

BIOLOGY

SECTION I

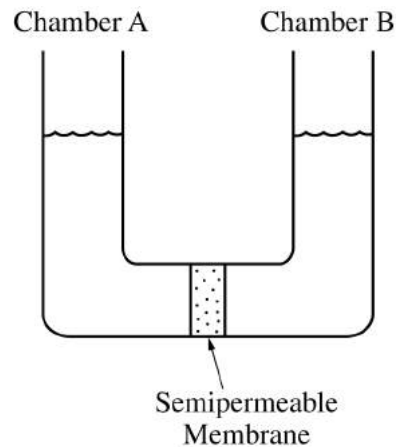
Time—1 hour and 30 minutes

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

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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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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).

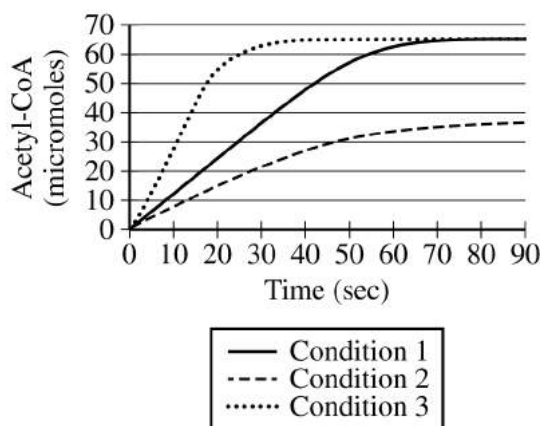


Figure 1. Accumulation of acetyl-CoA under different conditions

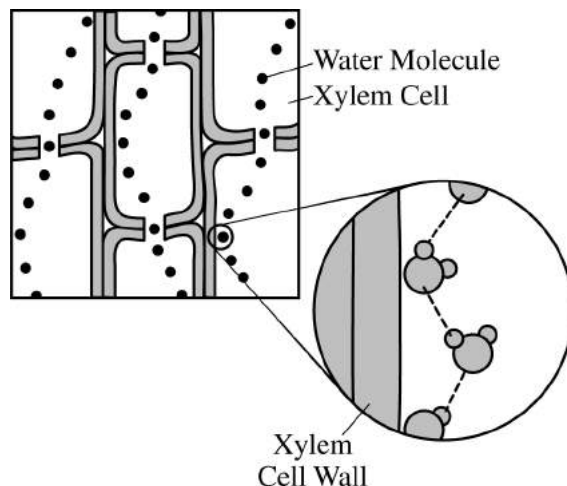
5. Which of the following best describes the cellular location where pyruvate dehydrogenase is most likely active?
- (A) The cytosol
 - (B) The lysosomes
 - (C) The nucleus
 - (D) The mitochondrial matrix
6. The maximum production rate of acetyl-CoA under condition 1 is closest to which of the following?
- (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.

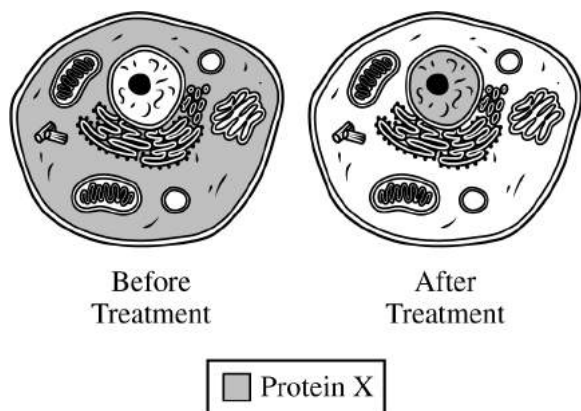
9. The diagram shows how water can adhere to the xylem in the stems of plants, which contributes to water movement in the plant. Which of the following best explains how water is able to move upward from the roots of a plant, through its xylem in the stem, and out to the leaves?



- (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.

