

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.

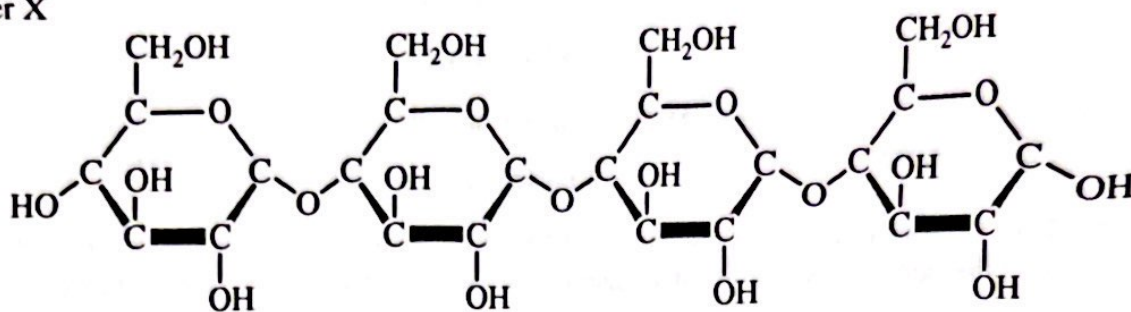
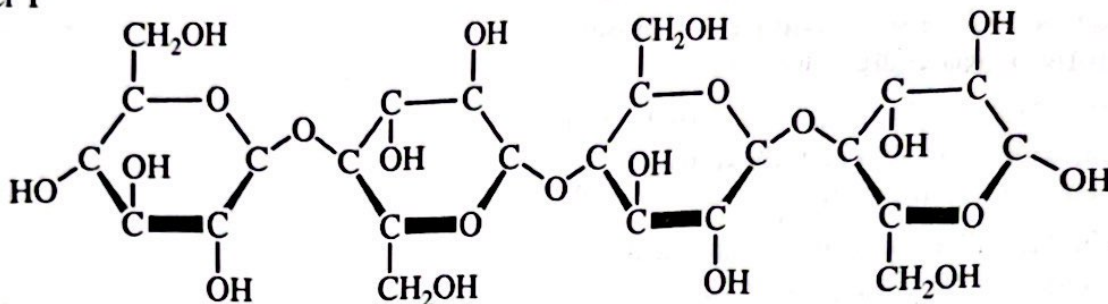
Polymer X**Polymer Y**

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.

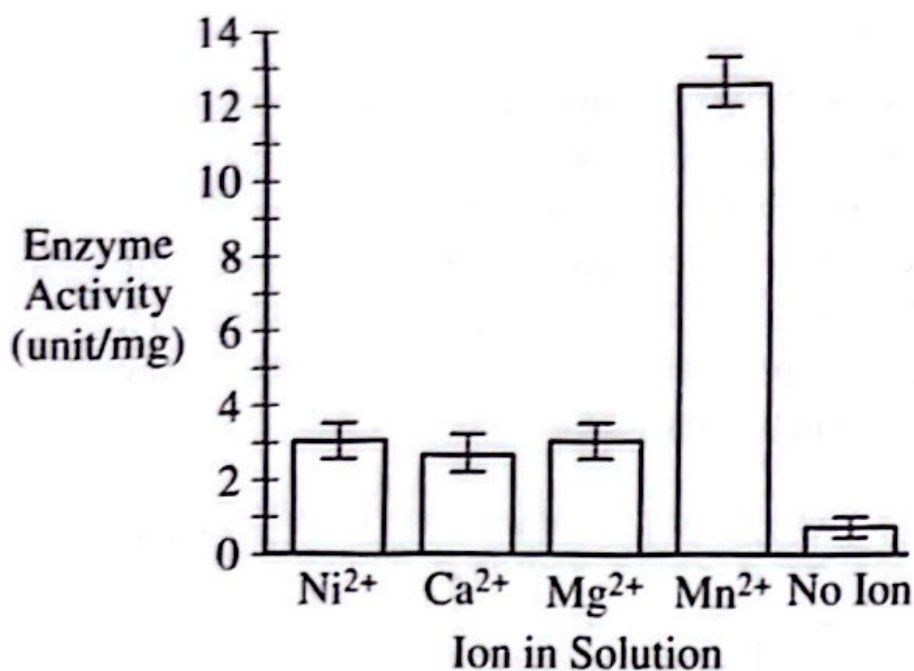


Figure 1. Activity of an enzyme in the presence of different positively charged ions. Error bars represent $\pm 2SE_x$.

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.

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 $\pm$ 0.03	0.53 $\pm$ 0.04
Number of notes within a call	6.06 $\pm$ 0.40	7.10 $\pm$ 0.45
Time between notes in a call (sec)	0.034 $\pm$ 0.002	0.041 $\pm$ 0.003
Call rate (calls / individual / min)	7.97 $\pm$ 1.60	15.03 $\pm$ 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 $\pm$ 17.3	207.4 $\pm$ 28.8
Shortest distance between songbird and a speaker (cm)	84.8 $\pm$ 25.3	224.3 $\pm$ 48.6

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.

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.

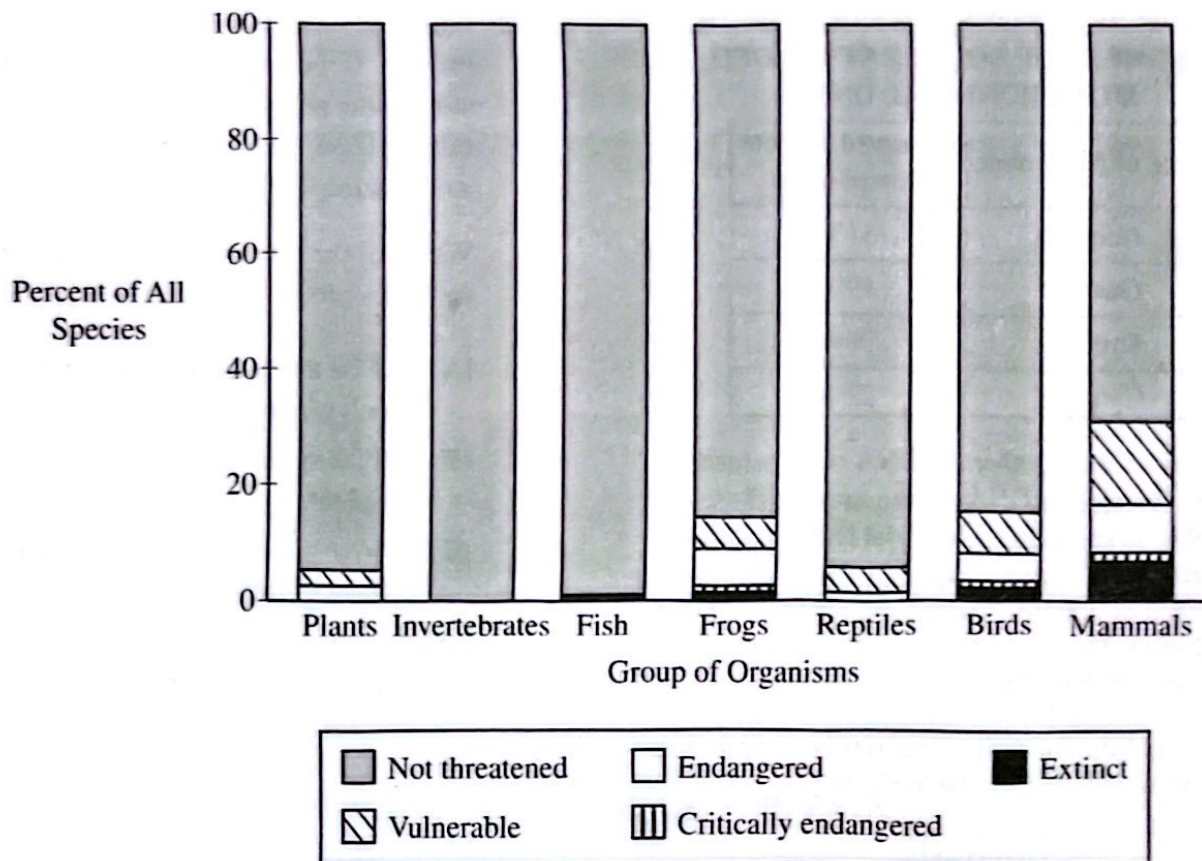


Figure 1. Comparison of the percent of species in different groups of organisms that are threatened with extinction

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

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 eIF2 α in specific brain cell types. eIF2 α works at the initiation step of translation. Which of the following best explains how eIF2 α promotes protein synthesis?

- (A) eIF2 α attaches to DNA and recruits RNA polymerase to make RNA.
- (B) eIF2 α splices DNA together to make mRNA.
- (C) eIF2 α binds to polypeptides and causes them to fold into proteins.
- (D) eIF2 α forms a complex with mRNA, which binds to a ribosome.

NO TEST MATERIAL ON THIS PAGE

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).

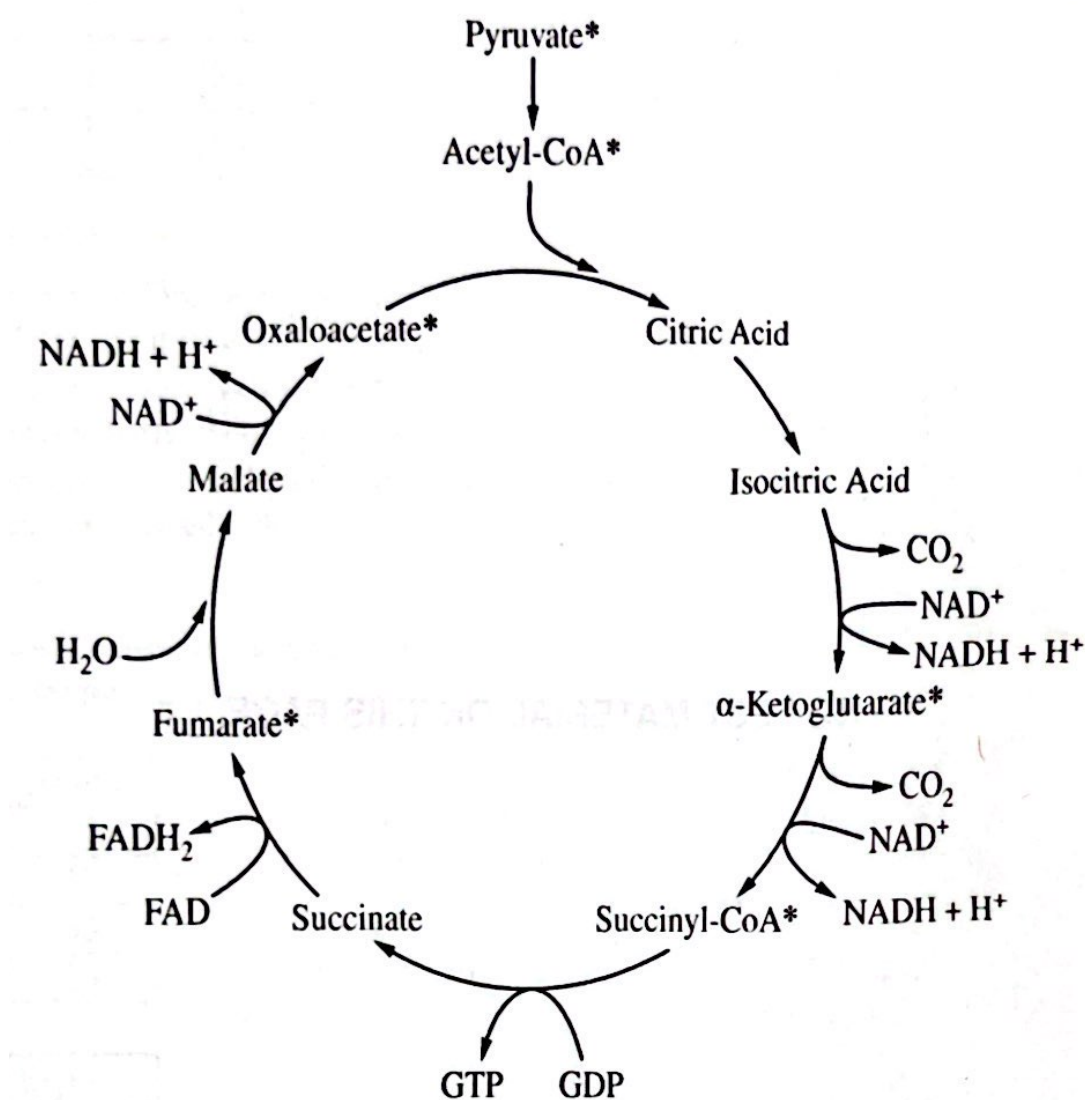


Figure 1. A representation of the Krebs cycle showing intermediate molecules and the locations at which electrons are transferred to NAD^+ and FAD. The asterisks (*) represent intermediates that can be formed from the carbon backbones of amino acids.

