

The University of the State of New York
REGENTS HIGH SCHOOL EXAMINATION

LIFE SCIENCE: BIOLOGY

Wednesday, August 19, 2026 — 12:30 to 3:30 p.m., only

Student Name _____

School Name _____

The possession or use of any communications device is strictly prohibited when taking this examination. If you have or use any communications device, no matter how briefly, your examination will be invalidated and no score will be calculated for you.

Print your name and the name of your school on the lines above.

Use your knowledge of **Life Science: Biology** to answer all questions in this examination.

You are to answer all questions in this examination. You may use scrap paper to work out the answers to the questions, but be sure to record your answers on your answer sheet and in your test booklet. A separate answer sheet for multiple-choice questions has been provided to you. Follow the instructions from the proctor for completing the student information on your answer sheet. Record your answers for the constructed response questions in your test booklet.

All answers in your test booklet should be written in pen, except for graphs and drawings, which should be done in pencil.

When you have completed the examination, you must sign the declaration printed on your separate answer sheet, indicating that you had no unlawful knowledge of the questions or answers prior to the examination and that you have neither given nor received assistance in answering any of the questions during the examination. Your answer sheet and test booklet cannot be accepted if you fail to sign this declaration.

NOTICE ...

A four-function or scientific calculator must be available for you to use while taking this examination.

Note that diagrams are not drawn to scale unless otherwise noted.

DO NOT OPEN THIS EXAMINATION BOOKLET UNTIL THE SIGNAL IS GIVEN.

Base your answers to questions 1 through 4 on the information below and on your knowledge of Life Science: Biology. Be sure to record your answers for multiple-choice questions on the separate answer sheet provided. Record your answers for constructed-response questions in your test booklet.

Star of the Tide Pool

Sea stars are invertebrate animals that are commonly found in tide pools. They are predators that feed on other invertebrates, such as snails, mussels, and clams.

Tide pools are shallow pools of seawater that form along shorelines as the tide changes. Changes in temperature and salinity as well as the actions of waves and predators are all challenges that organisms in a tide pool face.

The image below shows a tide pool at low tide.

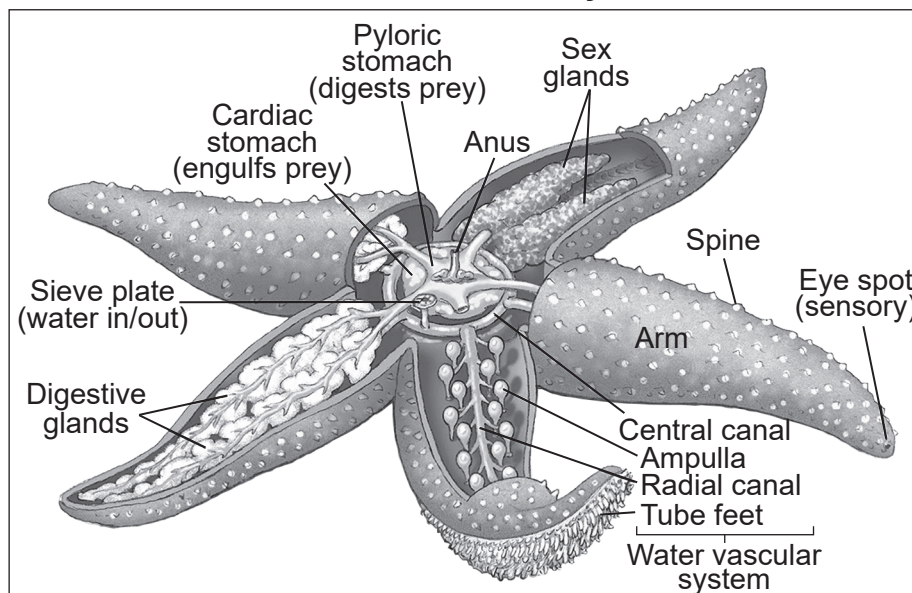
Tide Pool



Sea stars have many unusual characteristics. They do not have blood; instead they use seawater that flows through their body cavities. They move slowly using their tube feet, which are also used to force open the shells of their prey.

