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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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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

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

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

Standard Deviation

\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

<u>Factor</u>	<u>Prefix</u>	<u>Symbol</u>
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)

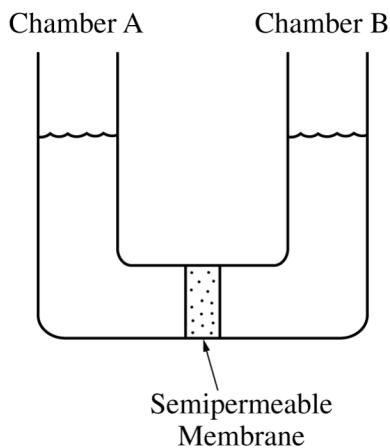
<p>Rate and Growth</p> <p>Rate</p> $\frac{dY}{dt}$ <p>Population Growth</p> $\frac{dN}{dt} = B - D$ <p>Exponential Growth</p> $\frac{dN}{dt} = r_{\max} N$ <p>Logistic Growth</p> $\frac{dN}{dt} = r_{\max} N \left(\frac{K - N}{K} \right)$	dY = amount of change dt = change in time B = birth rate D = death rate N = population size K = carrying capacity r_{\max} = maximum per capita growth rate of population	<p>Water Potential (Ψ)</p> $\Psi = \Psi_P + \Psi_S$ <p>Ψ_P = pressure potential</p> <p>Ψ_S = solute potential</p> <p>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.</p>
<p>Simpson's Diversity Index</p> <p>Diversity Index = $1 - \sum \left(\frac{n}{N} \right)^2$</p> <p>$n$ = total number of organisms of a particular species</p> <p>N = total number of organisms of all species</p>		
<p>Surface Area and Volume</p>		
<p>Surface Area of a Sphere</p> $SA = 4\pi r^2$ <p>Surface Area of a Rectangular Solid</p> $SA = 2lh + 2lw + 2wh$ <p>Surface Area of a Cylinder</p> $SA = 2\pi rh + 2\pi r^2$ <p>Surface Area of a Cube</p> $SA = 6s^2$		
<p>Volume of a Sphere</p> $V = \frac{4}{3}\pi r^3$ <p>Volume of a Rectangular Solid</p> $V = lwh$ <p>Volume of a Cylinder</p> $V = \pi r^2 h$ <p>Volume of a Cube</p> $V = s^3$		
r = radius l = length h = height w = width s = length of one side of a cube 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. Humans produce sweat as a cooling mechanism to maintain a stable internal temperature. Which of the following best explains how the properties of water contribute to this physiological process?

- (A) The high specific heat capacity of water allows the body to absorb a large amount of excess heat energy.
- (B) The high heat of vaporization of water allows the body to remove excess heat through a phase change of water from liquid to gas.
- (C) The high surface tension of water contributes to the physical process by which water leaves the body.
- (D) The high melting temperature of water allows the body to remove excess heat through a phase change of water from solid to liquid.



2. A student placed a semipermeable membrane inside a U-shaped channel with two chambers, as shown. The membrane permits the movement of water but not salt. The student wants to vary the rate of osmosis that occurs across the membrane. Which of the following experimental designs will result in the fastest net rate of water movement into chamber A?
- (A) Placing salt water in chamber A and distilled water in chamber B
 - (B) Placing distilled water in both chambers
 - (C) Placing distilled water in chamber A and salt water in chamber B
 - (D) Placing salt water in both chambers

GO ON TO THE NEXT PAGE.

3. Which of the following best describes the role of water in photosynthesis?
- (A) Water is the only source of protons for the formation of a proton gradient.
(B) Water molecules donate electrons to the electron transport chain.
(C) Water molecules combine with stored carbon molecules to produce glucose.
(D) Water is the terminal electron acceptor for electrons that pass through the electron transport chain.
4. What evolutionary advantage does compartmentalization of core metabolic processes offer eukaryotes?
- (A) Evolution of the mitochondria allowed eukaryotes to perform respiration.
(B) With the evolution of mitochondria in eukaryotes, the Krebs cycle and electron transport chain also evolved.
(C) Evolution of a nucleus in eukaryotes separates the processes of transcription and translation and they can be regulated separately.
(D) A nucleus in bacteria provides separation of respiration from transcription.

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NO TEST MATERIAL ON THIS PAGE

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Questions 5 - 8

Pyruvate dehydrogenase is an enzyme that converts pyruvate to acetyl-CoA. Acetyl-CoA is further metabolized in the Krebs cycle. A researcher measured the accumulation of acetyl-CoA in a reaction containing pyruvate and pyruvate dehydrogenase under several different conditions (Figure 1).

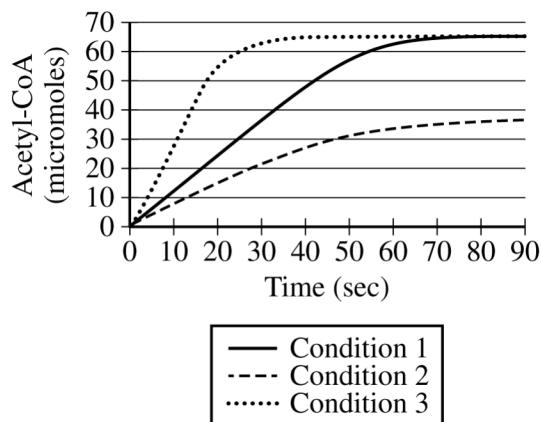


Figure 1. Accumulation of acetyl-CoA under different conditions

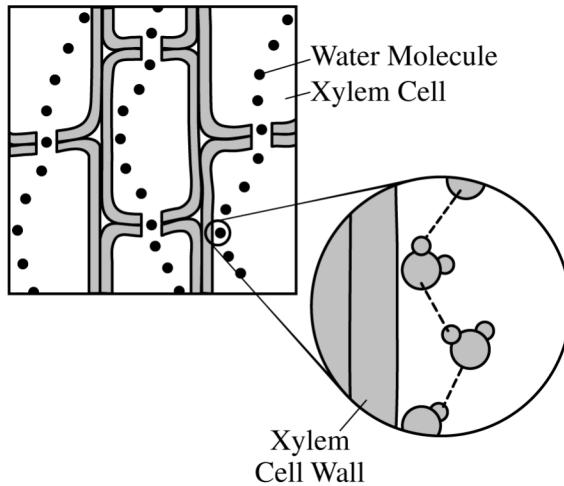
5. Which of the following best describes the cellular location where pyruvate dehydrogenase is most likely active?
- (A) The cytosol
 - (B) The lysosomes
 - (C) The nucleus
 - (D) The mitochondrial matrix
6. The maximum production rate of acetyl-CoA under condition 1 is closest to which of the following?
- (A) 1 micromole/sec
 - (B) 24 micromoles/sec
 - (C) 35 micromoles/sec
 - (D) 65 micromoles/sec
7. Which of the following observations provides the best evidence that acetyl-CoA negatively regulates pyruvate dehydrogenase activity?
- (A) The rate of the pyruvate dehydrogenase–catalyzed reaction is slower in the presence of a higher concentration of acetyl-CoA.
 - (B) The gene that encodes pyruvate dehydrogenase is transcribed when excess acetyl-CoA is detected.
 - (C) The accumulation of acetyl-CoA stops after 70 seconds, regardless of the reaction mixture.
 - (D) Acetyl-CoA is continuously broken down in the Krebs cycle.

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8. Pyruvate dehydrogenase deficiency is a genetic disease most commonly linked to a mutation in the α -subunit of the mitochondrial enzyme that causes the enzyme to cease functioning. As a result of the mutation, affected individuals build up dangerous amounts of lactic acid. Which of the following best explains the buildup of lactic acid in individuals with the mutation?

- (A) Cells use lactic acid to shunt electrons from pyruvate to the electron transport chain in the mitochondria.
 - (B) Cells undergo glycolysis because there is a buildup of pyruvate in affected individuals.
 - (C) Cells cannot transport pyruvate to the mitochondria in the absence of pyruvate dehydrogenase activity, so the pyruvate is broken down to lactic acid and ethanol.
 - (D) Cells undergo fermentation because pyruvate cannot be metabolized to proceed into the Krebs cycle.
-

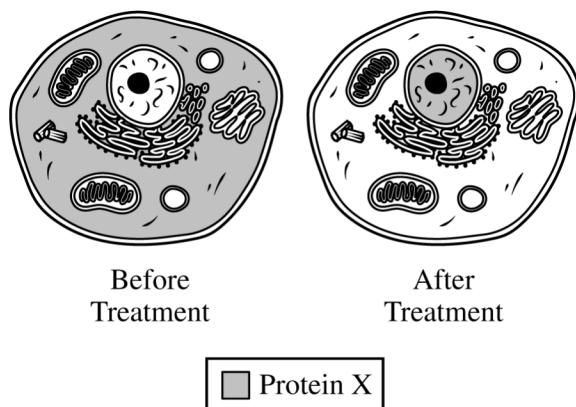
9. The diagram shows how water can adhere to the xylem in the stems of plants, which contributes to water movement in the plant. Which of the following best explains how water is able to move upward from the roots of a plant, through its xylem in the stem, and out to the leaves?



- (A) Water is polar, and the walls of the xylem are nonpolar. Water molecules have the ability to form hydrogen bonds with one another but not with the xylem walls.
- (B) Water is nonpolar, and the walls of the xylem are polar. Water molecules are able to form hydrogen bonds with the xylem walls, and they are pulled up the xylem.
- (C) Water and the xylem are both nonpolar. Water molecules have the ability to form hydrogen bonds with one another but not with the xylem walls.
- (D) Water and the xylem are both polar. Water molecules have the ability to form hydrogen bonds with each other and with the walls of the xylem.

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10. Protein X activates gene expression only in cells exposed to a specific signaling molecule. In a study, researchers determined the intracellular location of Protein X in cultured cells both before and after exposing the cells to the signaling molecule. The results of the study are shown in the diagram.



Based on the results, which of the following best describes what Protein X is?

- (A) Protein X is an RNA splicing enzyme.
- (B) Protein X is a cell membrane receptor protein.
- (C) Protein X is a transcription factor.
- (D) Protein X is a hormone.

11. The hormone prolactin has varying effects in many different animal species. All vertebrates produce prolactin, which is involved in signal transduction pathways. In mammals, prolactin stimulates the production of milk in mammary glands. In fish, prolactin plays an important role in osmoregulation. In birds, prolactin is involved in lipid metabolism.

Which of the following best explains the presence of prolactin in various vertebrate species?

- (A) Though all vertebrates produce prolactin, its varied uses indicate it arose as a result of convergent evolution and not as a result of common ancestry.
- (B) Prolactin is a homologous hormone because it has a common origin but different functions in various species.
- (C) Prolactin will bind only to intracellular receptors in animal species with phospholipid bilayers, so its effects are varied in different species.
- (D) Because of different receptors activating different signal transduction pathways within the same species, it is likely that prolactin production is a trait with highly selective pressure.

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Questions 12 - 17

Certain reef-building corals contain photosynthetic, symbiotic algae that have the ability to make dimethylsulphoniopropionate (DMSP), a chemical involved in the marine sulfur cycle. DMSP is released into the surrounding water, where it is converted to the gas dimethyl sulfide (DMS) by microorganisms and enters the atmosphere. Once in the atmosphere, it triggers the formation of sulfate aerosols, which induce cloud formation and block sunlight from heating up the water.

The symbiotic algae produce DMSP when they are stressed by a high water temperature. If water temperature is too high, corals will expel the symbiotic algae that produce DMSP. Researchers measured the amount of DMSP produced by juvenile and adult coral and their symbionts under normal and thermally stressed conditions. The data are shown in the graphs in Figure 1.

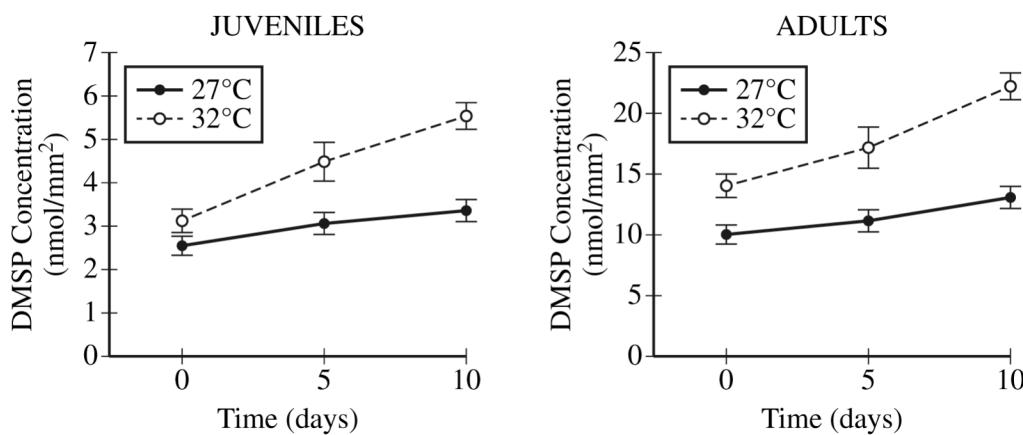


Figure 1: DMSP concentration in juvenile and adult corals and their symbionts in normal and thermally-stressed conditions. Error bars represent $\pm 2SE_{\bar{x}}$.

The researchers also measured the density of the symbiont as well as the photosynthetic yield in adult corals at the two temperatures. Photosynthetic yield is an index measure of energy output compared to sunlight energy input in which larger photosynthetic yield values represent photosynthetic organisms producing more energy.

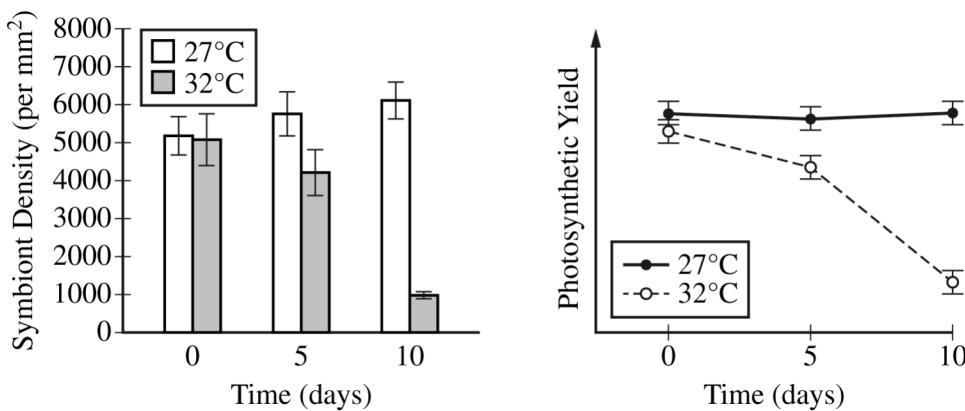


Figure 2: Variation in symbiont density and photosynthetic yield in adult corals grown in normal and thermally-stressed conditions. Error bars represent $\pm 2SE_{\bar{x}}$.