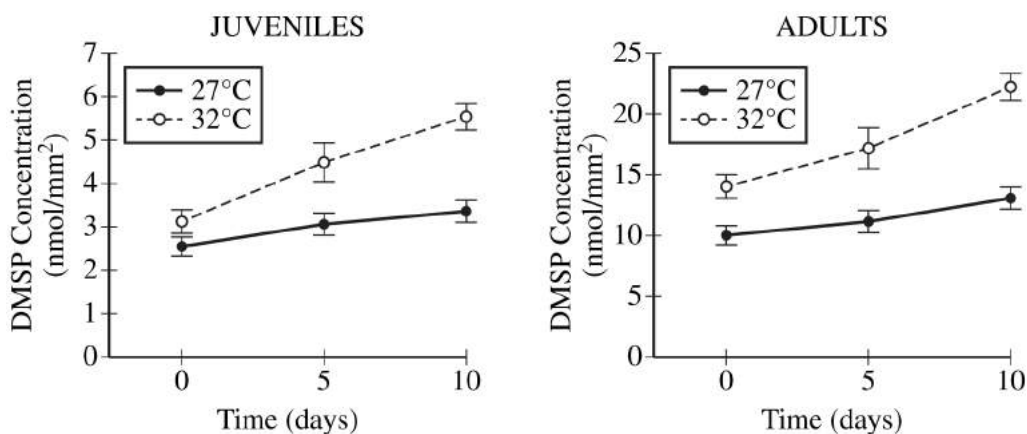


Figure 1: DMSP concentration in juvenile and adult corals and their symbionts in normal and thermally-stressed conditions. Error bars represent $\pm 2SE_{\bar{x}}$.

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.

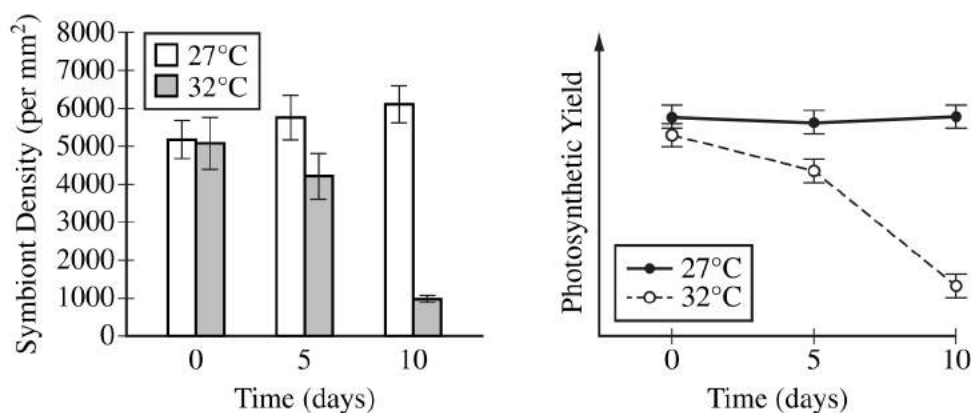


Figure 2: Variation in symbiont density and photosynthetic yield in adult corals grown in normal and thermally-stressed conditions. Error bars represent $\pm 2SE_{\bar{x}}$.

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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?

- (A) They are able to obtain more energy from their symbionts because the algae are receiving more light.
- (B) They are able to obtain more energy from their symbionts because the efficiency increases slightly over time.
- (C) They are able to obtain less energy from their symbionts because the algae have been expelled.
- (D) 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* ?

- (A) 0.203
- (B) 0.303
- (C) 0.405
- (D) 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				
		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?

- (A) Glu → Val
- (B) Val → Glu
- (C) Glu → Pro
- (D) Pro → Val

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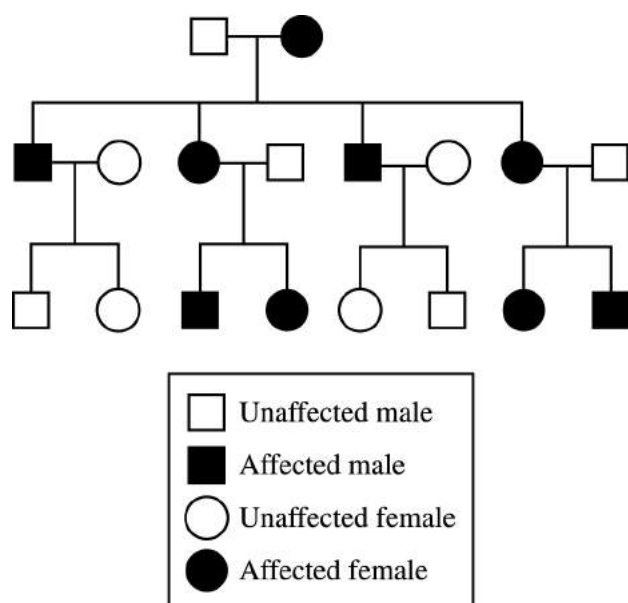


Figure 1. A pedigree of three generations of a family that have a high frequency of a particular genetic condition

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?