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.

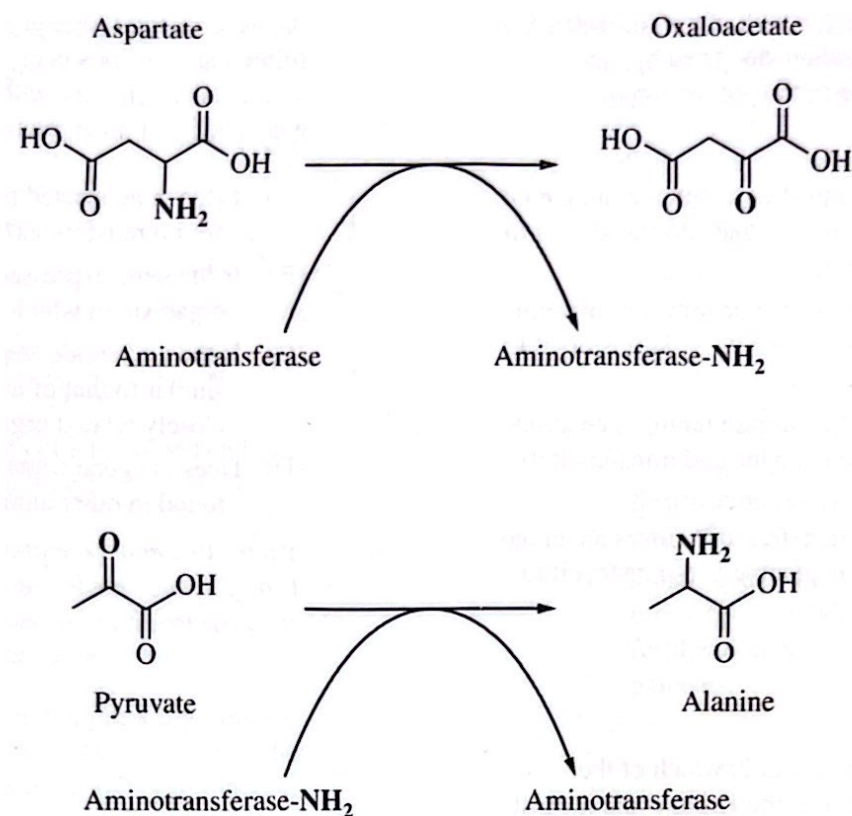


Figure 2. Role of an aminotransferase in the production of oxaloacetate. Aspartate and alanine are amino acids.

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 CO₂ 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.

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 FADH₂ 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?

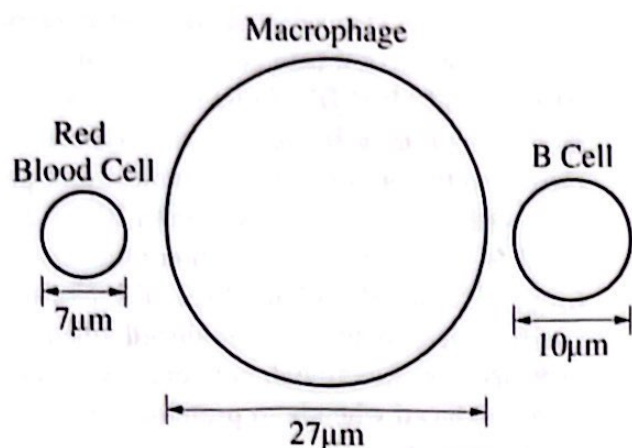


Figure 1. Diameters of a red blood cell, a macrophage, and a B cell

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.

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) $\pm 2\text{SE}_x$
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.

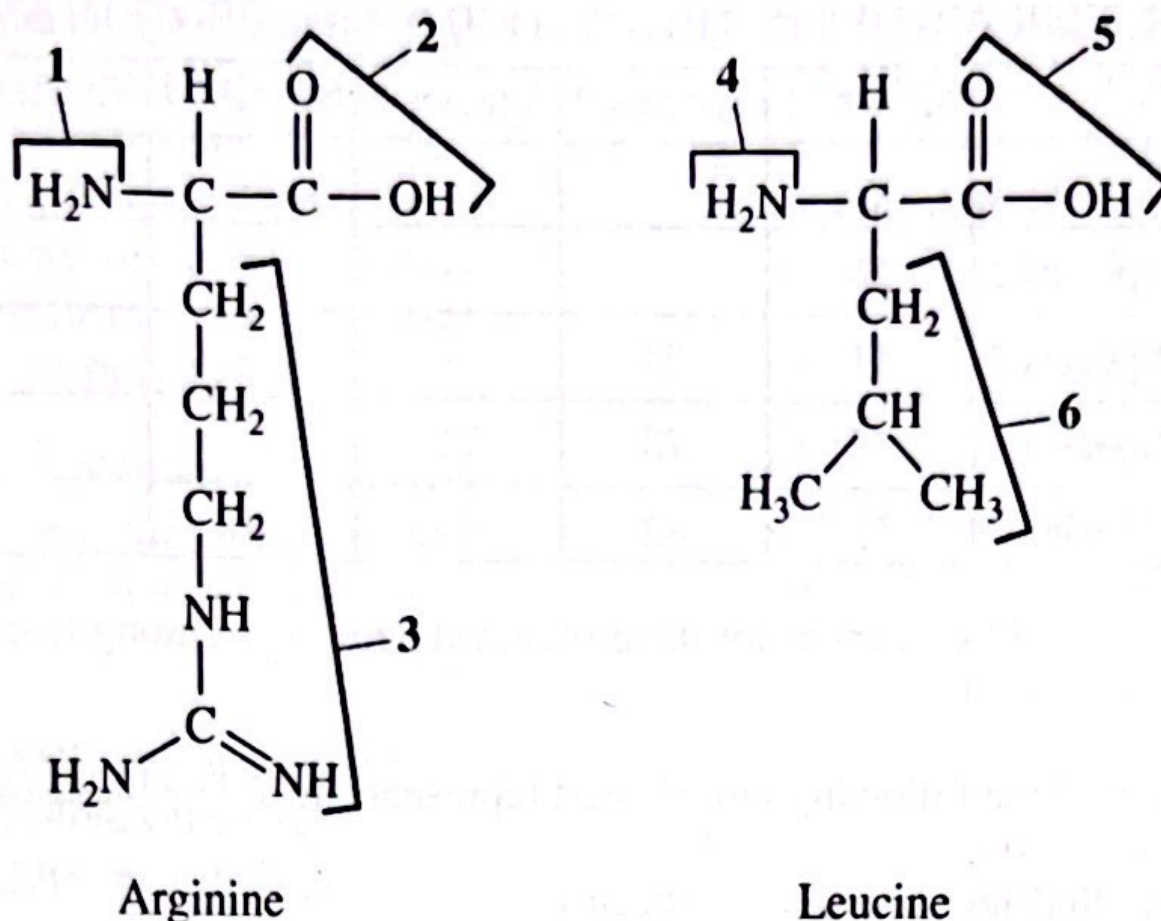


Figure 1. Structure of the amino acids arginine and leucine. Specific groups of atoms are identified by numbers.

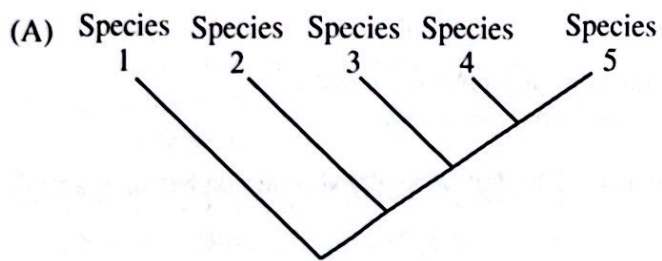
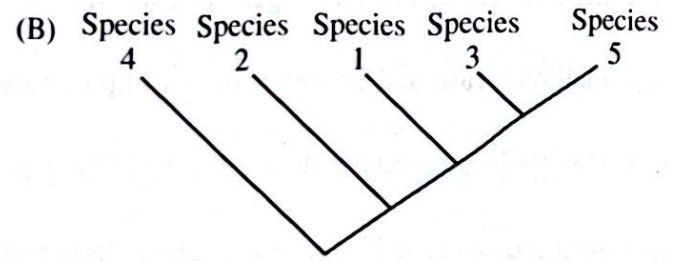
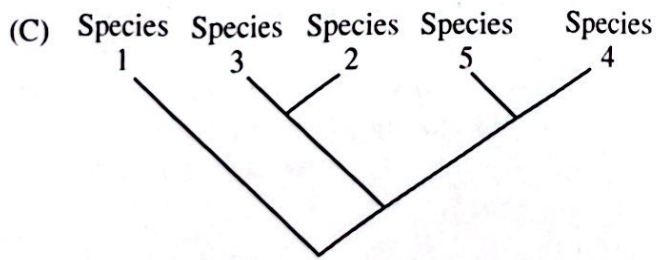
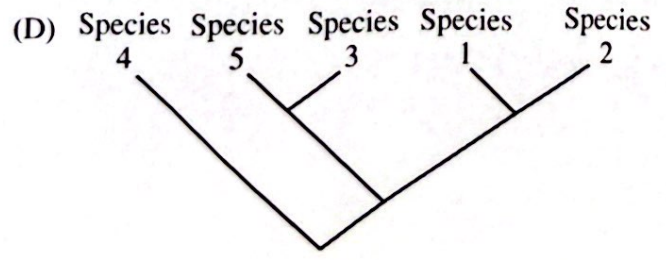
22. Based on Figure 1, which of the following best explains a dehydration synthesis reaction between arginine and leucine?

- (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.

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?



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

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).

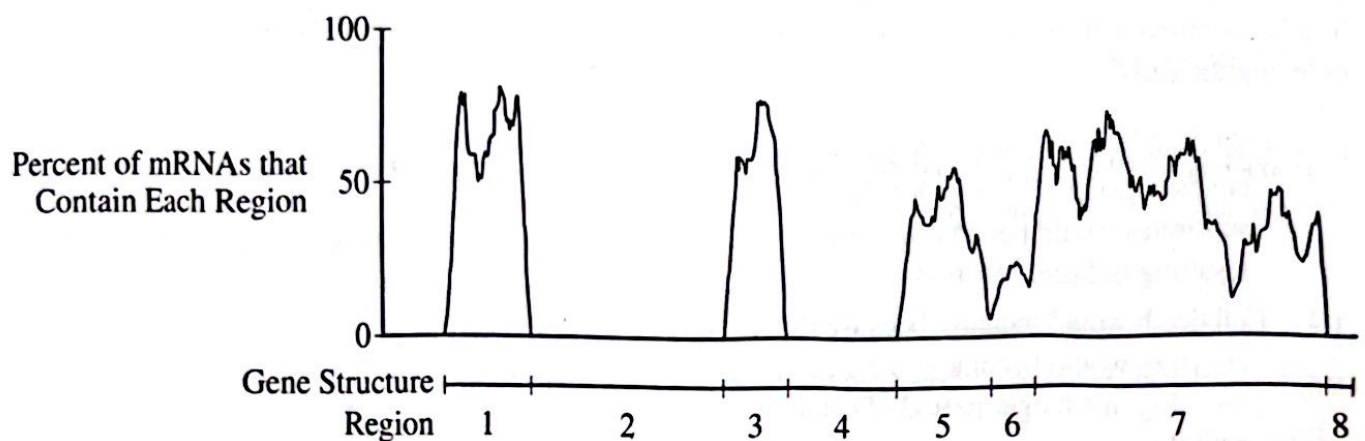


Figure 1. A histogram representing the percent of mature mRNA transcripts that contain each region of gene R

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).

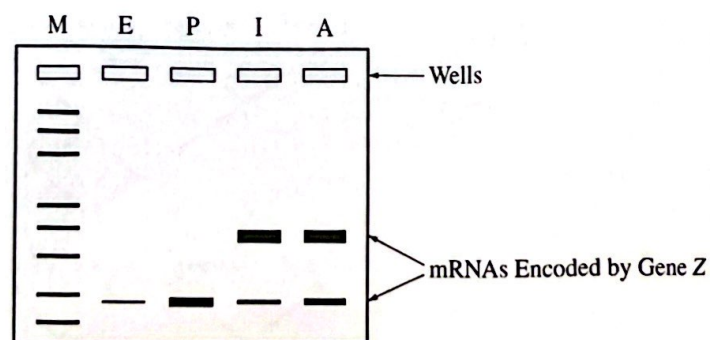


Figure 2. Four life cycle stages of mRNAs encoded by gene Z and analyzed by gel electrophoresis. A thicker band means that the band contains more mRNA. The lanes are as follows: DNA marker (M) with fragments of known sizes, eggs (E), pre-infection (P), early-infection (I), and adult (A).