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12. Which of the following best describes the production of DMSP by coral and coral symbionts?
- (A) A negative feedback mechanism that increases the environmental change
(B) A negative feedback mechanism that reverses the environmental change
(C) A positive feedback mechanism that increases the environmental change
(D) A positive feedback mechanism that reverses the environmental change
13. Which of the following best describes the effect of temperature on corals' ability to produce DMSP as shown in Figure 1 ?
- (A) Both juvenile and adult corals produce less DMSP at 27°C than at 32°C.
(B) Both juvenile and adult corals produce less DMSP at 32°C than at 27°C.
(C) The amount of DMSP produced over time increases at 32°C in juveniles only.
(D) The amount of DMSP produced over time increases at 32°C in adults only.
14. Which of the following best describes the difference between the total amount of DMSP produced by adults compared to juveniles at the start of the 32°C trial?
- (A) Adult corals produced 3 times more DMSP than juveniles produced.
(B) Adult corals produced 3 times less DMSP than juveniles produced.
(C) Adult corals produced 5 times more DMSP than juveniles produced.
(D) Adult corals produced 5 times less DMSP than juveniles produced.
15. In addition to the effect of temperature on DMSP produced by corals and their symbionts, which of the following relationships is also being considered in this experiment?
- (A) Effect of varying light levels and coral species
(B) Effect of additional DMSP produced by symbionts and the corals' age
(C) Effect of age and varying light levels
(D) Effect of coral species and additional DMSP produced by symbionts
16. Which of the following best describes the scientists' findings concerning the density of symbionts presented in Figure 2 ?
- (A) The symbiont density at 32°C on day 5 was less than the density on day 0 of the experiment.
(B) The symbiont density at 27°C on day 0 was less than the density on day 5 of the experiment.
(C) The symbiont density at 32°C was different from the density at 27°C on days 5 and 10 of the experiment.
(D) The symbiont density at 27°C was higher than the density at 32°C for the entire length of the experiment.

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17. Which of the following best explains the result of adult corals being exposed to elevated temperatures for extended periods?
- They are able to obtain more energy from their symbionts because the algae are receiving more light.
 - They are able to obtain more energy from their symbionts because the efficiency increases slightly over time.
 - They are able to obtain less energy from their symbionts because the algae have been expelled.
 - They are able to obtain less energy from their symbionts because more DMSP is being produced at lower temperatures.
-
18. A particular gene has two alleles, a dominant allele *A* and a recessive allele *a*. The frequency of allele *A* is 0.55. If the population is in Hardy-Weinberg equilibrium with respect to the gene, then what is the expected frequency of genotype *Aa*?
- 0.203
 - 0.303
 - 0.405
 - 0.495

19. A particular genetic disorder results from a single change in the amino acid sequence coded for in a gene. Parts of the sequence in normal and mutated genes are shown below.

Normal: TAC CTC GTG GAC TGA GGT CTC

Mutated: TAC CTC GTG GAC TGA GGT CAC

		Second Base				Third Base
		U	C	A	G	
First Base	U	Phe Phe Leu Leu	Ser Ser Ser Ser	Tyr Tyr Stop Stop	Cys Cys Stop Trp	U C A G
	C	Leu Leu Leu Leu	Pro Pro Pro Pro	His His Gln Gln	Arg Arg Arg Arg	U C A G
	A	Ile Ile Ile Met	Thr Thr Thr Thr	Asn Asn Lys Lys	Ser Ser Arg Arg	U C A G
	G	Val Val Val Val	Ala Ala Ala Ala	Asp Asp Glu Glu	Gly Gly Gly Gly	U C A G

Based on the codon chart above, which of the following amino acid changes is most likely found in the mutated protein?

- Glu → Val
- Val → Glu
- Glu → Pro
- Pro → Val

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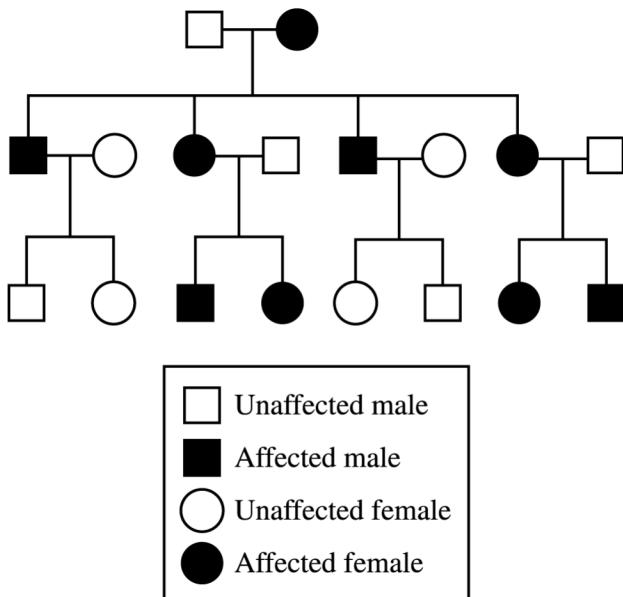


Figure 1. A pedigree of three generations of a family that have a high frequency of a particular genetic condition

20. Figure 1 shows the inheritance of a particular genetic condition in three generations of one family. Which of the following best explains the observed pattern of inheritance?
- The condition is passed randomly because of the independent assortment of chromosomes.
 - The condition is passed from fathers to sons via a Y-linked gene.
 - The condition is passed from mothers to sons via an X-linked gene.
 - The condition is passed from mothers to offspring via a mitochondrial gene.
21. Oncogenes are genes that can cause tumor formation as a result of a particular mutation. Which of the following potential therapies would be most effective at preventing the expression of an oncogene?
- Reducing the number of ribosomes in the cell to prevent the creation of the oncogene's proteins
 - Blocking membrane-bound receptors of transcription factors
 - Introducing a chemical that binds to transcription factors associated with the oncogene's promoter
 - Producing additional transcription factors for tumor suppressor genes in the cell
22. Ultraviolet (UV) radiation can damage DNA by breaking weak bonds. Which of the following best explains how this occurs?
- UV radiation disrupts the double helix structure by breaking the covalent bonds between the nitrogenous base pairs.
 - UV radiation disrupts the double helix structure by breaking the hydrogen bonds between the nitrogenous base pairs.
 - UV radiation is able to break DNA strands in two by breaking covalent bonds between the sugar-phosphate backbone molecules.
 - UV radiation is able to break DNA strands in two by breaking hydrogen bonds between the sugar-phosphate backbone molecules.

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23. Scientists are interested in determining the evolution of seven lizard species found on different islands of the Canary Island group. They isolated DNA from individuals of each species and sequenced the mitochondrial gene that encodes cytochrome *b*. The numbers of genetic differences between species are shown in the table below.

	Species A	Species B	Species C	Species D	Species E	Species F	Species G
Species A							
Species B	34						
Species C	39	23					
Species D	38	21	6				
Species E	38	17	8	4			
Species F	43	22	17	17	13		
Species G	47	26	17	19	15	2	

Based on the data in the table, which of the following lizard species are most closely related?

- (A) Species C and species B
- (B) Species E and species D
- (C) Species F and species B
- (D) Species G and species A

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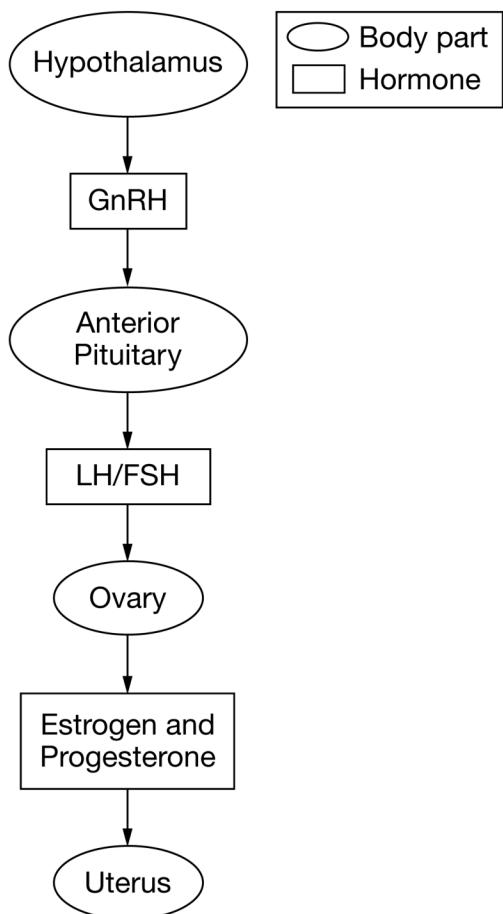


Figure 1. A model of an endocrine signaling pathway showing involved body parts and hormones. GnRH = gonadotropin-releasing hormone, LH = luteinizing hormone, and FSH = follicle-stimulating hormone.

24. Figure 1 shows a model of the endocrine signaling pathway that regulates ovulation. Which of the following observations would provide evidence of a positive feedback mechanism in this system?
- Estrogen from the ovaries inhibits the release of GnRH from the hypothalamus.
 - Progesterone from the ovaries stimulates the thickening of the uterine lining.
 - Progesterone from the ovaries inhibits the release of LH and FSH from the anterior pituitary.
 - Estrogen from the ovaries stimulates the hypothalamus and anterior pituitary to secrete more GnRH, LH, and FSH.

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Questions 25 - 28

Dichlorophenolindophenol (DCPIP) is a chemical dye. When DCPIP is chemically reduced, it changes color from blue to clear. DCPIP can be used as an electron acceptor in experiments that measure the rate of electron transport through the electron transport chain. A student performed an experiment to study the effects of a chemical, DCMU, on photosynthesis.

The student prepared four tubes with a liquid buffer and chloroplasts that had been extracted from spinach leaves. The student then added DCPIP to three of the tubes and added DCMU to one of them. Additionally, tube 3 was wrapped in tin foil. The contents of each tube are shown in the table. The student then incubated each tube for 60 minutes and measured the absorbance (A_{600}) of each solution at five-minute intervals. The absorbance readings of each solution are shown in Figure 1.

Tube 1:	Buffer and water
Tube 2:	DCPIP, buffer, and water
Tube 3:	DCPIP, buffer, and water (wrapped in foil)
Tube 4:	DCPIP, buffer, and 1.0 mM DCMU

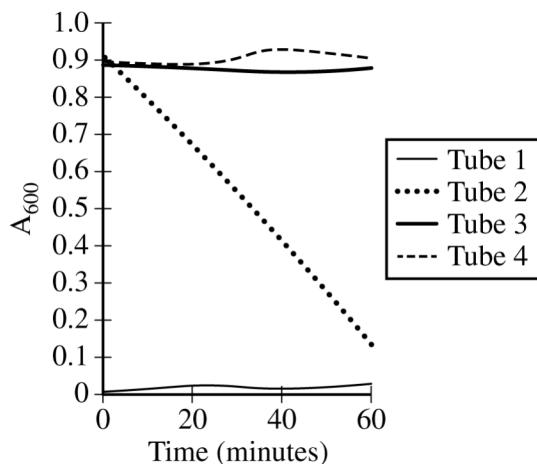


Figure 1. Absorbance readings of four prepared tubes with various solutions over a 60-minute period.

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25. In which of the following tubes did the greatest reduction of DCPIP occur after 60 minutes?
- (A) Tube 1
(B) Tube 2
(C) Tube 3
(D) Tube 4
26. Which of the following claims is best supported by the experimental results?
- (A) Light is required for the electron transport chain to transfer electrons.
(B) Water, not carbon dioxide, is the source of electrons used in the light-dependent reaction of photosynthesis.
(C) Carbon dioxide is the source of carbon used by green plants to build carbohydrates.
(D) DCPIP provides a significant source of electrons to the electron transport chain of the light reaction in the absence of light.
27. Which of the following best explains how DCMU affected the reaction?
- (A) DCMU acts as a second buffer in the reaction.
(B) DCMU acts as an additional carrier of electrons from photosystem II to DCPIP.
(C) DCMU acts as an additional source of electrons to the light reaction of photosynthesis.
(D) DCMU acts as an inhibitor to the movement of electrons within the light reaction of photosynthesis.
28. Which of the following best justifies the use of tube 2 as a control treatment?
- (A) It was a negative control for the accuracy of the spectrophotometer, ensuring that an accurate reading for treatment cuvette 2 would be made.
(B) It was a negative control for the chemical stability of the chlorophyll suspension, ensuring that changes in absorbance could only be attributed to changes in chlorophyll content.
(C) It was a positive control for the change in DCPIP color associated with changes in light intensity.
(D) It was a positive control for measuring the effect of DCMU on the reaction.

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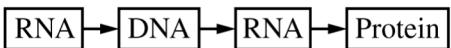
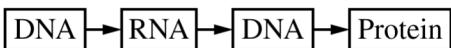
29. A scientist designed an experiment to test an artificial membrane that mimics the phospholipid bilayer of a cell.

The scientist built a tube that was divided by an artificial membrane and filled with distilled water. The scientist put a known amount of a protein into the water on one side of the membrane. After some time, the scientist measured the concentration of the protein on either side of the membrane but found that there had been no change.

Which of the following experimental changes would allow the scientist to observe transport of a solute across the artificial membrane?

- (A) Increase the solute concentration in the solution
- (B) Use a small, nonpolar solute instead of a protein
- (C) Increase the temperature of the solution
- (D) Add artificial aquaporins to the membrane

30. Which of the following best illustrates the flow of information required for the synthesis of proteins encoded in the genome of a retrovirus?

- (A) 
- (B) 
- (C) 
- (D) 

31. Which of the following best describes the process by which gas from the atmosphere is obtained by plants and used to build lipids?

- (A) Gas is fixed by plants as part of the sulfur cycle.
- (B) Gas is fixed by plants as part of the nitrogen cycle.
- (C) Gas is directly obtained by plants as part of the carbon cycle.
- (D) Gas is directly obtained by plants as part of the magnesium cycle.

32. Which of the following best explains how the phospholipid bilayer of a transport vesicle contributes to cellular functions?

- (A) The phospholipid bilayer allows the vesicle to fuse with the Golgi apparatus and the plasma membrane, allowing the exocytosis of proteins.
- (B) The phospholipid bilayer physically connects the nuclear envelope to the rough endoplasmic reticulum, thus increasing the rate of transcription and translation.
- (C) The phospholipid bilayer of a transport vesicle contains chemicals that digest the proteins made in the rough endoplasmic reticulum.
- (D) The phospholipid bilayer contains enzymes that catalyze the conversion of hydrogen peroxide to water and oxygen.

33. The diploid number of chromosomes in the cell of a domesticated dog is 78. Which of the following options includes the correct number of chromosomes in a cell after each cellular process (G_2 checkpoint, meiosis, and fertilization, respectively)?

	After G_2 Checkpoint	After Meiosis	After Fertilization
(A)	156	78	39
(B)	78	39	78
(C)	156	39	78
(D)	78	78	39

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34. Scientists were interested in testing the effects of rotenone, a broad-spectrum pesticide, on a cell culture. Cell culture A was used as a control, while culture B was treated with rotenone. After a period of time, the scientists measured the concentration of several metabolites in the mitochondria of cells in both cultures. Their results are shown in the table below.

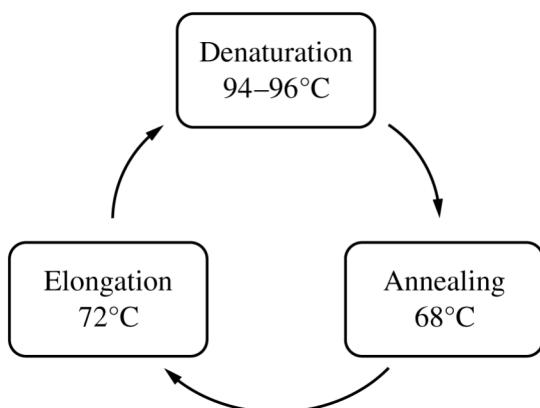
Metabolites	Concentration in Culture A (μM)	Concentration in Culture B (μM)
Pyruvate	25	25
NADH	55	550
NAD^+	55	5
ATP	85	5
ADP+P_i	55	100
FADH_2	25	26
FAD	25	25

Based on the data in the table, which of the following best explains the effects of rotenone on cellular respiration?