- (A) The condition is passed randomly because of the independent assortment of chromosomes.
- (B) The condition is passed from fathers to sons via a Y-linked gene.
- (C) The condition is passed from mothers to sons via an X-linked gene.
- (D) 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?

- (A) Reducing the number of ribosomes in the cell to prevent the creation of the oncogene's proteins
- (B) Blocking membrane-bound receptors of transcription factors
- (C) Introducing a chemical that binds to transcription factors associated with the oncogene's promoter
- (D) 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?

- (A) UV radiation disrupts the double helix structure by breaking the covalent bonds between the nitrogenous base pairs.
- (B) UV radiation disrupts the double helix structure by breaking the hydrogen bonds between the nitrogenous base pairs.
- (C) UV radiation is able to break DNA strands in two by breaking covalent bonds between the sugar-phosphate backbone molecules.
- (D) 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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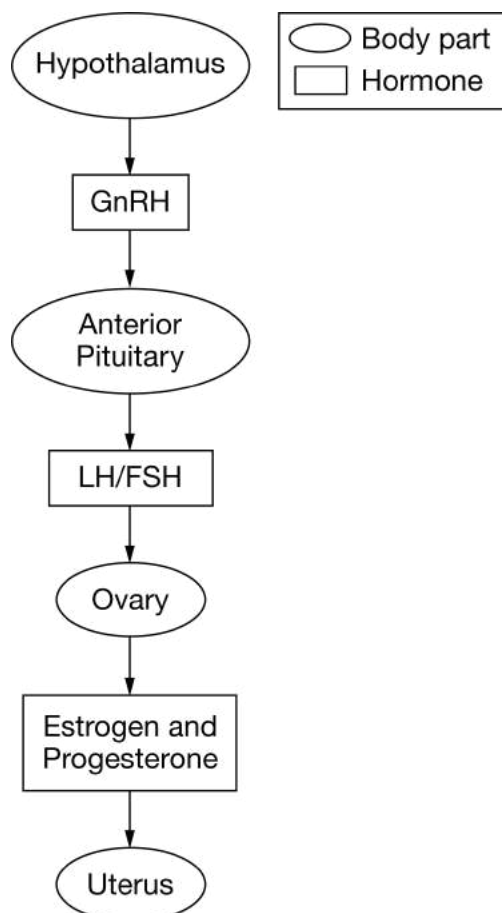


Figure 1. A model of an endocrine signaling pathway showing involved body parts and hormones. GnRH = gonadotropin-releasing hormone, LH = luteinizing hormone, and FSH = follicle-stimulating hormone.

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?
- (A) Estrogen from the ovaries inhibits the release of GnRH from the hypothalamus.
 - (B) Progesterone from the ovaries stimulates the thickening of the uterine lining.
 - (C) Progesterone from the ovaries inhibits the release of LH and FSH from the anterior pituitary.
 - (D) 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.

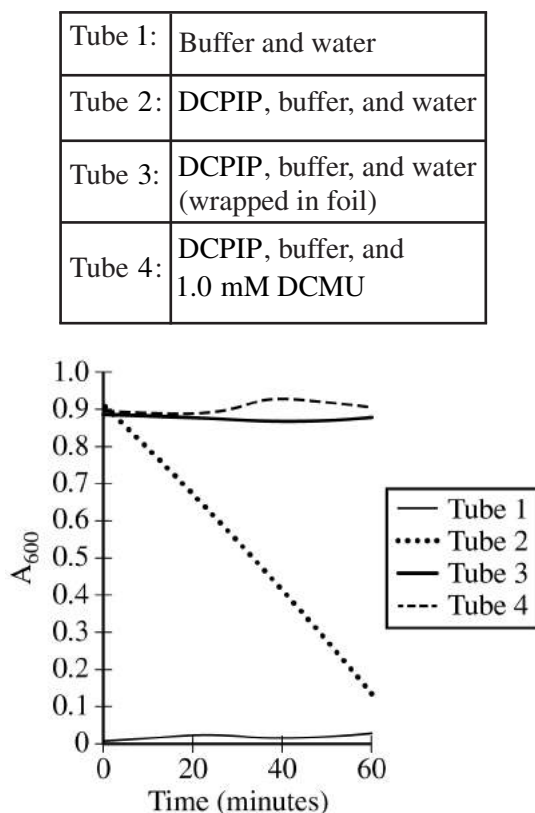


Figure 1. Absorbance readings of four prepared tubes with various solutions over a 60-minute period.