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.

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

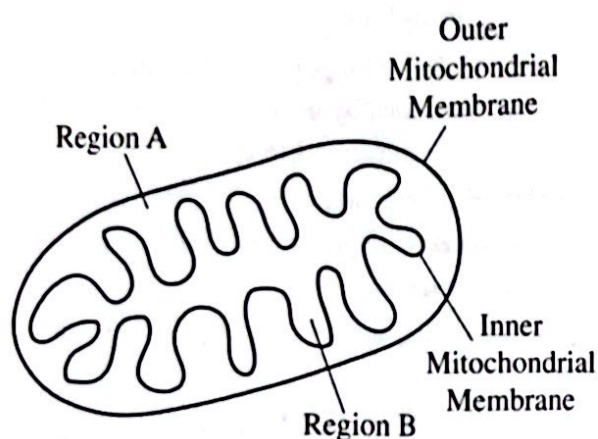


Figure 1. A model of a mitochondrion

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

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.

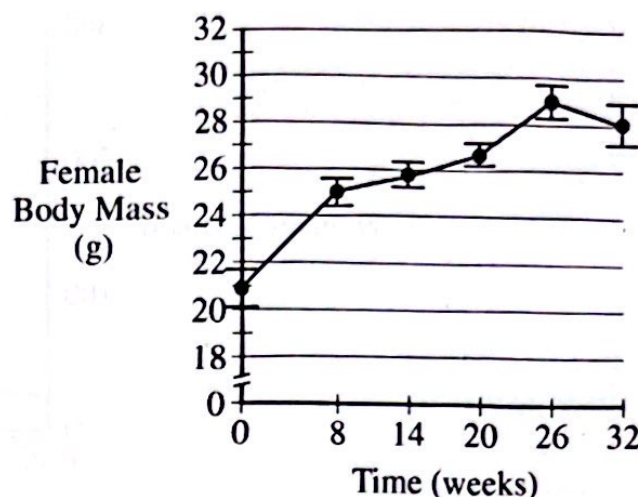


Figure 1. Average body mass of female mice fed a diet of fructose and glucose for 32 weeks. Error bars represent $\pm 2SE_{\bar{x}}$.

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%

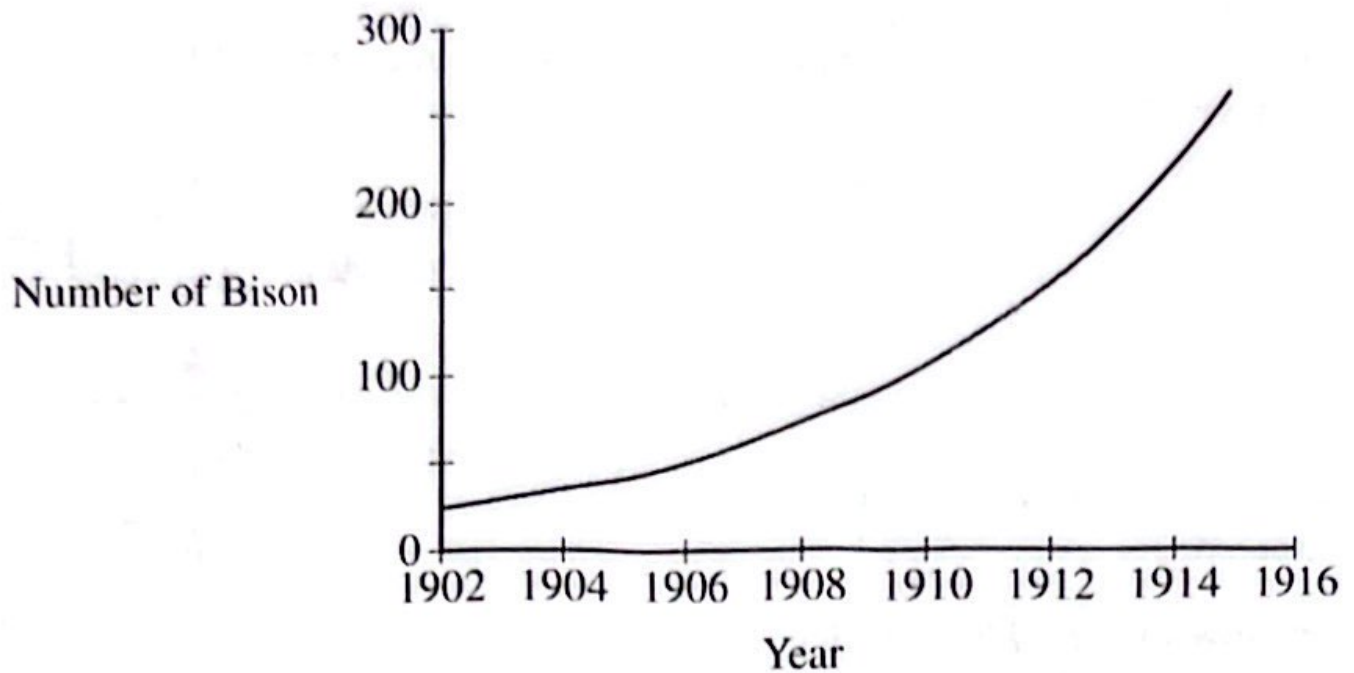


Figure 1. Number of American bison in one population between 1902 and 1915

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.

NO TEST MATERIAL ON THIS PAGE

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).

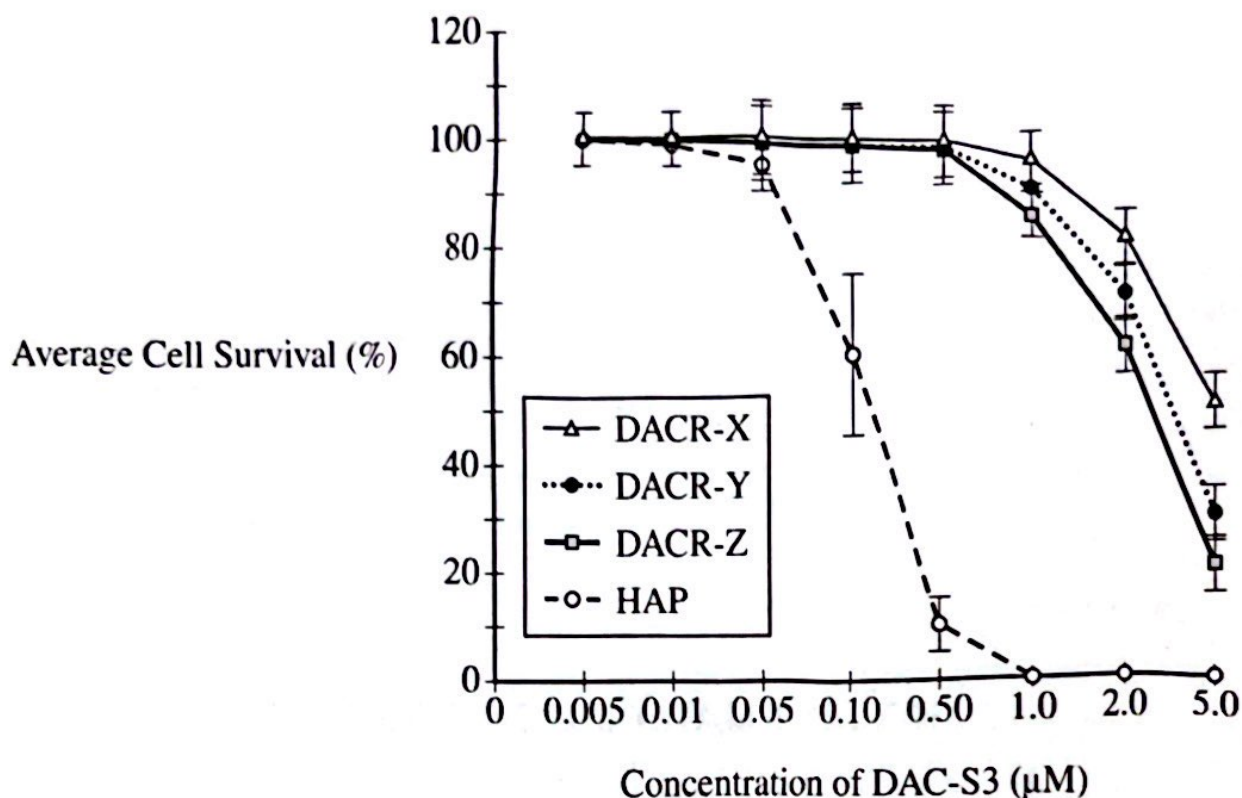


Figure 1. Average percent survival of HAP cancer cells and DAC-S3 resistant (DACR) cell lines at increasing concentrations of DAC-S3. Error bars represent $\pm 2SE_{\bar{x}}$.

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

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

- (A) At a DAC-S3 concentration of $1.0\ \mu\text{M}$, half as many HAP cells survive as do DACR cells.
- (B) As the concentration of DAC-S3 increases from $0.05\ \mu\text{M}$ to $0.10\ \mu\text{M}$, 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.

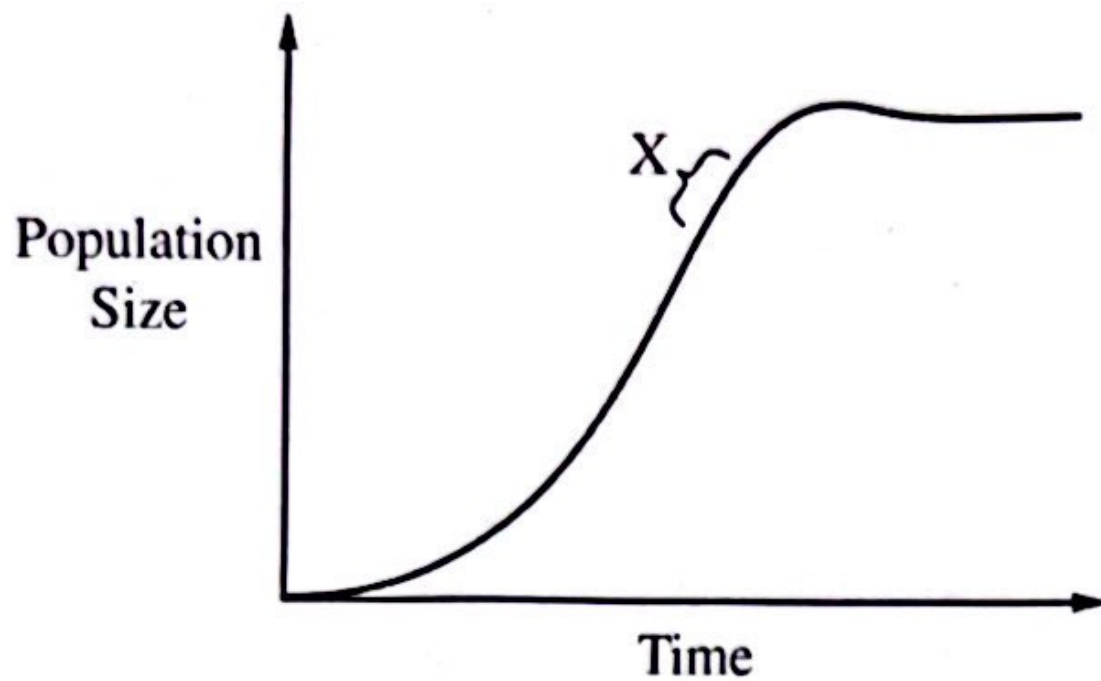


Figure 1. Change in the size of a population over time

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.

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.

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.

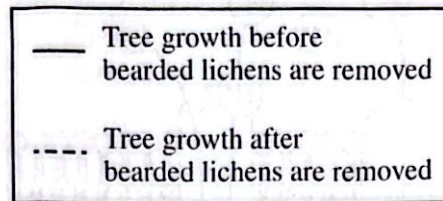
45. The protein TBK1 plays a role in the regulation of both cell division and apoptosis. Increased levels of TBK1 have been associated with certain forms of cancer. Which of the following predicts the likely effect of an increase in TBK1 on cell division?

- (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.