- (A) Rotenone acts as an inhibitor of the enzymes in the Krebs cycle.
- (B) NADH, produced during glycolysis, is not able to enter the mitochondria because transport proteins are blocked from entering.
- (C) Treated cells are not able to break down NADH because certain enzymes of the electron transport chain are inhibited.
- (D) Rotenone acts as an allosteric inhibitor of glycolytic enzymes, thus inhibiting cellular respiration.

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35. Which of the following best explains why triploid bananas do not produce seeds?
- The cells of the banana plant are unable to replicate DNA, thus preventing cell division and limiting growth.
 - The banana plants lack enough genetic diversity to properly hybridize.
 - The production of gametes is disrupted because of unequal pairing of homologous chromosomes during meiosis.
 - The production of seeds is not required because triploid plants produce gametes without fertilization.
36. PCR is a technique used to copy a target DNA sequence. Researchers often use DNA polymerase from *Thermus aquaticus*, a bacteria species that lives around hydrothermal vents.



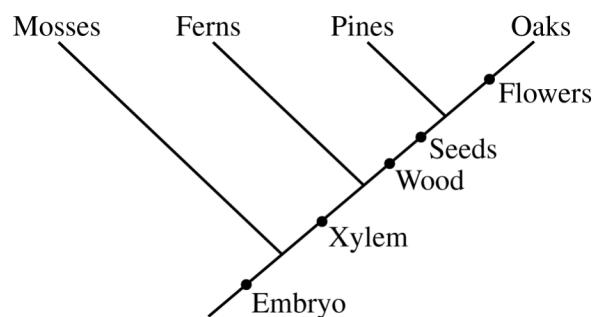
Which of the following best explains why the polymerase from the species *T. aquaticus* is often used for PCR?

- T. aquaticus* polymerase has an optimal temperature of 68°C.
- T. aquaticus* polymerase does not denature at high temperatures.
- T. aquaticus* polymerase can be used more than once without degrading.
- T. aquaticus* polymerase adds nucleotides to both the 3' and 5' ends of DNA.

37. A researcher is studying two different species. Which of the following sets of observations would best support the claim that the two species have structural similarities as a result of convergent evolution?

	Genetic Similarity	Function of Structure	Form of Structure
(A)	Low	Same	Different
(B)	Low	Different	Same
(C)	High	Same	Different
(D)	High	Different	Same

38. The cladogram shows shared traits among four plant taxa.



Based on the cladogram, which of the following are the traits shared between ferns and pines?

- Xylem only
- Seeds and wood only
- Embryo and xylem only
- Embryo, xylem, wood, and seeds only

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39. Snapdragons are a type of flowering plant. The flower color of the plants is determined by a single gene with two alleles: an incompletely dominant R allele and a recessive r allele. Researchers established a new population of snapdragon plants that they hypothesize will be in Hardy-Weinberg equilibrium. At the start of the study, the researchers randomly picked 100 individuals from a large population and recorded their flower color. They planted the snapdragons in an isolated area and returned after seven generations had passed. They randomly sampled 100 plants from the population and recorded their flower color. The results are shown in the table.

DISTRIBUTION OF SNAPDRAGON FLOWER COLOR PHENOTYPES			
Time	Number of Red (RR) Snapdragons	Number of Pink (Rr) Snapdragons	Number of White (rr) Snapdragons
At the start of study	34	43	23
After seven generations	39	34	27

The researchers performed a chi-square analysis to test their hypothesis. Assuming the researchers use a significance level of 0.05, which of the following is closest to the critical value the researchers should use in the chi-square analysis?

- (A) 3.84
- (B) 5.99
- (C) 7.82
- (D) 9.49

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Questions 40 - 44

Sea otters are native to the western coast of North America. Between 1750 and 1850, hunting had reduced the population from hundreds of thousands to only one thousand individuals. In the early 1900s, a small population of sea otters was discovered in Elkhorn Slough, an estuary in central California near a large human population center. The otters were then protected by the international fur seal treaty, which banned sea otter hunting. The sea otter population has rebounded to nearly three thousand individuals today.

Otters live in kelp forests and eelgrass beds and feed on crabs and shellfish (Figure 1). Most herbivores in the habitat eat algae that grows on the eelgrass and not the eelgrass itself. If there is too much algae, the eelgrass does not receive enough light for photosynthesis. As the otter population has increased, the eelgrass habitat has increased.

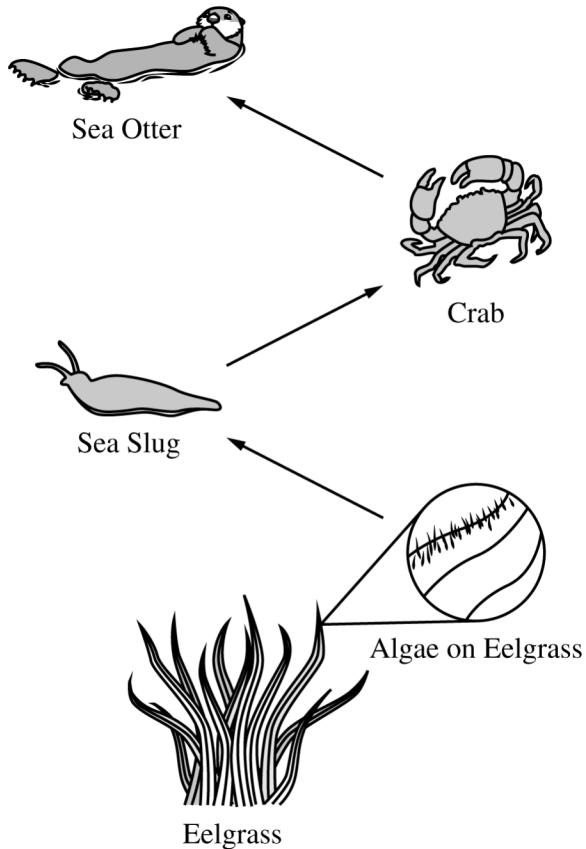


Figure 1. Partial food chain in eelgrass habitats

Recently, however, scientists have noticed the presence of two nonnative, predatory invertebrate species that may be colonizing the Elkhorn Slough, which would have been too cold for them three decades ago. Scientists have also observed that otters in the area are experiencing increased mortality because of an increase in harmful algal blooms, which occur as a result of nutrient pollution. The harmful algae are ingested by shellfish, which the otters eat.

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40. Which of the following best describes what happened to the otter population between 1750 and 1850 ?
- (A) The population decreased in size as a result of a loss of genetic diversity.
(B) The population decreased in size as a result of habitat loss.
(C) The population lost genetic diversity as a result of a bottleneck effect.
(D) The population lost genetic diversity as a result of the founder effect.
41. Based on the information provided in the passage, which of the following best describes the effect of harmful algal blooms on otter populations?
- (A) They are a density-dependent factor that increases otter mortality in larger populations.
(B) They are a density-dependent factor that reduces otter numbers at lower population sizes.
(C) They are a density-independent factor that negatively affects the otter population regardless of its size.
(D) They are a density-independent factor that increases otter mortality in only larger populations.
42. As otters were removed during the hunting years, there was a large decrease in the catches of fish species from the eelgrass habitats. Which of the following best explains why this decrease happened?
- (A) Otters are a keystone species, so their disappearance from the area affected the population size of one other species.
(B) Otters are a keystone species, so their disappearance from the area resulted in the collapse of an entire community.
(C) Otters have mutualistic relationships with many other species, so their disappearance from the area affected the population size of another species.
(D) Otters have mutualistic relationships with many other species, so their disappearance from the area resulted in the collapse of an entire ecosystem.
43. Climate change could affect the ecosystem of the Elkhorn Slough in many ways. From the information provided, which of the following predictions about the direct, local effects of climate change is most likely?
- (A) Ocean warming will favor population growth of nonnative species as their habitats shift northward.
(B) Ocean warming will decrease eelgrass habitat area as a result of increased herbivory by nonnative species.
(C) Harmful algal blooms will decrease otter populations as a result of increased mortality of otter prey species.
(D) Harmful algal blooms will decrease the availability of nutrients for eelgrass and other algae species.

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44. Based on the information, an increase in the sea slug population would most likely be directly related to which of the following?
- (A) An increase in the eelgrass population
(B) The introduction of nonnative invertebrates
(C) A decrease in algae availability
(D) A decrease in the crab population
-
45. Many fish species, such as fathead minnows, release a pheromone when their skin cells are damaged. Researchers placed pike, a predator of fathead minnows, in a choice chamber and released the minnow pheromone at one end of the chamber. The researchers observed that the pike oriented themselves toward the end of the chamber where the pheromone was released.

Which of the following questions will best guide a follow-up investigation about the role of pheromones in locating prey?

- (A) How do pike determine that the fathead minnow pheromone is present in the water?
(B) Why do pike prey on fathead minnows?
(C) Do pike have natural predators in the environment?
(D) Do pike release pheromones that are detected by fathead minnows?

46. Which of the following best explains why a cell's plasma membrane is composed of two layers of phospholipids rather than just a single layer?
- (A) Having two oppositely oriented layers of phospholipids allows only the hydrophilic heads to interact with water inside and outside of the cell.
(B) Having two oppositely oriented layers of phospholipids allows the hydrophilic heads to repel water both inside and outside of the cells.
(C) Having two identically oriented layers of phospholipids gives cells more protection from the exterior environment than just a single layer would.
(D) Having two identically oriented layers of phospholipids allows for the production of vacuoles while still maintaining a protective barrier.

47. A student calculated the average surface area-to-volume ratio of four different types of human epithelial cells. The results are shown in the table below.

Cell Type	Surface Area-to-Volume Ratio
Simple squamous	9
Simple cuboidal	6
Simple columnar	4
Simple spherical	3

Based on the data, which type of cell would be best suited for the lining the alveoli of the lungs, where diffusion of carbon dioxide and oxygen must occur very rapidly?

- (A) Simple squamous cells
(B) Simple cuboidal cells
(C) Simple columnar cells
(D) Simple spherical cells

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48. Which of the following best explains how the extensive folding of the inner mitochondrial membrane benefits a eukaryotic cell?
- (A) It enlarges the volume of the matrix, which allows for more enzymatic reactions.
 - (B) It increases the area available for proteins involved in energy transfer.
 - (C) It allows for greater area for the diffusion of water into and out of the mitochondria.
 - (D) It provides better insulation for reactions in the matrix from conditions outside the mitochondria.

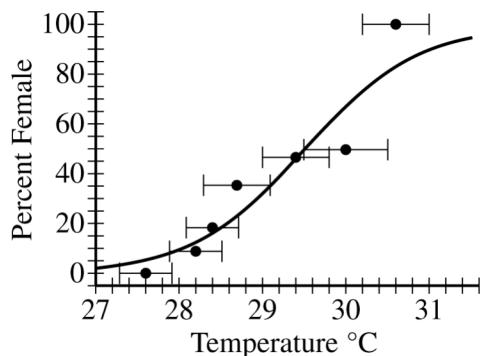


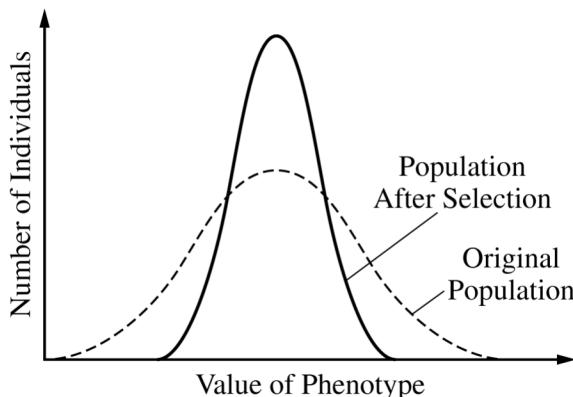
Figure 1. Percentage of sea turtles that develop as females at different average nest temperatures. The bars represent the temperature range observed within the nests.

49. Some green sea turtle females deposit their eggs in nests that are dug on warm, tropical beaches. Researchers have studied the effects of temperature on the hatching rate and the proportion of female to male hatchlings produced at different average nest temperatures in Suriname (Figure 1). At temperatures below 23°C or above 33°C, the eggs do not develop.

Which of the following best describes the results shown in Figure 1 ?

- (A) The percentage of hatchlings that survive to adulthood is directly proportional to average nest temperature.
- (B) Female sea turtles search for cooler beaches in order to have more male offspring.
- (C) Warmer nests produce more female sea turtles than do cooler nests.
- (D) The sex ratio of sea turtles is genetically determined.

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50. Which of the following describes a scenario that would result in the phenotypic change shown in the graph?
- A fish that has mouth parts adapted to eat moderately sized prey is introduced into a lake in which there are only large and small prey.
 - A population of mice live on the ground and in short trees. An invasive, tree-dwelling snake that preys on the mice is introduced into the area.
 - Climate change-induced warming of arctic tundra reduces average snow cover that lighter-colored arctic foxes rely on for camouflage. Darker-colored arctic foxes are better suited to the exposed moss and grass habitat.
 - House sparrows that lay smaller-than-average clutches of eggs produce fewer viable offspring, while larger-than-average clutches of eggs result in malnourished chicks that have a higher mortality rate.

51. Researchers have identified a molecule produced by *Ecteinascidia turbinata*, a marine invertebrate, from which the drug trabectedin is produced. Soft-tissue tumors treated with trabectedin rapidly decrease in size. In a preliminary study, healthy cells and tumor cells sampled from skin cancer patients treated with trabectedin were collected, and several characteristics of the cells were observed. The observed results of the study are shown in the table.

Characteristic	Healthy Cell	Tumor Cell
DNA (in picograms)	12 pg	6 pg
Nuclear envelope	Thinning	Present
Nucleolus	Absent	Present
Cyclin level	High	Low
General appearance	Round, firm	Shrunken

Which of the following best explains the most likely method by which this antitumor drug works?

- Trabectedin increases the production of cyclin proteins that signal the cancer cells to enter prophase.
- Trabectedin interferes with the plasma membrane, causing it to break down and expose the DNA to damage.
- Trabectedin interferes with the duplication of DNA during interphase and thus prevents cancer cells from passing the G₂ checkpoint.
- Trabectedin interferes with the regulations of cyclin proteins, causing their levels to increase and creating errors in DNA.

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NO TEST MATERIAL ON THIS PAGE

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Questions 52 - 56

Friedreich's ataxia is an inherited disorder. Friedreich's ataxia is caused by an insertion mutation in a noncoding portion of the *FXN* gene where a GAA triplet is repeated hundreds of times. The *FXN* gene encodes the protein frataxin. A pedigree of a family with members affected by this disorder is shown in Figure 1.

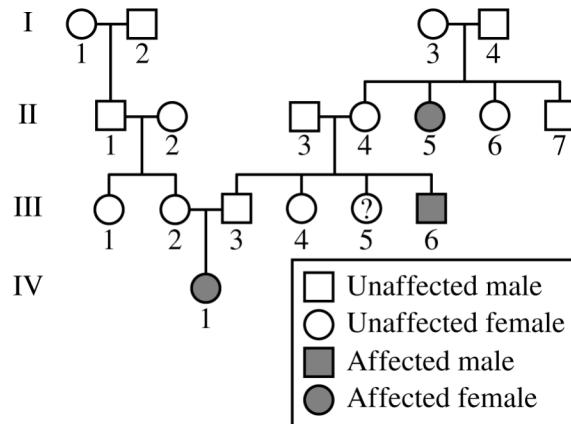


Figure 1. A pedigree of a family affected by Friedreich's ataxia

A researcher collected DNA from several members of the family and used PCR to amplify the *FXN* genes from each individual's DNA. The researcher then used DNA gel electrophoresis to separate the DNA. The results are shown in Figure 2.

