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 fill in the corresponding circle on the answer sheet.

1. Which of the following best describes the two divisions that occur in meiosis?

(A) The first division results in two diploid cells, and the second division results in four haploid cells.

(B) Homologous chromosomes separate in the first division, and paired chromatids separate in the second division.

(C) The first division results in cells with one-half of the original chromosome number, and the original chromosome number is restored in the second division.

(D) Crossing-over occurs during the first division, and independent assortment occurs during the second division.

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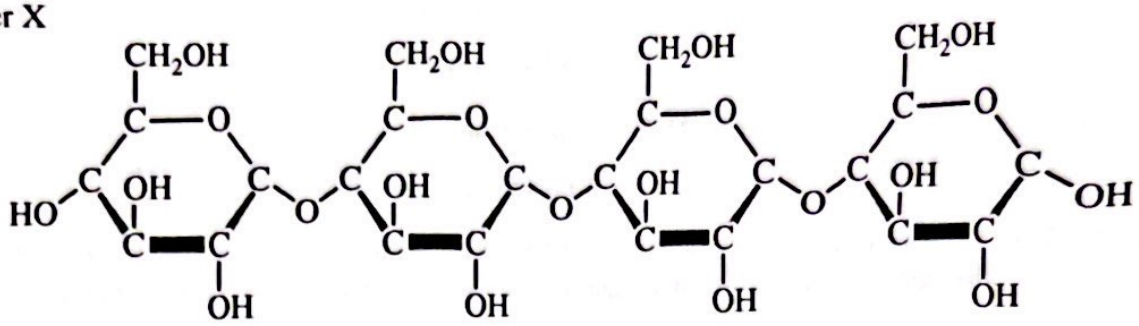
Polymer X



Polymer Y

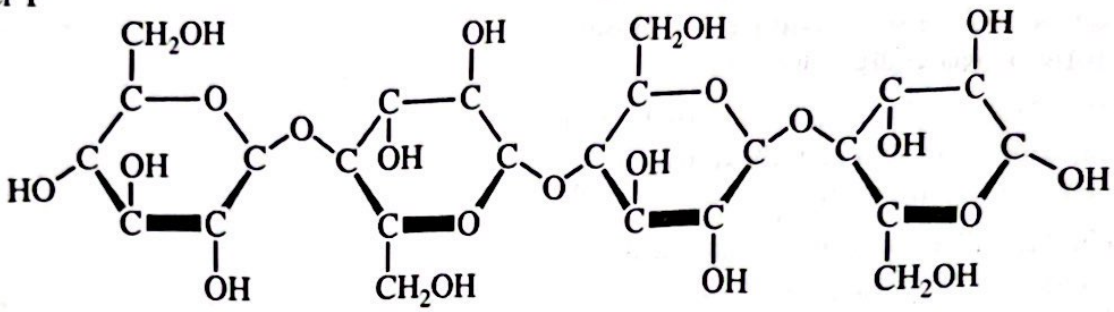


Figure 1. Two carbohydrate polymers

2. Which of the following best explains why the two carbohydrate polymers represented in Figure 1 have different biological functions?

(A) Polymer X is broken down by a hydrolysis reaction, whereas polymer Y is broken down by a dehydration reaction.

(B) The order of the monomers is important to the function of polymer Y but unimportant to the function of polymer X.

(C) The polymers differ in the types of atoms they contain.

(D) The orientation of the monomers relative to each other differs in the polymers.

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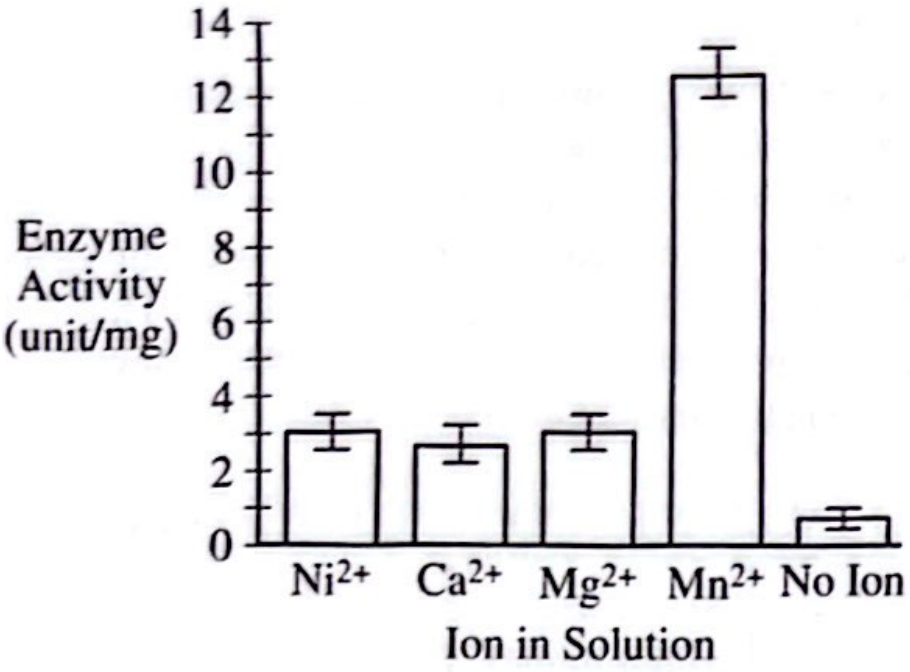

Figure 1. Activity of an enzyme in the presence of different positively charged ions. Error bars represent $\pm 2SE_{\bar{x}}$.

3. Some enzymes require the presence of certain positively charged ions to be fully functional. To determine whether a newly discovered enzyme requires the presence of positive ions, researchers determined the activity of the enzyme in solutions containing different ions (Figure 1). Which of the following claims about Mn^{2+} is supported by the data in Figure 1?

(A) Mn^{2+} increases enzyme activity, whereas the other ions do not alter enzyme activity.

(B) Mn^{2+} increases enzyme activity, whereas the other ions lower enzyme activity.

(C) Mn^{2+} is necessary for the enzyme-catalyzed reaction to take place.

(D) Mn^{2+} increases enzyme activity to a greater extent than do the other ions.

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Questions 4 - 8

Many species of birds protect themselves from predatory birds by emitting warning calls, then gathering together and chasing the predators. Researchers studied the responses by Parus major, a species of small, seed-eating songbird, to two predators, tawny owls (Strix aluco) and sparrowhawks (Accipiter nisus). The tawny owl is a low-threat predator to songbirds because the tawny owl prefers to eat small mammals and only occasionally eats small birds. The sparrowhawk is a high-threat predator to songbirds because it prefers to eat small birds. The researchers first determined the major characteristics of warning calls produced by the songbirds when they encountered lifelike models of tawny owls or sparrowhawks in their native habitat (Table 1).

TABLE 1. CHARACTERISTICS OF SONGBIRD WARNING CALLS IN RESPONSE TO TWO PREDATORS

Characteristic (mean $\pm 2SE_{\bar{x}}$)	Tawny Owl (low-threat)	Sparrowhawk (high-threat)
Length of call (sec)	0.42 ± 0.03	0.53 ± 0.04
Number of notes within a call	6.06 ± 0.40	7.10 ± 0.45
Time between notes in a call (sec)	0.034 ± 0.002	0.041 ± 0.003
Call rate (calls / individual / min)	7.97 ± 1.60	15.03 ± 4.25

In a second study, the researchers used speakers attached to trees to play recorded warning calls produced by the songbirds in response to tawny owls or sparrowhawks. The researchers performed several trials in which they analyzed the response of individual songbirds to the warning calls (Table 2). For each trial, they determined the shortest length of time for the first songbird to fly within 6 meters of a speaker and how close the bird flew to the speaker.

TABLE 2. RESPONSE OF THE SONGBIRDS TO SONGBIRD WARNING CALLS FOR TWO PREDATORS

Songbird Response (mean $\pm 2SE_{\bar{x}}$)	Warning Calls in Response to Tawny Owls (low-threat)	Warning Calls in Response to Sparrowhawks (high-threat)
Shortest time for first songbird to approach a speaker (sec)	135.6 ± 17.3	207.4 ± 28.8
Shortest distance between songbird and a speaker (cm)	84.8 ± 25.3	224.3 ± 48.6

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4. Based on Table 1, which of the following best describes a change in the warning calls of the songbirds as the threat level of a predator increases?

(A) The calls become shorter in length.

(B) The calls contain fewer notes.

(C) The calls have less time between notes.

(D) The call rate is increased.

5. Which of the following claims about the warning calls produced by the songbirds is best supported by the data in Table 2?

(A) The different warning calls determine the frequency with which the parent songbirds will leave their nests to protect their young from predators.

(B) The different warning calls affect how the songbirds approach each other to chase predators.

(C) The different warning calls determine the likelihood that the songbirds will be attacked by a predator.

(D) The different warning calls protect not only the species of songbird but also other bird species in the community.

6. Producing a bird call with multiple components is a complex process. There is a wide range of variation in any particular type of call produced by the individuals in a population of the songbird species. Which of the following best explains the wide range of variation in any particular bird call?

(A) The call phenotype is dependent on several interacting genes on different chromosomes.

(B) The call phenotype is dependent on a single gene with only one allele.

(C) The call phenotype is dependent on two linked genes, each with only two alleles.

(D) The call phenotype is dependent on a single gene with multiple alleles on a sex chromosome.

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7. At one time, farmers planted seeds treated with pesticides to protect the seeds from being eaten. Based on the information provided, which of the following most likely explains why this treatment greatly reduced the sparrowhawk population size but had much less effect on the tawny owl population size?

(A) Seed-eating birds were a larger portion of the sparrowhawks' diet than of the tawny owls' diet, and the pesticides built up to toxic levels in the sparrowhawks' bodies.

(B) The seed-eating birds hid from sparrowhawks less than they did from tawny owls, so the sparrowhawks ingested more pesticides in their prey than did the owls.

(C) Tawny owls were more likely than the sparrowhawks to develop resistance to the pesticides in the bodies of the seed-eating birds they ate.

(D) Sparrowhawks ingested more seeds from the ground when they captured their prey than tawny owls did, and the pesticide-covered seeds remained in their bodies.

8. An estimated population size of the songbird species in Europe is 130,000,000 birds. If in one year there are 1,500 births and 1,200 deaths per every 1,000 birds, which of the following is closest to the net growth of this European songbird population for the year?

(A) 300

(B) 104,000

(C) 39,000,000

(D) 65,000,000

9. Which of the following statements describes a mutualistic relationship between organisms of two separate species?

(A) One organism benefits at the expense of the other organism.

(B) One organism obtains resources more efficiently than the other organism does.

(C) When the organisms are separated, neither survives as well as when they are grown together.

(D) When the organisms are separated, one organism's growth decreases while the other's growth is unchanged.

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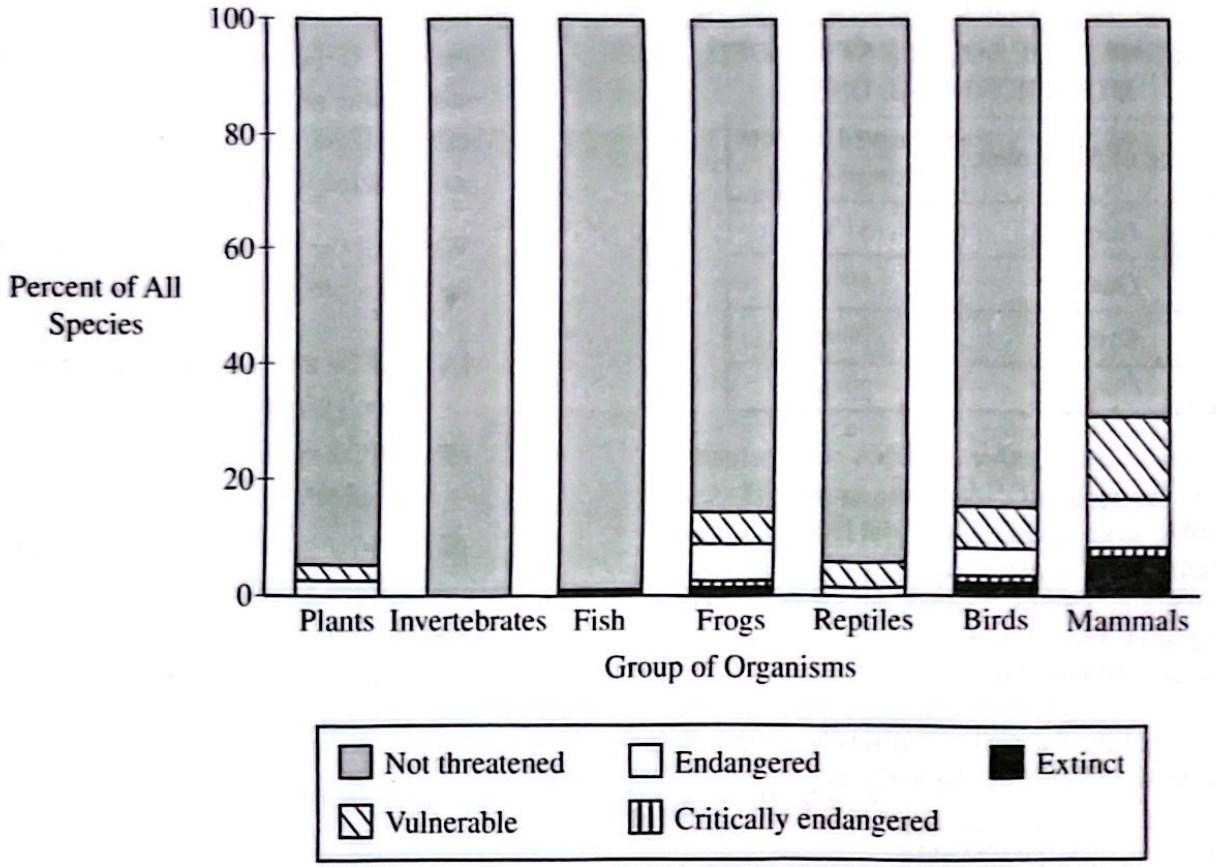

Figure 1. Comparison of the percent of species in different groups of organisms that are threatened with extinction

10. Researchers evaluated the numbers of native species in Australia over the past 200 years. They determined the percent of species in different groups of organisms at various threat-levels of extinction (Figure 1). Based on Figure 1, which two groups of organisms include the greatest percent of species that are not threatened?