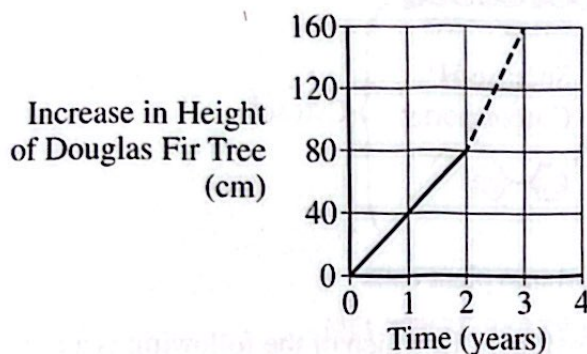
46. Which of the following best describes evidence that all eukaryotes share a common ancestor that is different from that of prokaryotes?

- (A) All eukaryotes have plasma membranes.
- (B) All eukaryotes have DNA.
- (C) All eukaryotes have membrane-bound organelles.
- (D) All eukaryotes have ribosomes.

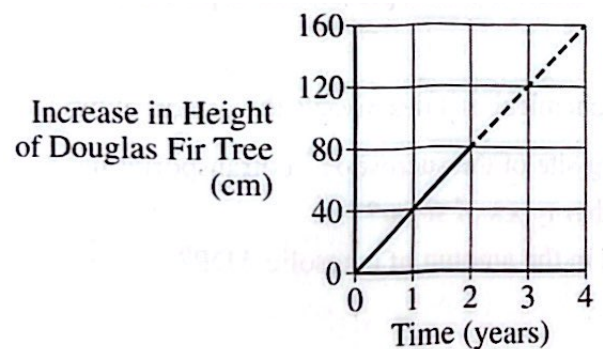
47. The bearded lichen, a symbiotic association composed of fungi and algae, hangs from the branches of Douglas fir trees. Scientists hypothesize that the lichens require the surface of the trees to live but neither harm nor benefit the trees. To test their hypothesis, they monitored the growth of Douglas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



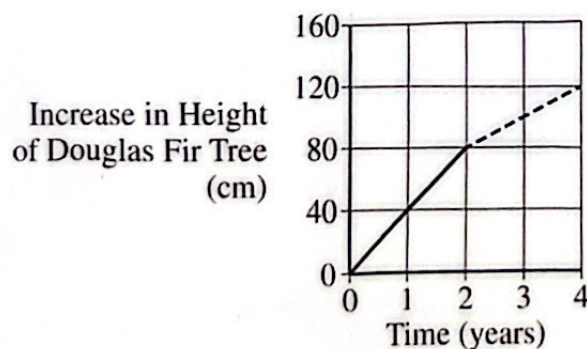
(A)



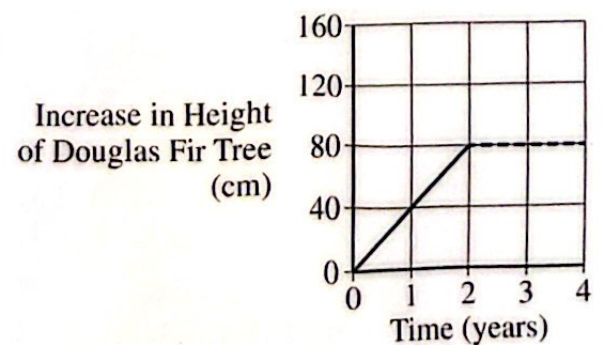
(B)



(C)



(D)



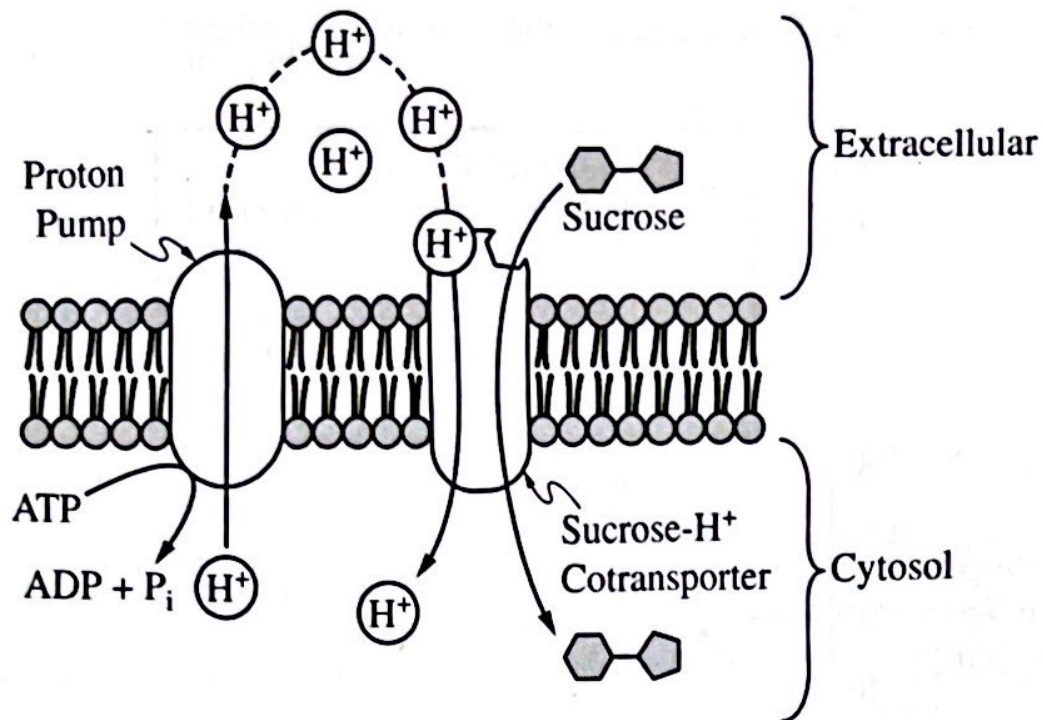


Figure 1. Model of sucrose transport into plant cells

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?

NO TEST MATERIAL ON THIS PAGE

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).

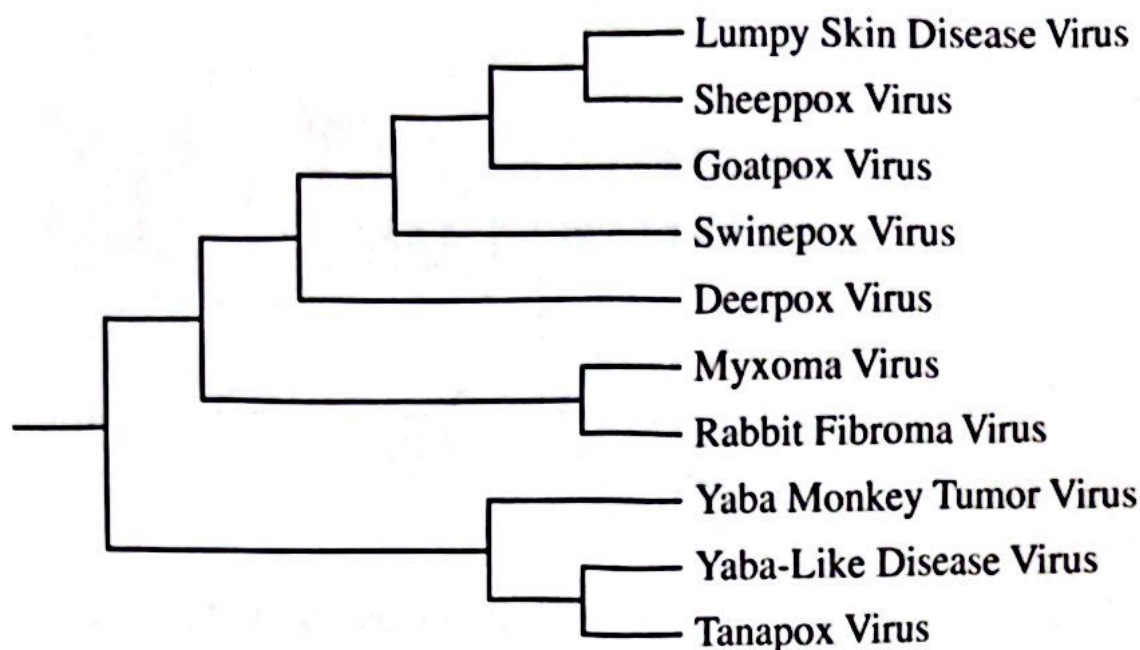


Figure 1. A partial cladogram of the Poxviridae family of viruses

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

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.

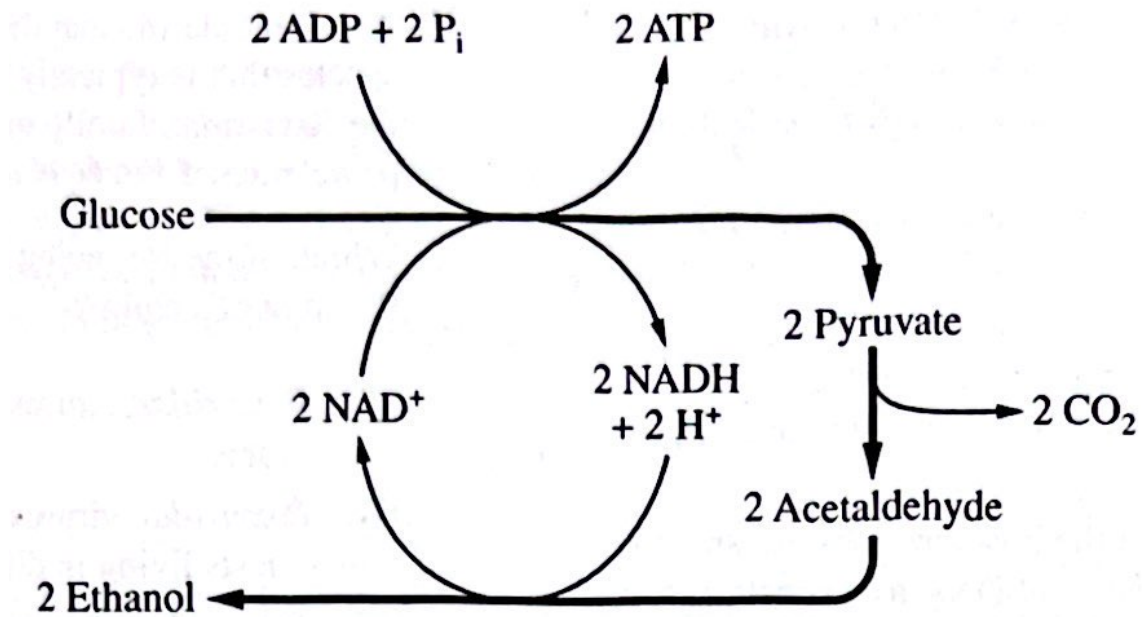


Figure 1. A model of cellular pathways that produce short-term energy storage molecules

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 CO₂ 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.

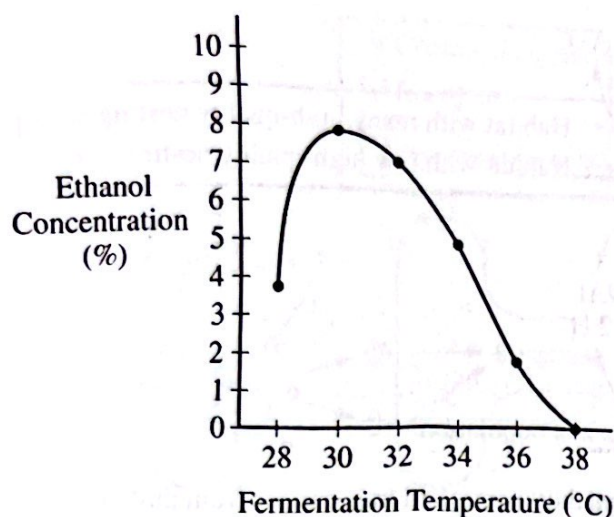


Figure 1. Effect of temperature on ethanol concentration during fermentation in yeast. All data points are statistically different from each other.

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.

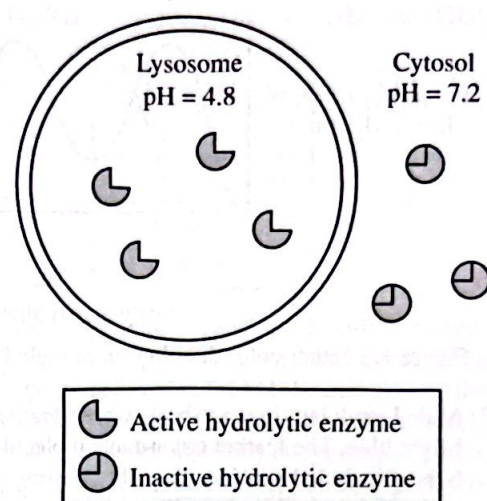


Figure 1. A model of hydrolytic enzyme activity in a lysosome and in the cytosol

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.