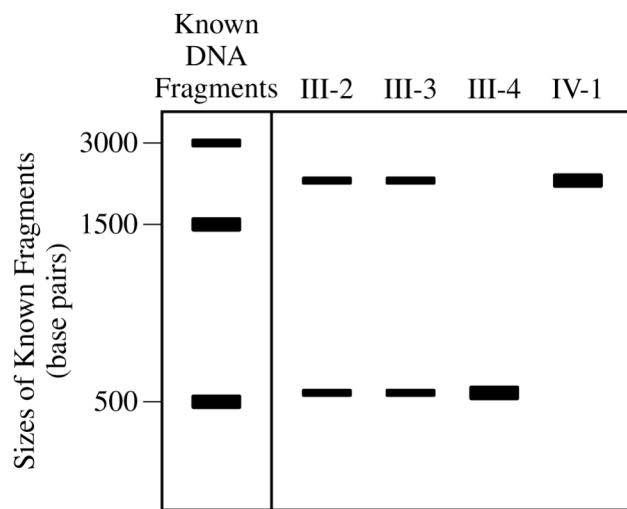


Figure 2. *FXN* gene fragment sizes for several family members. A sample of DNA with fragments of known lengths was used for comparison.

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The researcher also used a computer to model the structure of the mutant *FXN* allele. The model suggests that the repeated GAA triplets in the mutant *FXN* gene may lead to the formation of an unusual triple-stranded configuration of DNA (Figure 3).

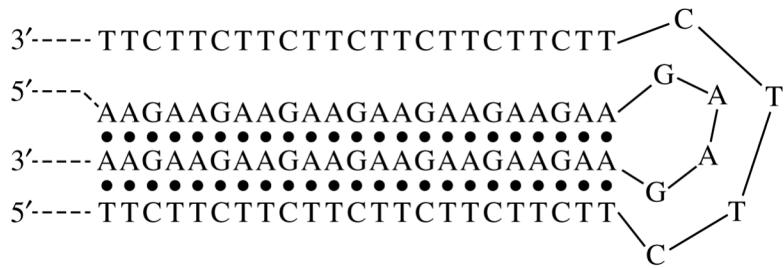


Figure 3. The modeled DNA triple-helix structure that can form in areas with multiple GAA triplets

52. Based on the data in Figure 1, which of the following best describes the inheritance pattern of Friedreich's ataxia?
- (A) Autosomal recessive
(B) Autosomal dominant
(C) Sex-linked recessive
(D) Sex-linked dominant
53. The probability that individual III-5 will develop Friedreich's ataxia is closest to which of the following?
- (A) 0%
(B) 25%
(C) 50%
(D) 75%
54. Which of the following statements best describes the results seen in Figure 2?
- (A) Individuals III-2 and III-3 carry two different alleles of the *FXN* gene, a mutant allele and a wild-type allele. Individual IV-1 inherited two copies of the mutant allele.
(B) Individuals III-2 and III-3 carry two different alleles of the *FXN* gene, a mutant allele and a wild-type allele. Individual IV-1 inherited two copies of the wild-type allele.
(C) Individuals III-2 and III-3 both carry two wild-type alleles. Individual IV-1 inherited two copies of the wild-type allele.
(D) Individuals III-2 and III-3 both carry two wild-type alleles, but individual IV-1 inherited one copy of the wild-type allele and one copy of the mutant allele.

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55. Which of the following best describes the most likely effect of the formation of a triplex DNA structure (Figure 3) on the synthesis of the frataxin protein?
- (A) The binding of the ribosome to the mRNA is prevented, resulting in a decrease in frataxin translation.
- (B) The DNA will not degrade in the cytoplasm, leading to an increase in frataxin translation.
- (C) RNA polymerase is prevented from binding to the DNA, resulting in a decrease in frataxin mRNA transcription.
- (D) The protein will include extra amino acids, resulting in a protein with an altered secondary structure.
56. Which of the following types of bonds is most likely responsible for the unusual base pairing shown in Figure 3 that results in the formation of a triplex DNA structure?
- (A) Hydrogen
- (B) Polar covalent
- (C) Ionic
- (D) Nonpolar covalent

57. A scientist is studying a population of lizards with three different color phenotypes. The color phenotype is controlled by a single gene with two alleles: an incompletely dominant allele *A* and a recessive allele *a*. The scientist collected data on the color of 100 lizards. The data are shown in the table.

Phenotype	Genotype	Number Observed
Red	<i>AA</i>	75
Purple	<i>Aa</i>	15
Blue	<i>aa</i>	10

To test the hypothesis that the population is at Hardy-Weinberg equilibrium, the scientist performed a chi-square test.

Which of the following values is closest to the chi-square value the scientist calculated?

- (A) 0.1
- (B) 1.9
- (C) 18.3
- (D) 23.1

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58. Scientists compared the chemical structure of several molecules that various bacterial species use for quorum sensing. Quorum sensing is an ability some bacteria have to detect the number of related cells nearby. The chemical structure of some of these molecules found in certain species of bacteria are shown in Figure 1.

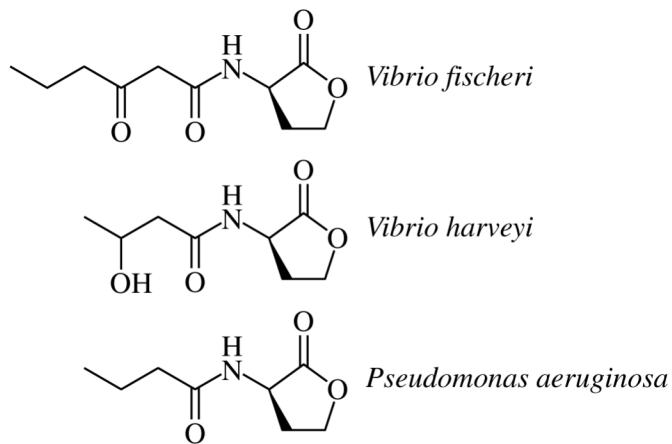


Figure 1. The chemical structure of several molecules used for quorum sensing in three species of bacteria

Which of the following research questions would best guide an investigation of the link between the structure of the signaling molecules and the evolution of quorum sensing?

- (A) Do these molecules require the same receptors in each bacteria species to generate a response?
 - (B) Did these species evolve from a common ancestor that used a similar signaling molecule?
 - (C) Do these species all perform the same action when the concentration of the signaling molecules is high enough?
 - (D) Did these species evolve from the same common ancestor that is still living today and uses the same receptors?
59. Carbon dioxide most likely enters a cell through which of the following processes?
- (A) Simple diffusion through the membrane
 - (B) Facilitated diffusion through membrane proteins
 - (C) Active transport through membrane proteins
 - (D) Active transport through aquaporins

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60. In pea seeds, yellow color (Y) is dominant to green color (y), and a round shape (R) is dominant to a wrinkled shape (r). A dihybrid cross between a true-breeding plant with yellow, round seeds ($YYRR$) and a true-breeding plant with green, wrinkled seeds ($yyrr$) results in an F_1 generation of plants with yellow, round seeds. Crossing two F_1 plants produces an F_2 generation with approximately nine times as many plants with yellow, round seeds as plants with green, wrinkled seeds.

Which of the following best explains these results?

- (A) The allele pairs of each parent stay together, resulting in gametes that are identical to the parents.
- (B) Gene segments on sister chromatids cross over.
- (C) Alleles that are on nonhomologous chromosomes recombine.
- (D) The genes for seed color and seed shape assort independently.

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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

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

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

Standard Deviation

\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

<u>Factor</u>	<u>Prefix</u>	<u>Symbol</u>
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)

<p>Rate and Growth</p> <p>Rate</p> $\frac{dY}{dt}$ <p>Population Growth</p> $\frac{dN}{dt} = B - D$ <p>Exponential Growth</p> $\frac{dN}{dt} = r_{\max} N$ <p>Logistic Growth</p> $\frac{dN}{dt} = r_{\max} N \left(\frac{K - N}{K} \right)$	<p>dY = amount of change</p> <p>dt = change in time</p> <p>B = birth rate</p> <p>D = death rate</p> <p>N = population size</p> <p>K = carrying capacity</p> <p>r_{\max} = maximum per capita growth rate of population</p>	<p>Water Potential (Ψ)</p> <p>$\Psi = \Psi_P + \Psi_S$</p> <p>Ψ_P = pressure potential</p> <p>Ψ_S = solute potential</p> <p>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.</p>																								
<p>Simpson's Diversity Index</p> <p>Diversity Index = $1 - \sum \left(\frac{n}{N} \right)^2$</p> <p>$n$ = total number of organisms of a particular species</p> <p>N = total number of organisms of all species</p>																										
<p>Surface Area and Volume</p>																										
<table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 33%;">Surface Area of a Sphere</td> <td style="width: 33%;">Volume of a Sphere</td> <td style="width: 33%;">r = radius</td> </tr> <tr> <td>$SA = 4\pi r^2$</td> <td>$V = \frac{4}{3}\pi r^3$</td> <td>l = length</td> </tr> <tr> <td>Surface Area of a Rectangular Solid</td> <td>Volume of a Rectangular Solid</td> <td>h = height</td> </tr> <tr> <td>$SA = 2lh + 2lw + 2wh$</td> <td>$V = lwh$</td> <td>w = width</td> </tr> <tr> <td>Surface Area of a Cylinder</td> <td>Volume of a Cylinder</td> <td>s = length of one side of a cube</td> </tr> <tr> <td>$SA = 2\pi rh + 2\pi r^2$</td> <td>$V = \pi r^2 h$</td> <td>SA = surface area</td> </tr> <tr> <td>Surface Area of a Cube</td> <td>Volume of a Cube</td> <td>V = volume</td> </tr> <tr> <td>$SA = 6s^2$</td> <td>$V = s^3$</td> <td></td> </tr> </table>			Surface Area of a Sphere	Volume of a Sphere	r = radius	$SA = 4\pi r^2$	$V = \frac{4}{3}\pi r^3$	l = length	Surface Area of a Rectangular Solid	Volume of a Rectangular Solid	h = height	$SA = 2lh + 2lw + 2wh$	$V = lwh$	w = width	Surface Area of a Cylinder	Volume of a Cylinder	s = length of one side of a cube	$SA = 2\pi rh + 2\pi r^2$	$V = \pi r^2 h$	SA = surface area	Surface Area of a Cube	Volume of a Cube	V = volume	$SA = 6s^2$	$V = s^3$	
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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.

1. Scientists studying transcription in yeast (*Saccharomyces cerevisiae*) created an experimental strain that produced a modified RNA polymerase containing a single amino acid substitution. The scientists determined the maximum elongation rate during transcription with and without the modified RNA polymerase enzyme (Figure 1).

The compound amanitin, which is commonly found in toxic mushrooms, is a specific RNA polymerase inhibitor. Amanitin binds to the RNA polymerase active site and inhibits transcription. In a second experiment, the scientists treated the wild-type and experimental strains of *S. cerevisiae* with a 40 µg / mL solution of amanitin and recorded the maximum elongation rate of the mRNA (Figure 2). Error bars represent $\pm 2SE_{\bar{x}}$.

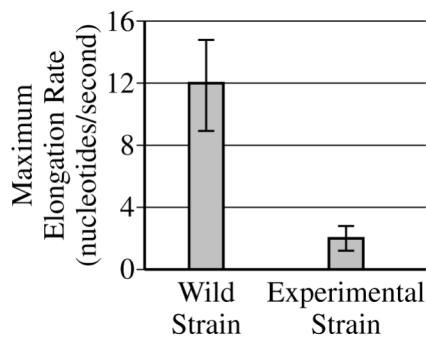


Figure 1. Maximum elongation rate under natural conditions

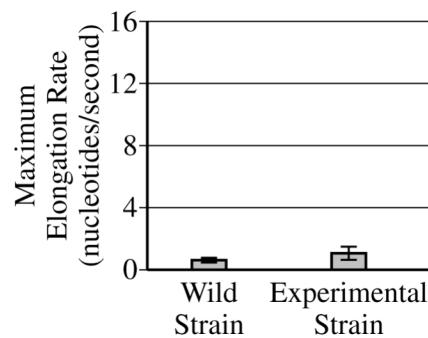


Figure 2. Maximum elongation rate in a 40 µg / mL amanitin solution

- (a) **Describe** the three structural components of an RNA nucleotide monomer. **Explain** the role of RNA polymerase during transcription.
- (b) **Identify** the dependent variable in the experiments. **Identify** a control group missing from the second experiment. **Justify** the need for this control group in the second experiment.
- (c) **Describe** the effect of amanitin on the maximum elongation rate for the wild-type and modified RNA polymerases. **Determine** the ratio of the average maximum elongation rate for the modified RNA polymerase compared to the wild strain RNA polymerase in Figure 1.
- (d) **State the null hypothesis** for the experiment in Figure 1. **Provide reasoning to justify** the claim that the change in the amino acid sequence in the modified RNA polymerase affected the shape of the active site on the enzyme.

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THIS PAGE MAY BE USED FOR TAKING NOTES AND PLANNING YOUR ANSWERS.

NOTES WRITTEN ON THIS PAGE WILL NOT BE SCORED.

WRITE ALL YOUR RESPONSES ON THE LINED PAGES.

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PAGE FOR ANSWERING QUESTION 1

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ADDITIONAL PAGE FOR ANSWERING QUESTION 1

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ADDITIONAL PAGE FOR ANSWERING QUESTION 1

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2. Scientists studied soybean plants grown in sunlit, controlled-environment chambers with a carbon dioxide (CO_2) concentration of $700 \mu\text{mol CO}_2 / \text{mol of air}$. The CO_2 concentration in the chambers was approximately double that of normal concentrations of environmental CO_2 .

Photosynthetic rate is measured by the amount of CO_2 exchanged in an area of leaf surface over time. The rate is directly influenced by the activity of the plant enzyme rubisco. During photosynthesis, rubisco fixes atmospheric carbon into an organic molecule as one of the first steps in the Calvin cycle.

Scientists measured the amount of carbon fixation that occurred in the leaves of soybean plants grown at each temperature shown in Table 1.

Table 1. Carbon Fixation by Rubisco Under Different Temperatures

Temperature ($^{\circ}\text{C}$)	Carbon Fixation $\pm 2\text{SE}_{\bar{x}} (\mu\text{mol / m}^2/\text{s})$
25	91 ± 9
30	96 ± 5
35	93 ± 8
40	104 ± 7
45	71 ± 7
50	59 ± 4

- (a) **Describe** the effect on an enzyme of an increase in environmental temperature above the optimum temperature range of the enzyme.
- (b) Using the template in the space provided for your response, **construct** an appropriately labeled graph to represent the data in Table 1. **Determine** whether there is a statistical difference in the amount of CO_2 fixed by rubisco at 30°C and 40°C .
- (c) Based on the data, **identify** the temperature range at which the soybean leaves are producing the lowest amount of carbohydrate.
- (d) Increased amounts of carbon dioxide in the atmosphere are correlated with increased global surface temperatures. Based on the data, **predict** how a surface temperature that continues to rise above 40°C most likely affects the amount of energy available to primary consumers in an ecosystem. Provide reasoning to **justify** your prediction. One model predicts that an increase in greenhouse gases will lead to a 2°C increase in average surface temperature on Earth. Based on the data from the experiment and the prediction of an increase in average surface temperature by the model, **predict** how the locations of plant species are expected to change over time.