The model below shows some information about sea star anatomy.

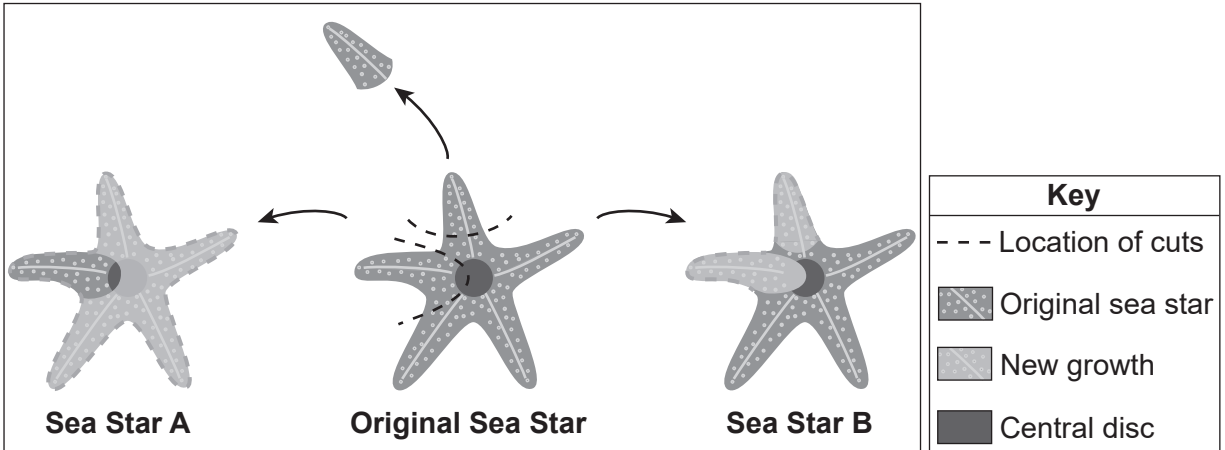
Sea Star Anatomy



- 1** Based on the information provided, which explanation indicates that the evolution of sea stars is the result of the challenging environmental conditions found in tide pools?
- (1) The number of producers available for consumption by sea stars varies greatly from high to low tide. Only sea stars able to survive on the limited food available survived and reproduced.
 - (2) The waves present in the tidal pools made it difficult to remain in this environment without being washed away. Only sea stars with tube feet that allowed them to cling to rocks were able to survive and pass on their genes.
 - (3) Snails, mollusks, and clams prey on sea stars. The sea stars that survived long enough to reproduce were those with adaptations enabling them to remain hidden from these predators during low tide.
 - (4) The multiple species of sea stars present in the tide pool worked together to increase their overall success. This led to increased survival and interbreeding, resulting in hybrid offspring.
- 2** Which components of the model show the interactions of two body systems used by sea stars during feeding?
- (1) Sea stars use the eye spot in their sensory system to find their prey and the digestive glands of their digestive system to open the shells of their prey.
 - (2) Sea stars use the tube feet of their reproductive systems to open the shells of their prey and the stomachs of their digestive system to remove nutrients.
 - (3) Sea stars use the tube feet of their water vascular system to open the shells of their prey, and the stomachs of their digestive system break down their prey into nutrient molecules.
 - (4) Sea stars use the stomachs of their digestive system to open the shell then transport the nutrients through the radial canal of the water vascular system.

Sea stars can regenerate (regrow) portions of their body. Regeneration only occurs if a part of the central disc is included in any of the pieces. The central disc contains cells which can reproduce and become many different cell types. The diagram below shows what happens when a sea star that has been cut into multiple pieces forms two sea stars.

Regeneration in Sea Stars



- 3 The original sea star in the model above has 44 chromosomes in each of its body cells. How does the genetic material in the cells in the new growth compare to the genetic material in the cells of the original sea star?
- (1) The new growth cells of Sea Star A have a different amount of genetic material with 22 chromosomes compared to the original sea star with 44 chromosomes.
 - (2) The new growth cells of Sea Star B have a different amount of genetic material with 88 chromosomes compared to the original sea star with 44 chromosomes.
 - (3) The genetic material in the cells of the new growth in both Sea Star A and B and the original sea star are identical with 22 chromosomes.
 - (4) The genetic material of the new growth in Sea Stars A and B and the original sea star are identical with 44 chromosomes.

