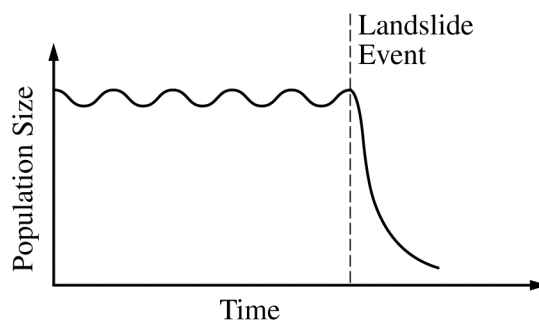


BIOLOGY
Section I
53 Multiple-Choice Questions
5 Grid-In Questions
Time—90 Minutes

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. A dog is following the scent of a jackrabbit. Which of the following accurately describes how the dog's brain integrates information for smell?
 - (A) Chemoreceptors in the brain send impulses for smell in the nasal cavity.
 - (B) Chemoreceptor cells in the nasal cavity send impulses to the appropriate area of the brain.
 - (C) Chemoreceptors on epithelial cells of the tongue send hormones to the appropriate area of the brain.
 - (D) Receptors originating in the nose send action potentials to the motor regions of the brain.
2. Thrips are insects that feed on rose pollen. Scientists noted that the thrips population increased in the spring and decreased dramatically during the summer. The researchers hypothesized that food abundance was the limiting factor for the population. Which of the following types of data would be most useful for the scientists to collect at regular intervals on a designated test plot of rose plants?
 - (A) Amount of sunlight (hours/day)
 - (B) Mean temperature ($^{\circ}\text{C}$)
 - (C) Density of rose pollen produced (g/m^2)
 - (D) Amount of pollen produced by each flower (g/flower)

3. If ATP breakdown (hydrolysis) is inhibited, which of the following types of movement across cell membranes is also inhibited?
 - (A) Movement of oxygen into a cell
 - (B) Movement of water through aquaporins
 - (C) Passage of a solute against its concentration gradient
 - (D) Facilitated diffusion of a permeable substance



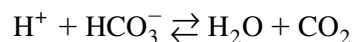
4. Undersea landslides can disrupt marine habitats by burying organisms that live on the ocean floor. The graph above shows the size of a population of a certain organism that lives on the ocean floor. The population was affected by a recent landslide at the time indicated on the graph. Which of the following best predicts how the population will be affected by the landslide?
 - (A) The surviving organisms will evolve into a new species.
 - (B) The reduced population will likely have allelic frequencies that are different from the initial population.
 - (C) The population will adapt to deeper waters to avoid future landslides.
 - (D) The reduced population will have a greater number of different genes than the initial population.

5. Which of the following questions is most relevant to understanding the Calvin cycle?

- (A) How does chlorophyll capture light?
- (B) How is ATP used in the formation of 3-carbon carbohydrates?
- (C) How is NADP⁺ reduced to NADPH?
- (D) How is ATP produced in chemiosmosis?

6. Rosalind Franklin's x-ray diffraction images taken in the 1950s most directly support which of the following claims about DNA?

- (A) The ratios of base pairs are constant.
- (B) The nucleotide sequence determines genetic information.
- (C) The two strands of DNA are antiparallel.
- (D) The basic molecular structure is a helix.



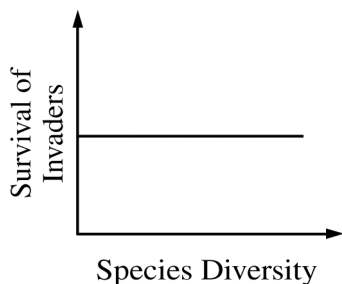
7. The equation above shows one of the reversible reactions that occur in blood. After exercise, an athlete's blood pH has dropped below the normal level. How will normal blood pH be restored?

- (A) An increase in O₂ concentration in the plasma will lead to an increase in H⁺ concentration.
- (B) An increase in temperature will lead to an increase in H⁺ concentration.
- (C) An increase in sweating will lead to a decrease in OH⁻ and H⁺ concentration.
- (D) An increase in breathing rate will lead to a decrease in blood CO₂ and H⁺ concentration.

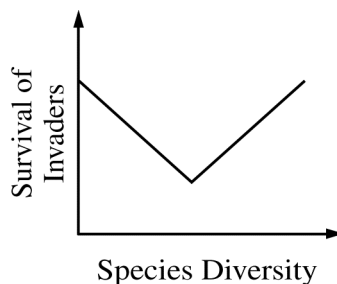
8. A researcher is investigating the relationship between the existing species diversity in a community and the ability of an introduced nonnative species to destabilize the community.

Which of the following graphs is most consistent with the claim that communities with high diversity are more resistant to change than are communities with low diversity?

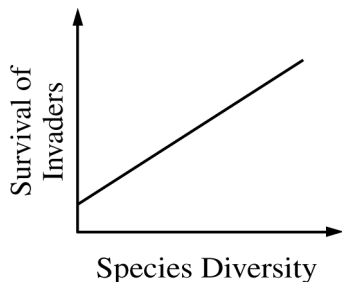
(A)



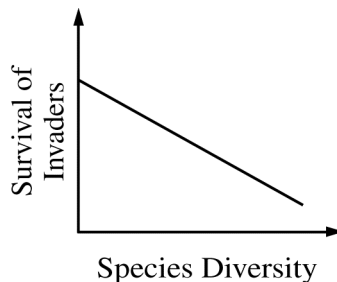
(B)



(C)



(D)

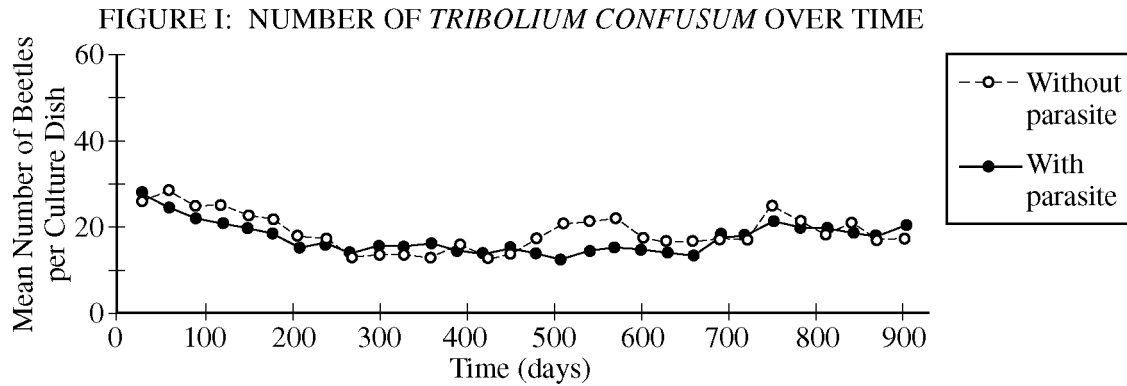
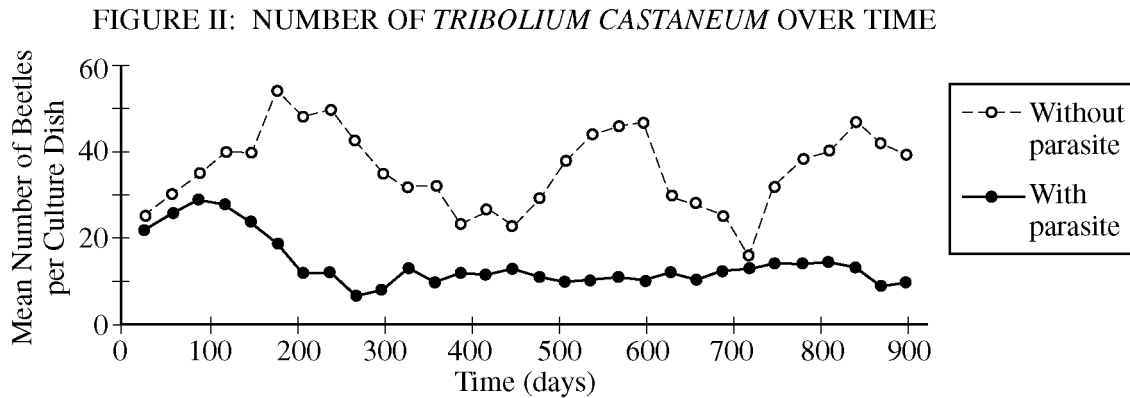


-
9. In 1944 Avery, MacLeod, and McCarty performed transformation experiments using live, harmless bacteria and extracts from virulent bacteria treated with various enzymes. Which of the following enzymes were used and why?

- (A) Proteases and RNases to rule out protein and RNA as the transforming factors
- (B) Lipase (an enzyme that facilitates the breakdown of lipids) to rule out lipoproteins as the transforming factor
- (C) Kinase (an enzyme that facilitates transfer of a phosphate group from ATP to a substrate molecule) to show that transformation is phosphorylation dependent
- (D) ATPase to show that transformation is not dependent on ATP

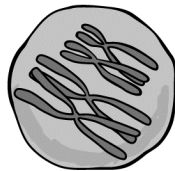
Questions 10-13

The figures below show the changes in populations of two species of flour beetles, *Tribolium confusum* (Figure I) and *Tribolium castaneum* (Figure II), in cultures without parasites (○) and in cultures infected with a parasite (●). Each data point represents the mean population size from ten culture dishes of equal size and food content.

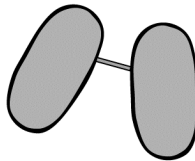


10. Under which of the following conditions is the observed number of beetles per culture dish the greatest?
- (A) *T. confusum* with parasite at 500 days
 - (B) *T. confusum* without parasite at 300 days
 - (C) *T. castaneum* with parasite at 100 days
 - (D) *T. castaneum* with parasite at 600 days
11. The data over the duration of the experiment provide the strongest support for which of the following conclusions regarding the effect of the parasite on *Tribolium* populations?
- (A) *T. confusum* is adversely affected by the parasite, while *T. castaneum* is not.
 - (B) *T. castaneum* is adversely affected by the parasite, while *T. confusum* is not.
 - (C) Both *T. confusum* and *T. castaneum* are adversely affected by the parasite.
 - (D) Both *T. confusum* and *T. castaneum* show increased fitness in the presence of the parasite.
12. In Figure I, the difference between the two curves can best be attributed to which of the following?
- (A) The difference between controlled laboratory conditions and the natural environment
 - (B) The effect of the host on its parasite
 - (C) The influence of competition for limited resources
 - (D) The natural variation among populations
13. If the experiment was continued for an additional 500 days, the population density of *T. castaneum* with the parasite would most likely stabilize at a value closest to which of the following?
- (A) 5 beetles/culture dish
 - (B) 10 beetles/culture dish
 - (C) 20 beetles/culture dish
 - (D) 25 beetles/culture dish

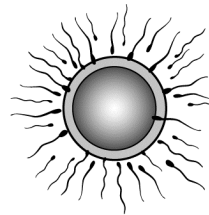
14. Beaked whales feed at various depths, but they defecate at the ocean's surface. Nitrogen-rich whale feces deposited in surface waters supply nutrients for algae that are eaten by surface-dwelling fish. Which of the following best predicts what would happen if the whale population decreased?
- (A) There would be a reduction in surface nitrogen concentration, which would cause an algal bloom.
 - (B) The surface fish populations would decline due to reduced populations of algae.
 - (C) The remaining whales would accumulate mutations at a faster rate.
 - (D) The remaining whales would be forced to forage in the deepest parts of the ocean.
-



Crossing Over



Conjugation

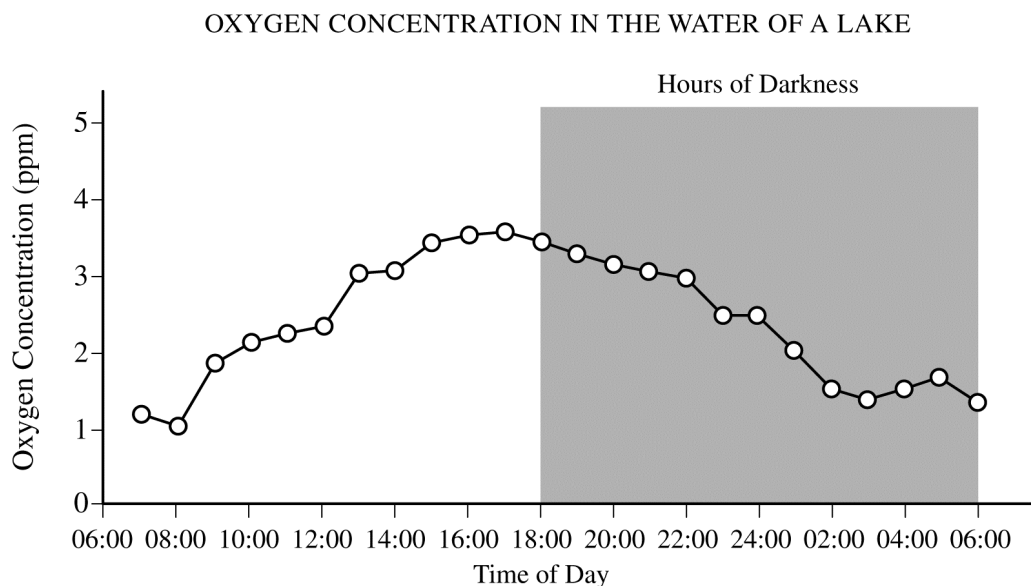


Fertilization

15. The processes illustrated in the models depicted above all result in which of the following?
- (A) Transcription
 - (B) An increase in genetic variation
 - (C) An increase in the chromosome number
 - (D) Horizontal gene transfer

16. The vertebrate forelimb initially develops in the embryo as a solid mass of tissue. As development progresses, the solid mass near the end of the forelimb is remodeled into individual digits. Which of the following best explains the role of apoptosis in remodeling of the forelimb?