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THIS PAGE MAY BE USED FOR TAKING NOTES AND PLANNING YOUR ANSWERS.

NOTES WRITTEN ON THIS PAGE WILL NOT BE SCORED.

WRITE ALL YOUR RESPONSES ON THE LINED PAGES.

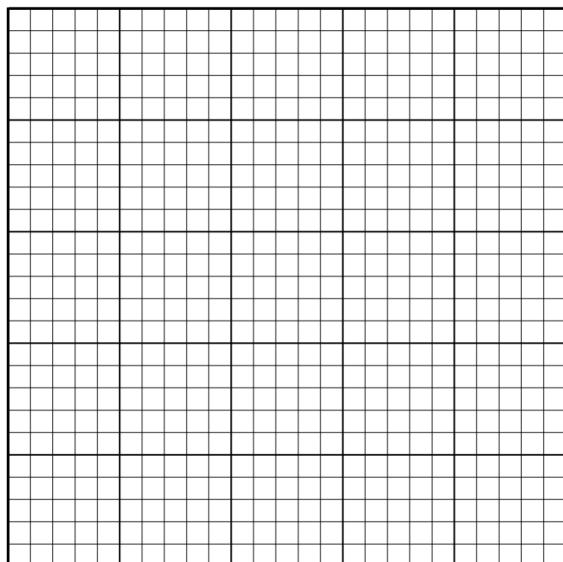
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PAGE FOR ANSWERING QUESTION 2

(data table reprinted for reference)

Table 1. Carbon Fixation by Rubisco Under Different Temperatures

Temperature (°C)	Carbon Fixation $\pm 2SE_{\bar{x}}$ ($\mu\text{mol} / \text{m}^2/\text{s}$)
25	91 \pm 9
30	96 \pm 5
35	93 \pm 8
40	104 \pm 7
45	71 \pm 7
50	59 \pm 4



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ADDITIONAL PAGE FOR ANSWERING QUESTION 2

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ADDITIONAL PAGE FOR ANSWERING QUESTION 2

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ADDITIONAL PAGE FOR ANSWERING QUESTION 2

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3. Pigeon lice (*Columbicola columbae*) are small parasites that feed on the feathers of the rock pigeon (*Columba livia*). The lice are host-specific, and transmission of lice between pigeons requires direct contact. Pigeons remove the lice with their beaks as they clean their feathers. Figure 1 shows the black and white phenotypes for pigeon feather color and the dark and light phenotypes for louse body color.

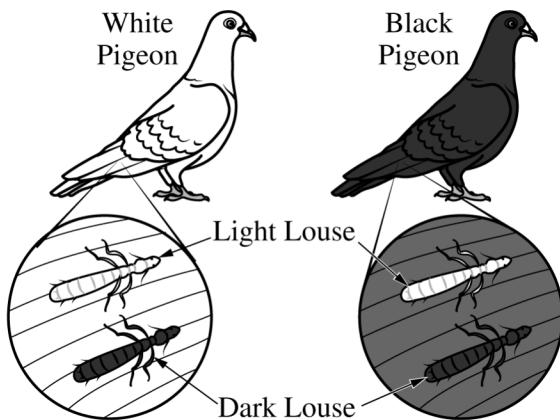


Figure 1. Pigeon and louse phenotypes, showing lice against pigeon feathers

Researchers designed an experiment to test the hypothesis that the evolution of coloration in lice is driven by birds. Researchers transferred 25 lice from a random sample of lice obtained from wild-caught rock pigeons to each individual in groups of black pigeons and white pigeons. Half of the pigeons from each color group were fitted with a harmless mouthpiece that stopped the beaks from entirely closing. The mouthpiece prevented pigeons from removing lice but did not affect the pigeons' ability to feed. Each pigeon was isolated and kept in identical environmental conditions for temperature, humidity, and amount of light. The lice have a generation time of 24 days. The researchers observed the phenotypes of the lice over a period of four years.

- Describe** the importance of phenotypic variation in louse body color among individuals in a population of lice.
- Justify** the decision of the researchers to hold lighting conditions constant in their experiment.
- Predict** the most likely effect of the pigeons cleaning their feathers on the phenotypes of the lice after four years.
- Provide reasoning** to support your prediction in part (c).

PAGE FOR ANSWERING QUESTION 3

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ADDITIONAL PAGE FOR ANSWERING QUESTION 3

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4. *Daphnia longicephala* is a freshwater crustacean that can detect chemical cues produced by the predator *Notonecta glauca*. Researchers raised *Daphnia* clones and observed that those exposed to *Notonecta* chemical cues during their development produced larger protective crests, as described in Figures 1 and 2. Crest height and width are measured as ratios to body length. The increase in the size of the crest width and height is not associated with a corresponding change to the *Daphnia*'s genome. Researchers hypothesize that growing a crest is energetically costly, so *Daphnia* do not develop the large crests in the absence of *Notonecta*.

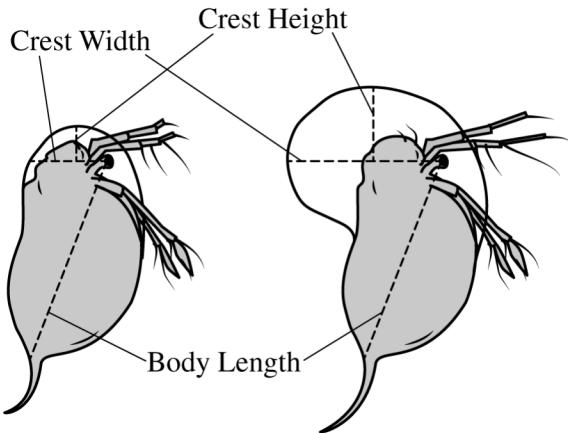


Figure 1. Comparison of *Daphnia* that developed in the absence (left) and the presence (right) of *Notonecta* chemical cues

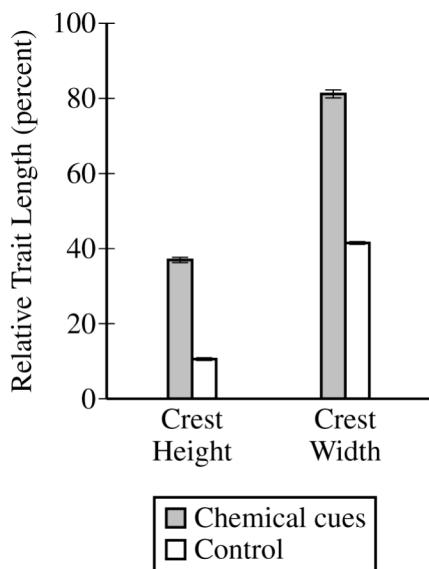


Figure 2. Comparison of mean relative crest height and width between control *Daphnia* and *Daphnia* exposed to *Notonecta* chemical cues during development. Error bars represent $\pm 2SE_{\bar{x}}$.

- Describe** the factors that influence an individual's phenotype.
- Explain** how the presence of *Notonecta* chemical cues affects gene expression in the *Daphnia*.
- As a follow-up experiment, researchers placed the *Daphnia* that were exposed to the *Notonecta* chemical cues into a tank without chemical cues. The *Daphnia* reproduced asexually, and the offspring developed in the tank without chemical cues. **Predict** the relative size of the crest height and width of offspring raised in the tank without chemical cues as compared to the parent *Daphnia*.
- Provide reasoning to **justify** your prediction in part (c).

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PAGE FOR ANSWERING QUESTION 4

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ADDITIONAL PAGE FOR ANSWERING QUESTION 4

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5. A student collected samples of cells from a woody plant during the spring and produced the drawings below. Sample 1 was collected from the woody stem of the plant. Sample 2 was collected from the root tip of the plant. Cells in different steps of mitosis are labeled with letters A, B, C, D, and E in Sample 2.

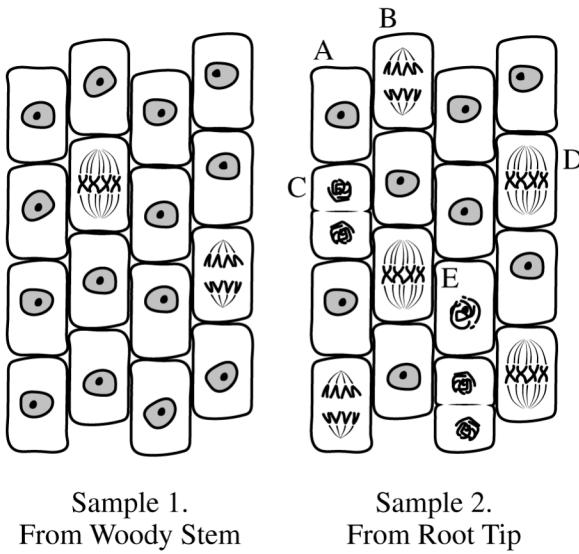
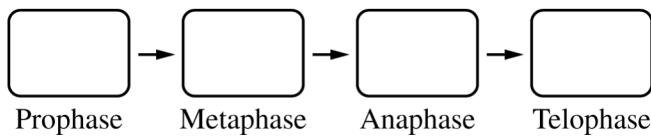


Figure 1. Drawings of samples of plant cells collected from two locations in a woody plant during the spring

- (a) **Describe** the role of mitosis in the growth of a plant.
- (b) **Explain** why there are more cells observed in mitosis in the root tip than in the woody stem.
- (c) **Refine** the model in the space provided for your response by using the letters from four of the cell labels of Sample 2 to represent the sequential steps of mitosis.
- (d) **Explain** how the arrangement of cellular components during the step of mitosis portrayed by cell D in Sample 2 facilitates the proper distribution of chromosomes to the two daughter cells.

PAGE FOR ANSWERING QUESTION 5



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ADDITIONAL PAGE FOR ANSWERING QUESTION 5

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6. Students were using the formulas for the surface area and volume of a rectangular solid to model cells of different sizes and shapes. They produced the data shown in the table.

Rectangular Solid	Length (cm)	Height (cm)	Width (cm)	Surface Area (cm^2)	Volume (cm^3)	Surface Area-to-Volume Ratio
1	2.00	1.00	1.00	10.00	2.00	5.00
2	2.67	0.50	1.50	12.18	2.00	6.08
3	4.00	0.25	2.00	19.00	2.00	9.50
4	6.05	0.13	2.65	34.24	2.00	17.09
5	10.68	0.06	3.00	65.79	2.00	32.85

- (a) **Identify** the rectangular solid that represents the cell with the smallest amount of plasma membrane per volume of cytoplasm.
- (b) **Describe** the relationship between the dimensions of the rectangular solids and their surface area-to-volume ratios.
- (c) Using the data from the model, **evaluate** the hypothesis that cells shaped like rectangular solids 1 and 2 are better suited for slow metabolism and the long-term storage of energy-containing molecules than are cells shaped like rectangular solids 4 and 5.
- (d) Based on the trends shown in the data, **explain** why some rectangular cells include folds or projections in their plasma membranes.

PAGE FOR ANSWERING QUESTION 6

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ADDITIONAL PAGE FOR ANSWERING QUESTION 6

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STOP

END OF EXAM

**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.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)	Incorrect. Water does have a high heat capacity; however, this property allows the body to rid itself of excess heat, not absorb it.	
(B)	Correct. Water has a high heat of vaporization. Sweat produced by the body decreases the temperature of the body by absorbing a large quantity of heat energy during the liquid to gas phase change.	
(C)	Incorrect. Water does have a high surface tension; however, this process is not responsible for the temperature-reducing properties of sweat.	
(D)	Incorrect. Water does have a high melting temperature; however, this process is not responsible for the temperature-reducing properties of sweat.	

Question 2

Skill	Learning Objective	Topic
2.A: Describe characteristics of a biological concept, process, or model represented visually.	ENE-2.H: Explain how concentration gradients affect the movement of molecules across membranes.	Tonicity and Osmoregulation
(A)	Correct. Distilled water from chamber B will move to chamber A because chamber A has a higher solute concentration.	
(B)	Incorrect. This arrangement would result in no net movement of water into chamber A.	
(C)	Incorrect. This arrangement would result in net movement of water into chamber B, not chamber A. Distilled water from chamber A will move to chamber B because chamber B has a higher solute concentration.	
(D)	Incorrect. This arrangement would result in no net movement of water into chamber A.	

Question 3

Skill	Learning Objective	Topic
1.C: Explain biological concepts, processes, and/or models in applied contexts.	ENE-1.J: Explain how cells capture energy from light and transfer it to biological molecules for storage and use.	Photosynthesis
(A)	Incorrect. The source of protons for the proton gradient is not only water but also protons that were pumped, by components of the electron transport chain, from the stroma to the interior of the thylakoids.	
(B)	Correct. Electrons are released from water molecules and donated to photosystem II.	
(C)	Incorrect. Glucose is produced using carbon dioxide molecules from the atmosphere, not stored carbon.	
(D)	Incorrect. NADH serves as the terminal electron acceptor for the electron transport chain.	

Question 4

Skill	Learning Objective	Topic
1.C: Explain biological concepts, processes, and/or models in applied contexts.	ENE-2.K: Describe the membrane-bound structures of the eukaryotic cell.	Cell Compartmentalization
(A)	Incorrect. Mitochondria did not evolve within a cell; they were endosymbiotically incorporated. Additionally, cells that lacked mitochondria were able to respire.	
(B)	Incorrect. Mitochondria did not evolve within a cell; they were endosymbiotically incorporated.	
(C)	Correct. The evolution of a nuclear membrane that contains genetic material allowed for cells to separate the copying of genetic material and the production of proteins.	
(D)	Incorrect. Bacteria do not have compartmentalization of cellular components.	

Question 5

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)	Incorrect. Glycolysis occurs in the cytosol, but the Krebs cycle occurs in the mitochondrial matrix.	
(B)	Incorrect. The lysosomes are typically where cellular material is broken down, not where the Krebs cycle occurs.	
(C)	Incorrect. Neither glycolysis nor the Krebs cycle occur in the nucleus.	
(D)	Correct. Pyruvate dehydrogenase plays a role in the Krebs cycle, which occurs in the mitochondrial matrix.	

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)	Correct. This value is closest to the steepest slope of the curve under condition 1.	
(B)	Incorrect. The approximate number of seconds it takes for the reaction to produce the maximum amount of acetyl- CoA under condition 3 is 24.	
(C)	Incorrect. The maximum micromoles produced under condition 2 is 35.	
(D)	Incorrect. The maximum micromoles produced under conditions 1 and 3 is 65.	

Question 7

Skill	Learning Objective	Topic
6.B: Support a claim with evidence from biological principles, concepts, processes, and/or data.	ENE-3.B: Explain how negative feedback helps to maintain homeostasis.	Feedback
(A)	Correct. This observation is an example of a negative feedback mechanism.	
(B)	Incorrect. This observation is an example of a positive regulatory mechanism.	
(C)	Incorrect. The accumulation of acetyl-CoA in the experiment could be affected by several factors, not just by regulatory feedback.	
(D)	Incorrect. The breakdown of acetyl-CoA does not address its regulatory effects.	

Question 8

Skill	Learning Objective	Topic
1.C: Explain biological concepts, processes, and/or models in applied contexts.	ENE-1.L: Explain how cells obtain energy from biological macromolecules in order to power cellular functions.	Cellular Respiration
(A)	Incorrect. Lactic acid does not provide electrons for the electron transport chain.	
(B)	Incorrect. Glycolysis does not produce lactic acid.	
(C)	Incorrect. Pyruvate dehydrogenase does not transport pyruvate.	
(D)	Correct. Pyruvate that cannot be broken down by the Krebs cycle will be further metabolized by fermentation.	