(A) Reptiles and fish

(B) Reptiles and plants

(C) Invertebrates and fish

(D) Invertebrates and reptiles

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TABLE 1. PERCENT OF EACH NUCLEOTIDE IN A SEGMENT OF DOUBLE-STRANDED MITOCHONDRIAL DNA

Type of Nucleotide	Observed Percent Composition
Adenine	31%
Guanine	19%
Thymine	28%
Cytosine	22%

11. To determine whether the DNA composition rules for nuclear DNA are the same as those for double-stranded mitochondrial DNA, scientists determined the percentage of each nucleotide in a strand of double-stranded mitochondrial DNA (Table 1). They then performed a chi-square analysis of their data. Which of the following data sets best represents the expected data for the analysis?

(A) Expected

Adenine	Guanine	Thymine	Cytosine
30	20	30	20

(B) Expected

Adenine	Guanine	Thymine	Cytosine
30	20	20	30

(C) Expected

Adenine	Guanine	Thymine	Cytosine
20	20	30	30

(D) Expected

Adenine	Guanine	Thymine	Cytosine
30	30	20	20

12. Scientists recently discovered that long-term memory formation may be partly controlled by stimulating protein synthesis with a protein called eIF2α in specific brain cell types. eIF2α works at the initiation step of translation. Which of the following best explains how eIF2α promotes protein synthesis?

(A) eIF2α attaches to DNA and recruits RNA polymerase to make RNA.

(B) eIF2α splices DNA together to make mRNA.

(C) eIF2α binds to polypeptides and causes them to fold into proteins.

(D) eIF2α forms a complex with mRNA, which binds to a ribosome.

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Questions 13 - 17

Aminotransferases are enzymes that play an important role in nitrogen metabolism in all living organisms. An aminotransferase catalyzes a reaction in which the amino (NH_2) group is removed from the carbon backbone of amino acids. The amino group is a major source of the nitrogen required for metabolic processes. The carbon backbones of many of the amino acids are incorporated into intermediates of the Krebs cycle pathway (Figure 1).

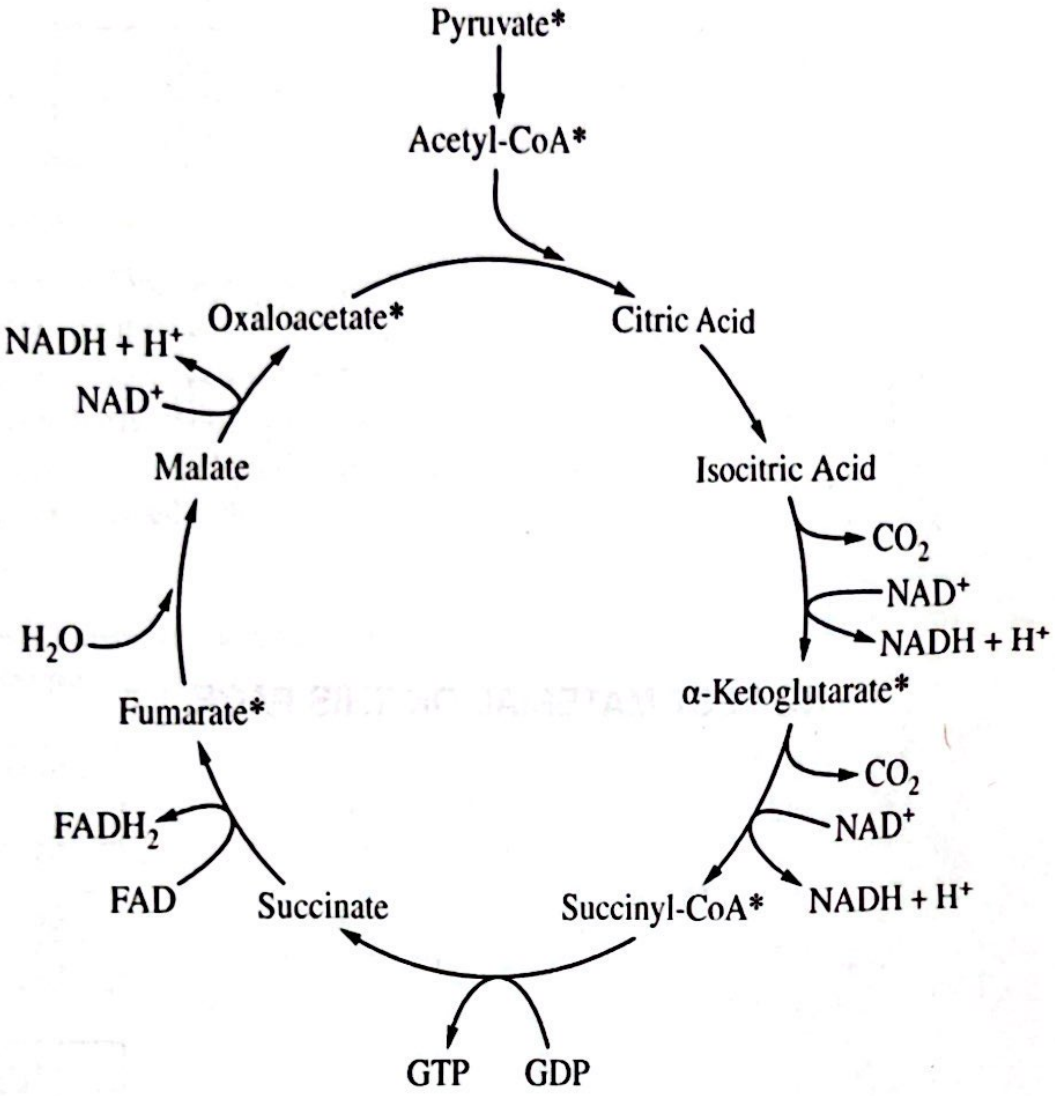

Figure 1. A representation of the Krebs cycle showing intermediate molecules and the locations at which electrons are transferred to NAD^+ and FAD. The asterisks (*) represent intermediates that can be formed from the carbon backbones of amino acids.

A particular aminotransferase plays a role in the conversion of the amino acid aspartate into oxaloacetate, a component of the Krebs cycle. The reactions involved in this process are shown in Figure 2.

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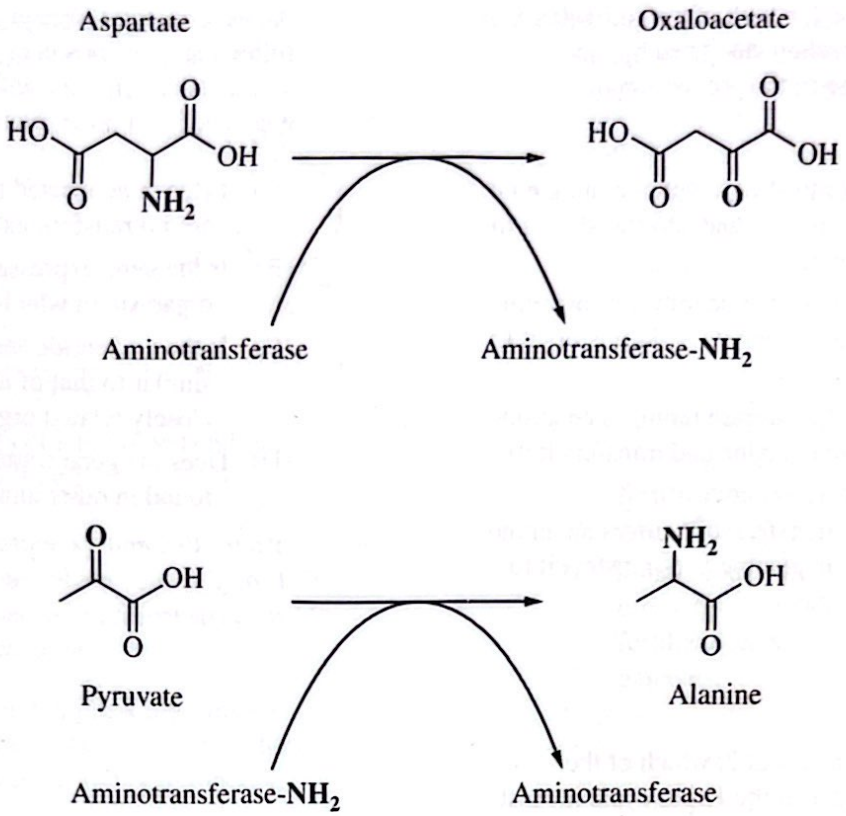

Figure 2. Role of an aminotransferase in the production of oxaloacetate. Aspartate and alanine are amino acids.

13. Which of the following best describes the reactions of the Krebs cycle in eukaryotes?

(A) The reactions release energy and therefore do not require enzymes to proceed.

(B) The reactions are identical to the reactions of the Calvin cycle but occur in the reverse order.

(C) The reactions occur in the matrix of the mitochondria.

(D) The reactions oxidize pyruvate that is produced in the smooth endoplasmic reticulum.

14. Based on the pathway shown in Figure 1, which of the following best explains how the carbon atoms of amino acid backbones that became a part of α-ketoglutarate might end up in citric acid?

(A) α-Ketoglutarate can be broken down, transferring carbons to isocitric acid and then to citric acid.

(B) Carbon atoms in the CO_2 that is released during the conversion of α-ketoglutarate to succinyl-CoA can be fixed into citric acid in the next round of the cycle.

(C) Carbon atoms that carry energy may be released from α-ketoglutarate and added to any molecule in the cycle, including citric acid.

(D) Carbon atoms in α-ketoglutarate are found in subsequent molecules of the cycle, including citric acid, as one molecule is converted to the next.

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15. Based on Figure 2, which of the following best describes the reaction catalyzed by the aminotransferase in the production of oxaloacetate?

(A) The aminotransferase removes an amino group from aspartate and transfers it to oxaloacetate.

(B) The aminotransferase removes an amino group from aspartate and transfers it to pyruvate.

(C) The aminotransferase removes an amino group from alanine and transfers it to aspartate.

(D) The aminotransferase removes an amino group from alanine and transfers it to oxaloacetate.

16. Based on Figures 1 and 2, which of the following changes to the Krebs cycle is most likely to occur if the aminotransferase that converts aspartate to oxaloacetate is nonfunctional?

(A) Less NADH will be produced because there will be a decrease in the amount of citric acid.

(B) More acetyl-CoA will be consumed because there will be a decrease in the amount of oxaloacetate.

(C) More $FADH_2$ will be produced because there will be an increase in the amount of succinate.

(D) Less GDP will be consumed because there will be an increase in succinyl-CoA.

17. An experiment designed to answer which of the following questions is most likely to help scientists determine whether a newly identified gene codes for an aminotransferase?

(A) Is the gene located near genes for other aminotransferases?

(B) Is the gene expressed in all cells of the organism in which it was identified?

(C) Is the nucleotide sequence of the gene similar to that of an aminotransferase in a closely related organism?

(D) Does the gene contain a promoter sequence found in other aminotransferases?

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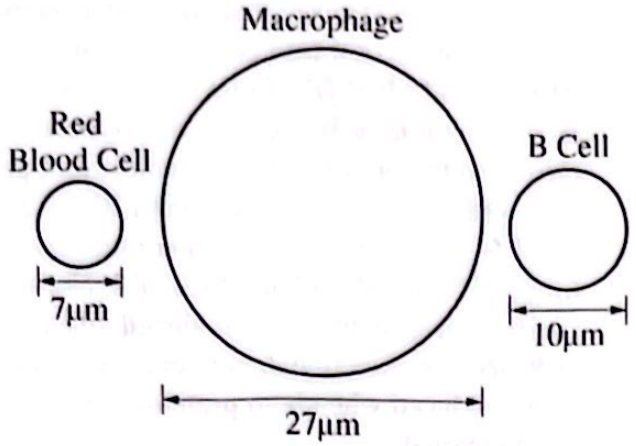

Figure 1. Diameters of a red blood cell, a macrophage, and a B cell

18. Two types of immune system cells, macrophages and B cells, and red blood cells (Figure 1) have different functions and different structures to perform those functions. Which of the following best explains the relationship between the size of cells shown in Figure 1 and the cells' ability to function?

(A) Red blood cells have a greater surface-area-to-volume ratio than macrophages do and, as a result, more efficiently exchange materials with the environment.

(B) Macrophages have a larger volume than red blood cells do and, as a result, can absorb nutrients more efficiently.

(C) Red blood cells have a smaller surface area than B cells do and, as a result, require more organelles to help absorb materials from the environment.

(D) Macrophages have a greater surface-area-to-volume ratio than B cells do and, as a result, more efficiently exchange materials with the environment.

19. Which of the following best explains mechanisms by which sexual reproduction increases genetic variation in a population?

(A) Sister (paired) chromatids undergo crossing-over, and then random fertilization occurs between haploid gametes.

(B) Sister (paired) chromatids independently assort, and then random fertilization occurs between diploid gametes.

(C) Homologous chromosomes undergo crossing-over, and then random fertilization occurs between haploid gametes.

(D) Homologous chromosomes undergo crossing-over, and then random fertilization occurs between diploid gametes.