- (A) Apoptosis replaces old cells with new ones that are less likely to contain mutations.
- (B) Apoptosis involves the regulated activation of proteins in specific cells of the developing forelimb that leads to the death of those cells.
- (C) Apoptosis involves the destruction of extra cells in the developing forelimb, which provides nutrients for phagocytic cells.
- (D) Apoptosis in the developing forelimb triggers the differentiation of cells whose fate was not already determined.



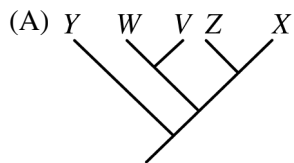
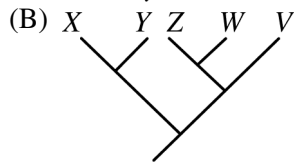
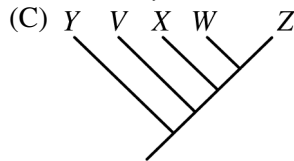
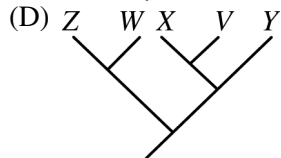
17. What most likely causes the trends in oxygen concentration shown in the graph above?

- (A) The water becomes colder at night and thus holds more oxygen.
- (B) Respiration in most organisms increases at night.
- (C) More organisms are respiring at night than during the day.
- (D) Photosynthesis produces more oxygen than is consumed by respiration during the day.

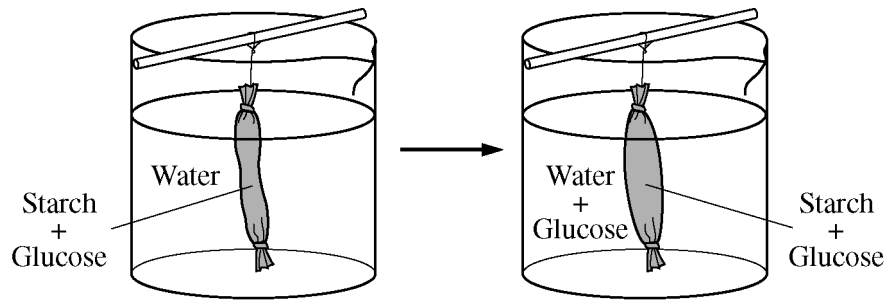
18. Data regarding the presence (+) or absence (–) of five derived traits in several different species are shown in the table below.

Species	Trait				
	1	2	3	4	5
V	+	+	+	–	–
W	+	+	–	–	–
X	+	–	–	+	+
Y	–	–	–	–	–
Z	+	–	–	–	+

Which of the following cladograms provides the simplest and most accurate representation of the data in the table?

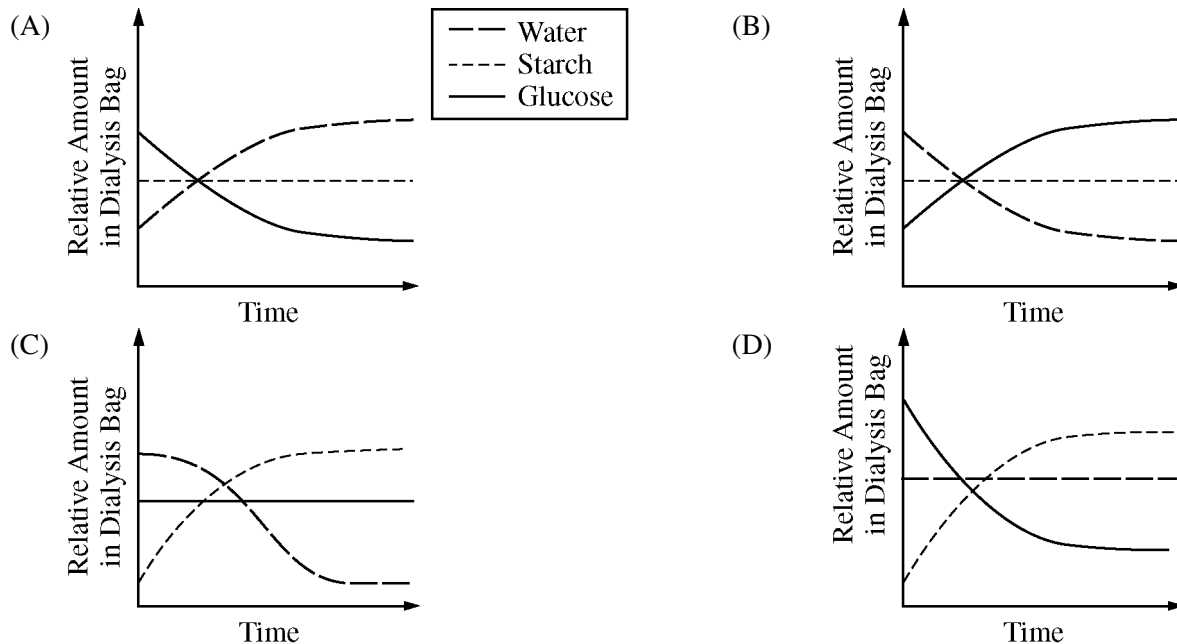


19. A common laboratory investigation involves putting a solution of starch and glucose into a dialysis bag and suspending the bag in a beaker of water, as shown in the figure below.



The investigation is aimed at understanding how molecular size affects movement through a membrane.

Which of the following best represents the amount of starch, water, and glucose in the dialysis bag over the course of the investigation?



Questions 20-22

Rhagoletis pomonella is a parasitic fly native to North America that infests fruit trees. The female fly lays her eggs in the fruit. The larvae hatch and burrow through the developing fruit. The next year, the adult flies emerge.

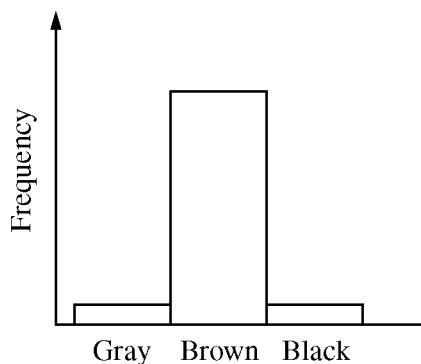
Prior to the European colonization of North America, the major host of *Rhagoletis* was a native species of hawthorn, *Crataegus marshallii*. The domestic apple tree, *Malus domestica*, is not native to North America, but was imported by European settlers in the late 1700s and early 1800s.

When apple trees were first imported into North America, there was no evidence that *Rhagoletis* could use them as hosts. Apples set fruit earlier in the season and develop faster, where hawthorns set later and develop more slowly.

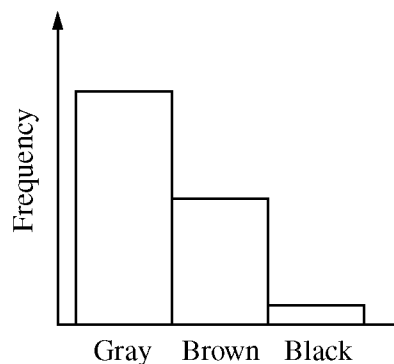
Recent analysis of *Rhagoletis* populations has shown that two distinct populations of flies have evolved from the original ancestral population of flies that were parasitic on hawthorns. One population infests only apple trees, and the other infests only hawthorns. The life cycles of both fly populations are coordinated with those of their host trees. The flies of each population apparently can distinguish and select mates with similar host preferences and reject mates from the population specific to the other host tree. There is very little hybridization (only about 5 percent) between the two groups.

20. The divergence between the two populations of *Rhagoletis* must have occurred very rapidly because
- (A) the apple tree was imported into North America with European settlement approximately 200 years ago
 - (B) flies were imported into North America with European settlement approximately 200 years ago
 - (C) long-distance rail transport of fruit increased only after the American Civil War (1861–1865)
 - (D) heavy use of gunpowder during the American Civil War (1861–1865) led to increased mutation rates in many natural populations of plants and animals
21. Initially, which of the following isolating mechanisms is likely to have been the most important in preventing gene flow between the two populations of *Rhagoletis*?
- (A) Gamete incompatibility
 - (B) Temporal isolation
 - (C) Mechanical isolation
 - (D) Reduced hybrid viability
22. Matings between individuals from the two populations of *Rhagoletis* produce hybrid flies that appear to be healthy and have normal life spans. The eggs laid by these hybrid flies, however, hatch less often than those of flies from either of the two populations. What isolating mechanism seems to be important in this hybrid population?
- (A) Prezygotic isolation
 - (B) Mechanical isolation
 - (C) Reduced hybrid fertility
 - (D) Habitat isolation

FUR COLOR DISTRIBUTION
IMMEDIATELY AFTER RELEASE

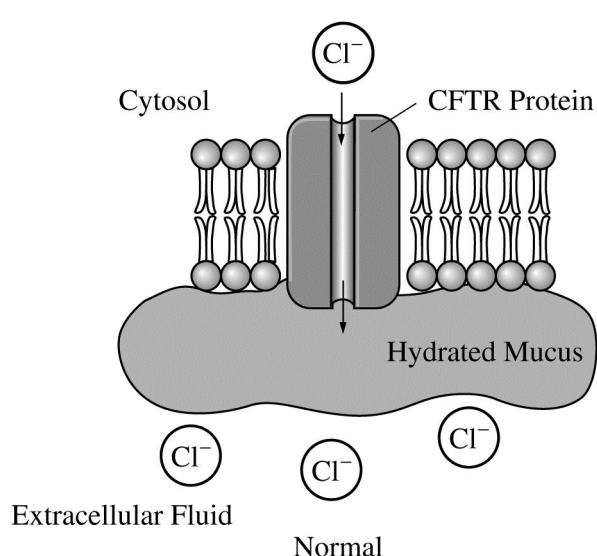
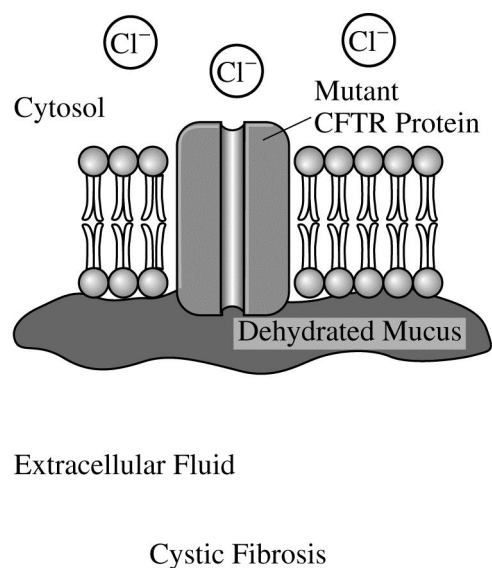


FUR COLOR DISTRIBUTION
AFTER TWENTY YEARS



23. A group of mice was released into a large field to which no other mice had access. Immediately after the release, a representative sample of the mice was captured, and the fur color of each individual in the sample was observed and recorded. The mice were then returned to the field. After twenty years, another representative sample of the mice was captured, and the fur color of each individual in the sample was again recorded. Which of the following best explains the change in the frequency distribution of fur color phenotypes in the mouse population, as shown in the figures above?
- (A) The allele for gray fur color is unstable, and over twenty years most of those alleles mutated to become alleles for black fur.
 - (B) The field was composed primarily of light-colored soil and little vegetation, affording gray mice protection from predators.
 - (C) Sexual selection led to increased mating frequency of black and brown versus gray and brown.
 - (D) The gray mice were hardest to capture and so were underrepresented in the twenty-year sample.

24. Scientists have found that the existing populations of a certain species of amphibian are small in number, lacking in genetic diversity, and separated from each other by wide areas of dry land. Which of the following human actions is most likely to improve the long-term survival of the amphibians?
- (A) Cloning the largest individuals to counteract the effects of aggressive predation
 - (B) Reducing the population size by one-fifth to decrease competition for limited resources
 - (C) Constructing a dam and irrigation system to control flooding
 - (D) Building ponds in the areas of dry land to promote interbreeding between the separated populations
25. A new mutation that arose in one copy of gene *X* in a somatic cell resulted in the formation of a tumor. Which of the following pieces of evidence best describes how the new mutation directly caused the tumor?
- (A) Protein X normally stimulates cell division, and the mutation created an overactive version of protein X.
 - (B) Protein X normally activates a growth hormone receptor, and the mutation decreased the stability of protein X.
 - (C) Protein X normally prevents passage through the cell cycle, and the mutation created an overactive version of protein X.
 - (D) Protein X normally regulates gene expression, and the mutation created an underactive version of protein X that blocked the cell cycle.