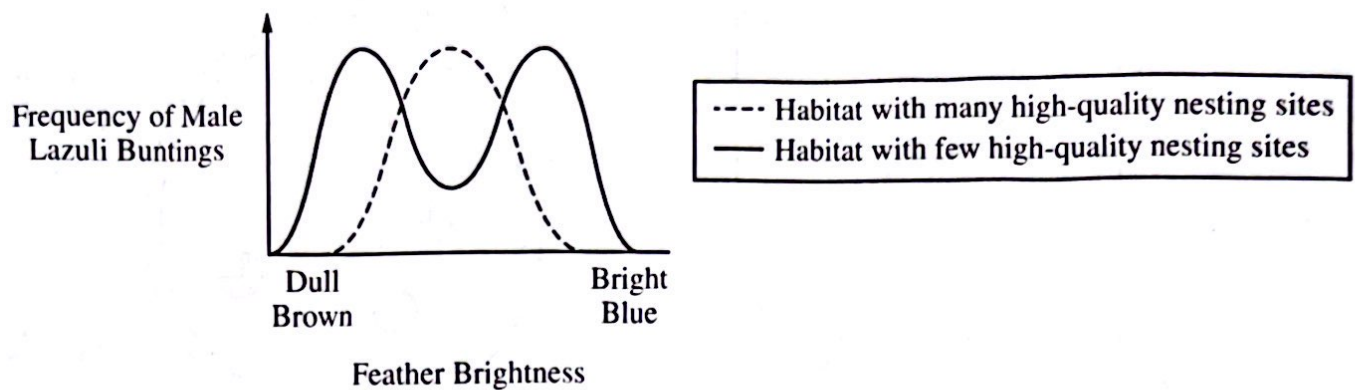


Figure 1. Feather color distribution of male Lazuli buntings in a population

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.

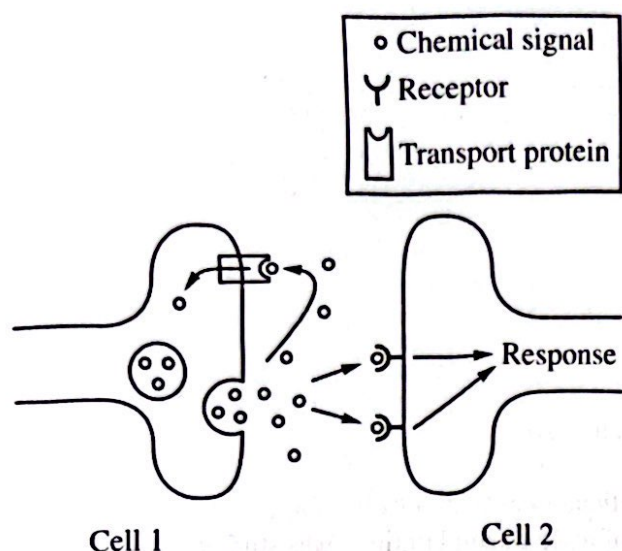


Figure 1. Model of chemical signaling between two nerve cells

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

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.

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.

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.

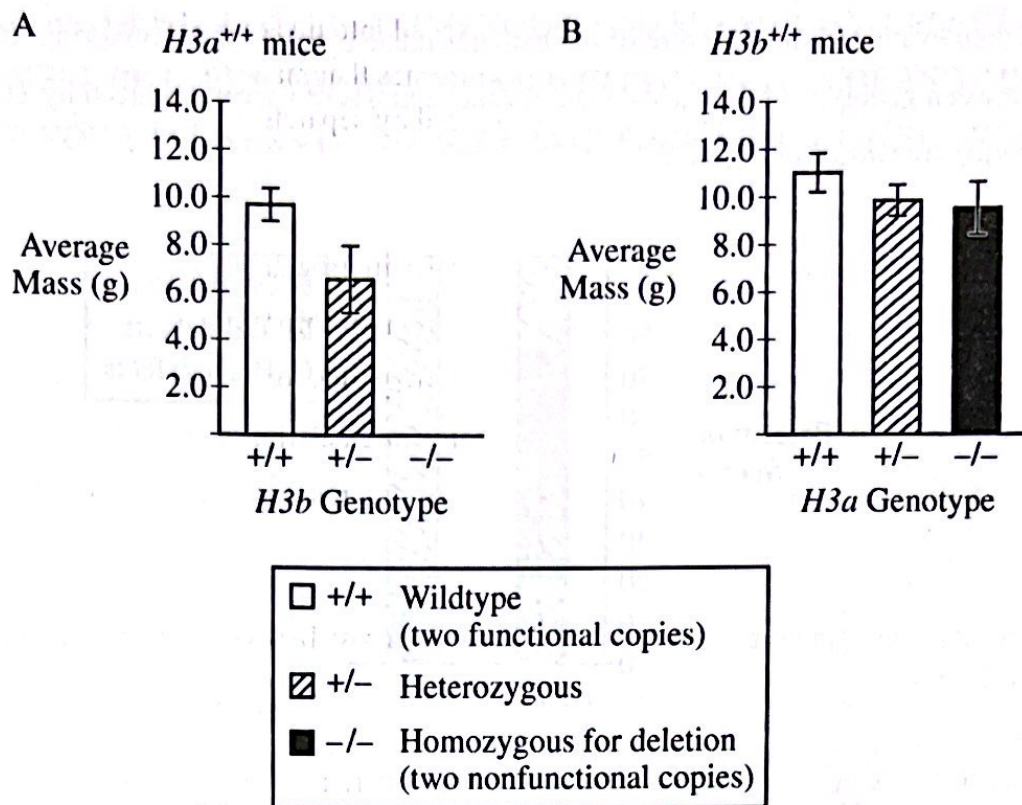


Figure 1. Average mass of three-week-old *H3a*^{+/+} mice when the *H3b* genotype is wild-type, heterozygous, or homozygous for a deletion (A), and average mass of three-week-old *H3b*^{+/+} mice when the *H3a* genotype is wild-type, heterozygous, or homozygous for a deletion (B). Error bars represent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

(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*^{+/-}).

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.

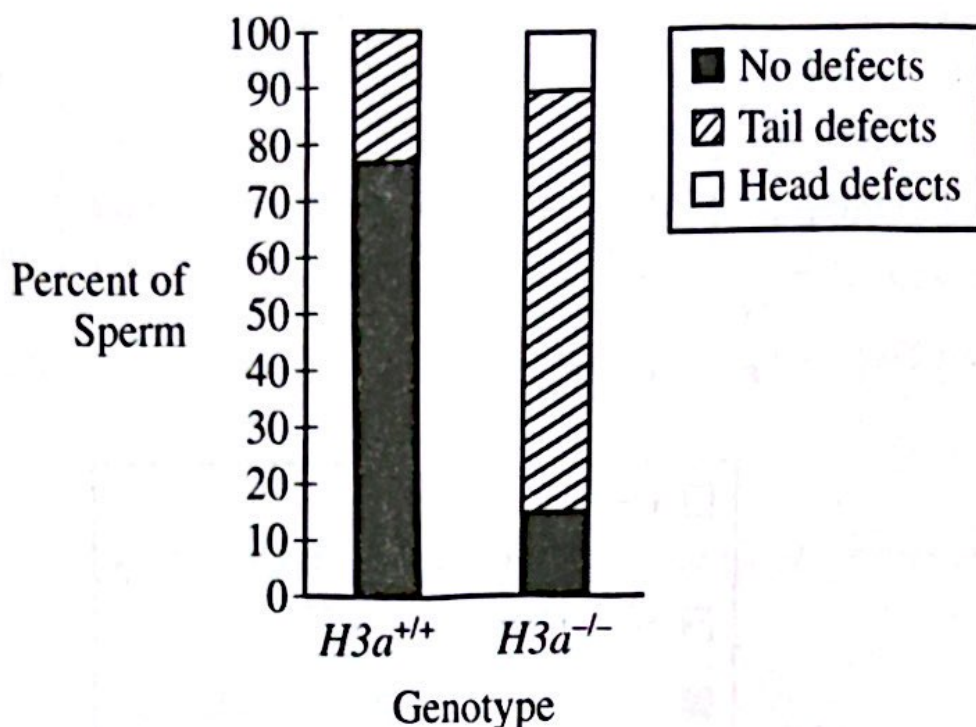


Figure 2. Analysis of sperm structure from $H3a^{+/+}$ mice and $H3a^{-/-}$ mice of the same age

(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.

Write your responses to this question only on the designated pages in the separate Free Response booklet. If there are multiple parts to this question, write the part letter with your response.

**THIS PAGE MAY BE USED FOR TAKING NOTES AND PLANNING YOUR ANSWERS.
NO CREDIT WILL BE GIVEN FOR ANYTHING WRITTEN IN THIS ORANGE BOOKLET.
WRITE YOUR ANSWERS IN THE SEPARATE FREE RESPONSE BOOKLET.**

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 $\pm 2SE_x$
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.

(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 .

Write your responses to this question only on the designated pages in the separate Free Response booklet. If there are multiple parts to this question, write the part letter with your response.

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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.

Write your responses to this question only on the designated pages in the separate Free Response booklet. If there are multiple parts to this question, write the part letter with your response.

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).

Write your responses to this question only on the designated pages in the separate Free Response booklet. If there are multiple parts to this question, write the part letter with your response.

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).

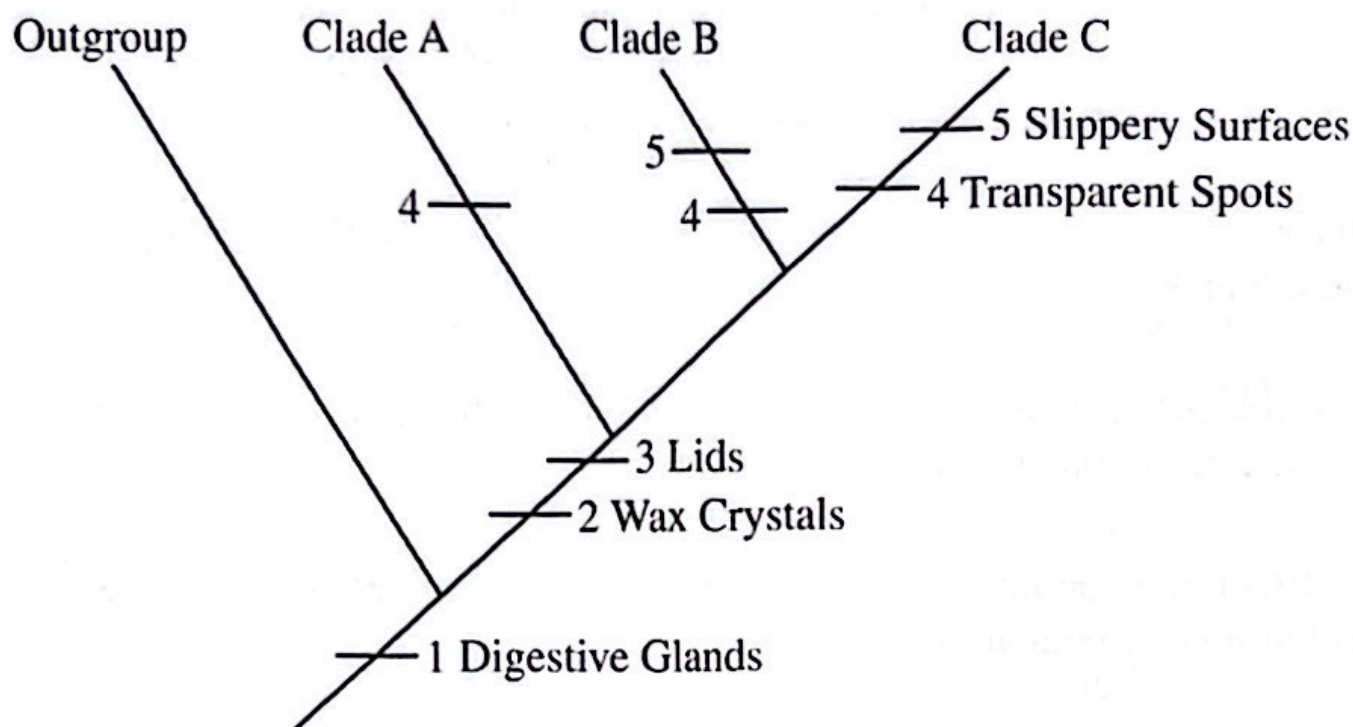


Figure 1. Cladogram of three clades of pitcher plants and an outgroup based on five different traits. Each hash mark represents the point at which the trait first appeared. Each numbered trait is labeled only once, on the main line of the cladogram.

- Describe one way a mutant allele can increase in frequency in a population over many generations.
- Explain how the cladogram in Figure 1 shows evidence of convergent evolution of pitcher plants in clades B and 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.
- 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.