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TABLE 1. THE EFFECT OF EXERCISE ON THE CONCENTRATION OF LAC-PHE

Time at Which Lac-Phe Was Measured	Average Concentration of Lac-Phe (μM) $\pm 2SE_{\bar{x}}$
Before exercise	0.25 ± 0.04
Immediately after exercise	1.27 ± 0.07
30 min after exercise	0.67 ± 0.10
60 min after exercise	0.21 ± 0.02

20. Researchers studying the effect of exercise on the signaling molecule Lac-Phe measured the Lac-Phe concentration in the blood of resting mice as well as in mice at various times after exercising (Table 1). Based on Table 1, which of the following best describes the relationship between exercise and the concentration of Lac-Phe in mice?

(A) The time required after exercise for the concentration of Lac-Phe to return to a before-exercise level is 30 minutes.

(B) The longer the time after exercising, the higher the concentration of Lac-Phe is.

(C) The concentration of Lac-Phe is highest when the mice are at rest and then decreases during exercise.

(D) The concentration of Lac-Phe is highest immediately after exercise and then decreases over time.

21. Scientists hypothesized that successful meiosis requires interaction between the proteins BRCA2 and MEILB2. To investigate the role of these two proteins in meiosis, researchers measured the production of gametes from parent cells with functional forms of both BRCA2 and MEILB2 and parent cells with nonfunctional forms of both BRCA2 and MEILB2. Normal numbers of gametes were produced when both proteins were functional, but very few gametes were produced when both proteins were nonfunctional. Which of the following investigations should the scientists perform next to learn more about the individual roles of BRCA2 and MEILB2 in meiosis?

(A) Compare the expression of the two proteins in the gametes produced when both proteins are functional.

(B) Measure the mass of DNA in gametes produced from parent cells when both proteins are functional or both are nonfunctional.

(C) Examine the ability of homologous chromosomes to form pairs in gametes produced from parent cells with mutated forms of both proteins.

(D) Examine the production of gametes from parent cells when one of the proteins is functional and the other is nonfunctional.

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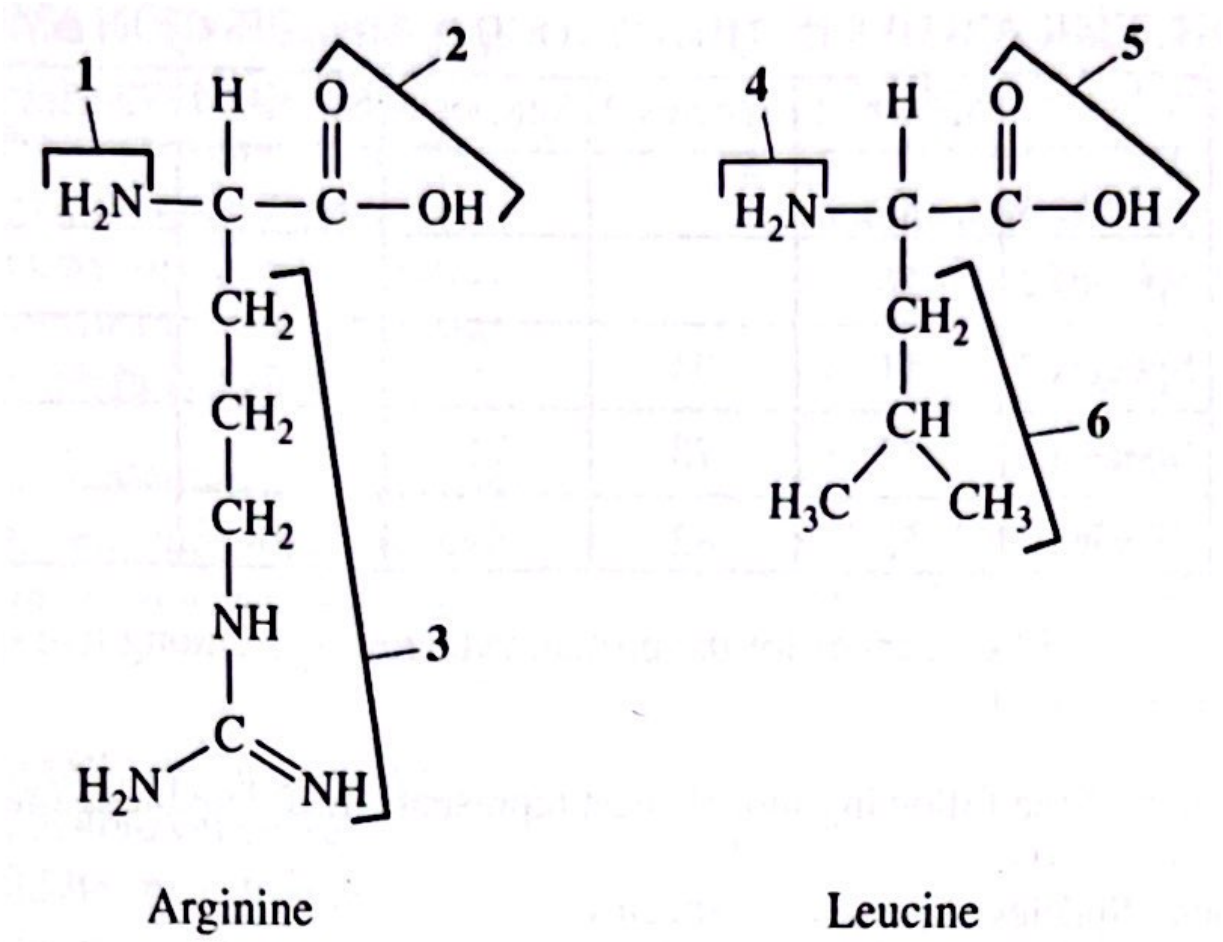

Figure 1. Structure of the amino acids arginine and leucine. Specific groups of atoms are identified by numbers.

22. Based on Figure 1, which of the following best explains a dehydration synthesis reaction between arginine and leucine?

(A) Atoms removed from groups 1 and 4 will form a small molecule, and a hydrogen bond will form between arginine and leucine.

(B) Atoms removed from groups 2 and 4 will form a small molecule, and a covalent bond will form between arginine and leucine.

(C) Atoms removed from groups 2 and 5 will form a small molecule, and a hydrogen bond will form between arginine and leucine.

(D) Atoms removed from groups 3 and 6 will form a small molecule, and a covalent bond will form between arginine and leucine.

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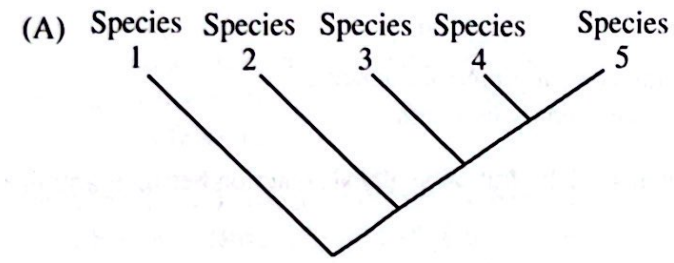
TABLE 1. PERCENT SIMILARITIES IN THE CYTOCHROME c PROTEIN AMONG FIVE SPECIES

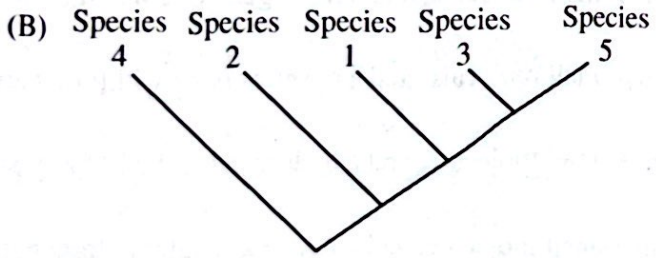
	Species 1	Species 2	Species 3	Species 4	Species 5
Species 1	--	--	--	--	--
Species 2	56	--	--	--	--
Species 3	51	95	--	--	--
Species 4	57	78	74	--	--
Species 5	53	82	80	98	--

23. Students compared amino acid sequences for the protein cytochrome c among five species. The percent similarities are shown in Table 1. Based on Table 1, which of the following models best represents the relatedness among the five species?

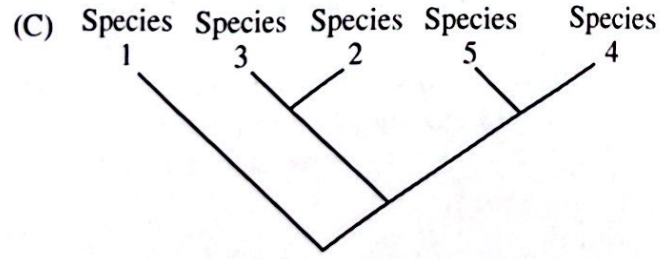
(A)



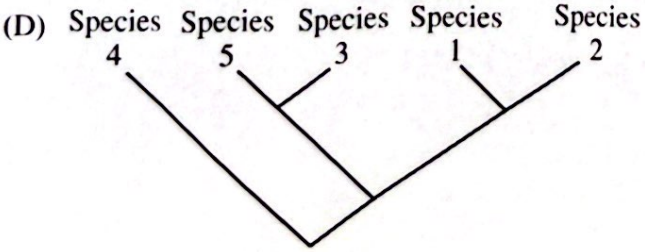
(B)



(C)



(D)



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24. Scientists modified a line of mammalian cells to express bacterial transport proteins in their plasma membranes. These proteins enable the delivery of certain enzymes into the cells. The enzymes catalyze reactions in the cytosol that cause particular proteins in the cells to increase in concentration, resulting in cell death. Which of the following explains the most likely effect on the cells if the enzymes were exposed to a less optimal pH for enzyme activity before entering the cells?

(A) Cell death would increase because the bonds between the enzymes and substrates would become stronger, resulting in faster reactions.

(B) Cell death would increase because the enzymes would become more stable, resulting in a longer period of catalytic activity.

(C) Cell death would decrease because bonds within the enzymes would break, disrupting the enzymes' catalytic activity.

(D) Cell death would decrease because the enzymes would digest the transport proteins, blocking enzyme entry into the cells.

25. The average mass of an amino acid is 110 daltons (a unit of mass for atoms). Which of the following is the best estimate for the combined mass of 7 polypeptides that have an average length of 117 amino acids?

(A) 770 daltons

(B) 12,870 daltons

(C) 90,090 daltons

(D) 270,270 daltons

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Questions 26 - 30

Schistosoma japonicum is a disease-causing parasitic flatworm with a life cycle that includes many morphologically distinct stages. To understand how gene expression directs the development of S. japonicum, researchers studied mRNAs produced at several life stages of this worm.

In their first experiment, the researchers isolated mature mRNA from S. japonicum at two life cycle stages and placed the transcripts into a single test tube. The researchers then determined the frequency at which different regions of gene R were found in the mature transcripts (Figure 1).

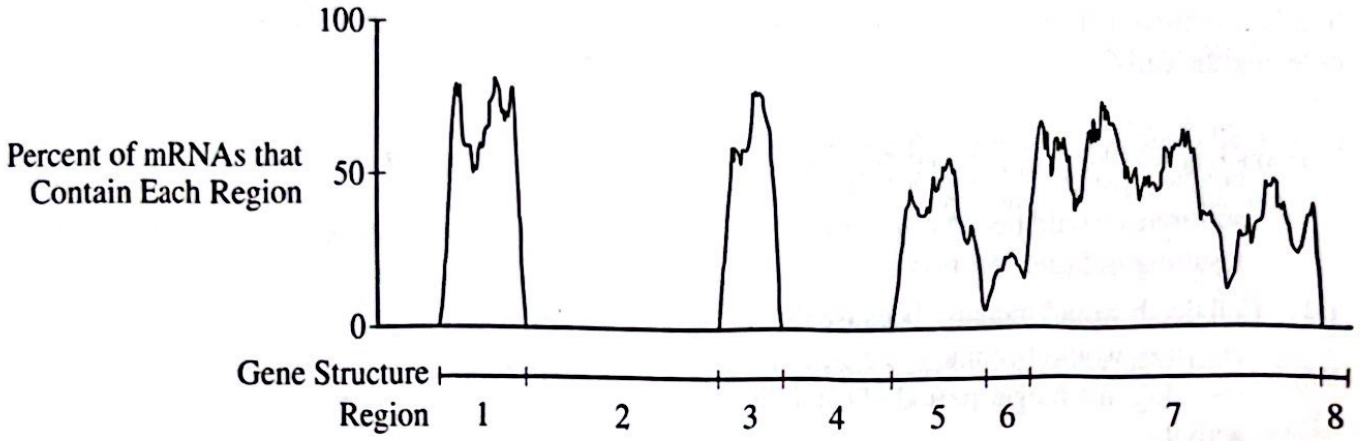

Figure 1. A histogram representing the percent of mature mRNA transcripts that contain each region of gene R

In a second experiment designed to investigate whether alternative splicing of mRNAs occurs at different life cycle stages of S. japonicum, researchers collected equal amounts of mature mRNA transcripts from four life cycle stages: eggs, a pre-infection stage, an early-infection stage, and adults. They performed a modified version of the polymerase chain reaction (PCR) and analyzed their samples by gel electrophoresis. This enabled the researchers to determine the lengths of mature mRNAs produced from a different gene, gene Z, at each of the life cycle stages (Figure 2).