Humans eat some of the same food sea stars prey upon. Fishermen farm mollusks, such as clams and mussels, in large sections within the ocean called beds. Sea stars will prey on the mollusks in the beds, competing with the fishermen for this resource.

Some fishermen propose that the most effective method of eliminating sea stars from the area and increasing the fishermen's harvest is to cut the sea stars in half that they find near the mollusks.

Others have suggested that the fishermen enclose the mollusk farm with nets and/or cages to prevent the sea stars from getting to the mollusks.

- 4 Evaluate **one** of the proposed solutions as to how well it solves the fishermen's problem while maintaining the biodiversity of the ecosystem. [1]

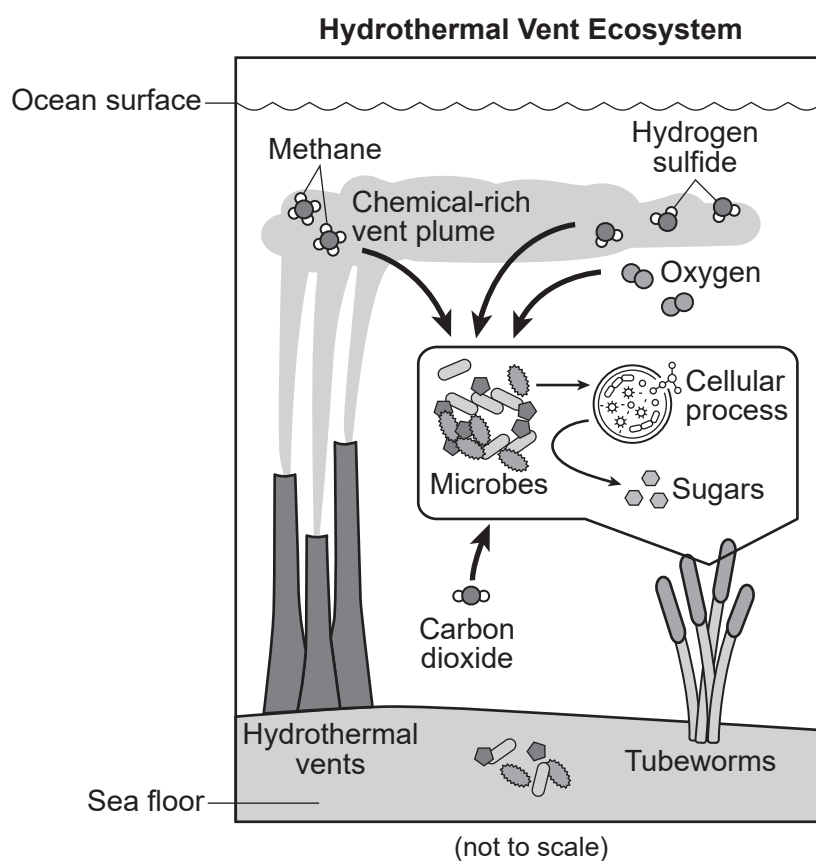
Base your answers to questions 5 through 8 on the information below and on your knowledge of Life Science: Biology.

Deep-Sea Dilemmas

All organisms that make their own food require a source of energy. Some organisms use chemicals, such as hydrogen sulfide (H_2S) and methane (CH_4), as a source of energy to perform a process known as chemosynthesis.

Deep within the ocean, hydrothermal vents are areas where cracks in the ocean floor release cloud-like plumes of heat, gases, and other materials. Tiny deep-water microbes (bacteria) that live near the vents use chemosynthesis to produce sugars. Some of these microbes live within the tissues of giant organisms called tubeworms.

The model below summarizes some of the interactions occurring within a hydrothermal vent ecosystem.