26. Cystic fibrosis is a recessively inherited disorder that results from a mutation in the gene encoding CFTR chloride ion channels located on the surface of many epithelial cells. As shown in the figure, the mutation prevents the normal movement of chloride ions from the cytosol of the cell to the extracellular fluid. As a consequence of the mutation, the mucus layer that is normally present on the surface of the cells becomes exceptionally dehydrated and viscous.

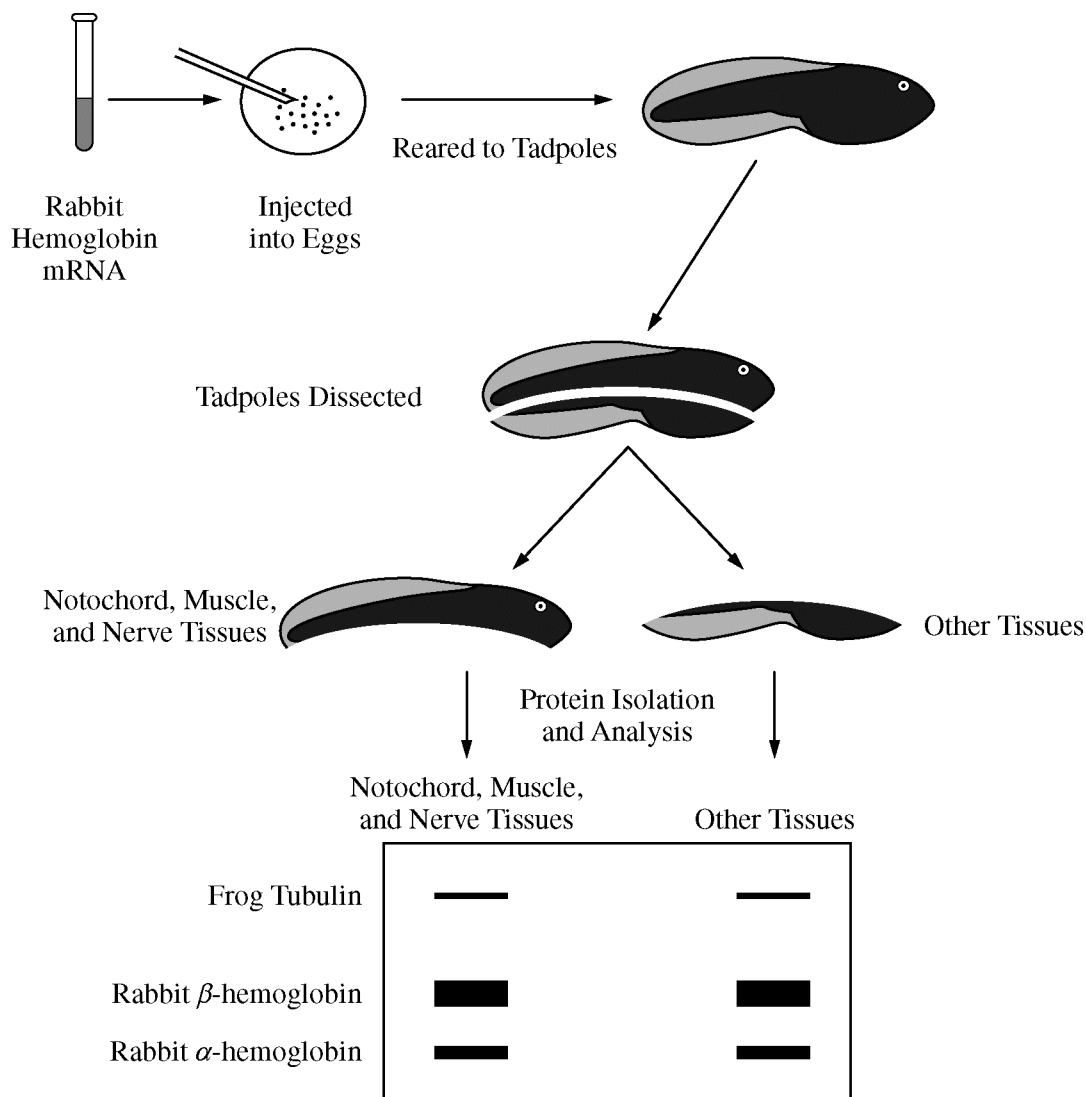
An answer to which of the following questions would provide the most information about the association between the CFTR mutation and the viscous mucus?

- (A) Is the mucus also secreted from the cells through the CFTR proteins?
- (B) How does the disrupted chloride movement affect the movement of sodium ions and water by the cell?
- (C) How does the mutation alter the structure of the CFTR proteins?
- (D) What is the change in nucleotide sequence that results in the CFTR mutation?

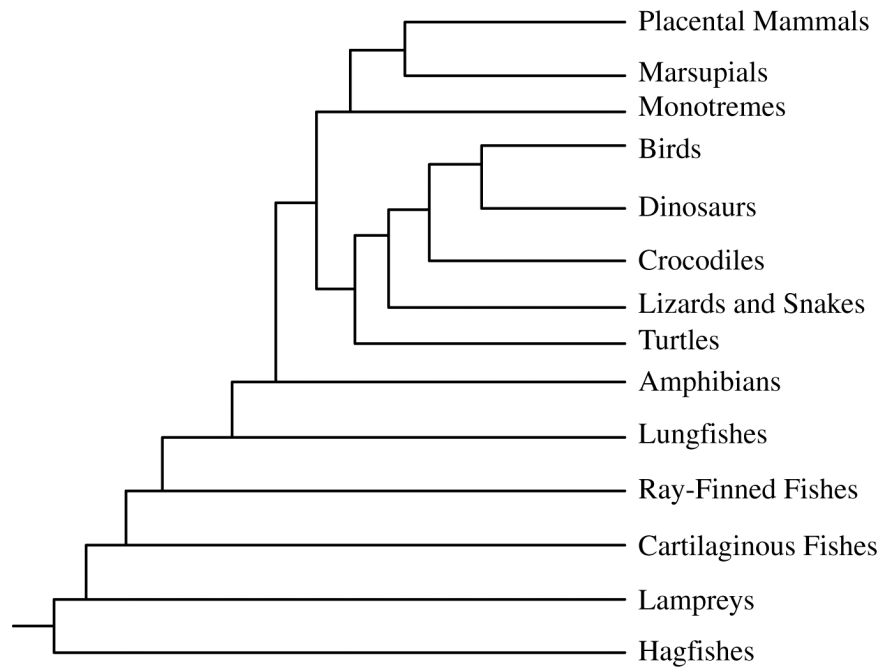
Questions 27-31

In a classic experiment from the 1970s investigating gene expression, a solution containing equal amounts of rabbit α -hemoglobin mRNA and β -hemoglobin mRNA, which encode subunits of a protein found in red blood cells, was injected into newly fertilized frog eggs. The injected mRNA was not degraded during the course of the experiment. Tadpoles that developed from the injected eggs were dissected into two fragments, one containing predominantly the notochord, muscle tissue, and nerve tissue and the other containing predominantly the other tissue types.

Equal amounts of total protein were analyzed after separation by electrophoresis to identify the relative amounts of the different proteins present in each sample. The thickness of the bands indicates the relative amounts of rabbit α -hemoglobin, rabbit β -hemoglobin, and frog tubulin (a cytoskeletal protein that is expressed at relatively constant levels in all tissues) present in each tadpole sample. The experimental protocol and results are summarized in the figure below.



27. The observation that the rabbit mRNA was successfully translated in the frog tissues supports which of the following conclusions?
- (A) Frog cells are able to replace their own hemoglobin with rabbit hemoglobin.
 - (B) Undeveloped frog eggs can be induced to form genetically identical copies of a rabbit.
 - (C) Rabbit hemoglobin can induce an immune response in frogs.
 - (D) Rabbits and frogs share a common genetic code for expressing heritable information.
28. The electrophoresis results best support which of the following conclusions?
- (A) Cell specialization during development results in some cells losing the ability to synthesize proteins.
 - (B) Cells from different tissues share a common ability to use genetic material from a foreign source to produce protein.
 - (C) In comparison with other cells, nerve cells have a superior ability to produce cytoskeletal proteins.
 - (D) Muscle cells produce more β -hemoglobin than do cells from the other tissues in a tadpole.
29. Which of the following is the best justification for why the rabbit hemoglobin proteins were found throughout the tadpole?
- (A) Rabbit mRNA is composed of nucleotides that are more stable than those in frog mRNA.
 - (B) Rabbit hemoglobin is synthesized more efficiently than frog hemoglobin in frog cells.
 - (C) After differentiation, the rabbit hemoglobin proteins move through the circulatory system of the tadpole to every cell.
 - (D) The mRNA injected into the newly fertilized frog eggs is distributed in the cytoplasm of every daughter cell during cell division.
30. Which of the following conclusions is most consistent with the results of the experiment?
- (A) Rabbit mRNA is composed of nucleotides that are absent from frog mRNA.
 - (B) A larger volume of blood circulates through a rabbit than through a frog.
 - (C) The subunits of hemoglobin differ in size, shape, or charge.
 - (D) Synthesis of β -hemoglobin occurs at a faster rate in muscle cells than in other body cells.
31. Given that equal amounts of the different mRNAs were injected into fertilized frog eggs, which of the following conclusions is most consistent with the electrophoresis results?
- (A) β -hemoglobin mRNA is translated more efficiently than is α -hemoglobin mRNA.
 - (B) α -hemoglobin is present only in cells where β -hemoglobin is absent.
 - (C) α -hemoglobin mRNA is more stable than β -hemoglobin mRNA.
 - (D) Tubulin inhibits translation of hemoglobin mRNA.



32. To determine the evolutionary history and relationships among organisms, scientists gather evidence from a wide variety of sources including paleontology, embryology, morphology, behavior, and molecular biology. A phylogenetic tree of vertebrates is shown.

Which of the following statements is most consistent with the phylogenetic tree shown?

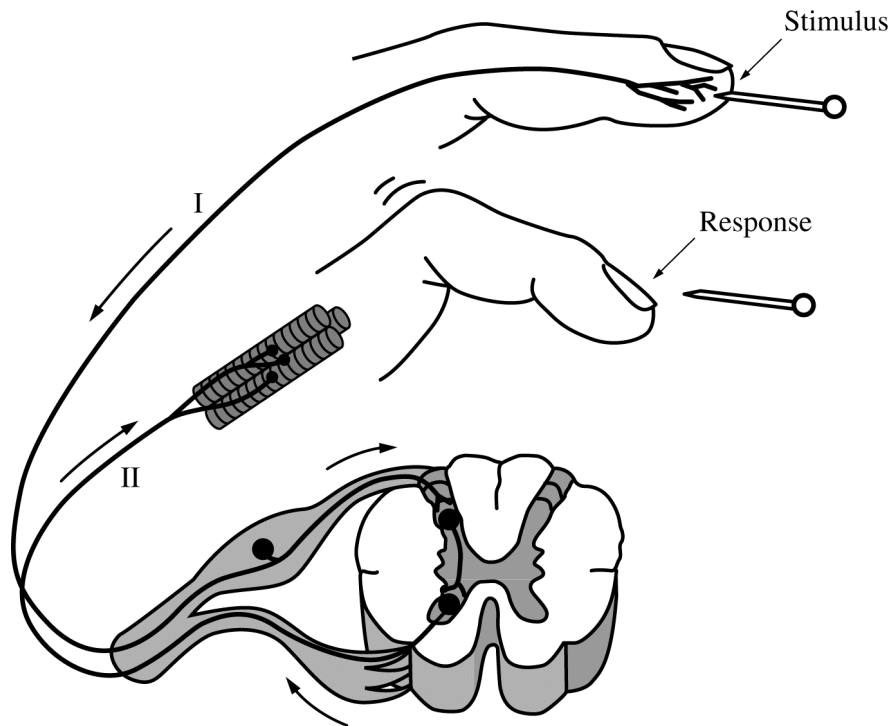
- (A) Birds and turtles evolved their own means of gas exchange independently of the other vertebrates.
- (B) Mammals are most closely related to birds because they share a direct common ancestor.
- (C) The common ancestor of reptiles, birds, and mammals produced amniotic eggs.
- (D) Crocodiles are direct descendants of ray-finned fishes since they live in the same environment.

33. A student in a biology class crossed a male *Drosophila melanogaster* having a gray body and long wings with a female *D. melanogaster* having a black body and apterous wings. The following distribution of traits was observed in the offspring.

<u>Phenotype</u>	<u>Number of Offspring</u>
Gray body, long wings	42
Black body, apterous wings	41
Gray body, apterous wings	9
Black body, long wings	8

Which of the following is supported by the data?

- (A) The alleles for gray body and long wings are dominant.
- (B) The alleles for gray body and long wings are recessive.
- (C) Genes for the two traits are located on two different chromosomes, and independent assortment occurred.
- (D) Genes for the two traits are located close together on the same chromosome, and crossing over occurred between the two gene loci.