Write your responses to this question only on the designated pages in the separate Free Response booklet. If there are multiple parts to this question, write the part letter with your response.

NO TEST MATERIAL ON THIS PAGE

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.

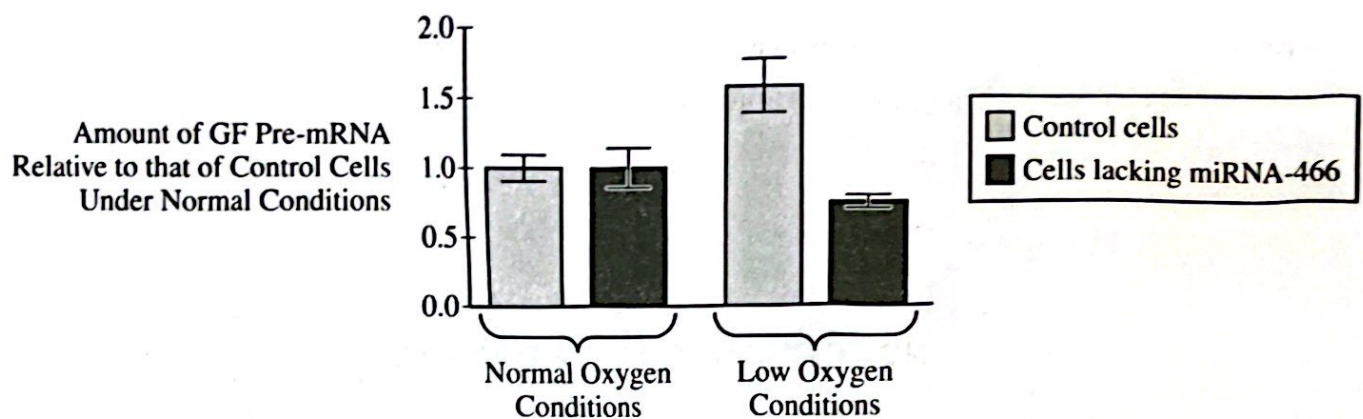


Figure 1. The amount of GF pre-mRNA produced by cells lacking miRNA-466 relative to control cells after exposure to normal and low oxygen conditions for 24 hours. Error bars represent $\pm 2SE_{\bar{x}}$.

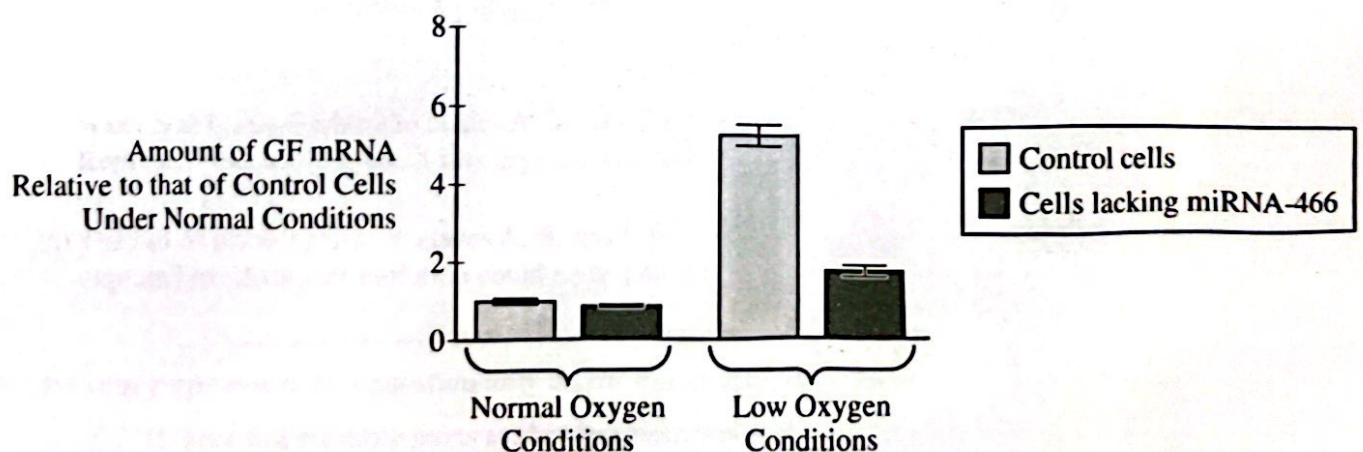


Figure 2. The amount of GF mRNA produced by cells lacking miRNA-466 relative to control cells after exposure to normal and low oxygen conditions for 24 hours. Error bars represent $\pm 2SE_{\bar{x}}$.

- (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.

Write your responses to this question only on the designated pages in the separate Free Response booklet. If there are multiple parts to this question, write the part letter with your response.

Appendix: answers and solutions

2024 supplied MCQ + FRQ paper | 60 MCQs and all 32 FRQ subparts

These answers were worked out from the exact supplied paper and its figures, then checked against the AP Biology framework. The separate supplied answer file was used only for comparison. This appendix provides suggested answers and model responses; it does not claim an official scoring allocation.

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

Navigation: MCQ explanations follow this sheet. Then come FRQ 1-6, including a plotted graph for FRQ 2 and a marked cladogram for FRQ 5. Answers start after the 53 reconstructed question pages.

Use the paper supplied here: The publicly released 2024 FRQ paper is a different question set; its scoring guide should not be substituted for these FRQs. Figure readings are approximate where the source is a scan.

MCQ explanations: 1-10

Source references below use the original PDF page number.

1. B - Meiosis I versus meiosis II (original PDF p.1)

Meiosis I separates homologous chromosomes; meiosis II separates sister chromatids. The first division reduces ploidy to haploid, and the second does not restore diploidy. Crossing-over and independent assortment both involve meiosis I.

2. D - Carbohydrate structure and function (original PDF p.2)

The relative orientations of the glucose monomers and their linkages differ. This changes the polymers' shapes, interactions, and biological functions. Both contain the same types of atoms, and both are broken down by hydrolysis rather than dehydration synthesis.

3. D - Ion-dependent enzyme activity (original PDF p.3)

Mn²⁺ produces the greatest activity, about 12.5 units/mg. Ni²⁺, Ca²⁺, and Mg²⁺ also increase activity above the no-ion control. Activity is not zero without Mn²⁺, so Mn²⁺ is not necessary for any reaction to occur.

4. D - Warning-call rate (original PDF p.5)

Call rate rises from 7.97 to 15.03 calls/individual/min for the higher-threat predator. Call length, number of notes, and time between notes also increase, so the directions proposed by A, B, and C are incorrect.

5. B - Response to warning calls (original PDF p.5)

The playback experiment shows that the warning calls change how songbirds approach a location: 135.6 versus 207.4 seconds and 84.8 versus 224.3 cm. It does not measure nest departure, predator attack probability, or protection of other species.

6. A - Polygenic variation (original PDF p.5)

Several interacting genes on different chromosomes can produce a broad range of a complex call phenotype. A single gene with one allele cannot explain this variation; the other choices describe much more restricted genetic models.

7. A - Pesticides in food webs (original PDF p.6)

Sparrowhawks eat more seed-eating birds, so pesticides in those prey can accumulate to toxic levels in the predators. Tawny owls mainly eat small mammals and receive less exposure through this particular pathway. The stimulus does not support resistance or direct seed eating by the predators.

8. C - Net population growth (original PDF p.6)

Net change per 1,000 birds is $1,500 - 1,200 = 300$. Therefore, net growth is $130,000,000 \times (300/1,000) = 39,000,000$ birds. This is the increase, not the final population size.

9. C - Mutualism (original PDF p.6)

Both species survive better together than separately, so both benefit. A describes exploitation, D describes a benefit to only one species, and B does not establish benefits to both partners.

10. C - Reading a stacked bar chart (original PDF p.7)

The shaded 'not threatened' portions are greatest for invertebrates and fish, both close to 100%. Reptiles and plants have visibly larger threatened portions and smaller not-threatened portions.

MCQ explanations: 11-20

Source references below use the original PDF page number.

11. A - Expected DNA base composition (original PDF p.8)

Complementary base pairing requires $A = T$ and $G = C$ for the double-stranded DNA comparison. Only A has these equalities: $A/T = 30/30$ and $G/C = 20/20$. A single isolated strand need not itself satisfy these equalities; use the question's double-stranded comparison.

12. D - Translation initiation (original PDF p.8)

An initiation factor participates in assembling a complex involving mRNA and the ribosome to start translation. Recruiting RNA polymerase would concern transcription, while splicing and polypeptide folding are different processes.

13. C - Location of the Krebs cycle (original PDF p.11)

In eukaryotes, the Krebs-cycle reactions occur in the mitochondrial matrix. They require enzymes; they are not the Calvin cycle in reverse. Glycolysis produces pyruvate in the cytosol, not the smooth endoplasmic reticulum.

14. D - Tracking carbon through a pathway (original PDF p.11)

Carbon remaining in alpha-ketoglutarate can pass through successive intermediates to oxaloacetate, which combines with acetyl-CoA to form citrate. Some carbon is lost as CO_2 , but retained carbon can continue around the cycle. The figure does not show reverse flow or CO_2 fixation.

15. B - Amino-group transfer (original PDF p.12)

The enzyme removes an amino group from aspartate, producing oxaloacetate, then transfers that group to pyruvate, producing alanine. The two arrows in Figure 2 determine the donor and recipient.

16. A - Reduced supply of oxaloacetate (original PDF p.12)

Loss of this aminotransferase reduces the supply of oxaloacetate from aspartate. Less oxaloacetate limits citrate formation and Krebs-cycle throughput, reducing NADH production. Reduced availability does not imply increased consumption or production of the other intermediates.

17. C - Inferring a gene's function (original PDF p.12)

Similarity to a known aminotransferase coding sequence in a closely related organism supports a shared encoded function. Location, widespread expression, or promoter similarity alone does not identify the protein's catalytic function. Sequence evidence supports a hypothesis; an activity assay could confirm it.

18. A - Surface-area-to-volume ratio (original PDF p.13)

The smaller red blood cells have a greater surface-area-to-volume ratio than the much larger macrophages, favoring exchange per unit volume. A larger volume by itself does not make exchange more efficient; the macrophages have a lower ratio than the smaller B cells.

19. C - Variation from sexual reproduction (original PDF p.13)

Crossing-over occurs between nonsister chromatids of homologous chromosomes, and random fertilization combines haploid gametes. Choices involving sister chromatids or diploid gametes misidentify these processes.

20. D - Lac-Phe after exercise (original PDF p.14)

The highest measured concentration is immediately after exercise, 1.27 μM ; it falls to 0.67 μM after 30 minutes and 0.21 μM after 60 minutes. The 30-minute value remains above the resting value of 0.25 μM .

MCQ explanations: 21-30

Source references below use the original PDF page number.

21. D - Separating two proteins' effects (original PDF p.14)

Testing BRCA2 functional/MEILB2 nonfunctional and the reciprocal condition isolates each protein's contribution. Comparing only conditions with both proteins functional or both nonfunctional cannot distinguish their individual roles.

22. B - Formation of a peptide bond (original PDF p.15)

Group 2 is a carboxyl group and group 4 is an amino group. Removing OH and H forms water, while a covalent peptide bond joins the amino acids. The bond is not a hydrogen bond and does not join the R-groups.

23. C - Protein similarity and relatedness (original PDF p.16)

Species 4 and 5 are 98% similar, and species 2 and 3 are 95% similar. Model C places each of these pairs together and places species 1 outside them. The other models fail to group both strongly supported pairs.

24. C - pH and enzyme structure (original PDF p.17)

A less optimal pH can disrupt interactions that maintain enzyme structure, reducing catalytic activity and the production of proteins that cause cell death. The other choices predict increased activity without support or introduce digestion of transport proteins that the stimulus does not describe.

25. C - Estimating polypeptide mass (original PDF p.17)

Combined mass = 7 polypeptides x 117 amino acids/polypeptide x 110 daltons/amino acid = 90,090 daltons. The smaller alternatives omit one of the required factors; 270,270 triples the estimate.

26. A - Frequency of transcript regions (original PDF p.19)

Regions 1 and 3 have the highest prominent peaks in Figure 1. Regions 2 and 4 are absent, while the other listed regions occur at lower frequencies in the mature transcripts.

27. D - Retention of an intron (original PDF p.19)

Region 6 is present at low but nonzero frequency, consistent with an intron retained in some processed transcripts. Regions 2 and 4 are absent from the mature transcripts; region 5 is present much more frequently and is more consistent with an exon.