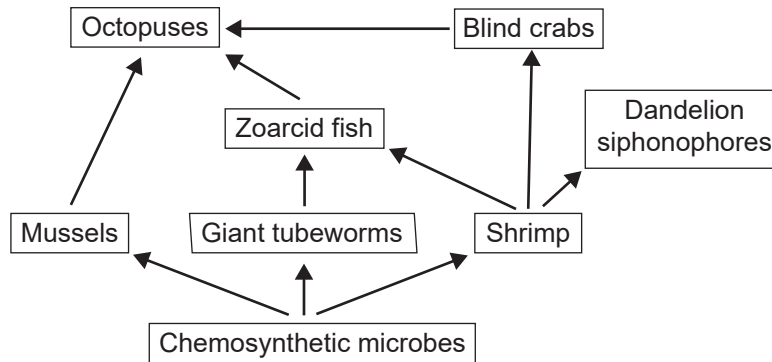


- 5 Using information from the model, which statement correctly describes the role of chemosynthesis in cycling carbon between two of Earth's spheres?
- (1) Chemosynthetic microbes, a part of the biosphere, release the energy within the bonds of H_2S (hydrogen sulfide) obtained from the atmosphere and store it within the bonds of $\text{C}_6\text{H}_{12}\text{O}_6$.
 - (2) Tubeworms have tissues that combine water from the hydrosphere and sulfur from the geosphere to produce $\text{C}_6\text{H}_{12}\text{O}_6$ as an energy source.
 - (3) The tubeworms grow very tall to absorb CO_2 from the atmosphere in order to produce $\text{C}_6\text{H}_{12}\text{O}_6$ for other organisms in the biosphere through the process of photosynthesis.
 - (4) CH_4 (methane), which is released into the hydrosphere by the hydrothermal vent, is used to produce organic compounds by the chemosynthetic microbes in the biosphere.
- 6 Which statement could be used to explain how energy flows among organisms within the deep-ocean vent ecosystem?
- (1) Organisms take in energy during the process of chemosynthesis and release the energy as O_2 for use during cellular respiration.
 - (2) The net amount of energy obtained by the tubeworms during cellular respiration is equal to the amount of energy stored in the glucose produced by chemosynthesis.
 - (3) An input of energy is required in order to provide the giant tubeworms with the raw materials they need to produce glucose by chemosynthesis.
 - (4) Chemosynthetic bacteria use the stored energy from H_2S (hydrogen sulfide) to form sugars for cellular respiration in tubeworms.

Deep-sea mining is being used to dig minerals from the sea floor, sometimes within hydrothermal vent ecosystems. Deep-sea mining vehicles make a lot of noise, cause vibration, and stir up large amounts of sediment that disrupt chemosynthetic processes.

A typical deep-sea hydrothermal vent food web is shown below.

A Hydrothermal Vent Food Web



- 7 Which evidence-based claim describes a result of the changing conditions caused by deep-sea mining on the complex interactions in the hydrothermal vent food web?
- (1) There will be increased competition between mussels and shrimp due to an increase in the shrimp population size.
 - (2) Carnivores, such as blind crabs, will increase due to an increase in their prey availability.
 - (3) With less sugar being produced by microbes, the octopus population will decrease over time.
 - (4) With more organic molecules being produced by microbes, shrimp will begin consuming more dandelion siphonophores, reducing their population size.

Deep-sea mining provides the minerals needed to manufacture some alternative energy sources. Whenever solutions are proposed to meet the energy needs of the human population, the trade-offs must be considered.

Potential environmental impacts of deep-sea mining techniques could include:

- organisms killed by mining equipment
- warming of the water by mining equipment
- wastewater discharge from the mining process
- noise and light from mining equipment disrupting organisms

- 8 Select **one** potential environmental impact and describe a solution that will meet the criteria of retrieving the required minerals through deep-sea mining while also minimizing that environmental impact. [1]