34. The diagram above depicts the response to a pinprick (stimulus) on the tip of a human finger. The arrows show the direction of impulse transmission along the labeled axons. If axon II was damaged before the pinprick, which of the following is most likely?
- (A) The person will not feel the pinprick.
 - (B) The person can no longer feel pain.
 - (C) The person's finger will not withdraw reflexively.
 - (D) The person cannot transmit nerve impulses to the brain.

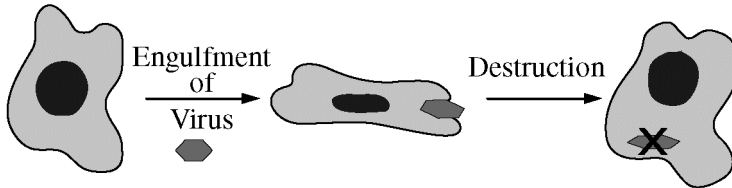
35. If chemical signals in the cytoplasm control the progression of a cell to the M phase of the cell cycle, then fusion of a cell in G_1 with a cell in early M phase would most likely result in the
- (A) replication of chromosomes only in the G_1 cell
 - (B) exiting of both cells from the cell cycle and into the G_0 phase
 - (C) condensation of chromatin in preparation of nuclear division in both cells
 - (D) transfer of organelles from the G_1 cell to the cell in the M phase

36. The healthy human immune system responds to pathogens with both specific and nonspecific processes. Which of the following models depicts a nonspecific response?

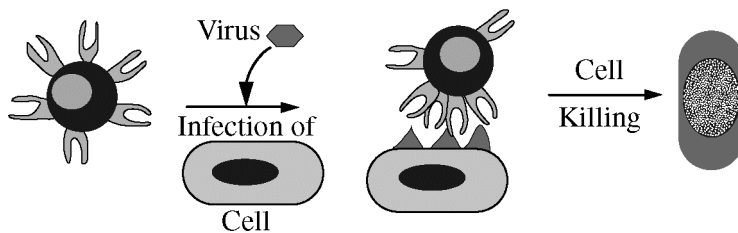
(A) B cell



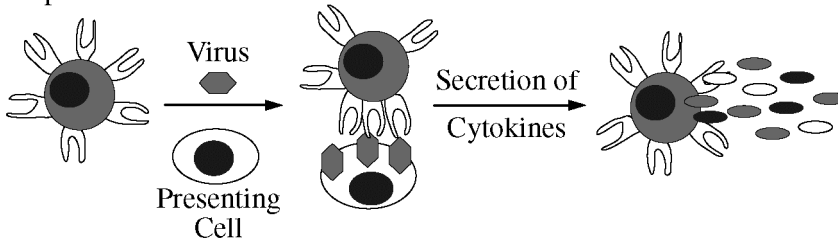
(B) Macrophage

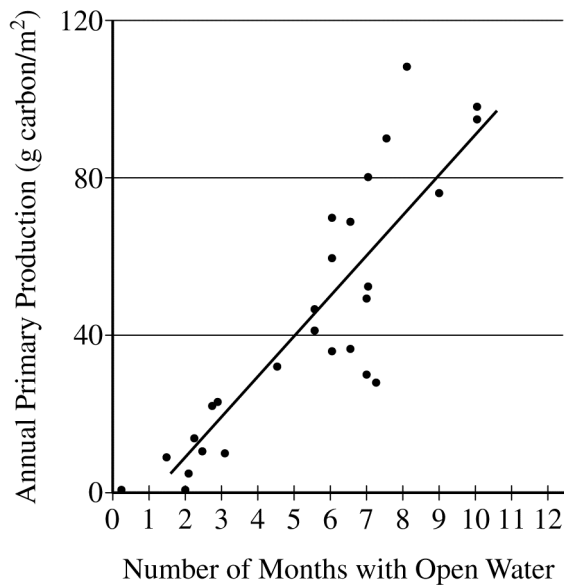


(C) Cytotoxic T cell

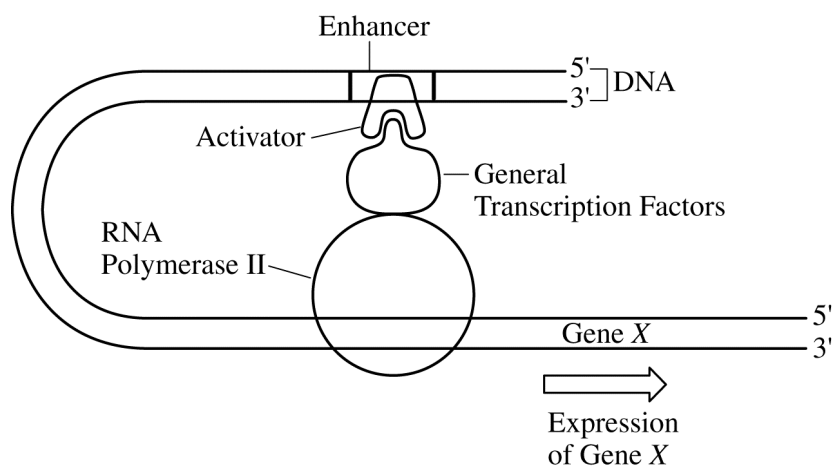


(D) Helper T cell

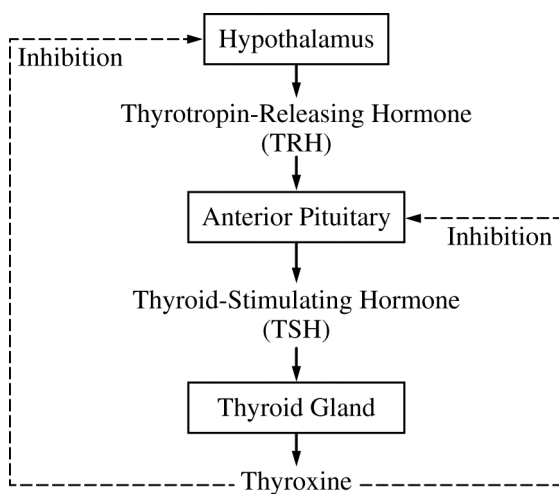




37. In the Arctic Ocean, the predominant primary producers are phytoplankton. Phytoplankton are consumed by zooplankton, which in turn are eaten by codfish. In years when there is more open water (less ice coverage), there are more zooplankton and fish than in years with less open water (more ice coverage). Based on the graph above, the difference is most likely because
- (A) when there is less open water, light is blocked from the zooplankton, so they cannot produce as much food for the fish
 - (B) when there is more open water, the temperature is warmer, so the zooplankton and fish populations increase in size
 - (C) the ice blocks the light, so in years with more ice coverage, there is less photosynthesis by the phytoplankton
 - (D) the ice increases the light available for photosynthesis, so primary production increases and zooplankton populations increase in size



38. The figure above depicts the DNA-protein complex that is assembled at the transcriptional start site of gene *X* when the expression of gene *X* is activated in liver cells. Previous studies have shown that gene *X* is never expressed in nerve cells. Based on the diagram, which of the following most likely contributes to the specific expression pattern of gene *X*?
- (A) Expression of gene *X* produces large amounts of tRNA but undetectable amounts of mRNA.
 - (B) The general transcription factors inhibit the activation of gene *X* in liver cells by blocking the activator from binding to RNA polymerase II.
 - (C) The activator is a sequence-specific DNA-binding protein that is present in some tissues but not in other tissues.
 - (D) The enhancer is a unique DNA segment that is added to the nuclear DNA of some cells of an organism during the process of mitotic cell division but not other cells.



39. The diagram above illustrates feedback control as exerted by the hormone thyroxine. Following surgical removal of the thyroid gland, the level of TSH in the blood will increase. Which of the following best explains this increase?

- (A) Residual blood thyroxine, from prior to thyroid gland removal, will bind to cells in the anterior pituitary, signaling more TSH secretion.
- (B) Thyroxine will remain bound to thyroxine receptors on various body cells, and these body cells will secrete additional hormones that stimulate the anterior pituitary to secrete TSH.
- (C) Thyroxine that was stored in the anterior pituitary prior to thyroid gland removal will signal more TSH secretion.
- (D) A decrease in thyroxine levels means a loss of inhibition to the hypothalamus and anterior pituitary, leading to increased TSH secretion.

40. The data below demonstrate the frequency of tasters and nontasters of a certain compound in four isolated populations that are in Hardy-Weinberg equilibrium. The allele for nontasters is recessive. In which population is the frequency of the recessive allele highest?

	<u>Population</u>	<u>Tasters</u>	<u>Nontasters</u>	<u>Size of Population</u>
(A)	1	110	32	142
(B)	2	8,235	4,328	12,563
(C)	3	215	500	715
(D)	4	11,489	2,596	14,085

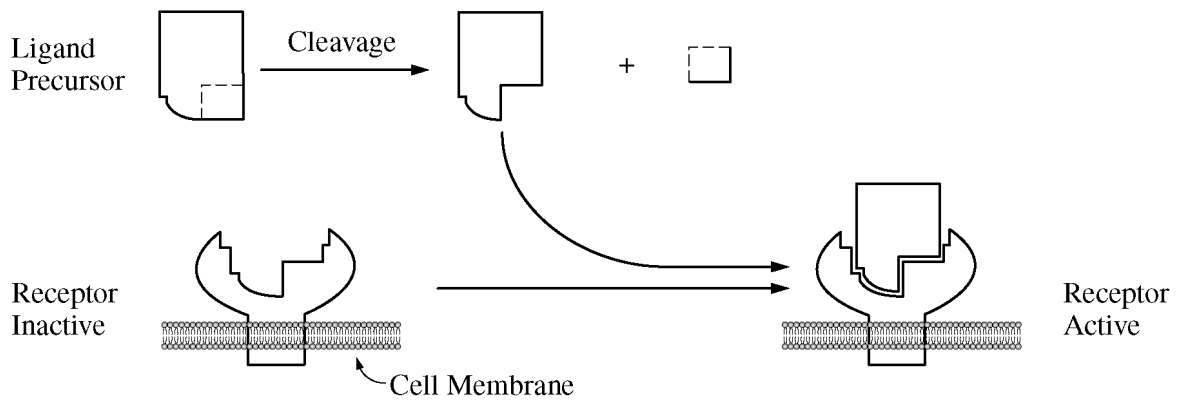
Questions 41-45

Photosynthetic activity can be measured using chloroplasts suspended in a buffered solution containing DCPIP, a dye that can accept electrons from the electron transport chain of photosynthesis. Transfer of electrons to DCPIP decreases the relative absorbance of a specific wavelength of light (605 nm) by a solution that contains the dye.

A buffered solution containing chloroplasts and DCPIP was divided equally among six identical samples. The samples were placed at various distances from a lamp, and then all samples were exposed to white light from the lamp for 60 minutes at room temperature. Sample 3 was wrapped in foil to prevent any light from reaching the solution. At 20-minute intervals, the photosynthetic activity in each sample was determined by measuring the relative absorbance of 605 nm light. The results of the experiment are provided below.

Sample	Distance from Lamp (cm)	Relative Absorbance of 605 nm Light (arbitrary units)			
		0 min	20 min	40 min	60 min
1	15	0.89	0.61	0.34	0.04
2	30	0.90	0.67	0.41	0.14
3*	30	0.88	0.87	0.86	0.87
4	45	0.86	0.69	0.47	0.26
5	60	0.92	0.75	0.59	0.41
6	75	0.88	0.79	0.71	0.58
* wrapped in foil					

41. Which of the following provides the best indication that light is required for the activation of electron transfer reactions in chloroplasts?
- (A) Calculating the rate of change of the absorbance for sample 1
 - (B) Comparing the observed results for sample 2 and sample 3
 - (C) Repeating the entire experimental procedure at night
 - (D) Including multiple trials for all the samples
42. Which of the following can be reasonably concluded from the experimental results?
- (A) Chloroplasts must be suspended in a buffer solution to function properly.
 - (B) The optimal temperature for activation of electron transfer is 25°C.
 - (C) DCPIP inhibits biochemical reactions in suspended chloroplasts.
 - (D) Light from a lamp can substitute for sunlight in stimulating chloroplast processes.
43. If an additional sample containing the chloroplast/DCPIP solution was placed at a distance of 90 cm from the lamp, which of the following predictions would be most consistent with the experimental results?
- (A) The concentration of DCPIP in the solution will increase exponentially.
 - (B) The absorbance at 60 minutes will be roughly equal to 1.4.
 - (C) The change in absorbance over time in the solution will be less than that of the other samples.
 - (D) The temperature of the solution will exceed 75°C.
44. Which of the following descriptions of photosynthesis best explains the results of the experiment?
- (A) Availability of electrons for transfer to DCPIP depends on light energy.
 - (B) Movement of DCPIP across chloroplast membranes occurs in less than 60 minutes.
 - (C) Chlorophyll molecules degrade rapidly in the presence of DCPIP.
 - (D) DCPIP can only be used to measure photosynthetic activity at low light levels.
45. Which of the following scientific questions could be investigated using a similar experimental setup?
- (A) How much carbon dioxide is required by a plant cell to produce one molecule of glucose?
 - (B) What wavelength of light best activates electron transfer reactions in chloroplasts?
 - (C) Which molecule in chloroplasts accepts activated electrons from DCPIP during photosynthesis?
 - (D) Are the same genes that are expressed in chloroplasts also expressed in mitochondria?