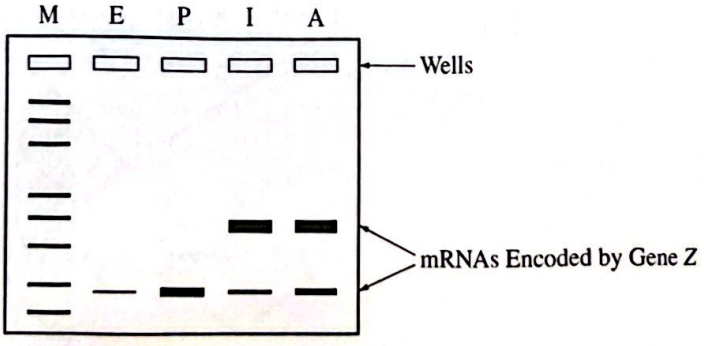

Figure 2. Four life cycle stages of mRNAs encoded by gene Z and analyzed by gel electrophoresis. A thicker band means that the band contains more mRNA. The lanes are as follows: DNA marker (M) with fragments of known sizes, eggs (E), pre-infection (P), early-infection (I), and adult (A).

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26. Based on the data in Figure 1, which of the following regions of gene R are most frequently found in the mRNA?

(A) Regions 1 and 3

(B) Regions 3 and 5

(C) Regions 4 and 7

(D) Regions 7 and 8

27. Based on Figure 1, which of the following regions is most likely an intron that is found in some mature mRNA transcripts?

(A) Region 2

(B) Region 4

(C) Region 5

(D) Region 6

28. The majority of the mature mRNAs analyzed in the second experiment would have been found in which of the following cellular compartments?

(A) The nucleus, which is where translation occurs

(B) The cytoplasm, which is where processed mRNA is located

(C) The mitochondria, which are where splicing occurs

(D) The endoplasmic reticulum, which is where proteins are modified

29. Which of the following claims about mRNAs encoded by gene Z is best supported by the data shown in Figure 2?

(A) Adult and early-infection life cycle stage mRNAs include more regions of gene Z than do pre-infection and egg stage mRNAs.

(B) The mRNAs of all four life cycle stages contain the same gene Z exons, but different quantities of mRNA are present in each stage.

(C) Only the longer of the two mRNAs encoded by gene Z is produced by the pre-infection life cycle stage.

(D) Equal amounts of two mRNAs of different sizes are produced by adult life cycle stages.

30. The life cycle of many organisms includes morphologically distinct stages, the earliest of which is known as the larval stage. These organisms may produce a protein when they are in the larval stage but not when they are in later life cycle stages. Which of the following most likely explains why the protein is no longer produced at later life cycle stages?

(A) The order of the codons encoding the protein changes as the organism advances from the larval stage to later life cycle stages.

(B) The gene encoding the protein is deleted from the cells of the organism at the end of the larval stage.

(C) Ribosomes cannot transcribe the mRNA encoding the protein at any stage after the larval stage.

(D) Transcription factors that bind to the promoter of the gene encoding the protein are produced only during the larval stage.

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31. Which of the following describes a population that would likely be highly resilient in response to environmental change?

(A) A population with a low reproductive rate

(B) A population with the same alleles for most genes

(C) A population with high genetic diversity

(D) A population with very few individuals

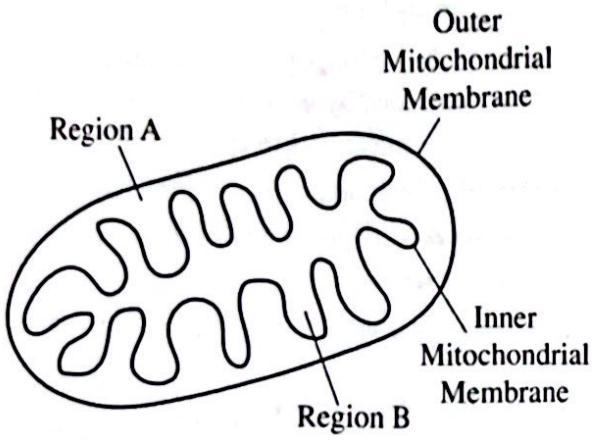

Figure 1. A model of a mitochondrion

32. Based on Figure 1, which of the following best explains the movement of hydrogen ions across the inner mitochondrial membrane in a cell undergoing aerobic cellular respiration?

(A) The hydrogen ion concentration of region A is lower than that of region B because hydrogen ions are actively transported into region A.

(B) The hydrogen ion concentration of region A is lower than that of region B because hydrogen ions passively flow into region A.

(C) The hydrogen ion concentration of region A is higher than that of region B because hydrogen ions are actively transported into region A.

(D) The hydrogen ion concentration of region A is higher than that of region B because hydrogen ions passively flow into region A.

33. Researchers examined the habitat preferences of flatworms by placing a group of them into a chamber containing three surfaces: a smooth surface, a slightly rough surface, and a very rough surface, and measured the number of flatworms in each section after a period of time. The researchers performed a chi-square analysis to compare the observed number of worms in each section with that expected by random worm distribution. Which of the following chi-square values would cause the researchers to reject the null hypothesis at a p-value of 0.05?

(A) Any value less than 6.64

(B) Any value less than 7.81

(C) Any value greater than 3.84

(D) Any value greater than 5.99

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34. Tyrosinase is an enzyme required for the production of brown pigment in the fur of mice. Scientists created a new strain of mice by introducing a regulatory sequence into the promoter of Tyr, the gene encoding tyrosinase. The scientists also introduced gene jle into the new strain of mice. Gene jle encodes a repressor protein JLE that binds to the regulatory sequence introduced into the Tyr promoter. Under the conditions used, the repressor protein was continuously produced. The scientists then investigated whether they could regulate expression of Tyr by adding an inhibitor of the JLE repressor protein to the drinking water of the mice. Which of the following is the most likely effect when the inhibitor is added?

(A) Transcription of jle will decrease, and the mice will produce brown pigment.

(B) Transcription of jle will increase, and the mice will not produce brown pigment.

(C) Transcription of Tyr will decrease, and the mice will not produce brown pigment.

(D) Transcription of Tyr will increase, and the mice will produce brown pigment.

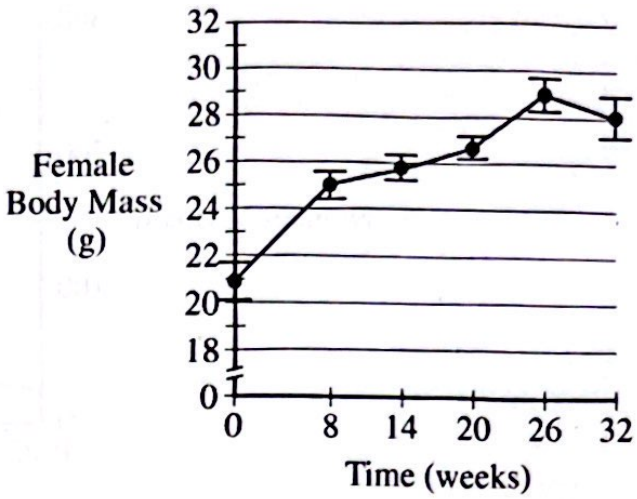

Figure 1. Average body mass of female mice fed a diet of fructose and glucose for 32 weeks. Error bars represent $\pm 2SE_{\bar{x}}$.

35. To study the dietary effect of the intake of different carbohydrates on the body mass of mice, scientists fed female mice a diet consisting of a combination of fructose and glucose for 32 weeks and measured their mass (Figure 1). Which of the following is closest to the percent increase in average body mass of female mice fed a diet of fructose and glucose from week 8 to week 26?

(A) 4%

(B) 16%

(C) 50%

(D) 86%

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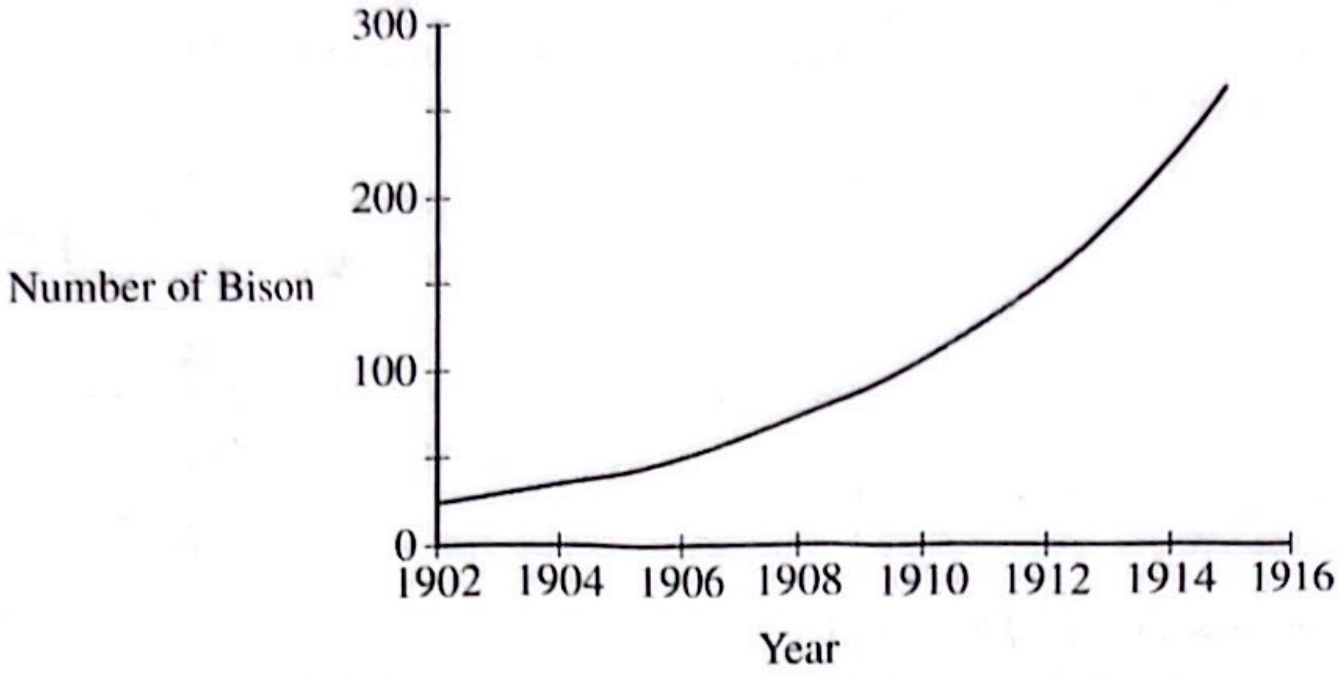

Figure 1. Number of American bison in one population between 1902 and 1915

36. After the number of American bison declined in the 1800s, land was set aside to protect the bison. Scientists recorded the growth of one population of American bison on protected land between 1902 and 1915 (Figure 1). Based on Figure 1, which of the following best explains the observed growth of this population of American bison?

(A) By 1915 the death rate of the bison exceeded the birth rate, resulting in a decrease in the rate of population growth.

(B) In 1912 a density-dependent factor affected the bison population, resulting in a decrease in the rate of population growth.

(C) The small initial population size led to an increase in competition for mates, resulting in logistic population growth.

(D) The small initial population size ensured an abundance of resources and lack of competition, resulting in exponential population growth.

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Questions 37 - 41

DAC-S3 is a chemical that causes cell death in rapidly dividing cells such as cancer cells. To investigate why certain cells can be killed by DAC-S3, scientists studied a cancer cell line (HAP) and several different DAC-S3 resistant (DACR) cell lines derived from the HAP cell line. The scientists exposed the cell lines to increasing concentrations of DAC-S3 and measured the average percent survival for each cell line (Figure 1).

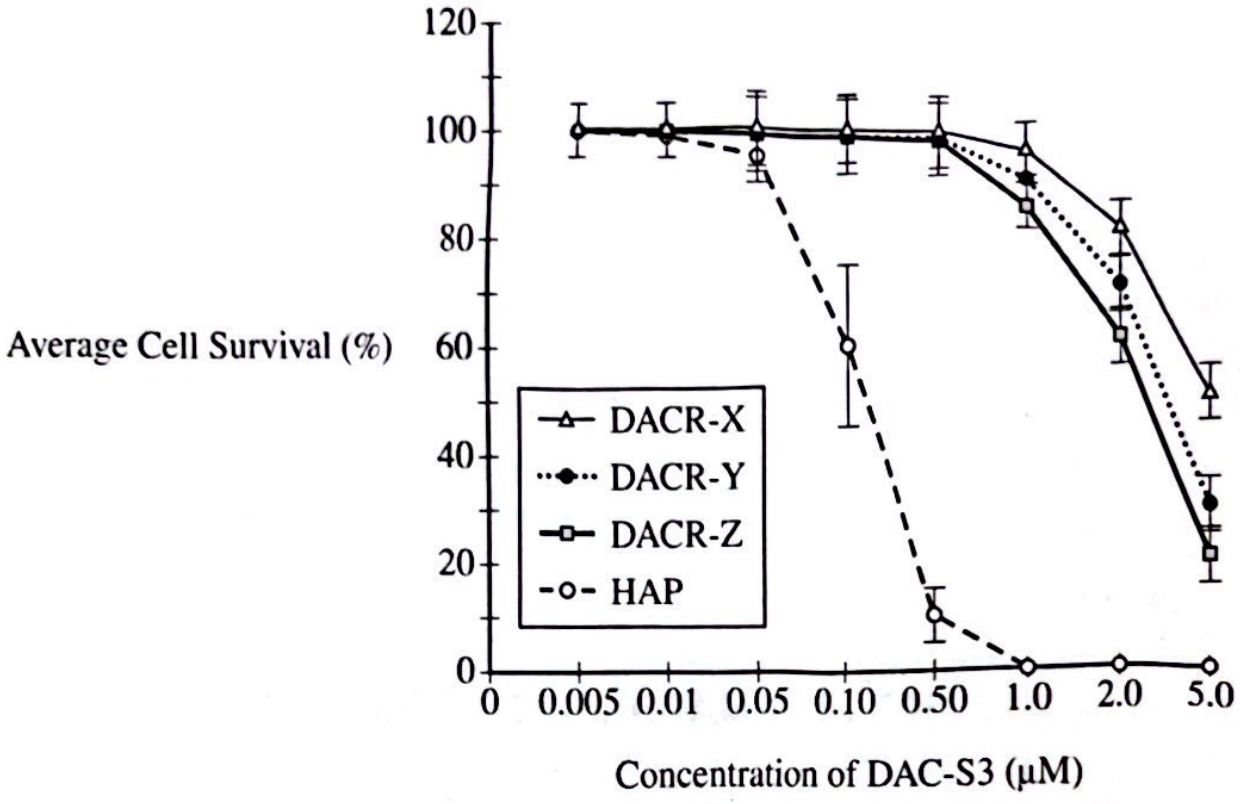

Figure 1. Average percent survival of HAP cancer cells and DAC-S3 resistant (DACR) cell lines at increasing concentrations of DAC-S3. Error bars represent $\pm 2SE_{\bar{x}}$.