Environmental Impact: _____

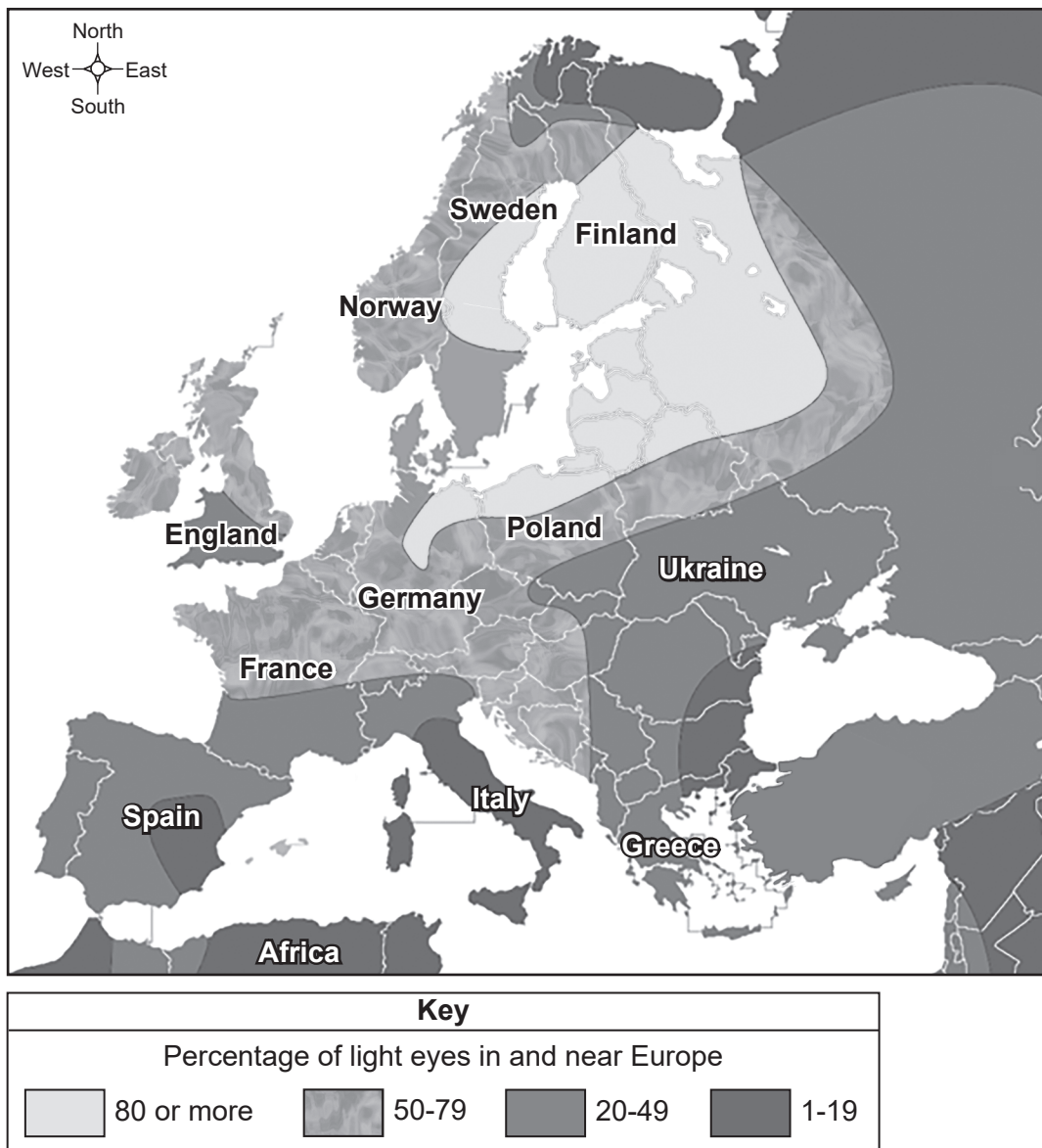
Solution Description: _____

Base your answers to questions 9 through 12 on the information below and on your knowledge of Life Science: Biology

Human Variations in Eye Color

Modern humans show a high degree of inheritable variation in skin, hair, and eye coloration that was not present in earlier populations. Scientists believe that most early humans originating in Africa had traits of brown hair and eyes. These traits provide protection from cellular damage caused by exposure to the sun's ultraviolet radiation. Today, blue eyes are the lightest variety, but there are many intermediate colors, such as hazel, amber, green, and gray. Some information about eye color is shown below.