28. B - Location of mature mRNA (original PDF p.19)

Most processed mRNA used for protein synthesis is in the cytoplasm. Eukaryotic translation does not occur in the nucleus, and these transcripts are not primarily explained by mitochondrial splicing or ER protein modification.

29. A - Transcript lengths on a gel (original PDF p.19)

Early-infection and adult lanes contain a longer transcript, shown by an upper band closer to the wells, in addition to the shorter transcript. Egg and pre-infection lanes show only the shorter one. The adult bands differ in thickness, so they do not represent equal amounts.

30. D - Stage-specific gene expression (original PDF p.19)

Larval-stage transcription factors can activate the protein's gene only during that stage. Their later absence prevents activation. Development does not normally reorder codons or delete the gene, and ribosomes translate rather than transcribe RNA.

MCQ explanations: 31-40

Source references below use the original PDF page number.

31. C - Resilience and genetic diversity (original PDF p.20)

High genetic diversity increases the chance that some individuals possess alleles advantageous under changed conditions. A small population, low reproduction, or uniform alleles generally reduces the population's capacity to withstand change.

32. C - Mitochondrial proton gradient (original PDF p.20)

Region A is the intermembrane space, and region B is the matrix. The electron transport chain uses released energy to pump H^+ from the matrix into region A, making the H^+ concentration in A higher. Return flow through ATP synthase is down the gradient.

33. D - Chi-square rejection threshold (original PDF p.20)

There are three categories, so degrees of freedom = $3 - 1 = 2$. The critical chi-square value at $\alpha = 0.05$ is 5.99; reject the null hypothesis when the calculated value exceeds it. Values below the threshold do not justify rejection.

34. D - Inhibiting a repressor (original PDF p.21)

The inhibitor blocks JLE's repressor activity, allowing more transcription of Tyr and more tyrosinase production. Brown pigment therefore increases. The experiment alters JLE activity; it does not establish a change in transcription of jle.

35. B - Percent change in mouse mass (original PDF p.21)

Read approximately 25 g at week 8 and 29 g at week 26. Percent increase = $(29 - 25)/25 \times 100 = 16\%$. Use the starting mass as the denominator; a 4 g increase is not a 4% increase.

36. D - Exponential population growth (original PDF p.22)

The upward-curving trajectory shows an increasing absolute growth rate, consistent with exponential growth when resources are plentiful and competition is limited. It does not level off as logistic growth would, and it does not show a population decline.

37. A - Enzyme catalysis (original PDF p.24)

Enzymes lower the activation energy required for reactions to proceed. They do not raise that barrier or regulate reactions simply by changing the amount of substrate required. They also do not change the reaction's overall free-energy difference.

38. D - Reading a dose-response curve (original PDF p.24)

The HAP curve is at about 10% survival at 0.50 μM DAC-S3. At 0.10 μM it is about 60%, and at the smaller concentrations survival is much higher.

39. B - Comparing response changes (original PDF p.25)

Between 0.05 and 0.10 μM , HAP survival falls from about 95% to 60%, while DACR survival stays near 100%. At the lowest doses survival is similar, and at higher doses the three DACR curves differ, ruling out the broader claims.

40. B - A comparison cell line (original PDF p.25)

HAP cells exposed to DAC-S3 provide the nonresistant comparison for DACR cell lines exposed to the same chemical. This isolates the difference in resistance under treatment rather than comparing cells in unrelated organisms or different exposure conditions.

MCQ explanations: 41-50

Source references below use the original PDF page number.

41. C - Blocking formation of a toxic product (original PDF p.25)

Inhibiting SDR2 reduces conversion of DAC-S3 into DACones. Because DACones cause misfolding and death, fewer DACones should increase the percentage of viable HAP cells. This prediction follows the direction of the enzyme's reaction.

42. B - Approaching carrying capacity (original PDF p.26)

In region X the curve is still rising but its slope is decreasing. Resource limitation increasingly restricts reproduction as the population approaches carrying capacity. A death rate exceeding birth rate would instead make population size fall.

43. A - Z-linked dominant inheritance (original PDF p.27)

Blue is dominant and the gene is Z-linked. A brown male ZbZb crossed with a blue female ZBW produces blue sons ZBZb and brown daughters ZbW. The sex-specific result cannot be explained by the proposed autosomal models.

44. B - Water potential and osmosis (original PDF p.28)

Water moves from the rainwater's higher water potential into seeds with lower water potential, causing swelling. Water uptake does not require active pumping; describing the seeds as hypotonic would predict the opposite net direction.

45. B - Cancer and apoptosis (original PDF p.28)

An increase associated with cancer is best explained here by stimulation of division together with inhibition of apoptosis. This combination increases the persistence and number of cells, whereas the alternatives include reduced division or increased cell death.

46. C - A shared eukaryotic feature (original PDF p.28)

Membrane-bound organelles distinguish the eukaryotic organization from prokaryotic organization and support shared eukaryotic ancestry. Plasma membranes, DNA, and ribosomes occur in both groups, so those choices do not establish the requested distinction.

47. B - Commensalism and tree growth (original PDF p.29)

The hypothesis predicts that tree growth is unaffected by removing lichens. In B, the line continues with the same slope before and after removal. A increases the slope, C decreases it, and D stops height increase.

48. A - Testing a proton-gradient requirement (original PDF p.30)

Deactivating the proton pump directly tests whether sucrose transport depends on the gradient the pump maintains. Mutating the sucrose-binding site tests a different requirement, while sugar identity or cytosolic ADP does not isolate the proton gradient as directly.

49. C - Most recent common ancestors (original PDF p.32)

Tanapox branches in one major lineage, while deerpox and myxoma are in the other. Its most recent common ancestor with either is therefore the same basal node. Swinepox is closer to goatpox than deerpox, and lumpy skin disease has different common-ancestor nodes with swinepox and deerpox.

50. A - Viral evolutionary fitness (original PDF p.32)

The number of new viruses produced per infected organism per day measures reproductive output, the closest available measure of fitness. Genome length, particle diameter, and the number of protein types do not directly measure reproductive success.

MCQ explanations: 51-60

Source references below use the original PDF page number.

51. B - Replication outside the nucleus (original PDF p.33)

The stimulus states that poxviruses and their DNA cannot enter the host nucleus, where the relevant host DNA-replication enzymes are located. Encoding their own replication enzymes allows viral DNA replication in the cytoplasm; it does not imply independence from a host cell.

52. C - Genetic change and selection (original PDF p.33)

Acquired genes or alleles change the viral genotype and may produce a phenotype favored by natural selection. This is a possible benefit, not a guaranteed improvement. Larger size, lower mutation rate, or a parent-cell/daughter-cell description is not supported.

53. B - Availability of alternative hosts (original PDF p.33)

The family includes viruses infecting many hosts in different environments, so extinction of one host species need not remove the entire family's hosts. The stimulus describes frequent mutation, not low mutation or little diversity. This does not imply that every member infects every host.

54. C - NAD⁺ regeneration (original PDF p.34)

Glycolysis reduces NAD⁺ to NADH; ethanol fermentation reoxidizes NADH to NAD⁺, permitting glycolysis to continue while glucose is available. ATP is produced by glycolysis in the depicted pathway, and ethanol is a product rather than the required starting fuel.

55. A - Designing a sugar-concentration experiment (original PDF p.35)

The highest ethanol concentration occurs at 30 degrees C. Hold that temperature and sugar source constant while varying sugar concentration. This tests the requested variable without changing sugar identity, and avoids the lower-yield temperatures.

56. D - Compartment-specific conditions (original PDF p.35)

The lysosomal membrane maintains an acidic interior, pH 4.8, where hydrolytic enzymes work, separate from cytosol at pH 7.2 where they are inactive. This illustrates regulation through distinct chemical environments, rather than free enzyme diffusion between compartments.

57. C - Disruptive selection (original PDF p.36)

With few high-quality nesting sites, the solid curve has peaks at both dull and bright extremes and a trough at intermediate colors. This supports greater fitness of both extremes, the pattern of disruptive selection, rather than advantage to one extreme or to the intermediate.

58. B - Blocking signal reuptake (original PDF p.37)

Blocking the first cell's reuptake transporter leaves more signal in the extracellular fluid, allowing more receptor activation in the second cell. Blocking the receptor or increasing reuptake would instead decrease the response.

59. D - Combining nucleotide proportions (original PDF p.37)

Exon 1: $G + C = 0.32 + 0.31 = 0.63$. Intron 1: $G + C = 0.21 + 0.20 = 0.41$. The requested ratio is 0.63:0.41, not a comparison of guanine alone.

60. C - Inhibiting SIRT1 (original PDF p.38)

SIRT1 protects c-Myc from degradation and inhibits apoptosis. Inhibiting SIRT1 permits more c-Myc degradation and more apoptosis, predicting lower c-Myc levels and fewer cancer cells.

FRQ 1: histones and growth

Original PDF pp.40-42 | Model answers, parts (a)-(b)

(a) Expected genotype ratio

The expected ratio is 1 homozygous functional (+/+) : 2 heterozygous (+/-) : 1 homozygous deletion (-/-), or 25% : 50% : 25%, from a +/- x +/- cross. This is the Mendelian expectation at conception; subsequent death of a genotype can alter the ratio among surviving offspring.

(b)(i) Dependent variable

The dependent variable is the mass of the three-week-old offspring, measured in grams (reported as average mass for each genotype). Genotype is the comparison variable, not the measured response.

(b)(ii) Wild-type control

Wild-type mice establish the mass expected when both alleles are functional. Comparing deletion genotypes with this baseline allows the scientists to assess whether losing functional histone alleles affects growth.

(b)(iii) Age control

Mouse mass changes with age. Using mice of the same age controls for age-related growth, so differences in mass are less likely to result from developmental timing rather than genotype.

(b)(iv) Compare loss of one allele

Losing one H3a allele produces a smaller apparent decrease in mean mass, approximately 11 to 10 g, than losing one H3b allele, approximately 9.5 to 6.5 g. The H3a wild-type and heterozygote error bars overlap; the H3b error bars do not. Thus, loss of one H3b allele has the larger, clearer effect on mass.

Data check: Compare each deletion genotype with the wild-type bar in its own panel. Panels A and B hold different histone genes functional; do not compare bars as if they were one uncontrolled experiment.

FRQ 1: sperm structure

Original PDF p.42 | Model answers, parts (c)-(d)

(c)(i) Effect on sperm structure

The H3a $-/-$ genotype increases the proportion of sperm with structural defects compared with H3a $+/+$. Tail defects rise from about 23% to 75%, head defects appear at about 10%, and the proportion with no defects falls from about 77% to 15%.

(c)(ii) Calculate the number with defects

About 15% of H3a $-/-$ sperm have no defects, so 85% have a tail or head defect. Number with defects = $200 \times (1 - 0.15) = 170$ sperm. Equivalently, $(75\% \text{ tail} + 10\% \text{ head}) \times 200 = 170$. Counting the 10% head defects alone would give only 20 and omit the tail defects.

(d)(i) Null hypothesis

H3a genotype has no effect on the proportions of sperm with normal structure, tail defects, or head defects; any observed differences between H3a $+/+$ and H3a $-/-$ mice result from chance.

(d)(ii) Support the noncompensation claim

In Figure 1A, all mice have two functional H3a alleles, but H3b $+/-$ mice still have lower mean mass, about 6.5 g versus about 9.5 g for H3b $+/+$ mice. H3b $-/-$ mice die during development. Therefore, two functional H3a alleles do not compensate fully for loss of H3b function. The missing bar for H3b $-/-$ indicates no surviving offspring, not a measured mass of zero grams.

Worked result: $(100\% - 15\%) \times 200 = 170$ sperm with defects. The chart is stacked: count tail and head defects together.

FRQ 2: enzyme inhibition

Original PDF pp.44-45 | Nucleotide components and the required graph

(a) DNA nucleotide

A DNA nucleotide consists of a phosphate group, a five-carbon deoxyribose sugar, and a nitrogenous base (adenine, thymine, guanine, or cytosine). Ribose is the RNA sugar; an amino acid is not a nucleotide component.

(b)(i) Line graph

Use NSAH concentration (μM) on the x-axis and percent of maximum hRR activity (%) on the y-axis. Plot (3,100), (5,98), (10,92), (25,55), (50,41), and (100,24), with numeric x-axis spacing reflecting actual concentrations, and connect successive points. Include vertical error bars of ± 2 , ± 8 , ± 6 , ± 8 , ± 8 , and ± 4 percentage points, respectively; these values are already ± 2 SE.