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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) DNA → RNA → Protein
- (B) RNA → DNA → Protein
- (C) RNA → DNA → RNA → Protein
- (D) DNA → RNA → DNA → Protein

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 (G₂ 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.

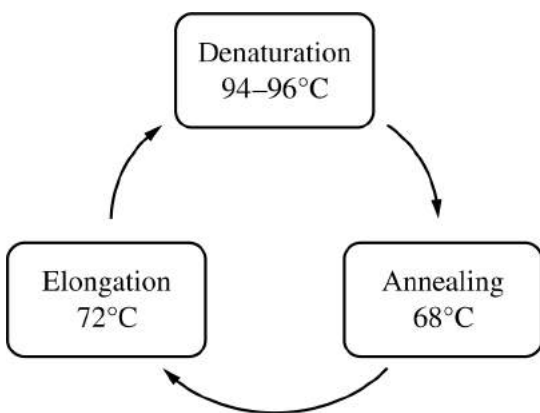
Metabolites	Concentration in Culture A (μM)	Concentration in Culture B (μM)
Pyruvate	25	25
NADH	55	550
NAD ⁺	55	5
ATP	85	5
ADP+P _i	55	100
FADH ₂	25	26
FAD	25	25

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?
- (A) The cells of the banana plant are unable to replicate DNA, thus preventing cell division and limiting growth.
 - (B) The banana plants lack enough genetic diversity to properly hybridize.
 - (C) The production of gametes is disrupted because of unequal pairing of homologous chromosomes during meiosis.
 - (D) 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.



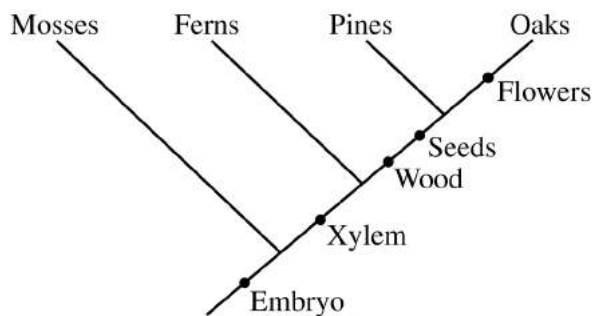
Which of the following best explains why the polymerase from the species *T. aquaticus* is often used for PCR ?

- (A) *T. aquaticus* polymerase has an optimal temperature of 68°C.
- (B) *T. aquaticus* polymerase does not denature at high temperatures.
- (C) *T. aquaticus* polymerase can be used more than once without degrading.
- (D) *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?

	<u>Genetic Similarity</u>	<u>Function of Structure</u>	<u>Form of Structure</u>
(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?

- (A) Xylem only
- (B) Seeds and wood only
- (C) Embryo and xylem only
- (D) 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.

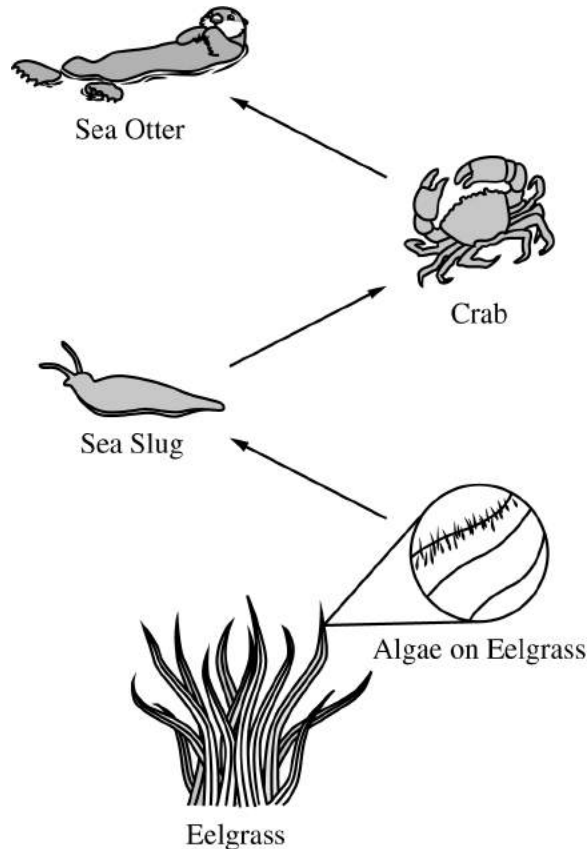


Figure 1. Partial food chain in eelgrass habitats

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.