37. Which of the following best describes how enzymes regulate biological processes?

(A) Enzymes decrease the activation energy needed for chemical reactions to occur.

(B) Enzymes increase the amount of substrate needed for chemical reactions to occur.

(C) Enzymes increase the activation energy needed for chemical reactions to occur.

(D) Enzymes decrease the amount of substrate needed for chemical reactions to occur.

38. Based on Figure 1, which of the following concentrations of DAC-S3 resulted in 10% survival of HAP cells?

(A) 0.01 μM

(B) 0.05 μM

(C) 0.10 μM

(D) 0.50 μM

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39. Which of the following claims is best supported by the data in Figure 1?

(A) At a DAC-S3 concentration of 1.0 μM, half as many HAP cells survive as do DACR cells.

(B) As the concentration of DAC-S3 increases from 0.05 μM to 0.10 μM, the decrease in cell survival is greater for HAP cells than for DACR cells.

(C) At each concentration of DAC-S3, the percentage of surviving cells is the same for the three DACR cell lines.

(D) At all concentrations of DAC-S3, the percentage of surviving HAP cells is less than the percentage of surviving DACR cells.

40. Based on the experiment, which of the following justifies the use of HAP cells exposed to DAC-S3?

(A) They can be compared with HAP cells not exposed to DAC-S3.

(B) They can be compared with DACR cell lines exposed to DAC-S3.

(C) They can be compared with HAP cells in other organisms.

(D) They can be compared with DACR cell lines not exposed to DAC-S3.

41. The scientists screened the DAC-S3-resistant cells for mutation and found that they all shared a mutation in a protein called SDR2. Normally, SDR2 catalyzes a reaction that converts each molecule of DAC-S3 into a DACone. DACones cause protein misfolding and cell death, but mutant SDR2 is unable to catalyze this reaction. In a follow-up experiment, the scientists exposed HAP cells to DAC-S3 and an allosteric inhibitor of SDR2 and measured the percentage of surviving cells. Which of the following predicts how the presence of the allosteric inhibitor of SDR2 will most likely affect the HAP cells?

(A) There will be fewer DACones, resulting in a decrease in the percentage of viable HAP cells.

(B) There will be more DACones, resulting in a decrease in the percentage of viable HAP cells.

(C) There will be fewer DACones, resulting in an increase in the percentage of viable HAP cells.

(D) There will be more DACones, resulting in an increase in the percentage of viable HAP cells.

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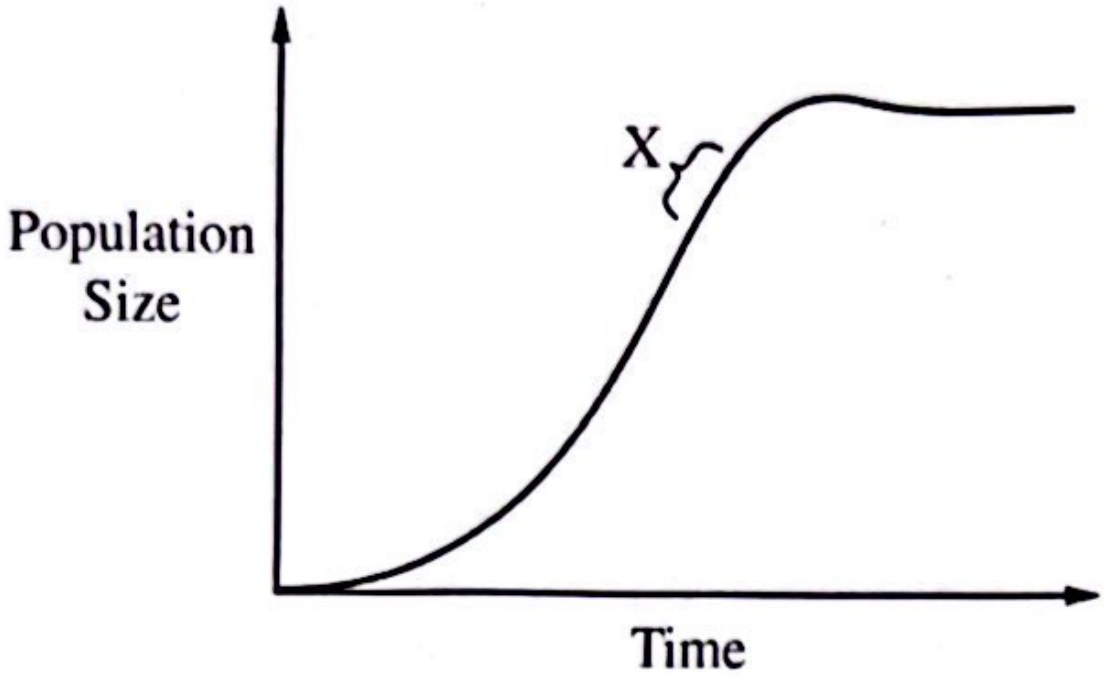

Figure 1. Change in the size of a population over time

42. Based on Figure 1, which of the following statements best explains the change in the size of the population shown in region X of the graph?

(A) The death rate exceeds the birth rate.

(B) The availability of resources starts to limit reproduction.

(C) The population is only limited by density-independent events.

(D) The size of the population exceeds the carrying capacity of the environment.

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TABLE 1. CROSSES BETWEEN PIGEONS AND THE PHENOTYPES OF THE OFFSPRING

Cross Performed	Phenotypes of F_1 Offspring
Male (ZZ) with blue feathers × Female (ZW) with brown feathers	All males and all females have blue feathers.
Male (ZZ) with brown feathers × Female (ZW) with blue feathers	Males have blue feathers. Females have brown feathers.

43. The genome of pigeons contains 39 pairs of autosomes (non-sex chromosomes) and 1 pair of sex chromosomes. Male pigeons inherit the sex chromosomes ZZ, while females inherit the sex chromosomes ZW. Researchers performed crosses to investigate the inheritance pattern of feather color in pigeons (Table 1). Which of the following best explains the inheritance pattern of feather color in pigeons?

(A) The gene for feather color is sex-linked, and the allele for blue feathers is dominant.

(B) The gene for feather color is autosomal, and the allele for blue feathers is dominant.

(C) The gene for feather color is sex-linked, and the allele for blue feathers is recessive.

(D) The gene for feather color is autosomal, and the allele for blue feathers is recessive.

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44. Which of the following statements explains why seeds swell when they are exposed to rainwater?

(A) The seeds are hypotonic as compared with the rainwater.

(B) The seeds have a lower water potential than the rainwater has.

(C) Protein pumps in the membranes of the cells of the seeds actively transport rainwater into the seeds.

(D) Membrane channels in the cells of the seeds close and prevent the loss of rainwater to the soil.

45. The protein TBK1 plays a role in the regulation of both cell division and apoptosis. Increased levels of TBK1 have been associated with certain forms of cancer. Which of the following predicts the likely effect of an increase in TBK1 on cell division?

(A) TBK1 will stimulate apoptosis and inhibit cell division.

(B) TBK1 will inhibit apoptosis and stimulate cell division.

(C) TBK1 will stimulate both apoptosis and cell division.

(D) TBK1 will inhibit both apoptosis and cell division.

46. Which of the following best describes evidence that all eukaryotes share a common ancestor that is different from that of prokaryotes?

(A) All eukaryotes have plasma membranes.

(B) All eukaryotes have DNA.

(C) All eukaryotes have membrane-bound organelles.

(D) All eukaryotes have ribosomes.

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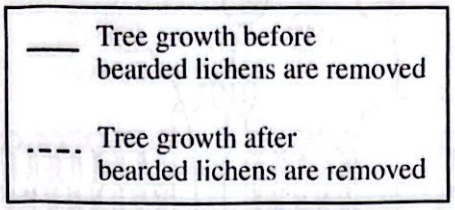
47. The bearded lichen, a symbiotic association composed of fungi and algae, hangs from the branches of Douglas fir trees. Scientists hypothesize that the lichens require the surface of the trees to live but neither harm nor benefit the trees. To test their hypothesis, they monitored the growth of Douglas fir trees before and after bearded lichens were removed. Which of the following sets of data best supports the scientists' hypothesis?



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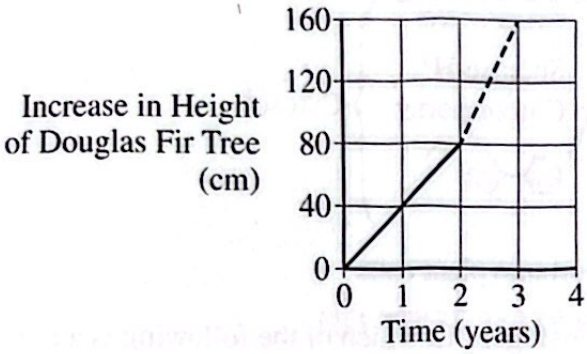

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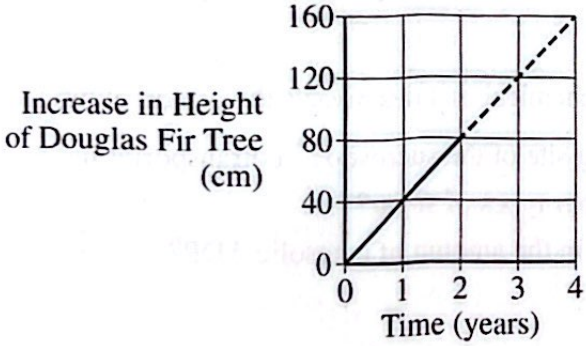
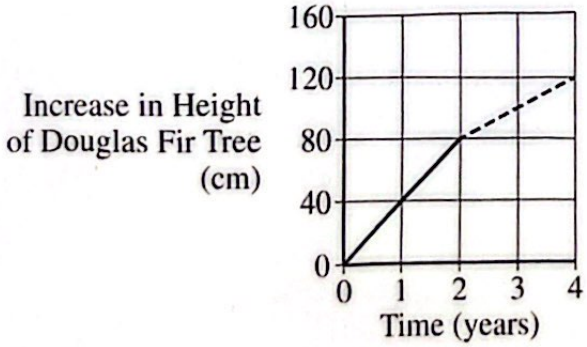
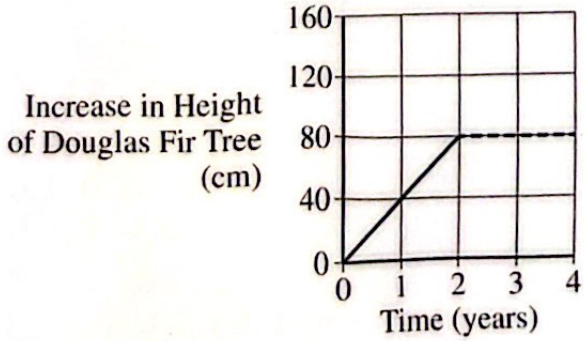


(C)



(D)



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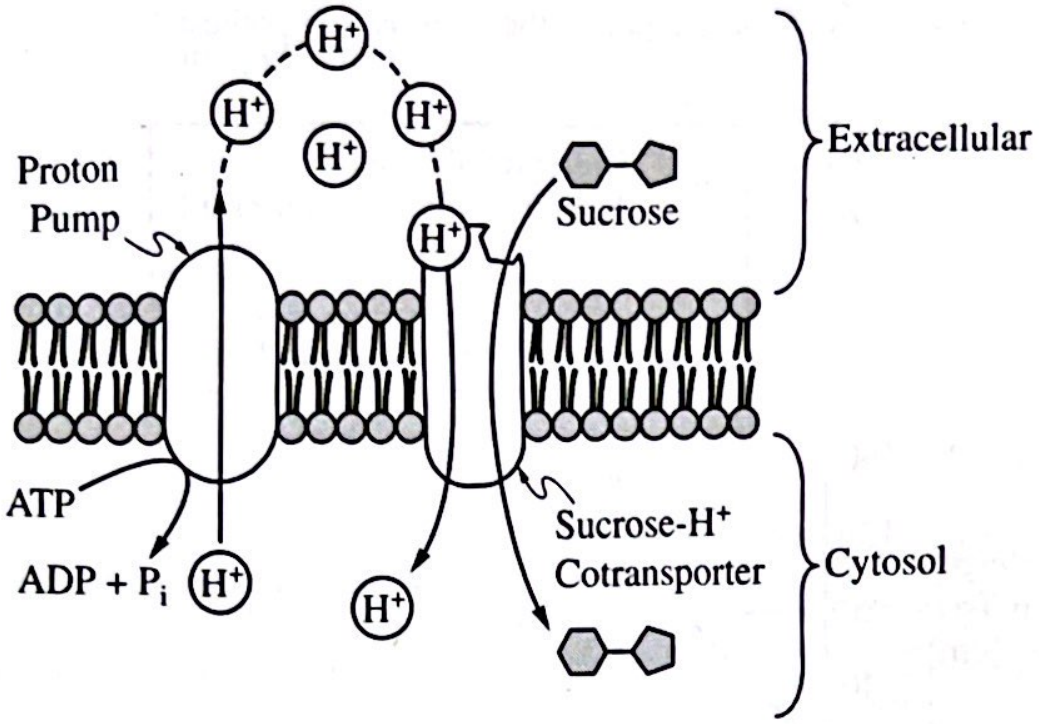

Figure 1. Model of sucrose transport into plant cells

48. Based on the model of sucrose transport into plant cells (Figure 1), which of the following is a testable question that would most directly help researchers determine whether a proton gradient is required for sucrose transport to occur?