Distribution of Light Eyes Across Europe



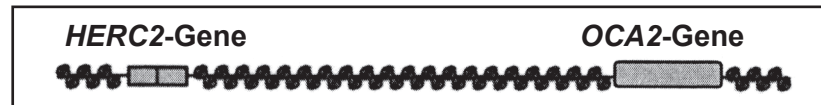
9 Which claim best explains the cause of inheritable variation that resulted in lighter-colored eyes?

- (1) An error occurred in DNA replication during meiosis that resulted in eye colors other than brown in northern Europe.
- (2) Differentiation resulted in the production of fewer pigments, resulting in lighter eyes in southern Europe.
- (3) Environmental conditions in Europe, such as less direct ultraviolet light than in Africa, caused eyes to become lighter.
- (4) Gene recombination during mitosis resulted in lighter eye colors in Europe than in Africa.

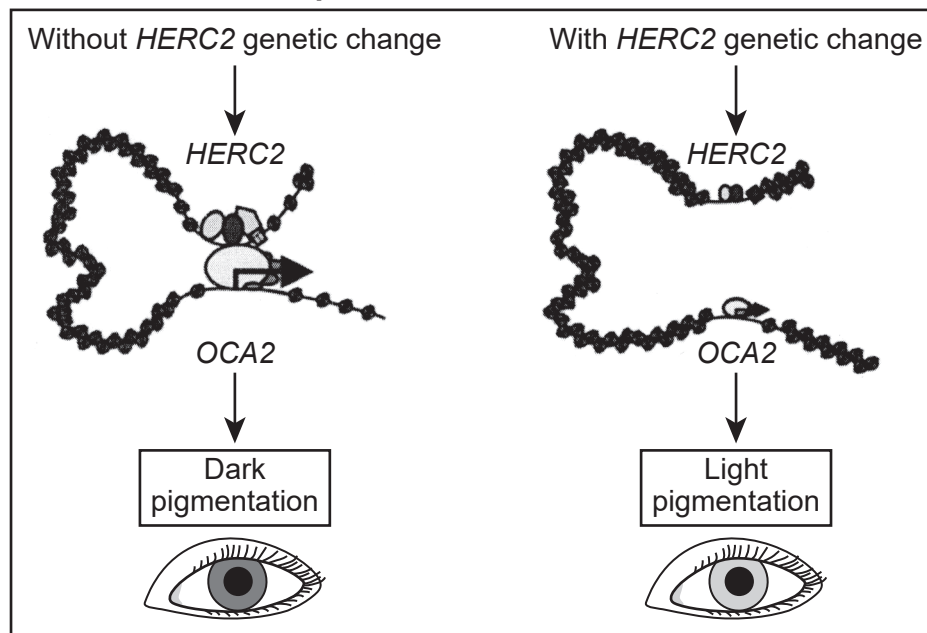
10 Analyze and interpret the data to describe the distribution of the expressed trait of lighter-colored eyes in populations across Europe. [1]

The *OCA2* gene codes for a protein that is required for the production of melanin, a dark pigment. The *HERC2* gene is close to the *OCA2* gene on chromosome 15. *HERC2* includes a control region that regulates how much protein is produced by the *OCA2* gene. *OCA2* gene expression does not always get turned off entirely but may be reduced, resulting in lightening brown eyes to blue. The models below show a section of chromosome 15 and its corresponding gene expression.

Chromosome Section with Location of Specific Genes



Expression of *OCA2* Gene



- 11** Construct an explanation based on evidence for how a change in the structure of the *HERC2* gene alters melanin production in specific cells, resulting in the color variation seen in eyes. [1]

Humans show great variation in eye pigmentation. Brown and blue eyes are the most common, but other colors are possible, such as green, which occurs in 2% of the world's population.