46. The figure above shows a model of a ligand precursor being cleaved to produce an active ligand that binds to a specific receptor. Which of the following is most likely to reduce the binding of the active ligand to its receptor?
- (A) A change in the cytoskeletal attachment of transmembrane proteins
 - (B) The presence of a large amount of the precursor form of the ligand
 - (C) An increase in the ratio of the number of unsaturated to the number of saturated fatty acid tails of the membrane lipids
 - (D) A mutation in the receptor gene that causes a substitution of a charged amino acid for a nonpolar amino acid in the ligand binding site of the receptor

47. Students in a class measured the mass of various living organisms. They then kept the organisms in the dark for 24 hours before remeasuring them. None of the organisms were provided with nutrients during the 24-hour period. The data are as follows.

Organism	Starting Mass (g)	Final Mass (g)
<i>Elodea</i> (submerged aquatic plant)	15.10	14.01
Goldfish	10.10	9.84
Sea anemone	25.60	24.98

Which of the following is the best explanation for the pattern of change in mass of the organisms over time?

- (A) Water loss due to evaporation
- (B) Cellular respiration
- (C) The law of conservation of matter
- (D) Growth and reproduction

Questions 48-51

The following figures display data collected while studying a family, some members of which have sickle-cell disease—a rare genetic disorder caused by a mutation in the hemoglobin beta gene (*HBB*). There are at least two alleles of the *HBB* gene: the *HbA* allele encodes wild-type hemoglobin and the *HbS* allele encodes the sickle-cell form of hemoglobin. Genetic testing provided insight into the inheritance pattern for sickle-cell disease.

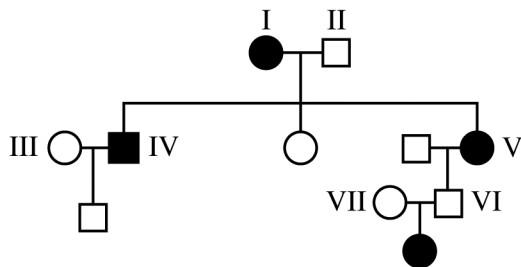


Figure 1. Pedigree of a family with affected individuals. Squares represent males, circles represent females, shaded symbols represent individuals with sickle-cell disease.

5' CTG ACT CCT GAG GAG AAG TCT 3' Non-template Strand
3' GAC TGA GGA CTC CTC TTC AGA 5' Template Strand

Figure 2. A portion of the DNA sequence from the wild-type hemoglobin allele (*HbA*) that codes for normal hemoglobin.

		Second Base in Codon				
		U	C	A	G	
First Base in Codon	U	UUU } Phe UUC } UUA } Leu UUG }	UCU } UCC } Ser UCA } UCG }	UAU } Tyr UAC } UAA Stop UAG Stop	UGU } Cys UGC } UGA Stop UGG Trp	U C A G
	C	CUU } CUC } Leu CUA } CUG }	CCU } CCC } Pro CCA } CCG }	CAU } His CAC } CAA } Gln CAG }	CGU } CGC } Arg CGA } CGG }	U C A G
	A	AUU } AUC } Ile AUA } AUG Met or Start	ACU } ACC } Thr ACA } ACG }	AAU } Asn AAC } AAA } Lys AAG }	AGU } Ser AGC } AGA } Arg AGG }	U C A G
	G	GUU } GUC } Val GUA } GUG }	GCU } GCC } Ala GCA } GCG }	GAU } Asp GAC } GAA } Glu GAG }	GGU } GGC } Gly GGA } GGG }	U C A G

Figure 3. Codon table showing nucleotide sequences for each amino acid.

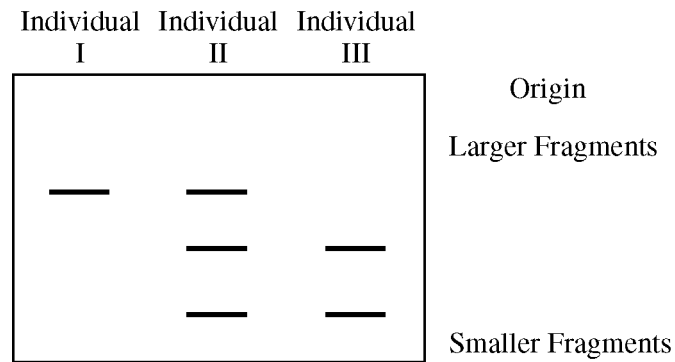


Figure 4. Image of a gel following electrophoretic separation of DNA fragments of the *HBB* gene from three individuals in the pedigree in Figure 1.

48. Based on the data shown in Figure 1, which of the following best describes the genotypes of individual family members in the pedigree?
- (A) All affected individuals possess at least one dominant allele of the hemoglobin beta gene.
 - (B) Healthy individuals may possess one mutant allele (*HbS*) of the hemoglobin beta gene.
 - (C) Individuals IV and V must be heterozygous for the *HbS* (mutant) allele.
 - (D) Individuals II and VI possess two copies of the *HbA* (wild-type) allele.
49. The *HbS* allele, which causes sickle-cell disease, results from a mutation in the DNA sequence shown in Figure 2 that produces a valine (val) in the place of a glutamic acid (glu) residue in the hemoglobin protein. Which of the following mRNA sequences is derived from the *HbS* allele?
- (A) 5' GAC TGA GGA CTC CTC TTC AGA 3'
 - (B) 5' UCU GAA GAG GAA UCC UCA GUC 3'
 - (C) 5' AGA CTT CTC CTC AGG AGT CAG 3'
 - (D) 5' CUG ACU CCU GUG GAG AAG UCU 3'
50. The restriction endonuclease *Mst* II recognizes the sequence 5' CCT(N)AG (where N = any nucleotide) and cuts DNA at that site, producing separate fragments. Which of the following best explains the banding patterns exhibited in Figure 4 ?
- (A) The *HbA* DNA contains a recognition site for the *Mst* II restriction enzyme.
 - (B) The *HbA/HbS* DNA contains three recognition sites for the *Mst* II restriction endonuclease.
 - (C) Individual I has only one copy of the hemoglobin gene; therefore there is only one band on the gel.
 - (D) The *HbS/HbA* DNA contains three different alleles for sickle-cell disease.
51. Possessing a single copy of the *HbS* allele has been shown to provide some resistance to infection by *Plasmodium falciparum*, the parasite that causes malaria. Which of the following individuals represented in the pedigree would have the greatest selective advantage in an area where malaria is common?
- (A) I
 - (B) II
 - (C) III
 - (D) V

52. Antidiuretic hormone (ADH) is important in maintaining homeostasis in mammals. ADH is released from the hypothalamus in response to high tissue osmolarity. In response to ADH, the collecting duct and distal tubule in the kidney become more permeable to water, which increases water reabsorption into the capillaries. The amount of hormone released is controlled by a negative feedback loop.

Based on the model presented, which of the following statements expresses the proper relationship between osmolarity, ADH release, and urine production?

- (A) As tissue osmolarity rises, more ADH is released, causing less water to be excreted as urine.
- (B) As tissue osmolarity rises, less ADH is released, causing less water to be excreted as urine.
- (C) As tissue osmolarity rises, more ADH is released, causing more water to be excreted as urine.
- (D) As tissue osmolarity rises, less ADH is released, causing more water to be excreted as urine.

53. Ellis-van Creveld syndrome is a recessive genetic disorder that includes the characteristics of short stature and extra fingers or toes. In the general population, this syndrome occurs in approximately 1 in 150,000 live births. In a particular isolated population, however, the incidence of this syndrome among live births is 1 in 500.

Assume that both the isolated population and the general population are in Hardy-Weinberg equilibrium with respect to this syndrome. Which of the following best describes the difference between the frequency of the allele that causes the syndrome in the general population and the frequency of the allele in the isolated population?

- (A) The frequency of the Ellis-van Creveld allele is 0.002 in the isolated population and 0.0000066 in the general population, which suggests that selection for this trait is occurring in both populations.
- (B) The frequency of the Ellis-van Creveld allele is 0.0447 in the isolated population and 0.0026 in the general population, showing that the rate of genetic mutation is highest among individuals in the isolated population.
- (C) The frequency of the Ellis-van Creveld allele is 0.002 in the isolated population and 0.0000066 in the general population, which demonstrates gametic incompatibility between the populations.
- (D) The frequency of the Ellis-van Creveld allele is 0.0447 in the isolated population and 0.0026 in the general population, which suggests that genetic drift has occurred in the isolated population.

Directions: The next five questions, numbered 121–125, require numeric answers. Determine the correct answer for each question and enter it in the grid on page 3 of the answer sheet. Use the following guidelines for entering your answers.

- Start your answer in any column, space permitting. Unused columns should be left blank.
- Write your answer in the boxes at the top of the grid and fill in the corresponding circles. Mark only one circle in any column. You will receive credit only if the circles are filled in completely.
- Provide your answer in the format specified by the question. The requested answer may be a negative sign, an integer, a decimal, or a fraction, and it may have a negative value.
- To enter a fraction, use one of the division slashes to separate the numerator from the denominator, as shown in the example below. Fractions only need to be reduced enough to fit in the grid.
- Do not enter a mixed number, as this will be scored as a fraction. For example, $2\frac{1}{2}$ (two and one-half) will be scored as $21/2$ (twenty-one halves).

Integer answer: 5024
(either position is correct)

	5	0	2	4	
☐	☐	☒	☒	☒	☐
☐	☐	☐	☐	☐	☐
0	☒	0	0	0	
1	☐	1	1	1	
2	☐	2	☒	2	
3	☐	3	☐	3	
4	☐	4	☐	☒	
☒	5	5	5	5	
6	☐	6	6	6	
7	☐	7	7	7	
8	☐	8	8	8	
9	☐	9	9	9	

Decimal answer
–4.13

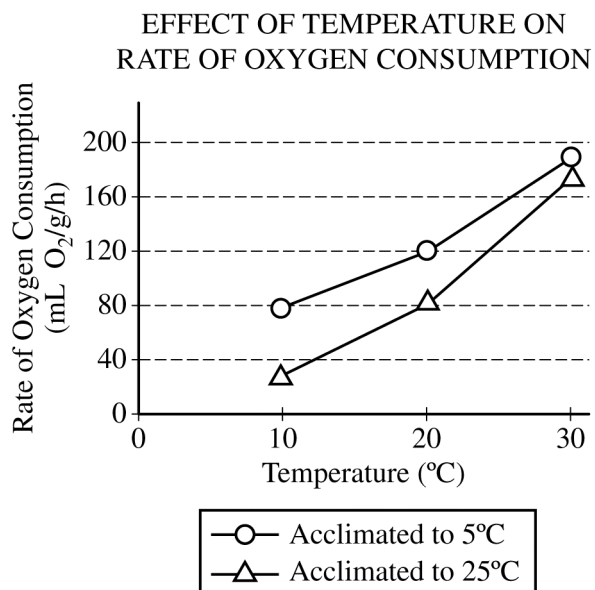
–		4	.	1	3
☒	☐	☒	☒	☒	☐
☐	☐	☐	☐	☐	☐
0	☐	0	☐	0	☐
1	☐	1	☐	☒	☐
2	☐	2	☐	2	☐
3	☐	3	☐	3	☒
4	☒	4	☐	4	☐
5	☐	5	☐	5	☐
6	☐	6	☐	6	☐
7	☐	7	☐	7	☐
8	☐	8	☐	8	☐
9	☐	9	☐	9	☐

Fraction answer: $-2/10$
(does not have to be reduced)

–		2	/	1	0
☒	☐	☒	☒	☒	☐
☐	☐	☐	☐	☐	☐
0	☐	0	☐	0	☒
1	☐	1	☐	☒	☐
2	☒	2	☐	2	☐
3	☐	3	☐	3	☐
4	☐	4	☐	4	☐
5	☐	5	☐	5	☐
6	☐	6	☐	6	☐
7	☐	7	☐	7	☐
8	☐	8	☐	8	☐
9	☐	9	☐	9	☐

GO ON TO THE NEXT PAGE.

121. Some people have the ability to taste a bitter chemical called phenylthiocarbamide (PTC). The ability to taste PTC is due to the presence of at least one dominant allele for the PTC taste gene. The incidence of nontasters in North America is approximately 45%. Assuming the population is in Hardy-Weinberg equilibrium, what percent of the North American population is homozygous dominant for the ability to taste PTC? Provide your answer as a number between 0 and 1 to the nearest hundredth.



122. Based on the data shown, calculate the average rate of increase in oxygen consumption for animals acclimated to 5°C as the temperature increases from 10°C to 30°C. Give the answer in mL O₂/g/h/°C to the nearest tenth.

123. To estimate the size of an animal population, researchers often use a method known as mark-recapture, which involves marking individuals from a large population for easy identification upon recapture. The mark-recapture method assumes that the proportion of marked individuals in the recapture group is equal to the proportion of marked individuals in the entire population.

Researchers used the mark-recapture method to estimate the number of individuals in a population. Using the results presented in the table below, estimate the total number of individuals in the population. Give your answer to the nearest whole number.