(A) Can sucrose be transported in the presence of a chemical that deactivates the proton pump?

(B) Can sucrose be transported if the sucrose binding site of the sucrose-H^+ cotransporter has mutated?

(C) Can sucrose be transported in the presence of other types of sugar?

(D) Can sucrose be transported if there is a decrease in the amount of cytosolic ADP?

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Questions 49 - 53

Viruses infect host cells and use those host cells to make new viral copies. The Poxviridae family of viruses, commonly known as poxviruses, contains double-stranded DNA and infects only eukaryotes. Neither pox viruses nor their DNA can pass through the nuclear membrane. Pox viruses also lack DNA repair enzymes, resulting in frequent mutations in their genomes. The rapid mutation rate of pox viruses allows scientists to study the evolution of the viruses as infections spread in and between natural populations of host animals. DNA from pox viruses isolated from different types of host organisms was used to construct a cladogram (Figure 1).

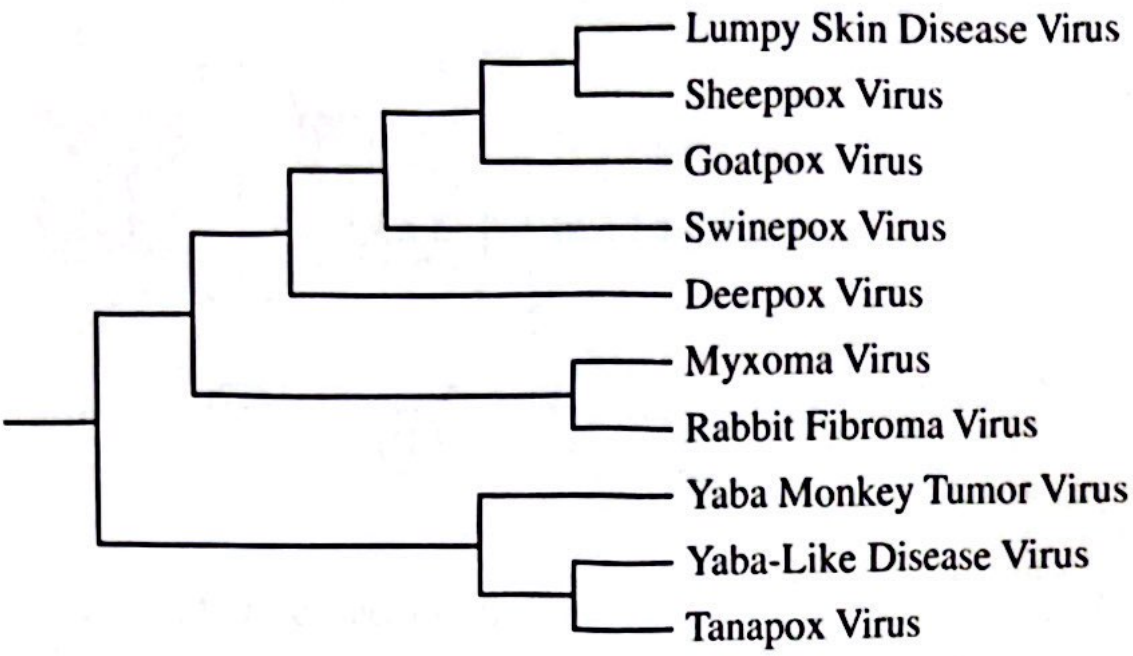

Figure 1. A partial cladogram of the Poxviridae family of viruses

49. Based on Figure 1, which of the following statements correctly describes a relationship within the Poxviridae family?

(A) Sheeppox virus shares a more recent common ancestor with myxoma virus than it does with rabbit fibroma virus.

(B) Swinepox virus shares a more recent common ancestor with deerpox virus than it does with goatpox virus.

(C) Tanapox virus shares the same most recent common ancestor with deerpox virus as tanapox does with myxoma virus.

(D) Lumpy skin disease virus shares the same most recent common ancestor with deerpox virus as lumpy skin disease virus does with swinepox virus.

50. Which of the following best describes a measurement of the evolutionary fitness of a virus?

(A) Number of viruses produced by an infected organism per day

(B) Number of different proteins encoded by the virus' genome

(C) Average diameter of the virus

(D) Average number of nucleotides in the genome of the virus

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51. Which of the following best explains why Poxviridae genomes must contain genes that encode enzymes necessary for DNA replication?

(A) Because DNA replication in Poxviridae viruses can occur in the absence of a host cell

(B) Because the host enzymes needed to replicate DNA are found in the nucleus of a host cell

(C) To ensure that the host enzymes are able to recognize the viral DNA as a substrate

(D) To ensure that the host cells are able to replicate DNA in the presence of Poxviridae

52. Viruses can gain different alleles of viral genes or new host genes when they infect and reproduce in host cells. Scientists are studying whether this process, known as transduction, has occurred within the Poxviridae. Which of the following best explains why transduction could be beneficial to a virus?

(A) It increases the number of genes in the virus, thus increasing the size of the virus.

(B) It allows the virus to transmit genetic information from a parent cell to two daughter cells.

(C) It changes the viral genotype, and the resulting phenotype may be favored by natural selection.

(D) It reduces the mutation rate of the virus, enabling the virus to infect a new host.

53. A student claims that the extinction of one host species that is typically infected by a member of the Poxviridae family may have no effect on the prevalence of Poxviridae. Which of the following statements best supports the student's claim?

(A) Poxviridae viruses have very low mutation rates.

(B) Poxviridae viruses have many different hosts living in different environments.

(C) Poxviridae viruses have adapted to surviving in one specific niche.

(D) The Poxviridae family has very little genetic diversity.

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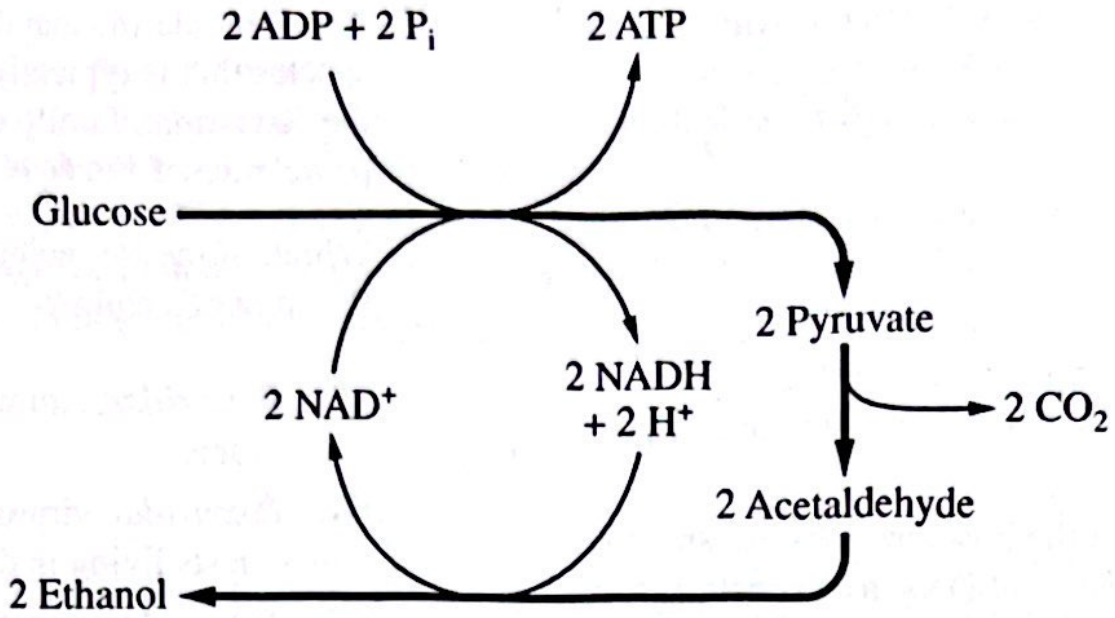

Figure 1. A model of cellular pathways that produce short-term energy storage molecules

54. The relationship between the cellular pathways of glycolysis and ethanol fermentation is shown in Figure 1. Based on Figure 1, which of the following best explains the relationship between glycolysis and fermentation?

(A) As long as CO_2 is available, cycling between ADP and ATP enables both pathways to continue.

(B) As long as ethanol is available, cycling between ADP and ATP enables both pathways to continue.

(C) As long as glucose is available, cycling between NAD^+ and NADH enables both pathways to continue.

(D) As long as ethanol is available, cycling between NAD^+ and NADH enables both pathways to continue.

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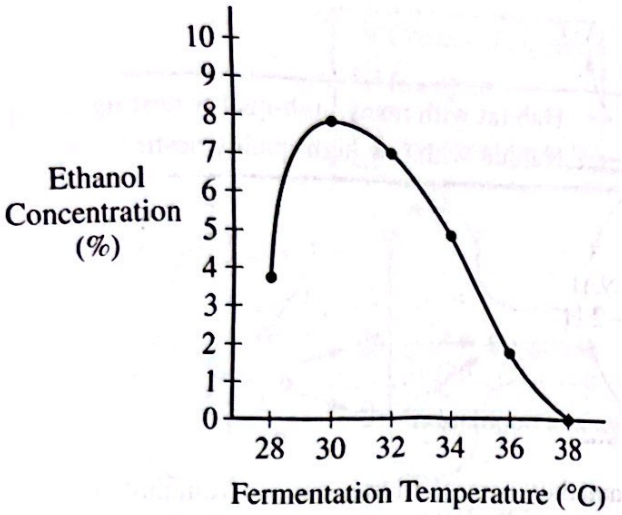

Figure 1. Effect of temperature on ethanol concentration during fermentation in yeast. All data points are statistically different from each other.

55. The ethanol produced during fermentation by certain microorganisms can be used as engine fuel. Researchers interested in maximizing ethanol production through fermentation investigated the effect of temperature on ethanol production in yeast (Figure 1). Based on the data in Figure 1, which of the following best describes a follow-up experiment the researchers should perform to determine the amount of sugar that will result in the maximum amount of ethanol production?

(A) Yeast should be grown at 30° C in solutions containing different concentrations of sugars from the same source.

(B) Yeast should be grown at 28° C in solutions containing different concentrations of sugars from the same source.

(C) Yeast should be grown at 32° C in solutions containing equal concentrations of sugars from different sources.

(D) Yeast should be grown at 36° C in solutions containing equal concentrations of sugars from different sources.

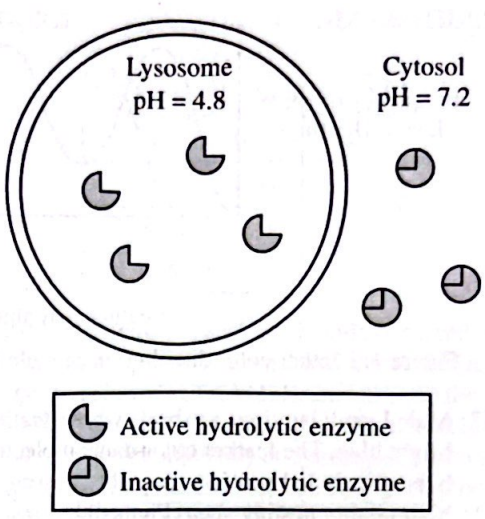

Figure 1. A model of hydrolytic enzyme activity in a lysosome and in the cytosol

56. Which of the following explains an advantage of cellular compartmentalization that is illustrated in the model shown in Figure 1 ?

(A) Internal membranes increase the rate of enzyme-catalyzed reactions by increasing the surface area available for reactions to occur.

(B) Internal membranes increase the rate of enzyme-catalyzed reactions by allowing enzymes to easily diffuse across the membranes to move to other areas of the cell.

(C) Internal membranes inhibit enzyme-catalyzed reactions by preventing substrates and their products from occupying the same space.

(D) Internal membranes help regulate enzyme-catalyzed reactions by creating regions with different environmental conditions.

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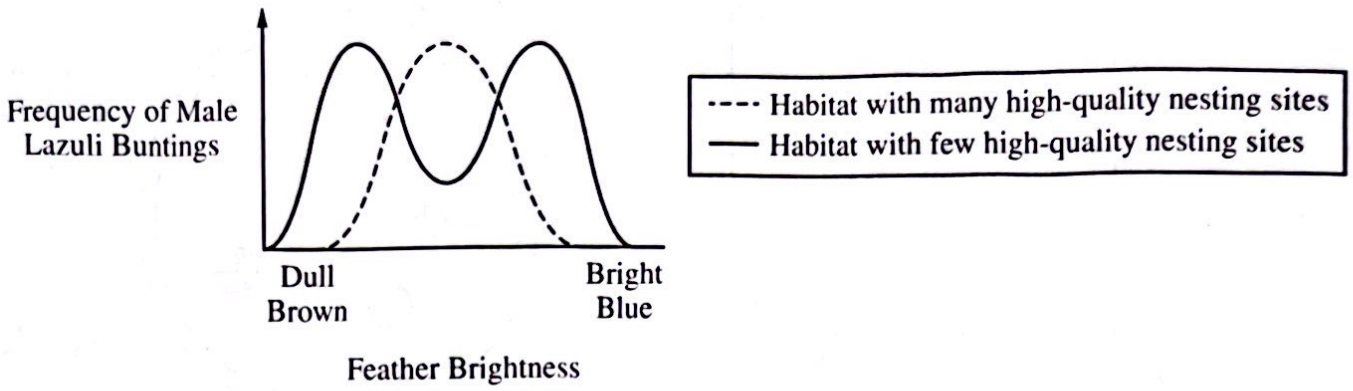

Figure 1. Feather color distribution of male Lazuli buntings in a population

57. Male Lazuli buntings are birds whose feather color, a genetically controlled trait, ranges from dull brown to bright blue. The feather color distribution of a population of male Lazuli buntings was studied when the birds' habitat included many high-quality nesting sites and, many generations later, when their habitat had few high-quality nesting sites (Figure 1). Which of the following claims about the effect of the reduction in nesting sites is best supported by the data?