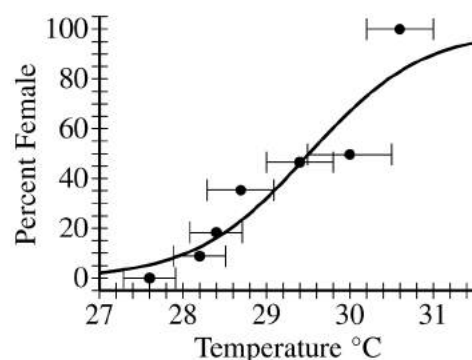


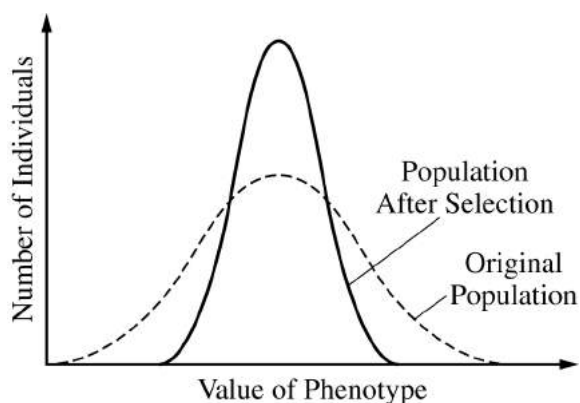
Figure 1. Percentage of sea turtles that develop as females at different average nest temperatures. The bars represent the temperature range observed within the nests.

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) 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.
 - (B) 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.
 - (C) 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.
 - (D) 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?

- (A) Trabectedin increases the production of cyclin proteins that signal the cancer cells to enter prophase.
- (B) Trabectedin interferes with the plasma membrane, causing it to break down and expose the DNA to damage.
- (C) Trabectedin interferes with the duplication of DNA during interphase and thus prevents cancer cells from passing the G₂ checkpoint.
- (D) 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.

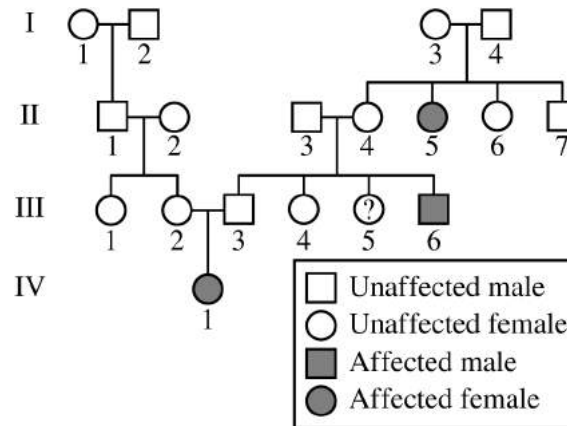


Figure 1. A pedigree of a family affected by Friedreich's ataxia

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.

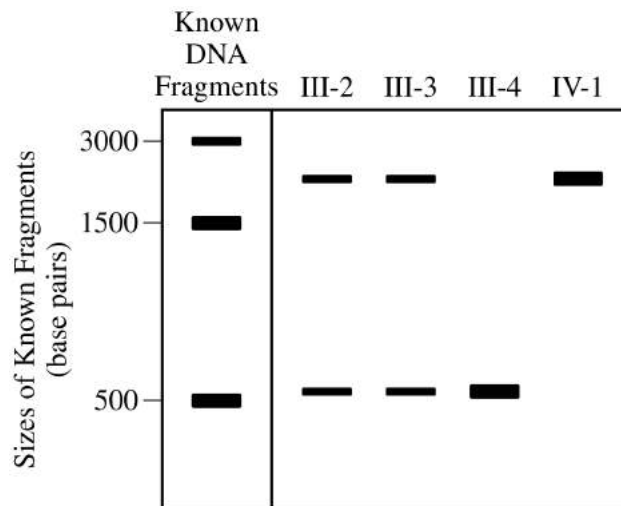


Figure 2. *FXN* gene fragment sizes for several family members. A sample of DNA with fragments of known lengths was used for comparison.

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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).

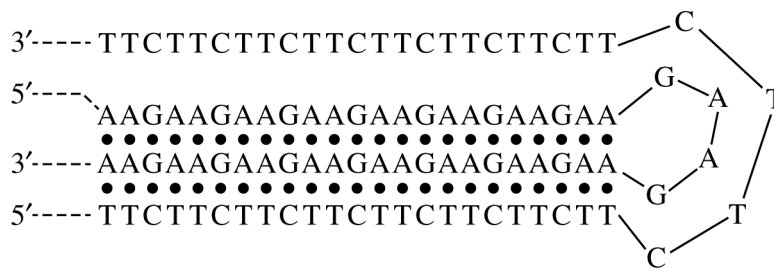


Figure 3. The modeled DNA triple-helix structure that can form in areas with multiple GAA triplets

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.