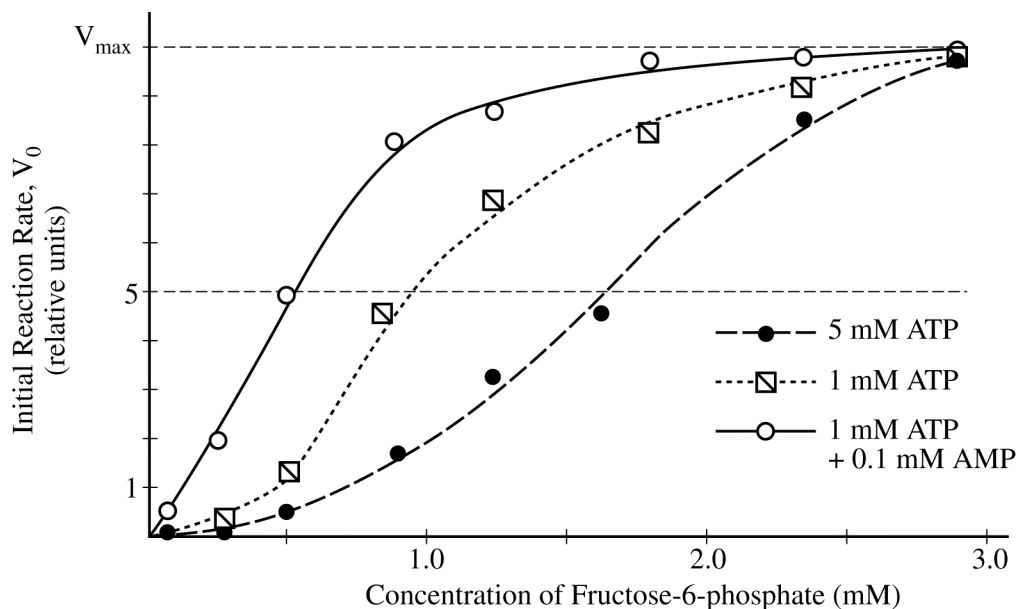
	Number of Marked Individuals	Total Number of Individuals
Recapture group	14	88
Entire population	180	?

124. A certain species of plant has four unlinked genetic loci, *W*, *X*, *Y*, and *Z*. Each genetic locus has one dominant allele and one recessive allele. For a plant with the genotype *WwXxYyZz*, what is the probability that the plant will produce a gamete with a haploid genotype of *Wxyz*? Give your answer as a fraction or as a value between 0 and 1, to four decimal places.

125. The enzyme phosphofructokinase (PFK) is an allosterically regulated enzyme that catalyzes the following reaction.



The graph below shows that at certain concentrations ATP inhibits the enzyme, whereas AMP activates it. According to the information presented in the graph, when the concentration of fructose-6-phosphate is 0.5 mM, how many times more active is PFK in cells with 1 mM ATP + 0.1 mM AMP than in cells with 5 mM ATP? Express your answer to the nearest whole number.



BIOLOGY

Section II

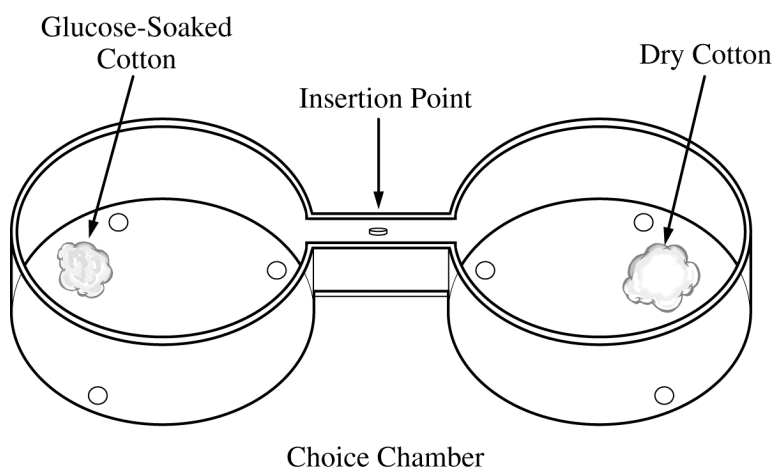
8 Questions

Planning Time—10 minutes

Writing Time—80 minutes

Directions: Questions 1 and 2 are long free-response questions that require about 22 minutes each to answer and are worth 10 points each. Questions 3–8 are short free-response questions that require about 6 minutes each to answer. Questions 3–5 are worth 4 points each and questions 6–8 are worth 3 points each.

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



1. In an investigation of fruit-fly behavior, a covered choice chamber is used to test whether the spatial distribution of flies is affected by the presence of a substance placed at one end of the chamber. To test the flies' preference for glucose, 60 flies are introduced into the middle of the choice chamber at the insertion point indicated by the arrow in the figure above. A cotton ball soaked with a 10% glucose solution is placed at one end of the chamber, and a dry cotton ball with no solution is placed at the other end. The positions of flies are observed and recorded every minute for 10 minutes.
 - (a) **Predict** the distribution of flies in the chamber after 10 minutes and **justify** your prediction.
 - (b) **Propose** ONE specific improvement to each of the following parts of the experimental design and **explain** how the modification will affect the experiment.
 - Experimental control
 - Environmental factors
 - (c) The experiment described above is repeated with ripe bananas at one end and unripe bananas at the other end. Once again the positions of the flies are observed and recorded every minute for 10 minutes. The positions of flies after 1 minute and after 10 minutes are shown in the table below.

DISTRIBUTION OF FLIES IN CHOICE CHAMBER

Time (minutes)	Position in Chamber		
	End with Ripe Banana	Middle	End with Unripe Banana
1	21	18	21
10	45	3	12

Perform a chi-square test on the data for the 10-minute time point in the banana experiment. **Specify** the null hypothesis that you are testing and **enter** the values from your calculations in the table below.

- (d) **Explain** whether your hypothesis is supported by the chi-square test and **justify** your explanation.
- (e) Briefly **propose** a model that describes how environmental cues affect the behavior of the flies in the choice chamber.

**THIS PAGE MAY BE USED FOR TAKING NOTES AND PLANNING YOUR ANSWERS.
NOTES WRITTEN ON THIS PAGE WILL NOT BE SCORED.
WRITE ALL YOUR RESPONSES ON THE LINED PAGES.**

PART (C): CHI-SQUARE CALCULATION

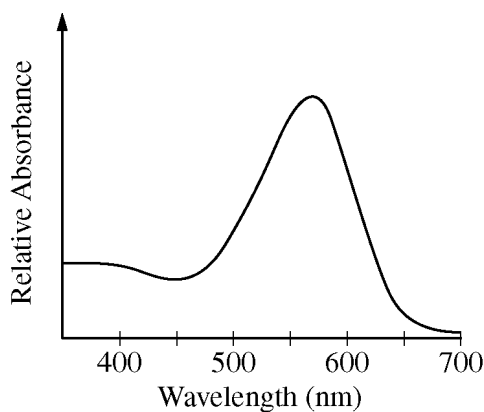
<u>Null Hypothesis:</u>			
	Observed (o)	Expected (e)	$(o - e)^2/e$
End with ripe banana			
Middle			
End with unripe banana			
Total			

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

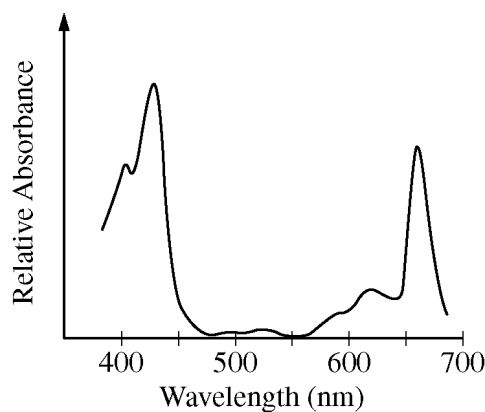
This image shows a single page of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

[illegible]

[illegible]



Graph I



Graph II

Color	Wavelength (nm)
Violet	380–450
Blue	450–475
Cyan	475–495
Green	495–570
Yellow	570–590
Orange	590–620
Red	620–750

2. An absorption spectrum indicates the relative amount of light absorbed across a range of wavelengths. The graphs above represent the absorption spectra of individual pigments isolated from two different organisms. One of the pigments is chlorophyll *a*, commonly found in green plants. The other pigment is bacteriorhodopsin, commonly found in purple photosynthetic bacteria. The table above shows the approximate ranges of wavelengths of different colors in the visible light spectrum.
- Identify** the pigment (chlorophyll *a* or bacteriorhodopsin) used to generate the absorption spectrum in each of the graphs above. **Explain** and **justify** your answer.
 - In an experiment, identical organisms containing the pigment from Graph II as the predominant light-capturing pigment are separated into three groups. The organisms in each group are illuminated with light of a single wavelength (650 nm for the first group, 550 nm for the second group, and 430 nm for the third group). The three light sources are of equal intensity, and all organisms are illuminated for equal lengths of time. **Predict** the relative rate of photosynthesis in each of the three groups. **Justify** your predictions.
 - Bacteriorhodopsin has been found in aquatic organisms whose ancestors existed before the ancestors of plants evolved in the same environment. **Propose** a possible evolutionary history of plants that could have resulted in a predominant photosynthetic system that uses only some of the colors of the visible light spectrum.

**THIS PAGE MAY BE USED FOR TAKING NOTES AND PLANNING YOUR ANSWERS.
NOTES WRITTEN ON THIS PAGE WILL NOT BE SCORED.
WRITE ALL YOUR RESPONSES ON THE LINED PAGES.**

GO ON TO THE NEXT PAGE.

[illegible]

-14-

[illegible]

[illegible]

[illegible]

3. Fossils of lobe-finned fishes, which are ancestors of amphibians, are found in rocks that are at least 380 million years old. Fossils of the oldest amphibian-like vertebrate animals with true legs and lungs are found in rocks that are approximately 363 million years old.

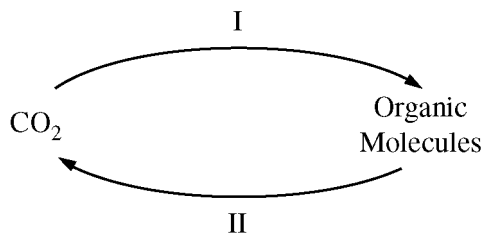
Three samples of rocks are available that might contain fossils of a transitional species between lobe-finned fishes and amphibians: one rock sample that is 350 million years old, one that is 370 million years old, and one that is 390 million years old.

- Select** the most appropriate sample of rocks in which to search for a transitional species between lobe-finned fishes and amphibians. **Justify** your selection.
- Describe** TWO pieces of evidence provided by fossils of a transitional species that would support a hypothesis that amphibians evolved from lobe-finned fishes.

PAGE FOR ANSWERING QUESTION 3

[illegible]

4. Matter continuously cycles through an ecosystem. A simplified carbon cycle is depicted below.



- (a) **Identify** the key metabolic process for step I and the key metabolic process for step II, and briefly **explain** how each process promotes movement of carbon through the cycle. For each process, your explanation should focus on the role of energy in the movement of carbon.
- (b) **Identify** an organism that carries out both processes.

PAGE FOR ANSWERING QUESTION 4

5. The table below shows the amino acid sequence of the carboxyl-terminal segment of a conserved polypeptide from four different, but related, species. Each amino acid is represented by a three-letter abbreviation, and the amino acid residues in the polypeptide chains are numbered from the amino end to the carboxyl end. Empty cells indicate no amino acid is present.

	Relative Amino Acid Position									
Species	1	2	3	4	5	6	7	8	9	10
I	Val	His	Leu	Val	Glu	Glu	His	Val	Glu	His
II	Val	His	Leu	Lys	Glu	Glu	His	Val	Glu	His
III	Val	His	Leu	Val	Glu	Glu	His	Val		
IV	Val	His	Leu	Val	Arg	Trp	Ala	Cys	Met	Asp

- (a) Assuming that species I is the ancestral species of the group, **explain** the most likely genetic change that produced the polypeptide in species II and the most likely genetic change that produced the polypeptide in species III.
- (b) **Predict** the effects of the mutation on the structure and function of the resulting protein in species IV. **Justify** your prediction.

PAGE FOR ANSWERING QUESTION 5

[illegible]

6. The following data were collected by observing subcellular structures of three different types of eukaryotic cells.

RELATIVE AMOUNTS OF ORGANELLES IN THREE CELL TYPES

Cell Type	Smooth ER	Rough ER	Mitochondria	Cilia	Golgi Bodies
X	Small amount	Small amount	Large number	Present	Small amount
Y	Large amount	Large amount	Moderate number	Absent	Large amount
Z	Absent	Absent	Absent	Absent	Absent

Based on an analysis of the data, **identify** a likely primary function of each cell type and **explain** how the data support the identification.

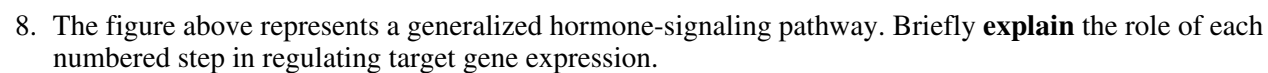
PAGE FOR ANSWERING QUESTION 6

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

- ### THREE-HOUR URINE OUTPUT FOLLOWING FLUID INGESTION

- Pose** ONE scientific question that the researchers were most likely investigating with the experiment.
- State** a hypothesis that could be tested to address the question you posed in part (a).
- Using the data in the table, **describe** the effect of ethyl alcohol on urine production.