Question 9

Skill	Learning Objective	Topic
2.C: Explain how biological concepts or processes represented visually relate to larger biological principles, concepts, processes or theories.	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)	Incorrect. If the walls of xylem are nonpolar, polar water would not stick to them through adhesion.	
(B)	Incorrect. Water is a polar molecule, which explains why it can adhere to the polar surface of the xylem.	
(C)	Incorrect. Water and xylem are both polar and could form bonds with one another.	
(D)	Correct. Water has a high surface tension as a result of the hydrogen bonds that water molecules form between each other because both the xylem and the water are polar.	

Question 10

Skill	Learning Objective	Topic
2.C: Explain how biological concepts or processes represented visually relate to larger biological principles, concepts, processes or theories.	IST-2.A: Describe the types of interactions that regulate gene expression.	Regulation of Gene Expression
(A)	Incorrect. RNA splicing enzymes would not be found in the cytoplasm.	
(B)	Incorrect. Cell membrane proteins would be found in the cell membrane and not in the cytoplasm or nucleus.	
(C)	Correct. The movement of Protein X from the cytoplasm to the nucleus indicates that it is a transcription factor.	
(D)	Incorrect. Hormones produced by a cell would not be located throughout the cytoplasm and would not translocate to the nucleus following signal transduction.	

Question 11

Skill	Learning Objective	Topic
1.C: Explain biological concepts, processes, and/or models in applied contexts.	EVO-2.B: Describe the fundamental molecular and cellular features shared across all domains of life, which provide evidence of common ancestry.	Evidence for Evolution
(A)	Incorrect. Convergent evolution results in similarly functioning traits in different species, and prolactin does not function similarly across different species.	
(B)	Correct. Prolactin is not highly conserved, because it has multiple functions in different organisms. Therefore, its presence in these organisms indicates a common origin.	
(C)	Incorrect. The passage does not indicate that prolactin always binds to intracellular receptors.	
(D)	Incorrect. The passage indicates that different types of organisms, not different organisms within a species, have varied uses for prolactin.	

Question 12

Skill	Learning Objective	Topic
1.A: Describe biological concepts and/or processes.	ENE-3.B: Explain how negative feedback helps to maintain homeostasis.	Feedback
(A)	Incorrect. This is a negative feedback mechanism in which DMSP is produced to prevent further environmental change as a result of increasing water temperatures.	
(B)	Correct. This is a negative feedback mechanism in which DMSP is produced to prevent, not encourage, further environmental change as a result of increasing water temperatures.	
(C)	Incorrect. This is a negative, not positive, feedback mechanism that prevents, not encourages, further environmental change.	
(D)	Incorrect. This is a negative, not positive, feedback mechanism that prevents further environmental change.	

Question 13

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-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)	Correct. The graphs show that both age groups of corals produce less DMSP at 27°C than they do at 32°C.	
(B)	Incorrect. The graphs show that both age groups of corals produce less DMSP at 27°C, not 32°C .	
(C)	Incorrect. The graphs show that the amount of DMSP increases in both juveniles and adults at 32°C.	
(D)	Incorrect. The graphs show that the amount of DMSP increases in both juveniles and adults at 32°C.	

Question 14

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-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. This answer compares the DMSP produced by adult corals to juveniles at 27°C rather than 32°C.	
(B)	Incorrect. This answer compares the DMSP produced by juveniles to adults, rather than adults compared to juveniles, at 27°C rather than 32°C.	
(C)	Correct. The DMSP produced by adult corals at 32°C was approximately 14 nmol/mm ² , and the DMSP produced by juveniles was approximately 3 nmol/mm ² .	
(D)	Incorrect. This answer compares the DMSP in juveniles to adults 32°C rather than the reverse relationship.	

Question 15

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-4.B: Explain how interactions within and among populations influence community structure.	Community Ecology
(A)	Incorrect. The passage states that the corals of the same species were grown in the same laboratory conditions.	
(B)	Correct. This experiment is also measuring the difference between the amount of DMSP produced by corals versus algae and corals together. It is also looking at the difference in DMSP produced by different-aged corals.	
(C)	Incorrect. This experiment is testing the effect of age, but the passage states that the corals were grown in the same laboratory conditions.	
(D)	Incorrect. This experiment is also measuring the difference between the amount of DMSP produced by corals versus corals and algae together but is not measuring the difference between coral species.	

Question 16

Skill	Learning Objective	Topic
5.B: Use confidence intervals and/or error bars (both determined using standard errors) to determine whether sample means are statistically different.	ENE-3.B: Explain how negative feedback helps to maintain homeostasis.	Feedback
(A)	Incorrect. The error bars at 32°C overlap between days 0 and 5, indicating they are not statistically different.	
(B)	Incorrect. The error bars at 27°C overlap between days 0 and 5, indicating they are not statistically different.	
(C)	Correct. The error bars for days 5 and 10 do not overlap between temperature treatments, indicating that they are statistically different.	
(D)	Incorrect. The error bars for the temperature treatments on day 0 overlap. Therefore, the symbiont density was not statistically greater at 27°C than it was at 32°C through the entire experiment.	

Question 17

Skill	Learning Objective	Topic
6.D: Explain the relationship between experimental results and larger biological concepts, processes, or theories.	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 corals are less, not more, photosynthetically active at higher temperatures. Even if higher temperatures are a function of more sunlight availability, the algae are expelled from the coral and therefore not able to provide energy.	
(B)	Incorrect. The corals are less, not more, photosynthetically active at higher temperatures. The graphs do not indicate algae efficiency.	
(C)	Correct. The corals and algae have less photosynthetic ability at higher temperatures because the algae density has been reduced.	
(D)	Incorrect. The corals do have less photosynthetic ability at higher temperatures but not because of the amount of DMSP. The amount of DMSP produced is a function of algae density.	

Question 18

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 option multiplies the recessive allele frequency by itself instead of 2 times p times q .	
(B)	Incorrect. This option multiplies the dominant recessive allele frequency by itself instead of 2 times p times q .	
(C)	Incorrect. This option multiplies 2 times the recessive allele times itself instead of 2 times p times q .	
(D)	Correct. This option correctly calculates the heterozygote frequency from the dominant allele frequency.	

Question 19

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.	IST-2.E: Describe the various types of mutation.	Mutations
(A)	Correct. The change in the gene code from a T to an A results in an amino acid change from Glu to Val.	
(B)	Incorrect. The change in the gene code from a T to an A results in an amino acid change from "Glu to Val, not Glu to Val.	
(C)	Incorrect. The change in the gene code from a T to an A results in an amino acid change from Glu to Val, not Glu to Pro.	
(D)	Incorrect. The change in the gene code from a T to an A results in an amino acid change from Glu to Val, not Pro to Val.	

Question 20

Skill	Learning Objective	Topic
2.C: Explain how biological concepts or processes represented visually relate to larger biological principles, concepts, processes or theories.	IST-1.J: Explain deviations from Mendel's model of the inheritance of traits.	Non-Mendelian Genetics
(A)	Incorrect. The condition is not random and does have a recognizable inheritance pattern in which all children of affected mothers also have the condition.	
(B)	Incorrect. This condition is found in female offspring, which indicates that it is not Y-linked.	
(C)	Incorrect. The condition is not passed on from affected fathers to their female offspring, which indicates that it is not X-linked.	
(D)	Correct. This condition is inherited by all children of affected mothers, regardless of sex, which indicates a mitochondrial inheritance pattern.	

Question 21

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.	IST-2.A: Describe the types of interactions that regulate gene expression.	Regulation of Gene Expression
(A)	Incorrect. Reducing the number of ribosomes would reduce, but not eliminate, the production of oncogene proteins and would also reduce the production of all cellular proteins.	
(B)	Incorrect. Blocking transcription factor receptors would impact all cells, not just tumor cells.	
(C)	Correct. If a transcription factor is bound to a chemical, it cannot bind to the oncogene promoter, thus preventing gene expression that would result in tumor formation.	
(D)	Incorrect. Producing transcription factors for tumor suppressor genes may reduce the expression of oncogenes but may not completely eliminate it.	

Question 22

Skill	Learning Objective	Topic
1.C: Explain biological concepts, processes, and/or models in applied contexts.	SYI-1.C: Explain how a change in the subunits of a polymer may lead to changes in structure or function of the macromolecule.	Structure and Function of Biological Macromolecules
(A)	Incorrect. The bonds between nitrogenous base pairs are weak hydrogen bonds, not strong covalent bonds.	
(B)	Correct. Hydrogen bonds, like those found between nitrogenous base pairs, are weaker than covalent bonds and are easily broken by UV radiation.	
(C)	Incorrect. The covalent bonds between sugar-phosphate backbone molecules are strong and not easily broken by UV radiation.	
(D)	Incorrect. The bonds between sugar-phosphate backbone molecules are strong covalent bonds, not weak hydrogen bonds, and are therefore not easily broken by UV radiation.	

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.	EVO-3.C: Explain how a phylogenetic tree and/or cladogram can be used to infer evolutionary relatedness.	Phylogeny
(A)	Incorrect. These species have more genetic differences than a pair of species in another choice.	
(B)	Correct. These species have the fewest mitochondrial genetic differences.	
(C)	Incorrect. These species have more genetic differences than a pair of species in another choice.	
(D)	Incorrect. These species have more genetic differences than a pair of species in another choice.	

Question 24

Skill	Learning Objective	Topic
2.C: Explain how biological concepts or processes represented visually relate to larger biological principles, concepts, processes or theories.	ENE-3.C: Explain how positive feedback affects homeostasis.	Feedback
(A)	Incorrect. This choice describes a negative feedback mechanism in which later stages in the signaling pathway inhibit earlier stages from progressing.	
(B)	Incorrect. This choice describes an observation that would not affect the signaling pathway according to the information provided in the diagram.	
(C)	Incorrect. This choice describes a negative feedback mechanism in which later stages in the signaling pathway inhibit earlier stages from progressing.	
(D)	Correct. This choice describes an observation in which the production of estrogen stimulates systems at earlier stages in the signaling pathway to produce hormones that further stimulate the ovaries.	

Question 25

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.G: Explain how the cellular environment affects enzyme activity.	Environmental Impacts on Enzyme Function
(A)	Incorrect. Over the 60-minute experiment, the absorbance of tube 1 did not change because DCPIP was not present in the solution.	
(B)	Correct. Over the 60-minute experiment, the absorbance of tube 2 decreased, indicating that DCPIP was reduced.	
(C)	Incorrect. Over the 60-minute experiment, the absorbance of tube 3 did not change, indicating that DCPIP was not reduced.	
(D)	Incorrect. Over the 60-minute experiment, the absorbance of tube 4 did not change, indicating that DCPIP was not reduced.	

Question 26

Skill	Learning Objective	Topic
6.B: Support a claim with evidence from biological principles, concepts, processes, and/or data.	ENE-1.J: Explain how cells capture energy from light and transfer it to biological molecules for storage and use.	Photosynthesis
(A)	Correct. Tube 2 showed a reduction in absorbance while tube 3 did not, which suggests that light was required for the reaction.	
(B)	Incorrect. This experiment does not address the source of the electrons in the electron transport chain.	
(C)	Incorrect. This experiment does not address the source of carbon used by plants for producing carbohydrates.	
(D)	Incorrect. DCPIP is an electron acceptor, not an electron donor.	

Question 27

Skill	Learning Objective	Topic
6.D: Explain the relationship between experimental results and larger biological concepts, processes, or theories.	ENE-1.G: Explain how the cellular environment affects enzyme activity.	Environmental Impacts on Enzyme Function
(A)	Incorrect. There is no evidence that DCMU acts as a buffer.	
(B)	Incorrect. Even if DCMU were also an electron carrier, some change in absorbance over the course of the experiment is still expected.	
(C)	Incorrect. If DCMU were also an electron source, then a faster decrease in absorbance rather than no change over the length of the experiment is expected.	
(D)	Correct. The lack of change in absorbance over the length of the tubes containing DCMU indicates that it prevents the flow of electrons. These results are similar to those observed in tube 3, when the lack of light prevent electrons from flowing.	

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.	ENE-1.I: Describe the photosynthetic processes that allow organisms to capture and store energy.	Photosynthesis
(A)	Incorrect. Tube 2 did not serve as a calibration tube for the spectrophotometer.	
(B)	Incorrect. Tube 2 did not control for any changes in chlorophyll content during the course of the experiment.	
(C)	Incorrect. Tube 2 did not control for light intensity.	
(D)	Correct. Tubes 4 and 2 differed only by the presence of DCMU so any changes in the outcome of the experiment could be attributed only to DCMU.	

Question 29

Skill	Learning Objective	Topic
3.E: Propose a new/next investigation based on- a. An evaluation of the evidence from an experiment. b. An evaluation of the design/methods.	ENE-2.J: Describe the processes that allow ions and other molecules to move across membranes.	Mechanisms of Transport
(A)	Incorrect. Increasing the solute concentration will not result in an effect if the solute is incapable of diffusing through the membrane at any concentration.	
(B)	Correct. Small, nonpolar molecules are able to diffuse through cell membranes, while large proteins are not.	
(C)	Incorrect. Increasing the temperature of the solution will not result in an effect if the solute is incapable of diffusing through the membrane.	
(D)	Incorrect. Aquaporins are used to transport large volumes of water, not solutes.	

Question 30

Skill	Learning Objective	Topic
2.A: Describe characteristics of a biological concept, process, or model represented visually.	IST-1.O: Describe how the phenotype of an organism is determined by its genotype.	Translation
(A)	Incorrect. Retroviruses have an RNA genome, not a DNA genome.	
(B)	Incorrect. DNA is not directly translated into proteins.	
(C)	Correct. The genome of a retrovirus is composed of RNA. It must first be reverse-transcribed into DNA and integrated into a host cell's DNA before it is transcribed and the RNA is translated.	
(D)	Incorrect. Retroviruses have an RNA genome, not a DNA genome, and DNA is not directly translated into proteins.	

Question 31

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)	Incorrect. Lipids are made of hydrocarbon chains whose main component is carbon, not sulfur. Additionally, plants obtain carbon directly from the atmosphere in the form of carbon dioxide and do not fix it as they would nitrogen.	
(B)	Incorrect. Lipids are made of hydrocarbon chains whose main component is carbon, not nitrogen. Plants do obtain nitrogen through fixation, but this process is not used to obtain carbon from the atmosphere in the form of carbon dioxide.	
(C)	Correct. Lipids are made of hydrocarbon chains whose main component is carbon. Plants obtain this carbon directly from the atmosphere in the form of carbon dioxide.	
(D)	Incorrect. Lipids are made of hydrocarbon chains whose main component is carbon, not magnesium.	

Question 32

Skill	Learning Objective	Topic
1.B: Explain biological concepts and/or processes.	ENE-2.C: Explain how the structure of biological membranes influences selective permeability.	Membrane Permeability
(A)	Correct. The phospholipid bilayer allows for the transport of proteins from inside the cell to outside through the use of vesicles.	
(B)	Incorrect. The phospholipid bilayer of a transport vesicle does not connect the nuclear membrane to the endoplasmic reticulum.	
(C)	Incorrect. The phospholipid bilayer itself does not contain chemicals that break down proteins.	
(D)	Incorrect. The phospholipid bilayer does not contain enzymes that perform this process.	