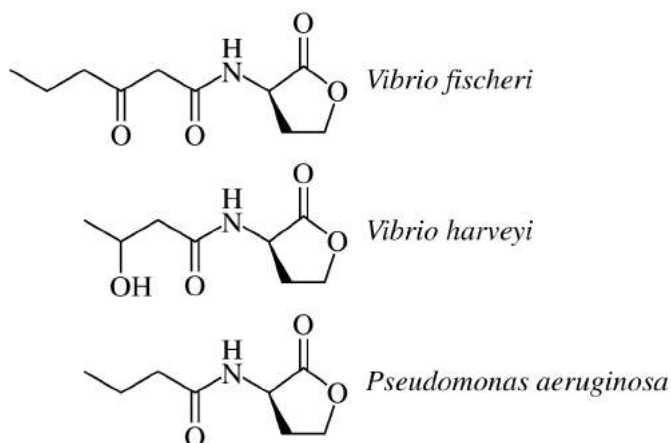


Figure 1. The chemical structure of several molecules used for quorum sensing in three species of bacteria

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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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 $40\text{ }\mu\text{g / mL}$ solution of amanitin and recorded the maximum elongation rate of the mRNA (Figure 2). Error bars represent $\pm 2\text{SE}_{\bar{x}}$.

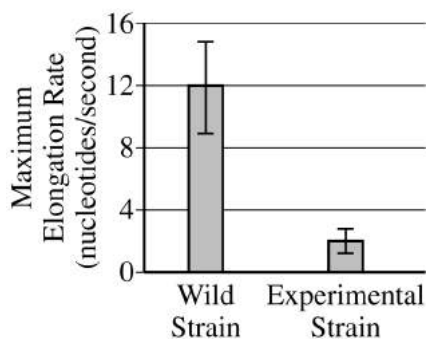


Figure 1. Maximum elongation rate under natural conditions

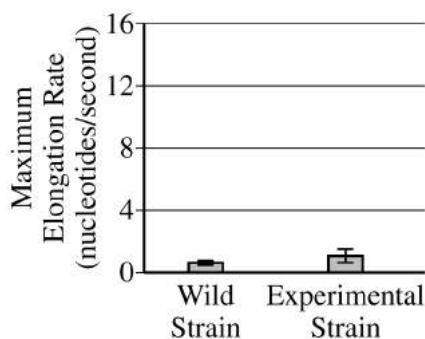


Figure 2. Maximum elongation rate in a $40\text{ }\mu\text{g / mL}$ amanitin solution

- (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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[illegible]

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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 $\pm 2\text{SE}_{\bar{x}} (\mu\text{mol} / \text{m}^2/\text{s})$
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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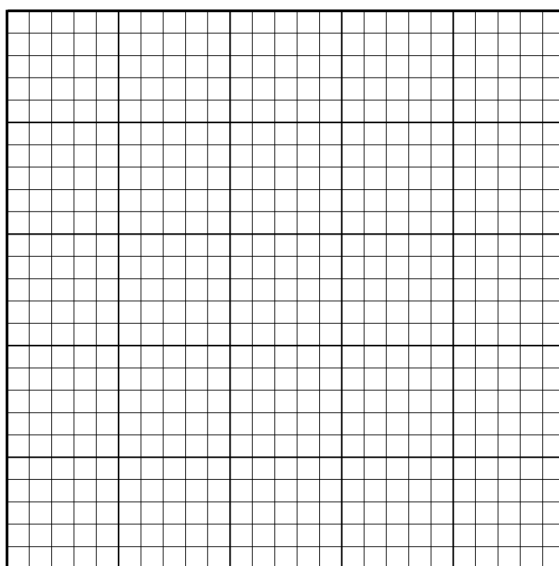
WRITE ALL YOUR RESPONSES ON THE LINED PAGES.

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(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 ± 9
30	96 ± 5
35	93 ± 8
40	104 ± 7
45	71 ± 7
50	59 ± 4

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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.