[illegible]

[illegible]

AP® BIOLOGY EQUATIONS AND FORMULAS

Statistical Analysis and Probability

Mean

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

Standard Deviation

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

Standard Error of the Mean

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

Chi-Square

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

Chi-Square Table

p value	Degrees of Freedom							
	1	2	3	4	5	6	7	8
0.05	3.84	5.99	7.82	9.49	11.07	12.59	14.07	15.51
0.01	6.64	9.21	11.34	13.28	15.09	16.81	18.48	20.09

Laws of Probability

If A and B are mutually exclusive, then:

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

If A and B are independent, then:

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

Hardy-Weinberg Equations

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

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

$\bar{x}$ = sample mean

n = size of the sample

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

o = observed results

e = expected results

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

Metric Prefixes

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

Mode = value that occurs most frequently in a data set

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

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

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

<p style="text-align: center;">Rate and Growth</p> <p>Rate $\frac{dY}{dt}$</p> <p>Population Growth $\frac{dN}{dt} = B - D$</p> <p>Exponential Growth $\frac{dN}{dt} = r_{\max} N$</p> <p>Logistic Growth $\frac{dN}{dt} = r_{\max} N \left(\frac{K - N}{K} \right)$</p> <p>Temperature Coefficient Q_{10} $Q_{10} = \left(\frac{k_2}{k_1} \right)^{\frac{10}{T_2 - T_1}}$</p> <p>Primary Productivity Calculation $\frac{\text{mg O}_2}{\text{L}} \times \frac{0.698 \text{ mL}}{\text{mg}} = \frac{\text{mL O}_2}{\text{L}}$ $\frac{\text{mL O}_2}{\text{L}} \times \frac{0.536 \text{ mg C fixed}}{\text{mL O}_2} = \frac{\text{mg C fixed}}{\text{L}}$ (at standard temperature and pressure)</p>	<p>dY = amount of change dt = change in time B = birth rate D = death rate N = population size K = carrying capacity $r_{\max}$ = maximum per capita growth rate of population</p> <p>T_2 = higher temperature T_1 = lower temperature k_2 = reaction rate at T_2 k_1 = reaction rate at T_1 Q_{10} = the factor by which the reaction rate increases when the temperature is raised by ten degrees</p>	<p>Water Potential (Ψ) $\Psi = \Psi_P + \Psi_S$ Ψ_P = pressure potential Ψ_S = solute potential</p> <p>The water potential will be equal to the solute potential of a solution in an open container because the pressure potential of the solution in an open container is zero.</p> <p>The Solute Potential of a Solution $\Psi_S = -iCRT$ i = ionization constant (this is 1.0 for sucrose because sucrose does not ionize in water) C = molar concentration R = pressure constant ($R = 0.0831$ liter bars/mole K) T = temperature in Kelvin ($^{\circ}\text{C} + 273$)</p>
<p style="text-align: center;">Surface Area and Volume</p> <p>Volume of a Sphere $V = \frac{4}{3} \pi r^3$</p> <p>Volume of a Rectangular Solid $V = \ell wh$</p> <p>Volume of a Right Cylinder $V = \pi r^2 h$</p> <p>Surface Area of a Sphere $A = 4\pi r^2$</p> <p>Surface Area of a Cube $A = 6s^2$</p> <p>Surface Area of a Rectangular Solid $A = \sum \text{surface area of each side}$</p>	<p>r = radius ℓ = length h = height w = width s = length of one side of a cube A = surface area V = volume Σ = sum of all</p>	<p>Dilution (used to create a dilute solution from a concentrated stock solution) $C_i V_i = C_f V_f$ i = initial (starting) C = concentration of solute f = final (desired) V = volume of solution</p> <p>Gibbs Free Energy $\Delta G = \Delta H - T\Delta S$ ΔG = change in Gibbs free energy ΔS = change in entropy ΔH = change in enthalpy T = absolute temperature (in Kelvin)</p> <p>$\text{pH} = -\log_{10} [\text{H}^+]$</p>

APPENDIX - ANSWERS

AP BIOLOGY 2013

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

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

Grid-in answers

121: Any value from 0.09 to 0.11, inclusive, or Any value from 9/100 to 11/100, inclusive

122: Any value from 5.0 to 5.5, inclusive, or Any value from 5/1 to 55/10, inclusive

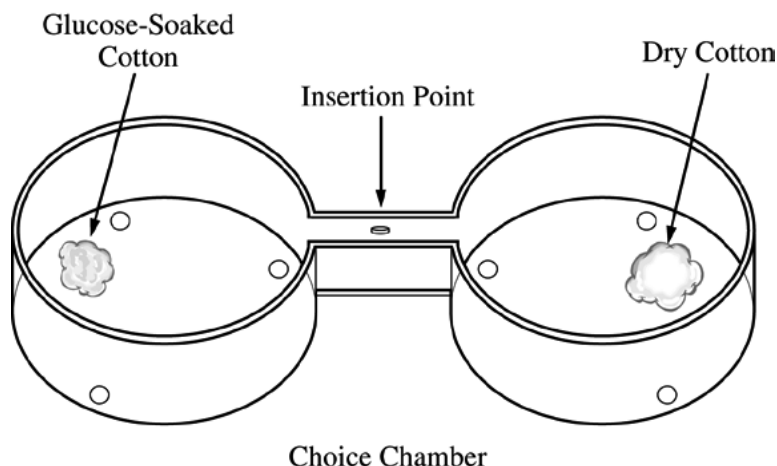
123: 1131

124: .0625 or 1/16

125: Any value from 10 to 15, inclusive, or Any value from 10/1 to 15/1, inclusive

AP[®] BIOLOGY 2013 SCORING GUIDELINES

Question 1



In an investigation of fruit-fly behavior, a covered choice chamber is used to test whether the spatial distribution of flies is affected by the presence of a substance placed at one end of the chamber. To test the flies' preference for glucose, 60 flies are introduced into the middle of the choice chamber at the insertion point indicated by the arrow in the figure above. A cotton ball soaked with a 10 percent glucose solution is placed at one end of the chamber, and a dry cotton ball with no solution is placed at the other end. The positions of flies are observed and recorded every minute for 10 minutes.

- (a) **Predict** the distribution of flies in the chamber after 10 minutes and **justify** your prediction. (2 points maximum)
- 1 point for predicting the location of the flies in the choice chamber
 - 1 point for justifying the prediction
- (b) **Propose** ONE specific improvement to each of the following parts of the experimental design and **explain** how the modification will affect the experiment. (4 points maximum)
- Experimental control
 - Environmental factors

	Proposed Improvement (includes but not limited to) (1 point maximum)	Explanation (1 point maximum)
Experimental control	Replace the dry cotton ball with a water-soaked cotton ball.	Ensures that glucose is the attractant
	Constant light or temperature or duration of experiment or time of day, etc.	Other variables must be held constant

	Proposed Improvement (includes but not limited to) (1 point maximum)	Explanation (1 point maximum)
Environmental factors	<ul style="list-style-type: none"> • Use different concentrations of glucose • Use different temperature(s) • Use different light levels • Use a different choice chamber (size/shape) • Vary duration of the experiment • Vary time of day when experiment is performed 	Attributes movement of flies only to glucose preference

AP[®] BIOLOGY 2013 SCORING GUIDELINES

Question 1 (continued)

- (c) The experiment described above is repeated with ripe bananas at one end and unripe bananas at the other end. Once again the positions of the flies are observed and recorded every minute for 10 minutes. The positions of flies after 1 minute and after 10 minutes are shown in the table below.

DISTRIBUTION OF FLIES IN CHOICE CHAMBER

Time (minutes)	Position in Chamber		
	End with Ripe Banana	Middle	End with Unripe Banana
1	21	18	21
10	45	3	12

Perform a chi-square test on the data for the 10-minute time point in the banana experiment.

Specify the null hypothesis that you are testing and **enter** the values from your calculations in the table below. (2 points maximum)

PART (c): CHI-SQUARE CALCULATION

Null Hypothesis: (1 point)			
The flies will be evenly distributed across the three different parts of the choice chamber.			
	Observed (o)	Expected (e)* (1 point)	(o - e) ² /e
End with ripe banana	45	20	31.25
Middle	3	20	14.45
End with unripe banana	12	20	3.2
Total	60	60	48.9
*Expected values must be those predicted by the null hypothesis provided in the student response, add up to 60, and include no cells equal to 0.			

- (d) **Explain** whether your hypothesis is supported by the chi-square test and **justify** your explanation. (1 point maximum)

- Correct explanation with justification of why the stated null hypothesis is rejected or not rejected. Response must clarify each of the following:
 - degrees of freedom (df) = 2 and p = 0.05 (critical value = 5.99)
 - OR
 - degrees of freedom (df) = 2 and p = 0.01 (critical value = 9.21)
 - how the calculated test statistic compares to the selected critical value
 - whether the null hypothesis should be rejected

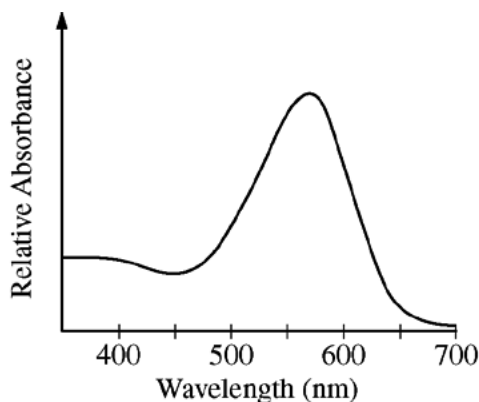
AP[®] BIOLOGY
2013 SCORING GUIDELINES

Question 1 (continued)

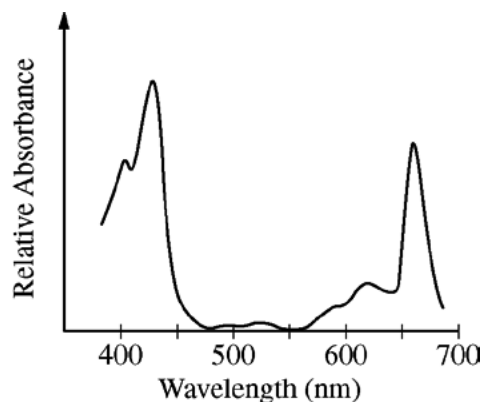
- (e) Briefly **propose** a model that describes how environmental cues affect the behavior of the flies in the choice chamber. (**1 point maximum**)
- Stimulus → Response
 - Input → (possible integration) → Output

AP[®] BIOLOGY
2013 SCORING GUIDELINES

Question 2



Graph I



Graph II

Color	Wavelength (nm)
Violet	380–450
Blue	450–475
Cyan	475–495
Green	495–570
Yellow	570–590
Orange	590–620
Red	620–750

An absorption spectrum indicates the relative amount of light absorbed across a range of wavelengths. The graphs above represent the absorption spectra of individual pigments isolated from two different organisms. One of the pigments is chlorophyll *a*, commonly found in green plants. The other pigment is bacteriorhodopsin, commonly found in purple photosynthetic bacteria. The table above shows the approximate ranges of wavelengths of different colors in the visible light spectrum.

- (a) **Identify** the pigment (chlorophyll *a* or bacteriorhodopsin) used to generate the absorption spectrum in each of the graphs above. **Explain** and **justify** your answer. (3 points maximum)

1 point per box

Identify BOTH pigments:

Graph 1 = bacteriorhodopsin AND graph 2 = chlorophyll *a*

Explain that an organism containing bacteriorhodopsin appears purple because the pigment absorbs light in the green range of the light spectrum and/or reflects violet or red and blue light. The reflected red and blue light appears purple.

Explain that an organism containing chlorophyll *a* appears green because the pigment absorbs light in the red and blue ranges of the light spectrum and/or reflects green light.

AP[®] BIOLOGY

2013 SCORING GUIDELINES

Question 2 (continued)

- (b) In an experiment, identical organisms containing the pigment from Graph II as the predominant light-capturing pigment are separated into three groups. The organisms in each group are illuminated with light of a single wavelength (650 nm for the first group, 550 nm for the second group, and 430 nm for the third group). The three light sources are of equal intensity, and all organisms are illuminated for equal lengths of time. **Predict** the relative rate of photosynthesis in each of the three groups. **Justify** your predictions. (5 points maximum)

Wavelength (Group)	Prediction (1 point each box)	Justification (1 point each box)
650 nm (1 st Group)	Intermediate rate	An intermediate level of absorption occurs at 650 nm (compared to 430 nm and 550 nm); <i>therefore</i> , an intermediate amount of energy is available to drive photosynthesis.
550 nm (2 nd Group)	Lowest rate	The lowest level of absorption occurs at 550 nm; <i>therefore</i> , the least amount of energy is available to drive photosynthesis.
430 nm (3 rd Group)	Highest rate	The highest level of absorption occurs at 430 nm; <i>therefore</i> , the greatest amount of energy is available to drive photosynthesis.