Question 33

Skill	Learning Objective	Topic
5.A: Perform mathematical calculations, including- a. Mathematical equations in the curriculum. b. Means. c. Rates. d. Ratios. e. Percentages.	IST-1.F: Explain how meiosis results in the transmission of chromosomes from one generation to the next.	Meiosis
(A)	Incorrect. This choice calculates the number of chromatids after the G ₂ checkpoint instead of chromosomes. After meiosis, the diploid chromosome number is halved to equal 39, not 78. After fertilization, the chromosome number is doubled as a result of the combination of the chromosomes from two gametes.	
(B)	Correct. This choice correctly identifies that although chromatids are duplicated after the G ₂ checkpoint, they still form 78 chromosome pairs. After meiosis, the chromosome number is divided in half. After fertilization, the chromosomes from two gametes are combined to form 78 chromosomes.	
(C)	Incorrect. This choice calculates the number of chromatids after the G ₂ checkpoint as twice as many as would be expected.	
(D)	Incorrect. This choice correctly identifies that although chromatids are duplicated after the G ₂ checkpoint, they still form 78 chromosome pairs. This number is halved after meiosis, during gamete formation, and does not remain the same. After fertilization, the number is doubled as the chromosomes from two gametes are combined.	

Question 34

Skill	Learning Objective	Topic
6.D: Explain the relationship between experimental results and larger biological concepts, processes, or theories.	ENE-1.L: Explain how cells obtain energy from biological macromolecules in order to power cellular functions.	Cellular Respiration
(A)	Incorrect. The data indicate that products of the Krebs cycle other than NADH are relatively unaffected by the pesticide.	
(B)	Incorrect. Transport proteins are not blocked from entering the mitochondria; they are embedded in the mitochondrial membrane.	
(C)	Correct. The data indicate that NADH concentrations are significantly increased in cell culture B.	
(D)	Incorrect. Glycolysis is occurring in the presence of rotenone, as indicated by the buildup of NADH in cell culture B.	

Question 35

Skill	Learning Objective	Topic
1.C: Explain biological concepts, processes, and/or models in applied contexts.	IST-1.H: Explain how the process of meiosis generates genetic diversity.	Meiosis and Genetic Diversity
(A)	Incorrect. The presence of an extra copy of genetic material does not inhibit its replication.	
(B)	Incorrect. Hybridization is not inhibited because of a lack of genetic diversity.	
(C)	Correct. If an organism has three copies of its genes, chromosomes cannot properly pair and separate during meiosis.	
(D)	Incorrect. The presence of an extra copy of genetic material inhibits the production of gametes.	

Question 36

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-1.P: Explain the use of genetic engineering techniques in analyzing or manipulating DNA.	Biotechnology
(A)	Incorrect. The diagram indicates that the polymerase from <i>T. aquaticus</i> is used during steps of PCR that reach temperatures above 68°C.	
(B)	Correct. The polymerase enzyme of <i>T. aquaticus</i> is used because it evolved to function at temperatures close to boiling without denaturing.	
(C)	Incorrect. Polymerase from other organisms can be used repetitively, but only the polymerase from heat-tolerant organisms like <i>T. aquaticus</i> can be used in PCR, during which the polymerase is repeatedly used at high temperatures that would degrade polymerase from other species.	
(D)	Incorrect. Polymerase is widely conserved across organisms, and its functionality does not vary.	

Question 37

Skill	Learning Objective	Topic
6.B: Support a claim with evidence from biological principles, concepts, processes, and/or data.	EVO-1.G: Explain the relationship between changes in the environment and evolutionary changes in the population.	Artificial Selection
(A)	Correct. Convergent evolution results in similarly functioning traits whose structure differs as a result of genetic differences between distantly related species.	
(B)	Incorrect. Convergent evolution results in similarly functioning traits whose structure differs as a result of genetic differences between distantly related species.	
(C)	Incorrect. Convergent evolution results in similarly functioning traits whose structure differs as a result of genetic differences between distantly, not closely, related species.	
(D)	Incorrect. Convergent evolution results in similarly functioning traits whose structure differs as a result of genetic differences between distantly, not closely, related species.	

Question 38

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. Xylem tissue is not the only shared characteristic between ferns and pines.	
(B)	Incorrect. Pines have seeds and wood, but ferns do not.	
(C)	Correct. The cladogram shows that ferns and pines have two shared characteristics: embryos and xylem tissue.	
(D)	Incorrect. Pines and ferns share embryos and xylem, but they do not share seeds or wood traits.	

Question 39

Skill	Learning Objective	Topic
5.C: Perform chi-square hypothesis testing.	EVO-1.K: Describe the conditions under which allele and genotype frequencies will change in populations.	Hardy-Weinberg Equilibrium
(A)	Correct. This is the critical value with 1 degree of freedom and a significance level of .05. Since this Hardy-Weinberg equilibrium question involves only 2 alleles and the frequency of 1 allele determines the frequency of the other allele, there is a single independent variable.	
(B)	Incorrect. This is the critical value with 2 degrees of freedom and a significance level of .05. While there are 3 phenotypes, this Hardy-Weinberg equilibrium question involves only 2 alleles, and the frequency of 1 allele determines the frequency of the other allele. Therefore, there is a single independent variable and 1 degree of freedom.	
(C)	Incorrect. This is the critical value with 3 degrees of freedom and a significance level of .05.	
(D)	Incorrect. This is the critical value with 4 degrees of freedom and a significance level of .05.	

Question 40

Skill	Learning Objective	Topic
6.A: Make a scientific claim	EVO-1.H: Explain how random occurrences affect the genetic makeup of a population.	Population Genetics
(A)	Incorrect. The loss of genetic diversity occurred as a result of the population decrease and not the reverse relationship.	
(B)	Incorrect. The passage states that hunting caused the greatest decrease in population size.	
(C)	Correct. The rapid decrease in population size as a result of hunting likely caused a decrease in genetic diversity. This is an example of a genetic bottleneck.	
(D)	Incorrect. The founder effect describes the low genetic diversity that is found in populations that grow from a few migrated individuals and not as a result of rapid population decline.	

Question 41

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. This option correctly describes one effect of a density-dependent factor, but algal blooms are a density-independent, not a density-dependent, factor that negatively affects otter populations.	
(B)	Incorrect. This option correctly describes one effect of a density-dependent factor, but algal blooms are a density-independent, not density-dependent, factor that negatively affects otter populations.	
(C)	Correct. The effect of harmful algal blooms is a factor negatively affecting otter populations that is independent of the otter population size.	
(D)	Incorrect. The effect of harmful algal blooms is a density-independent factor, but it affects otter populations regardless of size, not solely in larger populations.	

Question 42

Skill	Learning Objective	Topic
6.C: Provide reasoning to justify a claim by connecting evidence to biological theories.	SYI-3.G: Explain how the addition or removal of any component of an ecosystem will affect its overall short-term and long-term structure.	Biodiversity
(A)	Incorrect. Otters are a keystone species, but their disappearance negatively affected several species (eelgrass, herbivores, and predatory fish at minimum), not just a single species.	
(B)	Correct. Otters are a keystone species because their disappearance negatively affected the entire community.	
(C)	Incorrect. The information provided does not describe mutualism. Additionally, the disappearance of otters negatively affected multiple species, not just a single one.	
(D)	Incorrect. The information provided does not describe mutualism.	

Question 43

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.	SYI-2.B: Describe human activities that lead to changes in ecosystem structure and/or dynamics.	Disruptions to Ecosystems
(A)	Correct. The passage indicates that ocean warming has allowed for the introduction of nonnative species that could not previously live in Elkhorn Slough.	
(B)	Incorrect. The passage states that the nonnative species are predatory consumers, not herbivores.	
(C)	Incorrect. The passage states that harmful algal blooms are a result of excess nutrient pollution, not climate change.	
(D)	Incorrect. The passage states that harmful algal blooms are a result of excess nutrient pollution, not climate change.	

Question 44

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-4.B: Explain how interactions within and among populations influence community structure.	Community Ecology
(A)	Incorrect. An eelgrass population increase would be the likely result of a sea slug population increase, not the reverse relationship.	
(B)	Incorrect. While the nonnative species are predatory, the passage does not indicate that they are preying on the sea slugs.	
(C)	Incorrect. A decrease in algae would be a likely result of a sea slug population increase, not the cause of it.	
(D)	Correct. An increase in the sea slug population is likely the result of a decrease in their predator population, the crabs, as a result of increased sea otter populations.	

Question 45

Skill	Learning Objective	Topic
3.A: Identify or pose a testable question based on an observation, data, or a model.	ENE-4.B: Explain how interactions within and among populations influence community structure.	Community Ecology
(A)	Correct. This question focuses on the role of the pheromone in prey detection.	
(B)	Incorrect. This question focuses on pike ecology rather than prey detection.	
(C)	Incorrect. This question focuses on pike ecology rather than prey detection.	
(D)	Incorrect. This question focuses on pheromone detection by the prey, not the predator.	

Question 46

Skill	Learning Objective	Topic
1.B: Explain 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.	Properties of Biological Macromolecules
(A)	Correct. Phospholipids are oriented so the hydrophilic heads are on the membrane exterior and can interact with water inside and outside of the cell. The hydrophobic tails in the middle of the membrane create a protective barrier for the cell.	
(B)	Incorrect. Phospholipids are oriented so the hydrophilic heads are on the membrane exterior; however, this allows them to interact with, not repel, water inside and outside of the cell. The internal hydrophobic tails create the protective barrier.	
(C)	Incorrect. Phospholipid membrane layers are oppositely oriented, not identically oriented, which allows them to interact with both the internal and external environments while still providing a protective barrier.	
(D)	Incorrect. Phospholipid membrane layers are oppositely oriented, not identically oriented. This orientation allows them to create vacuoles that are able to be moved throughout a cell.	

Question 47

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.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. Diffusion happens very quickly in cells that have a high surface area-to-volume ratio. The data in the table show that the simple squamous cell has the highest ratio.	
(B)	Incorrect. Diffusion happens very quickly in cells that have a high surface area-to-volume ratio. The data in the table show that the simple cuboidal cell does not have the highest ratio.	
(C)	Incorrect. Diffusion happens very quickly in cells that have a high surface area-to-volume ratio. The data in the table show that the simple columnar cell does not have the highest ratio.	
(D)	Incorrect. Diffusion happens very quickly in cells that have a high surface area-to-volume ratio. The data in the table show that the simple spherical cell does not have the highest ratio.	

Question 48

Skill	Learning Objective	Topic
1.B: Explain biological concepts and/or processes.	SYI-1.F: Describe the structural features of a cell that allow organisms to capture, store, and use energy.	Cell Structure and Function
(A)	Incorrect. The extensive folding significantly increases the surface area, not the volume.	
(B)	Correct. The extensive folding provides more surface area for proteins involved in energy transfer.	
(C)	Incorrect. The extensive folding does increase the area over which diffusion of water can occur, but this is not the main advantage, and the inner membrane is not on the surface of the mitochondria.	
(D)	Incorrect. The extensive folding does not provide greater insulation for reactions.	

Question 49

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 graph shows the relationship between average nest temperature and hatchling sex ratio, not rates of hatchling survival to adulthood.	
(B)	Incorrect. This cannot be inferred from the graph.	
(C)	Correct. The graph indicates that more female sea turtles are produced in nests with a higher average nest temperature.	
(D)	Incorrect. The graph indicates that the sex of sea turtle hatchlings is influenced by temperature.	

Question 50

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.	EVO-1.E: Describe the importance of phenotypic variation in a population.	Natural Selection
(A)	Incorrect. This scenario would result in disruptive selection, not in the stabilizing selection shown in the graph.	
(B)	Incorrect. This scenario would result in directional selection toward mice that live on the ground, not in the stabilizing selection shown in the graph.	
(C)	Incorrect. This scenario would result in directional selection toward darker-colored foxes, not in the stabilizing selection shown in the graph.	
(D)	Correct. This scenario would result in stabilizing selection, as shown in the graph.	

Question 51

Skill	Learning Objective	Topic
6.D: Explain the relationship between experimental results and larger biological concepts, processes, or theories.	IST-1.E: Describe the effects of disruptions to the cell cycle on the cell or organism.	Regulation of Cell Cycle
(A)	Incorrect. The cancer cells are producing fewer cyclins.	
(B)	Incorrect. The data provide no information about the plasma membrane.	
(C)	Correct. The data indicate that tumor cells treated with the drug are not replicating their DNA and thus prevents the cells from passing the G ₂ checkpoint.	
(D)	Incorrect. The data indicate that cyclin levels are low compared to the levels in a healthy cell.	

Question 52

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.I: Explain the inheritance of genes and traits as described by Mendel's laws.	Mendelian Genetics
(A)	Correct. Affected offspring were born to unaffected parents, and unaffected males had affected offspring.	
(B)	Incorrect. Affected offspring were born to unaffected parents.	
(C)	Incorrect. An affected male was born to an unaffected male parent, and an affected female was born to an unaffected male parent.	
(D)	Incorrect. Affected offspring were born to unaffected parents.	

Question 53

Skill	Learning Objective	Topic
5.A: Perform mathematical calculations, including- a. Mathematical equations in the curriculum. b. Means. c. Rates. d. Ratios. e. Percentages.	IST-1.I: Explain the inheritance of genes and traits as described by Mendel's laws.	Mendelian Genetics
(A)	Incorrect. Both parents must be carriers because individual III-6 is affected. There is a 25% chance that III-5 inherited two recessive alleles. This would be more likely to be true if there was no affected sibling.	
(B)	Correct. Both parents must be carriers because individual III-6 is affected. There is a 25% chance that III-5 inherited two recessive alleles.	
(C)	Incorrect. This would require that at least one parent be affected and the other parent be a carrier of the recessive allele.	
(D)	Incorrect. This would require that both parents be carriers and the alleles that cause the disorder are dominant to the wild-type allele.	

Question 54

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.P: Explain the use of genetic engineering techniques in analyzing or manipulating DNA.	Biotechnology
(A)	Correct. Individuals with two different bands of DNA have two different alleles. Individuals with one band of approximately 2500 base pairs have two copies of the mutant allele, which is larger because of the insertion mutation.	
(B)	Incorrect. Individuals with two different bands of DNA have two different alleles. Individuals with two wild-type alleles would have only one band of approximately 500 base pairs.	
(C)	Incorrect. Individuals with two wild-type alleles would have only one band of approximately 500 base pairs.	
(D)	Incorrect. Individuals with two wild-type alleles would have only one band of approximately 500 base pairs. Individuals with two different bands of DNA have two different alleles.	

Question 55

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. The structure is formed by DNA, not RNA, so it would not be bound by ribosomes.	
(B)	Incorrect. Translation occurs with RNA, not DNA.	
(C)	Correct. The formation of a triple-strand structure prevents the binding of RNA polymerase, which requires a single strand to bind to.	
(D)	Incorrect. The insertion of extra triplets would affect the primary structure of the protein, except that, according to the information provided, the GAA triplets are in a noncoding portion of the <i>FXN</i> gene.	

Question 56

Skill	Learning Objective	Topic
1.A: Describe biological concepts and/or processes.	SYI-1.C: Explain how a change in the subunits of a polymer may lead to changes in structure or function of the macromolecule.	Structure and Function of Biological Macromolecules
(A)	Correct. Hydrogen bonds form between the bases on complementary strands of DNA.	
(B)	Incorrect. Nucleotides on one strand of DNA are bound by polar covalent bonds. They do not form between complementary strands of DNA.	
(C)	Incorrect. DNA molecules do not rely on ionic bonds.	
(D)	Incorrect. Nucleotides on one strand of DNA are bound by polar covalent bonds. Nonpolar covalent bonds do not form between complementary strands of DNA.	