Percent of maximum hRR activity (%)

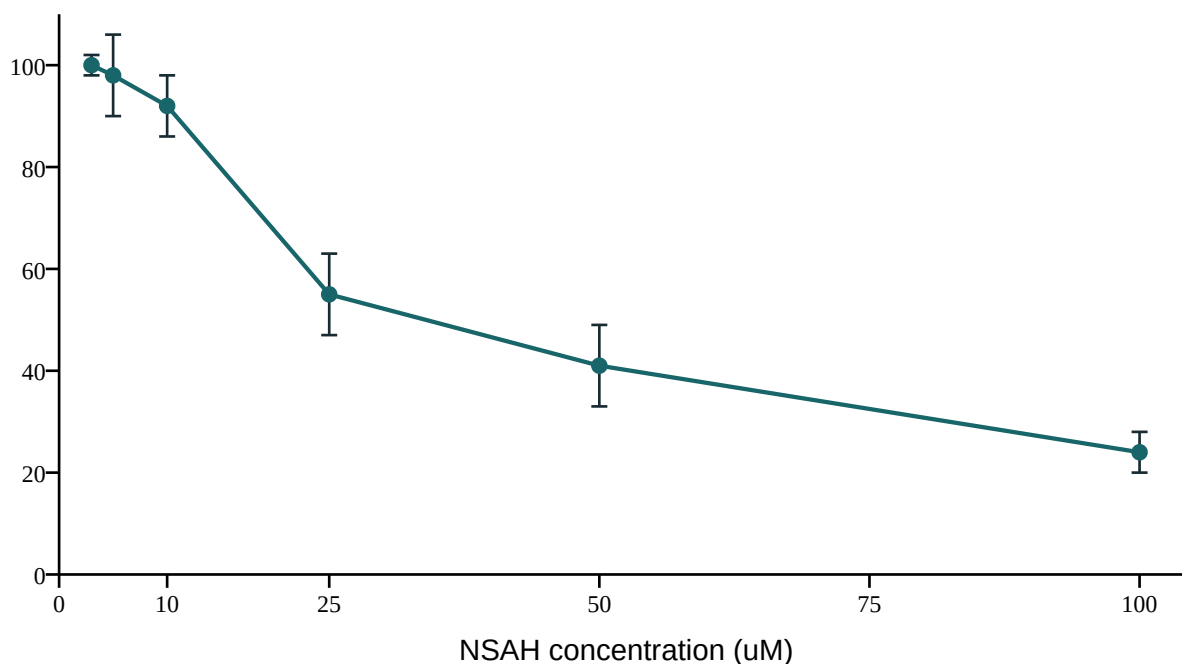


Figure A1. Source Table 1 plotted with concentration on a numeric axis. Vertical error bars show the supplied ± 2 SE values; they have not been doubled again.

FRQ 2: interpreting inhibition

Original PDF pp.44-45 | Model answers, parts (b)(ii)-(d)

(b)(ii) Concentration giving greater inhibition

100 μM is the clearest single answer: activity is 24%, versus 55% at 25 μM , corresponding to 76% versus 45% inhibition. Its error interval, 20-28%, does not overlap 47-63% at 25 μM . The 50 μM treatment also has a lower mean activity, 41%, but its 33-49% interval overlaps the 25 μM interval slightly. If interpreting only mean inhibition, both 50 and 100 μM have greater mean inhibition; 100 μM avoids the uncertainty.

(c) Concentrations bracketing 75% activity

10 μM and 25 μM . The measured activity decreases from 92% at 10 μM to 55% at 25 μM , so 75% lies between these measurements. An exact concentration at 75% was not measured.

(d)(i) Prediction for higher substrate

A higher concentration of NSAH will generally be needed to achieve the same degree of hRR inhibition when the substrate concentration increases.

(d)(ii) Justification

NSAH binds reversibly to the active site and competes with substrate. Higher substrate concentration increases the chance that substrate occupies the active site rather than inhibitor. Increasing NSAH concentration restores competition in favor of inhibitor; the enzyme is not permanently destroyed.

(d)(iii) Reversible versus irreversible inhibition

A reversible inhibitor can dissociate from hRR, allowing enzyme activity to recover as inhibitor concentration falls. An irreversible inhibitor leaves affected enzyme molecules persistently inactive, so recovery generally requires replacement enzymes. The possibility of restoring nucleotide production can reduce prolonged damage to healthy cells. Reversible does not mean harmless or selective only for cancer cells.

FRQ 3: CedV and membranes

Original PDF pp.48 | Model answers

(a) Plasma membrane structure

The plasma membrane is a phospholipid bilayer with embedded and associated proteins. Hydrophilic phosphate heads face the aqueous cytoplasm and extracellular fluid, while hydrophobic fatty acid tails face inward toward one another. Cholesterol and carbohydrate-containing membrane components contribute to its fluid mosaic organization.

(b) Wild-type control

Wild-type CedV provides the baseline level of endocytosis when the tyrosine-containing sequence is unchanged. Comparing mutants with this baseline helps determine whether replacing tyrosine with alanine alters endocytosis rather than merely reflecting the normal behavior of CedV or the experimental procedure.

(c) Fluorescence prediction

As the number of alanine substitutions increases, green fluorescence at the plasma membrane should increase relative to red fluorescence inside the cell. If endocytosis decreases, more CedV remains in the membrane and less is taken into the cell, where it would receive the red label.

(d) Hydrophobic membrane-spanning region

The interior of the bilayer is formed by nonpolar fatty acid tails. Nonpolar, hydrophobic R-groups in the membrane-spanning region interact favorably with this environment and avoid the surrounding water. This helps keep that region embedded in the membrane; polar regions can face aqueous environments.

FRQ 4: pine trees and seed dispersal

Original PDF pp.49 | Model answers

(a) Density-dependent competition

As population density increases, competition for limited resources generally becomes stronger. Reduced resource availability per individual lowers reproductive success and/or increases mortality, decreasing the per-capita population growth rate as the population approaches carrying capacity.

(b) Effect of seed release and dispersal

Nutcrackers free the seeds from protective cone scales and bury some away from the parent tree. Seeds that are not retrieved can germinate, establishing new pine trees and increasing recruitment into the population. Eating some seeds does not eliminate the benefit of dispersal for those that survive.

(c) Prediction for the bird population

A continued increase in mountain pine beetles is likely to decrease the number of nutcrackers in this ecosystem.

(d) Justification

More beetles kill more whitebark pine trees, reducing the production and availability of pine seeds. Nutcrackers then have less food, which can lower survival and reproduction and thereby reduce their population. The prediction follows the resource link described in the stimulus.

FRQ 5: pitcher-plant evolution

Original PDF pp.50 | Model answers

(a) Increase in a mutant allele's frequency

If a mutation produces a heritable trait that increases survival and reproductive success in the current environment, carriers leave more offspring and pass the allele on more often. Over generations the allele can increase in frequency through natural selection. Random genetic drift can also increase an allele's frequency, particularly in a small population.

(b) Convergent evolution

Transparent spots (trait 4) and slippery surfaces (trait 5) are marked as separate gains on the B and C branches after the branches diverged. Their repeated appearance indicates independent evolution of similar features, rather than inheritance of these features from the most recent common ancestor of B and C.

(c) Location of wax-crystal loss

Place the X on the branch leading only to clade B, after its split from the lineage leading to C and before the species of B. An X on the shared main stem would incorrectly imply loss in another clade. The schematic below places the X on the B stem below its trait-4 and trait-5 marks.

(d) Divergent evolution of lids

Trait 3 arises before the A, B, and C lineages diverge, so their common ancestor had lids. Subsequent mutations and different selection pressures in the descendant lineages could modify that inherited structure in different ways, producing the distinct lid morphologies. This is divergence from a shared ancestral feature.

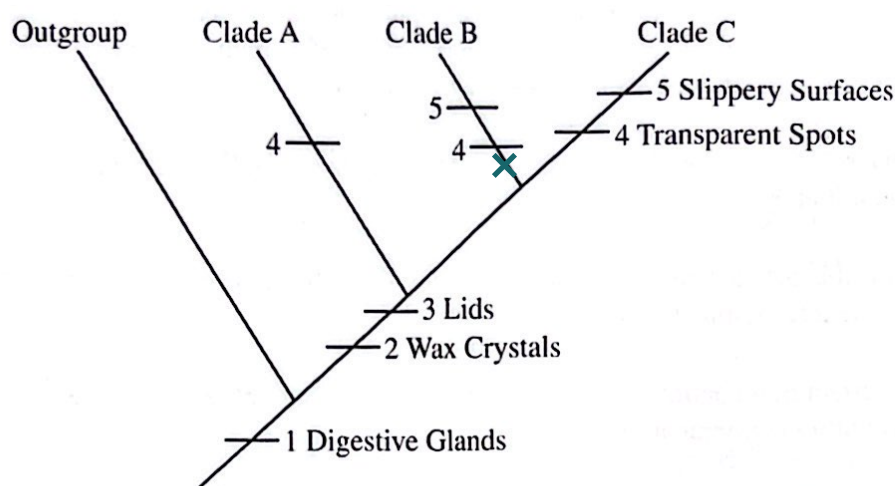


Figure A2. Original question figure with the required wax-crystal loss marked on the Clade B branch. Numbers refer to traits in the original figure.

FRQ 6: miRNA and gene expression

Original PDF pp.52-53 | Model answers

(a) Low oxygen in cells lacking miRNA-466

Low oxygen decreases GF pre-mRNA in cells lacking miRNA-466, from about 1.0 under normal oxygen to about 0.75 under low oxygen, relative to the normal-oxygen control baseline. This is an approximate 25% decrease, not an increase.

(b) Effect of deletion under low oxygen

Deleting the DNA encoding miRNA-466 reduces GF mRNA under low oxygen relative to control cells under the same low-oxygen conditions: approximately 1.7 versus 5.2 relative units. Compare the two low-oxygen bars, rather than comparing the deletion cells with their own normal-oxygen condition.

(c) Evidence for promotion of transcription

In low oxygen, control cells produce about 1.6 relative units of GF pre-mRNA, while cells lacking miRNA-466 produce only about 0.75. The error bars do not overlap. Because pre-mRNA is the initial RNA product associated with transcription, its higher abundance when miRNA-466 is present supports the claim that miRNA-466 promotes GF transcription under these conditions. These data support the claim without identifying the direct molecular mechanism.

(d) Gene expression and cell phenotype

Cells can share the same genome but activate different genes or express them at different levels. The resulting differences in RNA and protein types or amounts change cellular structures and biochemical activities, producing different phenotypes and specialized functions. A different phenotype does not require a different DNA sequence.

Checks and source alignment

How to interpret and verify this appendix

Coverage: All 60 MCQs have an answer and explanation. All 32 FRQ subparts have model answers, including the requested graph and evolutionary loss marker. Source graphs and tables were visually inspected, rather than relying only on OCR. No official point allocation or score conversion is inferred.

Key comparison: The independently derived letters differ from the separate supplied MCQ key on 14 questions: 1, 5, 12, 17, 23, 24, 27, 28, 30, 34, 48, 49, 50, 51. The appendix adopts the answers justified by the question wording and figures. FRQ 1(c)(ii) also corrects the defect count to 170.

Official reference: College Board, *AP Biology Course and Exam Description, Effective Fall 2019*. Historical framework used for this supplied 2024 paper. The original public reference is linked below; local source details and the question-by-question audit are retained with the build.

[Official historical AP Biology Course and Exam Description](#)

Macromolecules: topics 1.3-1.6; SYI-1.B/C; IST-1.A; CED printed pp.36-41.

Cells and transport: topics 2.3-2.9; ENE-1.B; ENE-2.A-J; CED printed pp.52-60.

Enzymes and respiration: topics 3.1-3.3, 3.6; ENE-1.D-G/K/L; CED printed pp.68-71,75-77.

Signaling and cell cycle: topics 4.1-4.4, 4.7; IST-3; IST-1.D/E; CED printed pp.84-88,91.

Heredity: topics 5.1-5.4; IST-1.F-J; CED printed pp.98-102.

Gene expression: topics 6.3-6.8; IST-1.N-P; IST-2.A-E; CED printed pp.114-122.

Evolution: topics 7.2,7.6,7.9-7.10; EVO-1.E; EVO-3.B/C/E; CED printed pp.130,135,139-141.

Ecology: topics 8.3-8.7; SYI-1.G/H; ENE-4.B/C; CED printed pp.156-163.

Methods and data: topics Science practices 3-6; Controls, graphs, tests, evidence; CED printed pp.14-15.

Scope: Structures, pathway intermediates, virus traits, and drug behavior supplied in the questions are used as evidence. They are not added as new memorization requirements. This is an answer appendix for one paper, not a full-course study guide.

Matched source: Bio24.pdf, 53 pages. SHA-256: 511328143271de46e5371e0adfe0cc78537f68cb46b61695e9e7afe5d4f913f. Prepared 10 October 2026.