NOTE: A student who combines two groups (e.g., “the 650 nm and 430 nm groups have higher rates of photosynthesis compared to the 550 nm group”) can earn a maximum of 4 points: up to 2 points for the prediction and up to 2 points for the justification.

- (c) Bacteriorhodopsin has been found in aquatic organisms whose ancestors existed before the ancestors of plants evolved in the same environment. **Propose** a possible evolutionary history of plants that could have resulted in a predominant photosynthetic system that uses only some of the colors of the visible light spectrum. (1 point per box; 2 points maximum)

Proposal that includes an environmental selective pressure:

- Green light was being absorbed by aquatic organisms using bacteriorhodopsin.
- Unabsorbed wavelengths of light were available resources that organisms could exploit.
- Absorbing visible light at all wavelengths may provide too much energy to the organism.
- Absorbing light from ultraviolet wavelengths (shorter wavelengths = higher energy) could cause damage to the organism.
- Absorbing light with longer wavelengths may not provide sufficient energy for the organism.

Appropriate reasoning to support the proposal:

- Natural selection favored organisms that rely on pigments that absorb available wavelengths of light.
- Endosymbiosis: chloroplasts evolved from cyanobacteria with pigments that used only certain wavelengths.
- Genetic drift eliminated pigments that absorbed certain wavelengths of light.
- Mutation(s) altered the pigment(s) used by organism.

AP[®] BIOLOGY
2013 SCORING GUIDELINES

Question 3

Fossils of lobe-finned fishes, which are ancestors of amphibians, are found in rocks that are at least 380 million years old. Fossils of the oldest amphibian-like vertebrate animals with true legs and lungs are found in rocks that are approximately 363 million years old.

Three samples of rocks are available that might contain fossils of a transitional species between lobe-finned fishes and amphibians: one rock sample that is 350 million years old, one that is 370 million years old, and one that is 390 million years old.

- (a) **Select** the most appropriate sample of rocks in which to search for a transitional species between lobe-finned fishes and amphibians. **Justify** your selection. **(2 points maximum)**
- Selection: Rocks from 370 MYA sample.
 - Justification: Transitional fossils are found between 380 MYA (when lobe-finned fishes lived) and 363 MYA (when amphibians appeared) OR between different strata/layers in the correct order.
- (b) **Describe** TWO pieces of evidence provided by fossils of a transitional species that would support a hypothesis that amphibians evolved from lobe-finned fishes. **(2 points maximum)**

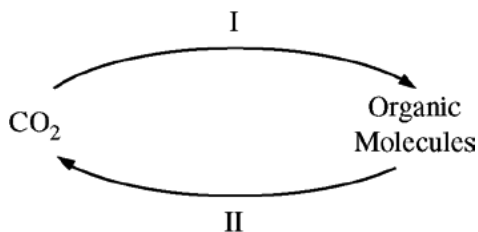
Descriptions include but are not limited to the following:

- Bones OR specific skeletal structures
 - legs /limbs/digits
 - vertebrae
 - flat skulls
 - (interlocking) ribs
 - flexible neck
- Scales
- Teeth
- Other homologous structures
- Has traits of both the lobe-finned fish and the amphibian
- Finding the transitional fossils in the same area/same environment as either the lobe-finned fish or the amphibian
- Molecular (DNA) evidence

AP[®] BIOLOGY 2013 SCORING GUIDELINES

Question 4

Matter continuously cycles through an ecosystem. A simplified carbon cycle is depicted below.



- (a) **Identify** the key metabolic process for step I and the key metabolic process for step II and briefly **explain** how each process promotes movement of carbon through the cycle. For each process, your explanation should focus on the role of energy in the movement of carbon.

Identification: **1 point maximum**

I = photosynthesis / Calvin cycle
AND
II = (cellular) respiration / citric acid cycle / Krebs cycle

Explanation: **1 point each row; 2 points maximum**

Process	Carbon Input	Role of Energy in the Movement of Carbon	Carbon Output
Photosynthesis	CO ₂ is fixed	Uses (light) energy OR ATP from light reactions	Organic molecules
(Cellular) Respiration	Organic molecules are hydrolyzed / broken down	Uses energy for cellular processes such as growth and /or ATP production	CO ₂

- (b) **Identify** an organism that carries out both processes. **(1 point maximum)**

- Plant
- Algae
- Photosynthetic protist (e.g., Euglena)
- Cyanobacterium
- CO₂ fixing bacterium
- Lichen (not fungus)

AP[®] BIOLOGY
2013 SCORING GUIDELINES

Question 5

The table below shows the amino acid sequence of the carboxyl-terminal segment of a conserved polypeptide from four different, but related, species. Each amino acid is represented by a three-letter abbreviation, and the amino acid residues in the polypeptide chains are numbered from the amino end to the carboxyl end. Empty cells indicate no amino acid is present.

	Relative Amino Acid Position									
Species	1	2	3	4	5	6	7	8	9	10
I	Val	His	Leu	Val	Glu	Glu	His	Val	Glu	His
II	Val	His	Leu	Lys	Glu	Glu	His	Val	Glu	His
III	Val	His	Leu	Val	Glu	Glu	His	Val		
IV	Val	His	Leu	Val	Arg	Trp	Ala	Cys	Met	Asp

- (a) Assuming that species I is the ancestral species of the group, **explain** the most likely genetic change that produced the polypeptide in species II and the most likely genetic change that produced the polypeptide in species III. **(2 points maximum)**

Explanation: **1 point per row**

NOTE: Specific names of mutation types are not required.

Species	Genetic Change in DNA / Bases	Result of Change to Polypeptide / Protein
II	mutation / substitution / point mutation / missense mutation	an amino acid change only at position 4 (Val to Lys)
III	mutation (e.g., substitution / insertion / deletion / point mutation / frameshift mutation / nonsense mutation) that introduces a stop codon after the codon for Val	termination of the polypeptide after the Val at position 8

- (b) **Predict** the effects of the mutation on the structure and function of the resulting protein in species IV. **Justify** your prediction. **(2 points maximum)**

Predicted Change (1 point maximum)	Justification of Prediction (1 point maximum)
Protein may have a different structure and a change in function.	Change in amino acid sequence of the protein starting at position 5 could alter the overall structure or local structural regions, interfering with function of the protein.
Protein may have a different structure and no change in function.	Change in amino acid sequence alters the shape / conformation / folding / binding region / regulatory region of the protein, but does not affect the critical functional region(s) of the protein.
Protein structure and function may not be affected.	Change in amino acid sequence does not alter the protein shape / conformation / folding and does not alter function.

AP[®] BIOLOGY

2013 SCORING GUIDELINES

Question 6

The following data were collected by observing subcellular structures of three different types of eukaryotic cells.

RELATIVE AMOUNTS OF ORGANELLES IN THREE CELL TYPES

Cell Type	Smooth ER	Rough ER	Mitochondria	Cilia	Golgi Bodies
X	Small amount	Small amount	Large number	Present	Small amount
Y	Large amount	Large amount	Moderate number	Absent	Large amount
Z	Absent	Absent	Absent	Absent	Absent

Based on an analysis of the data, **identify** a likely primary function of each cell type and **explain** how the data support the identification. (3 points maximum)

<u>Cell Type</u>	<u>Identify function</u>		<u>Explain how data support identification</u> (1 point each correct pair). <u>NOTE: No points for identification without explanation.</u>		
X	<ul style="list-style-type: none"> Locomotion Movement / surface transport 	<u>AND</u>	Has cilia for movement <u>and</u> large amounts of mitochondria to provide energy for locomotion of cell itself (ciliated protist) or movement of particles (mucus / oocyte) along cell surface		
Y	<ul style="list-style-type: none"> Secretion / exocytosis Protein synthesis 	<u>AND</u>	Has large amounts of rough ER <u>and</u> Golgi to produce and package proteins		
	<ul style="list-style-type: none"> Lipid/hormone synthesis Detoxification 	<u>AND</u>	Has large amounts of smooth ER to produce lipids / hormones		
Z	• Transport	<u>OR</u>	<ul style="list-style-type: none"> Oxygen transport in animal cells Water transport in plant cells 	<u>AND</u>	Does not require these organelles
	• Protection	<u>OR</u>	• Epidermal cells (stratum corneum, cork, nails)	<u>AND</u>	
	• Support	<u>OR</u>	<ul style="list-style-type: none"> Ground tissue (sclerenchyma) Vascular tissue (xylem) 	<u>AND</u>	
	• Storage	<u>OR</u>	• Maximizes volume / space available (hemoglobin, oxygen)	<u>AND</u>	
	• No function	<u>OR</u>	• Is a dead cell/is undergoing apoptosis	<u>AND</u>	

AP[®] BIOLOGY
2013 SCORING GUIDELINES

Question 7

In an experiment, rats averaging 300 g of body mass were tested several times over a three-month period. For each individual rat, urine was collected over a three-hour period after ingestion of 10 mL of liquid (water, 1 percent ethyl alcohol solution, or 5 percent ethyl alcohol solution). The volume of urine was then measured, and the results were averaged for all individuals within each experimental group. The data are shown in the table below.

THREE-HOUR URINE OUTPUT FOLLOWING FLUID INGESTION

Fluid ingested (10 mL)	Water	1% Ethyl Alcohol	5% Ethyl Alcohol
Average urine output (mL)	3.5	3.8	4.7

- (a) **Pose** ONE scientific question that the researchers were most likely investigating with the experiment. (1 point)

Appropriate questions include but are not limited to the following:

- How does alcohol consumption affect urine output in rats (or any mammal)?
- How does alcohol consumption affect regulation of the kidney?

- (b) **State** a hypothesis that could be tested to address the question you posed in part (a). (1 point)

Appropriate hypotheses include but are not limited to the following:

- Alcohol consumption increases urine output in rats.
- Alcohol consumption increases water retention/reabsorption in rat kidneys.
- Alcohol consumption reduces urine output in rats.
- Alcohol consumption has no effect on urine output in rats.

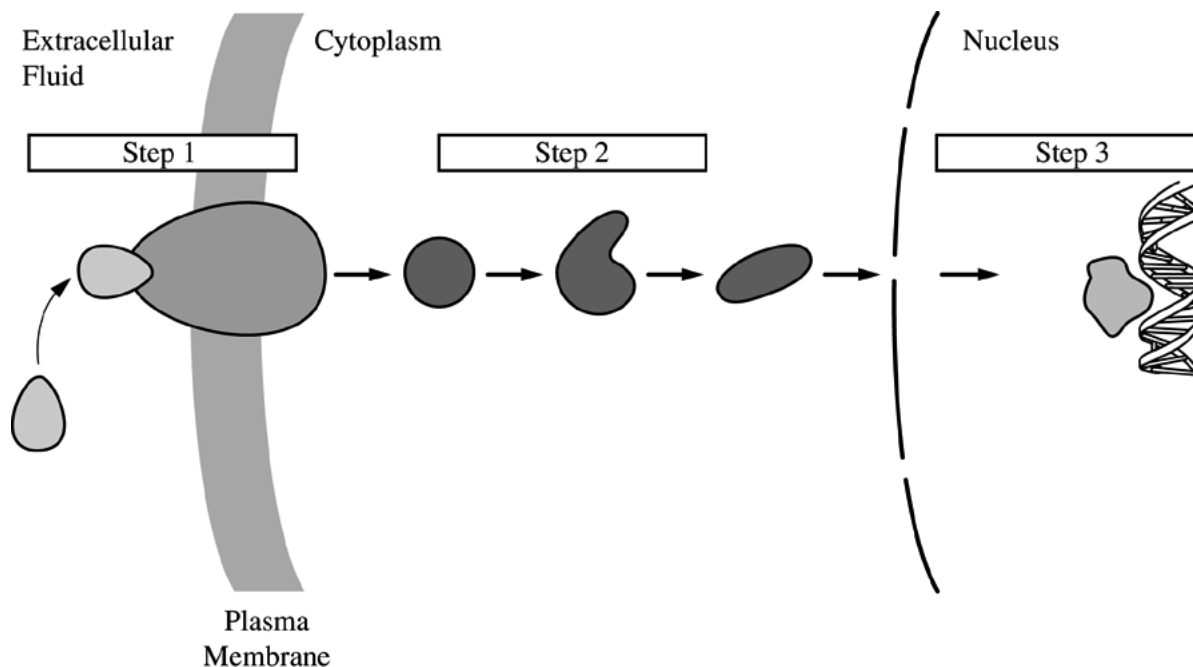
NOTE: This point may be earned without earning the point in part (a)

- (c) Using the data in the table, **describe** the effect of ethyl alcohol on urine production. (1 point)

- Alcohol consumption increases urine output.

AP[®] BIOLOGY
2013 SCORING GUIDELINES

Question 8



The figure above represents a generalized hormone-signaling pathway. Briefly **explain** the role of each numbered step in regulating target gene expression. (**3 points maximum**)

- Step 1 = hormone/ligand binding to receptor to initiate/trigger/induce signaling OR signal reception
- Step 2 = an intracellular cascade that transduces/amplifies/transfers the signal from plasma membrane to nucleus (or other cellular effectors)
- Step 3 = transcription/expression of target genes is stimulated/repressed