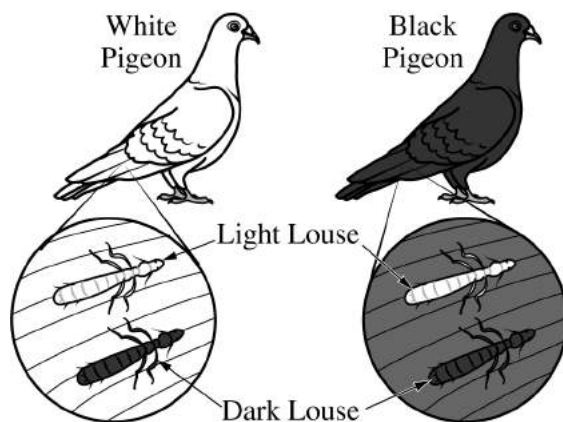


Figure 1. Pigeon and louse phenotypes, showing lice against pigeon feathers

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.

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

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*.

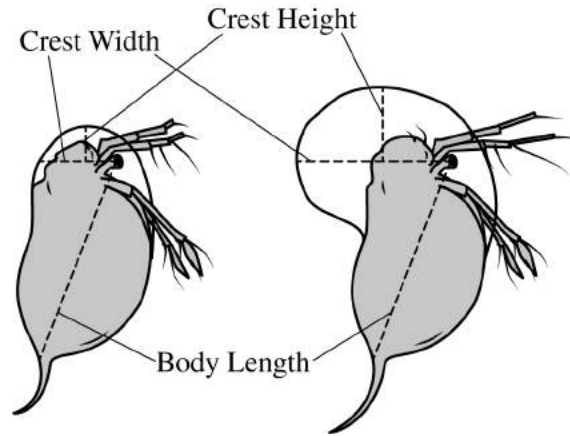


Figure 1. Comparison of *Daphnia* that developed in the absence (left) and the presence (right) of *Notonecta* chemical cues

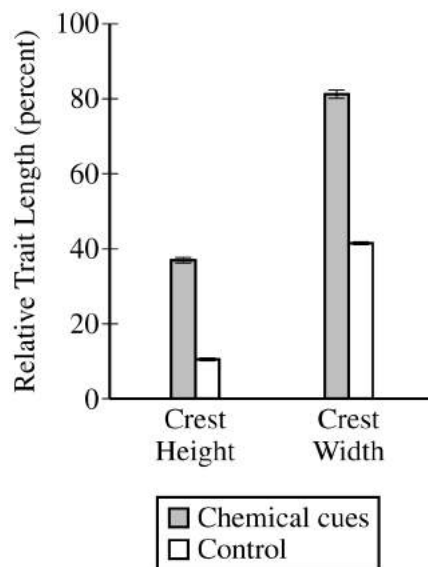


Figure 2. Comparison of mean relative crest height and width between control *Daphnia* and *Daphnia* exposed to *Notonecta* chemical cues during development. Error bars represent $\pm 2SE_{\bar{x}}$.

- 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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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. Cells in different steps of mitosis are labeled with letters A, B, C, D, and E in Sample 2.

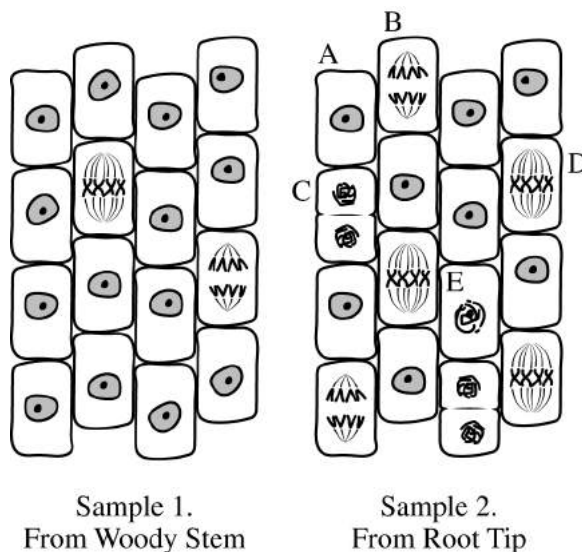
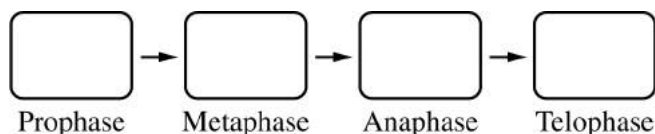


Figure 1. Drawings of samples of plant cells collected from two locations in a woody plant during the spring

- (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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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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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

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

Laws of Probability

If A and B are mutually exclusive, then:

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

If A and B are independent, then:

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

Hardy-Weinberg Equations

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

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

$\bar{x}$ = sample mean

n = sample size

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

o = observed results

e = expected results

Σ = sum of all

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

Metric Prefixes

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

APPENDIX - ANSWERS

AP BIOLOGY 2020

Multiple-choice answer key transcribed from the matching supplied source.