Question 57

Skill	Learning Objective	Topic
5.C: Perform chi-square hypothesis testing.	EVO-1.K: Describe the conditions under which allele and genotype frequencies will change in populations.	Hardy-Weinberg Equilibrium
(A)	Incorrect. This choice incorrectly subtracts the observed number of each phenotype from the expected number of each phenotype and divides by the observed number of each phenotype instead of expected number of each phenotype.	
(B)	Incorrect. This choice incorrectly divides by the expected number of each phenotype rather than observed.	
(C)	Incorrect. This choice incorrectly subtracts the observed number of each phenotype from the expected number of each phenotype.	
(D)	Correct. This choice correctly approximates the chi-square value from the data.	

Question 58

Skill	Learning Objective	Topic
3.A: Identify or pose a testable question based on an observation, data, or a model.	IST-3.F: Describe the different types of cellular responses elicited by a signal transduction pathway.	Signal Transduction
(A)	Incorrect. Investigating receptors would not provide direction information about the signaling molecules themselves.	
(B)	Correct. Bacteria species likely have similarly structured signaling molecules as a result of common ancestry.	
(C)	Incorrect. The function of the molecule is not necessarily related to its structure. A variety of different molecules can evolve to perform a similar function.	
(D)	Incorrect. A common ancestor does not need to be alive in the present day for shared characteristics to be observed.	

Question 59

Skill	Learning Objective	Topic
1.A: Describe biological concepts and/or processes.	ENE-2.C: Explain how the structure of biological membranes influences selective permeability.	Membrane Permeability
(A)	Correct. Carbon dioxide is a small molecule without a charge and so can pass through a cell membrane by simple diffusion.	
(B)	Incorrect. Carbon dioxide is a small molecule without a charge and so can pass through a cell membrane by simple diffusion and does not require facilitated diffusion through membrane proteins.	
(C)	Incorrect. Carbon dioxide is a small molecule without a charge and so can pass through a cell membrane by simple diffusion and does not require active transport through membrane proteins.	
(D)	Incorrect. Carbon dioxide is a small molecule without a charge and so can pass through a cell membrane by simple diffusion and does require active transport through aquaporins.	

Question 60

Skill	Learning Objective	Topic
6.A: Make a scientific claim	IST-1.I: Explain the inheritance of genes and traits as described by Mendel's laws.	Mendelian Genetics
(A)	Incorrect. The passage states that the offspring produced were not entirely identical to the parents, indicating that the alleles are not paired.	
(B)	Incorrect. Recombination between sister chromatids would not produce new genetic variation because sister chromatids are identical copies of one another.	
(C)	Incorrect. Alleles of the same gene would not typically be found on nonhomologous chromosomes.	
(D)	Correct. A ratio of nine to one of offspring with yellow, round seeds to those with green, wrinkled seeds is expected as a result of genes that are independently assorted.	

Answer Key and Question Alignment to Course Framework

Multiple-Choice Question	Answer	Skill	Learning Objective	Topic
1	B	1.C	SYI-1.A	Structure of Water and Hydrogen Bonding
2	A	2.A	ENE-2.H	Tonicity and Osmoregulation
3	B	1.C	ENE-1.J	Photosynthesis
4	C	1.C	ENE-2.K	Cell Compartmentalization
5	D	1.A	ENE-1.L	Cellular Respiration
6	A	4.B	ENE-1.L	Cellular Respiration
7	A	6.B	ENE-3.B	Feedback
8	D	1.C	ENE-1.L	Cellular Respiration
9	D	2.C	SYI-1.A	Structure of Water and Hydrogen Bonding
10	C	2.C	IST-2.A	Regulation of Gene Expression
11	B	1.C	EVO-2.B	Evidence for Evolution
12	B	1.A	ENE-3.B	Feedback
13	A	4.B	ENE-3.D	Responses to the Environment
14	C	5.A	ENE-3.D	Responses to the Environment
15	B	3.C	ENE-4.B	Community Ecology
16	C	5.B	ENE-3.B	Feedback
17	C	6.D	ENE-1.O	Energy Flow through Ecosystems
18	D	5.A	EVO-1.K	Hardy-Weinberg Equilibrium
19	A	6.E	IST-2.E	Mutations
20	D	2.C	IST-1.J	Non-Mendelian Genetics
21	C	6.E	IST-2.A	Regulation of Gene Expression
22	B	1.C	SYI-1.C	Structure and Function of Biological Macromolecules
23	B	4.B	EVO-3.C	Phylogeny
24	D	2.C	ENE-3.C	Feedback
25	B	4.B	ENE-1.G	Environmental Impacts on Enzyme Function
26	A	6.B	ENE-1.J	Photosynthesis
27	D	6.D	ENE-1.G	Environmental Impacts on Enzyme Function
28	D	3.C	ENE-1.I	Photosynthesis
29	B	3.E	ENE-2.J	Mechanisms of Transport
30	C	2.A	IST-1.O	Translation

Multiple-Choice Question	Answer	Skill	Learning Objective	Topic
31	C	1.A	ENE-1.A	Elements of Life
32	A	1.B	ENE-2.C	Membrane Permeability
33	B	5.A	IST-1.F	Meiosis
34	C	6.D	ENE-1.L	Cellular Respiration
35	C	1.C	IST-1.H	Meiosis and Genetic Diversity
36	B	2.B	IST-1.P	Biotechnology
37	A	6.B	EVO-1.G	Artificial Selection
38	C	2.A	EVO-3.B	Phylogeny
39	B	5.C	EVO-1.K	Hardy-Weinberg Equilibrium
40	C	6.A	EVO-1.H	Population Genetics
41	C	1.C	ENE-4.B	Community Ecology
42	B	6.C	SYI-3.G	Biodiversity
43	A	6.E	SYI-2.B	Disruptions to Ecosystems
44	D	2.B	ENE-4.B	Community Ecology
45	A	3.A	ENE-4.B	Community Ecology
46	A	1.B	SYI-1.B	Properties of Biological Macromolecules
47	A	4.B	ENE-1.B	Cell Size
48	B	1.B	SYI-1.F	Cell Structure and Function
49	C	4.B	SYI-3.B	Environmental Effects on Phenotype
50	D	2.B	EVO-1.E	Natural Selection
51	C	6.D	IST-1.E	Regulation of Cell Cycle
52	A	4.B	IST-1.I	Mendelian Genetics
53	B	5.A	IST-1.I	Mendelian Genetics
54	A	4.B	IST-1.P	Biotechnology
55	C	1.C	IST-1.N	Transcription and RNA Processing
56	A	1.A	SYI-1.C	Structure and Function of Biological Macromolecules
57	D	5.C	EVO-1.K	Hardy-Weinberg Equilibrium
58	B	3.A	IST-3.F	Signal Transduction
59	A	1.A	ENE-2.C	Membrane Permeability
60	D	6.A	IST-1.I	Mendelian Genetics

Free-Response Section

Scoring Guidelines

Question 1: Interpreting and Evaluating Experimental Results 9 points

Learning Objectives: SYI-1.B.2 SYI-1.C1 IST-1.N.3

- (A) Describe the three structural components of an RNA nucleotide monomer. 1 point

- An RNA nucleotide has the following three structural components:
a five-carbon sugar (ribose), a phosphate group, and a nitrogen base (adenine, cytosine, guanine, or uracil).

- Explain the role of RNA polymerase during transcription. 1 point

Accept one of the following:

- RNA polymerase synthesizes a new mRNA molecule based on a DNA template by matching the current DNA base with the proper complement.
- RNA polymerase joins or bonds the newly paired RNA nucleotide and the growing RNA strand with a covalent bond.

Total for part (A) 2 points

- (B) Identify the dependent variable in the experiments. 1 point

- The maximum elongation rate of the mRNA

- Identify a control group missing from the second experiment. 1 point

- An appropriate control group missing from the second experiment.
Either of the strains from the first experiment (wild strain or experimental strain) but without amanitin is an appropriate control for the second experiment, but there may be other appropriate controls.

- Justify the need for this control group in the second experiment. 1 point

- The response correctly indicates why the missing control is needed to correctly interpret the results of experiment 2. If either the wild strain or experimental strain from experiment 1 is selected, then the justification is that the effect of amanitin on the maximum elongation rate cannot be determined without comparison to the maximum elongation rate under the same conditions without amanitin.

Total for part (B) 3 points

(C) Describe the effect of amanitin on the maximum elongation rate for the wild-type and modified RNA polymerases. **1 point**
4.B

- Amanitin decreases the maximum elongation rate for the wild strain and does not affect the rate in the experimental strain.

Determine the ratio of the average maximum elongation rate for the modified RNA polymerase compared to the wild strain RNA polymerase in Figure 1. **1 point**
5.A

Accept one of the following (or appropriate multiples of these ratios):

- 1 : 6
- 1 / 6
- 1 to 6

Total for part (C) 2 points

(D) State the null hypothesis for the experiment in Figure 1. **1 point**
3.B

Accept one of the following:

- The modified RNA polymerase would not affect the maximum elongation rate.
- Any difference between the two elongation rates is due to chance.

Provide reasoning to justify the claim that the change in the amino acid sequence in the modified RNA polymerase affected the shape of the active site on the enzyme. **1 point**
6.B

- A change to the active site would explain the decrease in the elongation rate.

Total for part (D) 2 points

Total for question 1 9 points

Question 2: Interpreting and Evaluating Experimental Results with Graphing

9 points

Learning Objectives: ENE-1.F ENE-1.J ENE-1.N SYI-2.B

-
- (A) Describe the effect of an increase in environmental temperature above the optimum temperature range of the enzyme. **1 point**
1.A

Accept one of the following:

- An increase in temperature (above the optimum range) will denature the enzyme **and** reduce the reaction rate.
- An increase in temperature (above the optimum range) can alter the shape of the enzyme/active site **and** reduce the reaction rate.

Total for part (A) **1 point**

- (B) Using the template in the space provided for your response, construct an appropriately labeled graph to represent the data in the table. **3 points**
3.C

One point for each of the following:

- Axes properly labeled and scaled
- Line graph with accurately plotted points
- Error bars of appropriate magnitude

Determine whether there is a statistical difference in the amount of CO₂ fixed by rubisco at 30°C and 40°C. **1 point**
5.B

- No statistical difference

Total for part (B) **4 points**

- (C) Identify the temperature at which the soybean leaves are producing the lowest amount of carbohydrate. **1 point**
4.B

- Any value above 45°C and equal to or below 50°C

Total for part (C) **1 point**

-
- (D) Based on the data, predict how a surface temperature that continues to rise above 40°C most likely affects the amount of energy available to primary consumers in an ecosystem. **1 point**
3.B
- Less energy would be available.
-
- Provide reasoning to justify your prediction. **1 point**
- Carbon fixation decreases at temperatures above 40°C. **6.C**
-
- Based on the data from the experiment and the prediction of an increase in average surface temperature by the model, predict how the locations of plant species are expected to change over time. **1 point**
6.D
- Accept one of the following:**
- As temperatures warm, the ranges where individual plant species are found will move toward the poles.
 - As temperatures warm, the ranges where individual plant species are found will move toward higher altitudes.
 - As temperatures warm, the ranges where individual plant species are found will move toward cooler areas.

Total for part (D) 3 points

Total for question 2 9 points

Question 3: Scientific Investigation

4 points

Learning Objectives: EVO-1.E EVO-1.D EVO-1.C

- (A) Describe the importance of phenotypic variation in louse body color among individuals in a population of lice. **1 point**
1.A
- Increased variation increases the probability that some members of the population will survive (and reproduce) in a changing environment.
- (B) Justify the decision of the researchers to hold lighting conditions constant in their experiment. **1 point**
3.C
- Since pigeons clean their feathers by sight, variable light conditions would affect the effectiveness of this behavior.
- (C) Predict the most likely effect of the pigeons cleaning their feathers on the phenotypes of the lice after four years. **1 point**
3.B
- Accept one of the following:**
- Louse phenotypes that blended with their host's feather color would increase in frequency.
 - Louse phenotypes that contrasted with their host's feather color would decrease in frequency.
- (D) Provide reasoning to support your prediction in part (C). **1 point**
6.C
- Lice with a contrasting coloration to the host feathers were removed before they could reproduce. Lice with a similar coloration to the host feathers survived to reproduce.
-

Total for question 3 4 points

Question 4: Conceptual Analysis

4 points

Learning Objectives: SYI-3.B

- (A) Describe the factors that influence an individual's phenotype. **1 point**
• Phenotype is based on genetic potential that is influenced by environmental conditions. **1.A**
- (B) Explain how the presence of *Notonecta* chemical cues affects gene expression in the *Daphnia*. **1 point**
• The presence of *Notonecta* chemical cues enhanced expression of genes associated with crest development in the *Daphnia*. **2.B**
- (C) Predict the relative size of the crest height and width of offspring raised in the tank without chemical cues as compared to the parent *Daphnia*. **1 point**
• Offspring would resemble the original population. **3.B**
- (D) Provide reasoning to justify your prediction in part (C). **1 point**
• Without the *Notonecta* chemical cues, the genes for crest size would not be affected during development. **6.B**
-

Total for question 4 4 points

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

4 points

Learning Objectives: IST-1.C

- (A)** Describe the role of mitosis in the growth of a plant. **1 point**

- Mitosis provides new cells for growth and development.

1.A

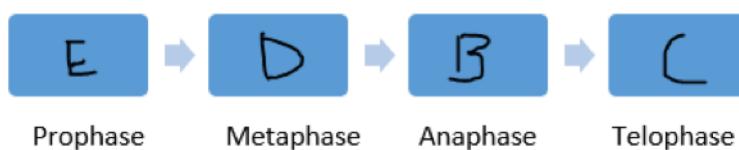
- (B)** Explain why there are a higher number of cells observed in mitosis in the root tip than in the woody stem. **1 point**

2.B

- The root tip is growing faster than the woody stem.

- (C)** Refine the model in the space provided for your response by using the letters from four of the cell labels of Sample 2 to represent the sequential steps of mitosis. **1 point**

2.D



- (D)** Explain how the arrangement of cellular components during the step of mitosis portrayed by cell D in Sample 2 facilitates the proper distribution of chromosomes to the two daughter cells. **1 point**

2.C

- By lining up at the equator, the two chromatids of each chromosome can be distributed to opposite ends of the cell.

Total for question 5 4 points

Question 6: Analyze Data

4 points

Learning Objectives: ENE-1.B

- (A) Identify the rectangular solid that represents the cell with the smallest amount of plasma membrane per volume of cytoplasm. **1 point**
4.B
- Rectangular solid 1.
- (B) Describe the relationship between the dimensions of the rectangular solids and their surface area-to-volume ratios (SA:V). **1 point**
4.B
- As the rectangular solid becomes longer, wider, AND thinner, the SA:V increases.
- (C) Using the data from the model, evaluate the hypothesis that cells shaped like rectangular solids 1 and 2 are better suited for slow metabolism and the long-term storage of energy-containing molecules than are cells shaped like rectangular solids 4 and 5. **1 point**
5.D
- The data in the table support the hypothesis, since cells with lower surface area-to-volume ratios, such as rectangular solids 1 and 2, require smaller amounts of plasma membrane and other cellular material to contain a given volume of materials than do cells with higher surface area-to-volume ratios, such as rectangular solids 4 and 5.
- (D) Based on the trends shown in the data, explain why some rectangular cells include folds or projections in their plasma membranes. **1 point**
6.D
- Folds and projections increase the SA:V without affecting the other dimensions of the cell.

Total for question 6 4 points

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