(A) Female Lazuli buntings prefer to mate with brightly colored males, so males with the brightest feathers had the greatest fitness.

(B) Brightly colored males are more easily spotted by predators, so males with dull brown feathers had the greatest fitness.

(C) Males with either dull brown or brightly colored feathers have greater fitness than males with feathers of intermediate color.

(D) Brightly colored males expend more energy maintaining their color, and dull brown males do not attract mates, so male birds of intermediate color had the greatest fitness.

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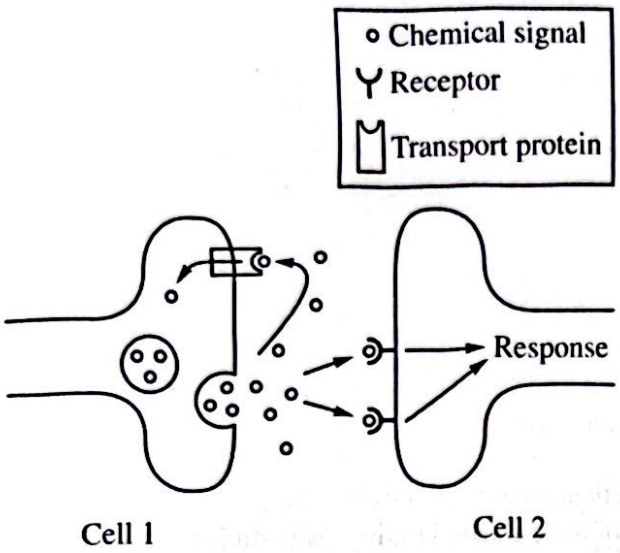

Figure 1. Model of chemical signaling between two nerve cells

58. Certain nerve cells release a chemical signal that diffuses through the extracellular fluid between two cells and binds to receptors on the plasma membrane of the second nerve cell, which then causes a response in the second nerve cell (Figure 1). The chemical signal can also reenter the first cell through a transport protein, reducing the concentration of the signal in the extracellular fluid between the two cells. Which of the following drugs will likely result in an increase in the response of the second nerve cell?

(A) A drug that binds to the receptor in the second cell, preventing signal binding

(B) A drug that binds to the transport protein, preventing the signal from reentering the first cell

(C) A drug that binds to the transport protein, increasing the rate at which the signal reenters the first cell

(D) A drug that binds to the chemical signal, changing the shape of the signal

TABLE 1. PROPORTION OF NUCLEOTIDES IN A GENE

Nucleotide	Exon 1	Intron 1
G	0.32	0.21
C	0.31	0.20
A	0.18	0.31
T	0.19	0.28

59. The proportion of each nucleotide observed in the coding strand of exon 1 and intron 1 of a gene is shown in Table 1. Scientists used the data to compare the proportion of nucleotides containing guanine (G) or cytosine (C) with the proportion of nucleotides containing adenine (A) or thymine (T). Based on the data in Table 1, which of the following is the ratio of the proportion of G- and C-containing nucleotides in exon 1 to the proportion in intron 1?

(A) 0.32:0.21

(B) 0.32:0.31

(C) 0.53:0.51

(D) 0.63:0.41

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60. Scientists investigated the mechanism by which a particular type of cell changed from its normal phenotype to that of a cancer cell. They found that the cancer cells contained a mutant c-Myc protein that caused an increase in the activity of the SIRT1 protein. SIRT1 inhibits apoptosis and protects c-Myc from normal intracellular degradation. Which of the following predicts the most likely effect of introducing an inhibitor of SIRT1 into the cancer cells?

(A) There will be increased levels of c-Myc and a decrease in the number of cancer cells.

(B) There will be reduced levels of c-Myc and an increase in the number of cancer cells.

(C) There will be reduced levels of c-Myc and a decrease in the number of cancer cells.

(D) There will be increased levels of c-Myc and an increase in the number of cancer cells.

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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. Answers must be written out in paragraph form. Outlines, bulleted lists, or diagrams alone are not acceptable. You may plan your answers in this orange booklet, but no credit will be given for anything written in this booklet. You will only earn credit for what you write in the separate Free Response booklet. Question 1 is on the following page.

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1. In the nucleus of eukaryotes, chromosomal DNA is packaged into nucleosomes, repeating units of DNA wound around conserved proteins called histones. Two of the histones that mammals produce are H3a and H3b, which differ only slightly in amino acid sequence and are encoded by separate, unlinked genes. H3a and H3b function during particular points in the cell cycle.

Scientists hypothesize that histones H3a and H3b play roles in growth and development of the diploid cells that divide to produce gametes. In order to investigate the relationship between the functions of H3a and H3b, scientists created two groups of mice. One group was heterozygous for a deletion in the gene encoding H3a (genotype $H3a^{+/-}$), and a second group was heterozygous for a deletion in the gene encoding H3b (genotype $H3b^{+/-}$). The + represents a functional allele, and the − represents an allele with a deletion, making the allele nonfunctional.

(a) Describe the expected genotype ratio of offspring from a cross between two mice that are heterozygous for a particular gene.

The scientists performed a cross between $H3a^{+/+}$ mice that were also $H3b^{+/-}$ and determined the H3b genotypes of the offspring (Figure 1A). The scientists performed another cross between $H3b^{+/+}$ mice that were also $H3a^{+/-}$ and determined the H3a genotypes of the offspring (Figure 1B). They then determined the mass of each of the offspring (Figure 1). Mice that were homozygous for deletions in H3b ($H3b^{-/-}$) died during development.

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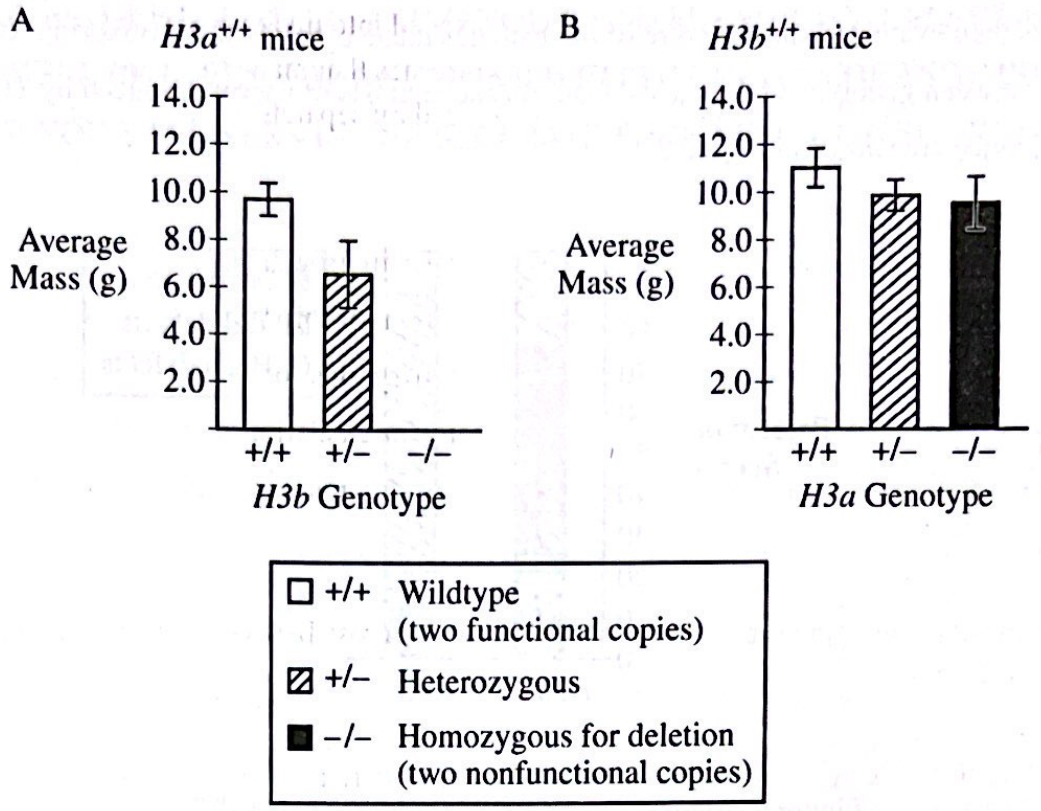

Figure 1. Average mass of three-week-old $H3a^{+/+}$ mice when the H3b genotype is wild-type, heterozygous, or homozygous for a deletion (A), and average mass of three-week-old $H3b^{+/+}$ mice when the H3a genotype is wild-type, heterozygous, or homozygous for a deletion (B). Error bars represent $\pm 2SE_{\bar{x}}$.

(b)

(i) Identify a dependent variable in the first experiment (data shown in Figure 1).

(ii) Justify why the scientists used the mass of wild-type (+/+) mice in the first experiment as a control.

(iii) Justify why the scientists used mice of the same age for the first experiment as another control.

(iv) Based on the data in Figure 1, describe the effect of losing one functional H3a allele ($H3a^{+/-}$) compared with the effect of losing one functional H3b allele ($H3b^{+/-}$).

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The scientists then examined the structure of the gametes made by each of the offspring to assess the relationship between genotype and meiosis. Data for the analysis of sperm produced by $H3a^{+/+}$ (wild-type) and $H3a^{-/-}$ mice are shown in Figure 2.

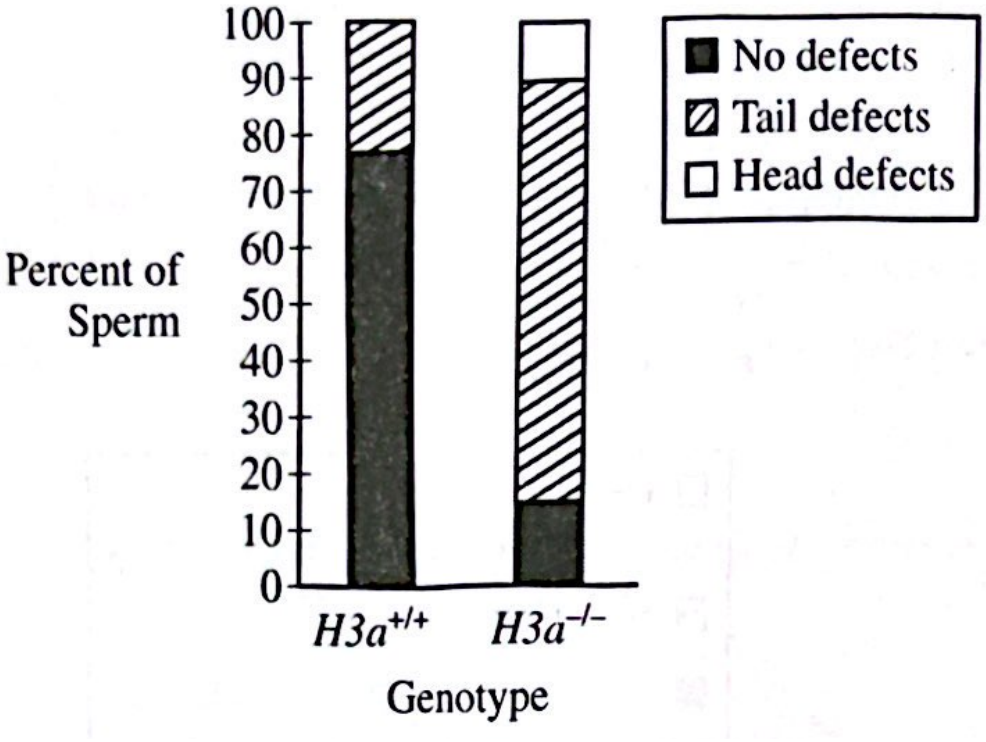

Figure 2. Analysis of sperm structure from $H3a^{+/+}$ mice and $H3a^{-/-}$ mice of the same age

(c)

(i) Based on Figure 2, describe an effect on the sperm structure of the $H3a^{-/-}$ genotype.

(ii) Assuming the scientists examined 200 $H3a^{-/-}$ sperm, calculate the approximate number of $H3a^{-/-}$ sperm that had structural defects.

(d)

(i) State the null hypothesis for the effect of genotype in the second experiment (data shown in Figure 2).

(ii) Scientists claim that having two wild-type H3a alleles cannot restore the loss of function caused by a deletion in the H3b gene. Using data from Figure 1, support the scientists' claim.

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2. The human ribonucleotide reductase (hRR) enzyme helps maintain the supply of available nucleotides in a cell, which is essential for DNA replication.

(a) Describe the three structural components of a DNA nucleotide.

Some commonly used anticancer drugs, while effective against cancer cells, often cause damage to healthy cells. In a search for cancer treatments that cause less damage to healthy cells, researchers identified the small molecule NSAH that reversibly binds to the active site of hRR and inhibits its activity. To determine the most effective concentration of NSAH, researchers measured the activity of hRR in the presence of six different concentrations of NSAH (Table 1).