Question	Answer	Question	Answer	Question	Answer
1	B	21	C	41	C
2	A	22	B	42	B
3	B	23	B	43	A
4	C	24	D	44	D
5	D	25	B	45	A
6	A	26	A	46	A
7	A	27	D	47	A
8	D	28	D	48	B
9	D	29	B	49	C
10	C	30	C	50	D
11	B	31	C	51	C
12	B	32	A	52	A
13	A	33	B	53	B
14	C	34	C	54	A
15	B	35	C	55	C
16	C	36	B	56	A
17	C	37	A	57	D
18	D	38	C	58	B
19	A	39	B	59	A
20	D	40	C	60	D

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 1.A
	<ul style="list-style-type: none">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 1.C
	<p>Accept one of the following:</p> <ul style="list-style-type: none">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 3.C
	<ul style="list-style-type: none">The maximum elongation rate of the mRNA	
	Identify a control group missing from the second experiment.	1 point 3.C
	<ul style="list-style-type: none">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 3.C
	<ul style="list-style-type: none">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)	<p>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.</p> <ul style="list-style-type: none"> • Less energy would be available. 	1 point 3.B
	<p>Provide reasoning to justify your prediction.</p> <ul style="list-style-type: none"> • Carbon fixation decreases at temperatures above 40°C. 	1 point 6.C
	<p>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.</p> <p>Accept one of the following:</p> <ul style="list-style-type: none"> • 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. 	1 point 6.D
		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. <ul style="list-style-type: none">• Increased variation increases the probability that some members of the population will survive (and reproduce) in a changing environment. | 1 point
1.A |
| <hr/> | | |
| (B) | Justify the decision of the researchers to hold lighting conditions constant in their experiment. <ul style="list-style-type: none">• Since pigeons clean their feathers by sight, variable light conditions would affect the effectiveness of this behavior. | 1 point
3.C |
| <hr/> | | |
| (C) | Predict the most likely effect of the pigeons cleaning their feathers on the phenotypes of the lice after four years.
Accept one of the following: <ul style="list-style-type: none">• 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. | 1 point
3.B |
| <hr/> | | |
| (D) | Provide reasoning to support your prediction in part (C). <ul style="list-style-type: none">• 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. | 1 point
6.C |
-

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. <ul style="list-style-type: none">• Phenotype is based on genetic potential that is influenced by environmental conditions. | 1 point
1.A |
| <hr/> | | |
| (B) | Explain how the presence of <i>Notonecta</i> chemical cues affects gene expression in the <i>Daphnia</i> . <ul style="list-style-type: none">• The presence of <i>Notonecta</i> chemical cues enhanced expression of genes associated with crest development in the <i>Daphnia</i>. | 1 point
2.B |
| <hr/> | | |
| (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 <i>Daphnia</i> . <ul style="list-style-type: none">• Offspring would resemble the original population. | 1 point
3.B |
| <hr/> | | |
| (D) | Provide reasoning to justify your prediction in part (C). <ul style="list-style-type: none">• Without the <i>Notonecta</i> chemical cues, the genes for crest size would not be affected during development. | 1 point
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

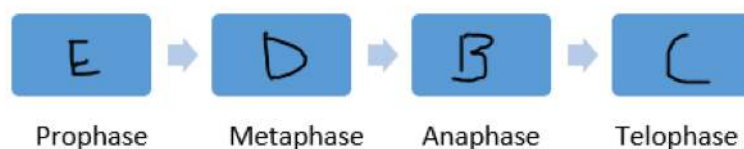
(A) Describe the role of mitosis in the growth of a plant. **1 point**
1.A

- Mitosis provides new cells for growth and development.

(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.

• Rectangular solid 1. | 1 point
4.B |
| <hr/> | | |
| (B) | Describe the relationship between the dimensions of the rectangular solids and their surface area-to-volume ratios (SA:V).

• As the rectangular solid becomes longer, wider, AND thinner, the SA:V increases. | 1 point
4.B |
| <hr/> | | |
| (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.

• 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. | 1 point
5.D |
| <hr/> | | |
| (D) | Based on the trends shown in the data, explain why some rectangular cells include folds or projections in their plasma membranes.

• Folds and projections increase the SA:V without affecting the other dimensions of the cell. | 1 point
6.D |
-

Total for question 6 4 points