TABLE 1. PERCENT OF MAXIMUM hRR ACTIVITY OBSERVED IN THE PRESENCE OF DIFFERENT CONCENTRATIONS OF NSAH

Concentration of NSAH (µM)	Percent of Maximum hRR Activity $\pm 2SE_{\bar{x}}$
3	100 ± 2
5	98 ± 8
10	92 ± 6
25	55 ± 8
50	41 ± 8
100	24 ± 4

(b)

(i) Using the template in the space provided for your response, construct a line graph that represents the data in Table 1. Your graph should be appropriately scaled and labeled.

(ii) Based on the data in Table 1, determine the measured concentration (µM) of NSAH that resulted in a greater inhibition (reduction) of hRR activity than was observed with the 25 µM NSAH treatment.

(c) Based on the data in Table 1, identify the two measured concentrations of NSAH (µM) between which the hRR activity was 75% of the maximum.

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(d)

(i) Among individuals with cancer, some individuals produce twice as much substrate for hRR as others do. Predict the effect of this increased substrate concentration on the amount of NSAH required to be effective in the treatment of these individuals.

(ii) Justify your prediction.

(iii) F_2C, a commonly used anticancer drug, functions as an irreversible inhibitor of hRR. Explain why treatment with a reversible inhibitor like NSAH might cause less damage to healthy cells than will treatment with an irreversible inhibitor such as F_2C.

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3. After being infected by a certain virus, host cells produce a viral protein, CedV, which then becomes embedded in the plasma membrane of the host cell. To become fully activated, CedV must undergo endocytosis from the plasma membrane. After endocytosis, CedV is cleaved into two fragments by a host-cell enzyme. These fragments are then embedded into the plasma membrane, where they will become part of future virus particles and facilitate future infections.

CedV contains a sequence in which many of the amino acids are tyrosine. To determine whether this tyrosine-containing sequence is required for CedV to undergo endocytosis once CedV is embedded in the plasma membrane, researchers created several different CedV mutant proteins in which the amino acid alanine was substituted for increasing numbers of tyrosine molecules. The researchers then used green fluorescent tags to label CedV proteins that remained embedded in the membrane and red fluorescent tags to label CedV proteins that were taken into the cell by endocytosis. The researchers compared the ability of cells to take in the different mutant CedV proteins by endocytosis with the ability of cells to take in the wild-type (nonmutant) CedV protein by endocytosis.

(a) Describe the structure of the eukaryotic plasma membrane.

(b) Justify why the researchers compared endocytosis of the mutant CedV proteins with endocytosis of the wild-type CedV protein as an experimental control.

(c) Researchers hypothesize that as the number of alanine substitutions in the CedV protein increases, the likelihood that CedV will undergo endocytosis decreases. Based on this hypothesis, predict the relative amount of green and red fluorescence the researchers will observe as the number of alanine substitutions in the CedV protein increases.

(d) Researchers claim that the portion of the CedV protein that becomes embedded in the plasma membrane is composed primarily of amino acids with hydrophobic R-groups. Provide reasoning to support the researchers' claim.

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4. Whitebark pine trees are native to high-elevation mountain ecosystems in North America. The seeds of the whitebark pine tree are contained in pine cones that are covered with thick scales (hard outer layers) that protect the seeds from the harsh conditions of these high elevations. In order for the seeds to be released, a small bird known as the Clark's nutcracker must break apart the scales. The nutcrackers eat some of the seeds immediately and bury others in different locations, where the nutcrackers may eat them at a later time. In recent years, the number of whitebark pine trees within a population has decreased dramatically due to several factors, including an infection caused by a nonnative fungus and an infestation (presence of an unusually large number) of mountain pine beetles, both of which cause the trees to die.

(a) Describe the relationship between the density of a population and the effect that competition has on the growth rate of that population.

(b) Explain how the nutcrackers' behavior of releasing seeds from the pine cones affects the number of whitebark pine trees within the population.

(c) Predict the effect of a continued increase in the number of mountain pine beetles on the number of nutcrackers within the population.

(d) Justify your prediction in part (c).

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5. Pitcher plants are plants that digest insects to obtain nutrients necessary for reproduction and growth. Scientists studying the diverse morphological features of pitcher plants created a cladogram representing an outgroup and the three clades of pitcher plants (A, B, and C). The cladogram includes the evolution of five traits: (1) digestive glands, (2) wax crystals, (3) lids, (4) transparent spots, and (5) slippery surfaces (Figure 1).

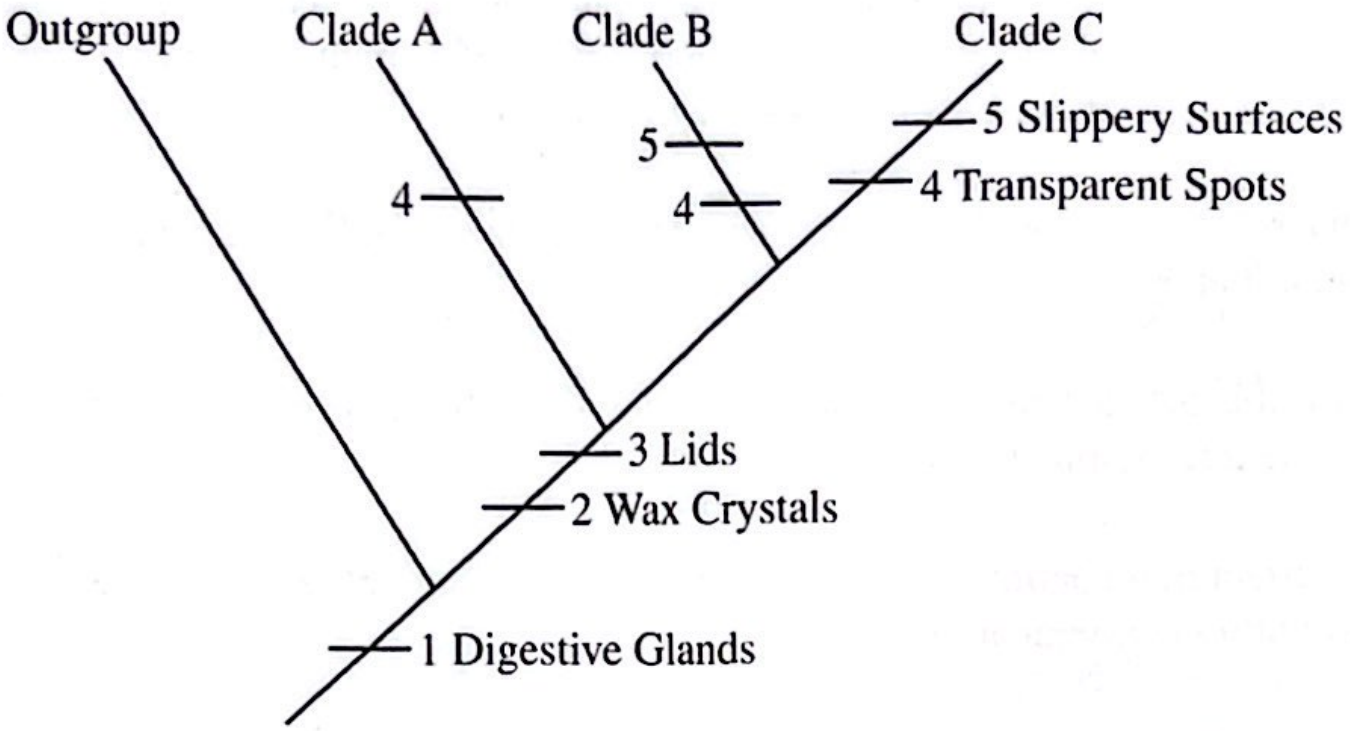

Figure 1. Cladogram of three clades of pitcher plants and an outgroup based on five different traits. Each hash mark represents the point at which the trait first appeared. Each numbered trait is labeled only once, on the main line of the cladogram.

(a) Describe one way a mutant allele can increase in frequency in a population over many generations.

(b) Explain how the cladogram in Figure 1 shows evidence of convergent evolution of pitcher plants in clades B and C.

(c) Wax crystals are ancestral to clades A, B, and C but are no longer present in any of the species of clade B. Represent the point at which wax crystals were lost by adding an X to the cladogram.

(d) The lids of pitcher plants in clades A, B, and C have different morphological characteristics. Using Figure 1, explain how divergent evolution could be responsible for these differences.

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6. Small RNA molecules can regulate transcription and translation. Scientists investigated the relationship between a small RNA molecule known as miRNA-466 and the expression of a gene that encodes a growth factor (GF). Expression of the GF varies in response to oxygen levels. Scientists observed that deleting the DNA that encodes miRNA-466 from the genomes of mice results in reduced levels of GF protein under low oxygen conditions (data not shown). To determine which stage of gene expression is regulated by miRNA-466, scientists harvested cells from the mice lacking the DNA encoding miRNA-466. They exposed the harvested cells and control cells to low oxygen conditions for 24 hours. They then measured the amount of GF pre-mRNA (Figure 1) and GF mRNA (Figure 2) produced by the cells under both normal and low oxygen conditions.

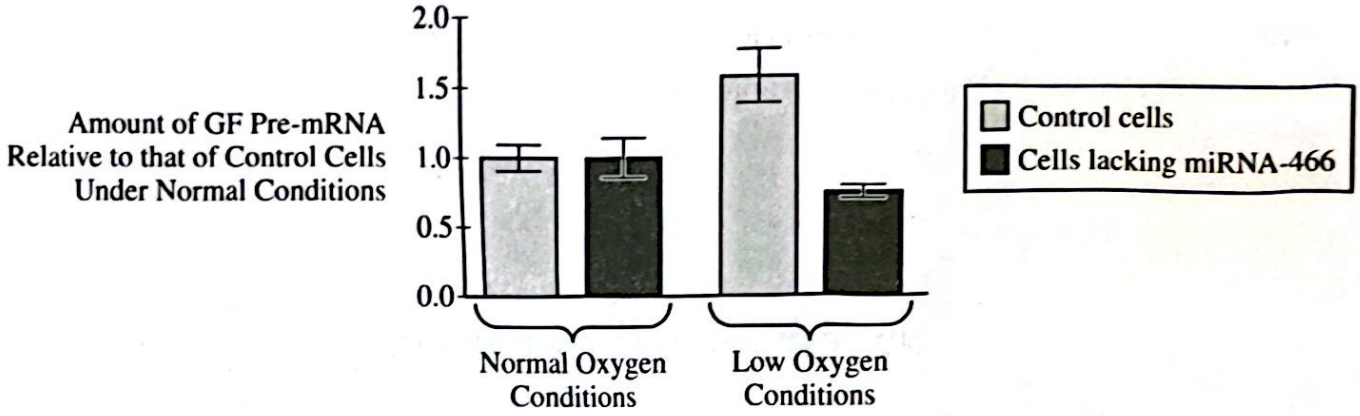

Figure 1. The amount of GF pre-mRNA produced by cells lacking miRNA-466 relative to control cells after exposure to normal and low oxygen conditions for 24 hours. Error bars represent $\pm 2SE_{\bar{x}}$.

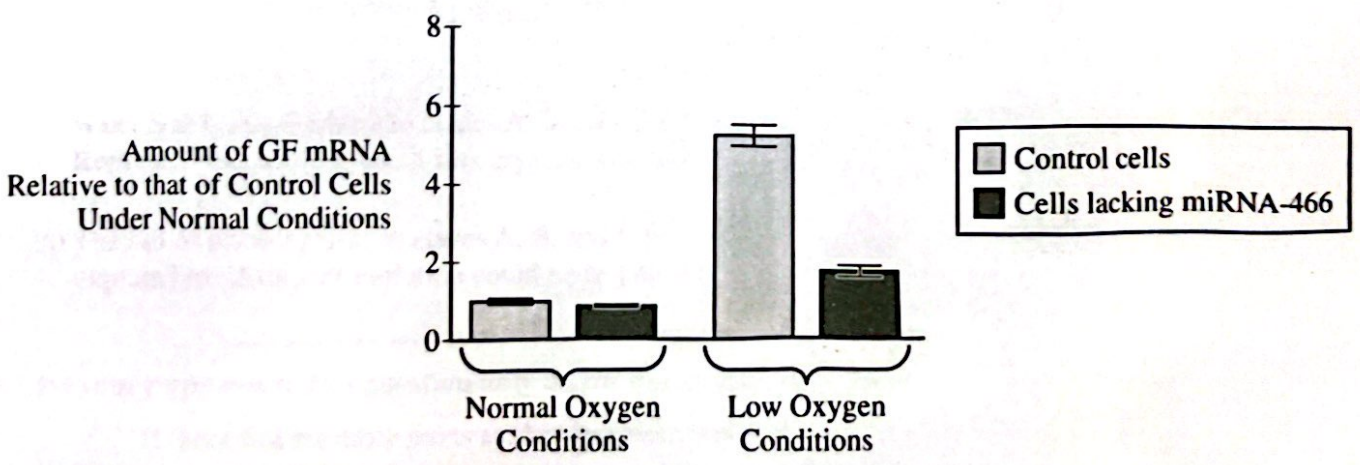

Figure 2. The amount of GF mRNA produced by cells lacking miRNA-466 relative to control cells after exposure to normal and low oxygen conditions for 24 hours. Error bars represent $\pm 2SE_{\bar{x}}$.

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(a) Based on Figure 1, describe the effect that low oxygen conditions had on the production of GF pre-mRNA in cells that do not express miRNA-466.

(b) Based on Figure 2, describe the effect that deleting the DNA encoding miRNA-466 had on the production of GF mRNA in low oxygen conditions.

(c) Scientists claim that miRNA-466 promotes the transcription of GF in low oxygen conditions. Using data from Figure 1, support the scientists' claim.

(d) Explain how the regulation of gene expression results in phenotypic differences among cells.

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