- 12** Which question could be asked to clarify the role of *OCA2* and *HERC2* genes in the 2% of individuals who inherit green eyes?
- (1) How does aging affect the expression of melanin-producing genes in individuals with green eyes?
 - (2) How does an individual's environment impact gene expression and the development of eye color?
 - (3) How does *HERC2* gene and *OCA2* gene interaction in the parents' eye cells result in mutations that lead to green eyes?
 - (4) How does the *HERC2* gene regulate the expression of the *OCA2* gene in the cells of green eyes compared to the process in blue-eye cells?

Base your answers to questions 13 through 16 on the information below and on your knowledge of Life Science: Biology.

Humongous Fungus

The giant puffball (*Calvatia gigantea*) is a species of multicellular fungus that can reach 0.9 meters (three feet) in diameter and weigh more than 11 kilograms (25 pounds). The visible part of a giant puffball is the reproductive structure known as the fruiting body.

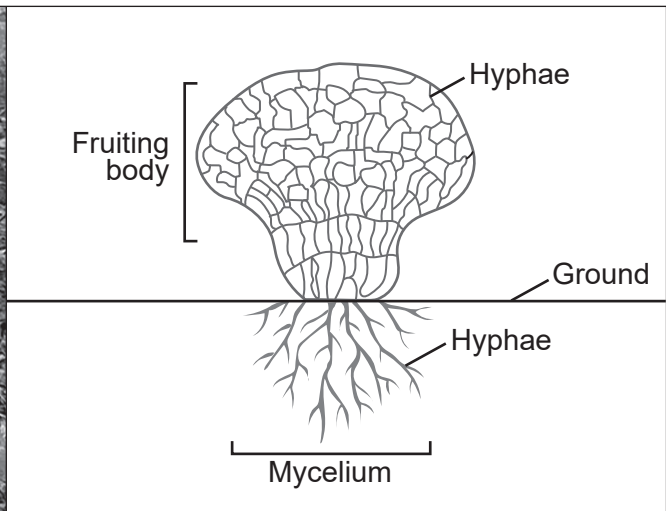
The cells of a puffball are arranged to form a network of strands (hyphae) that serve as the building blocks for all of the puffball's structures. Some strands grow into the soil and then branch to form an underground mass known as mycelium. The mycelium releases chemicals that break down dead organisms and then it absorbs the resulting nutrients.

The image and model below show some information about puffballs.

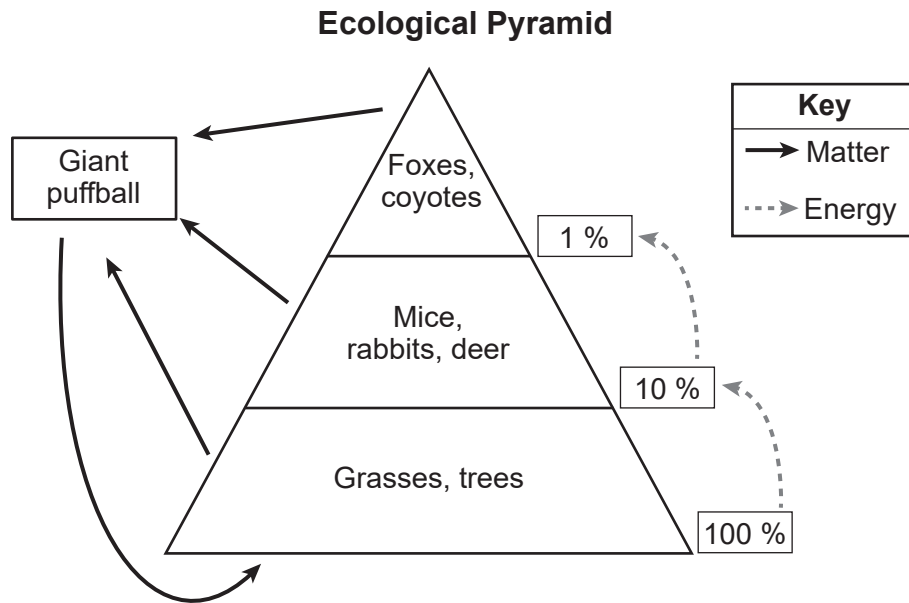
Mature Giant Puffball



Puffball Structure



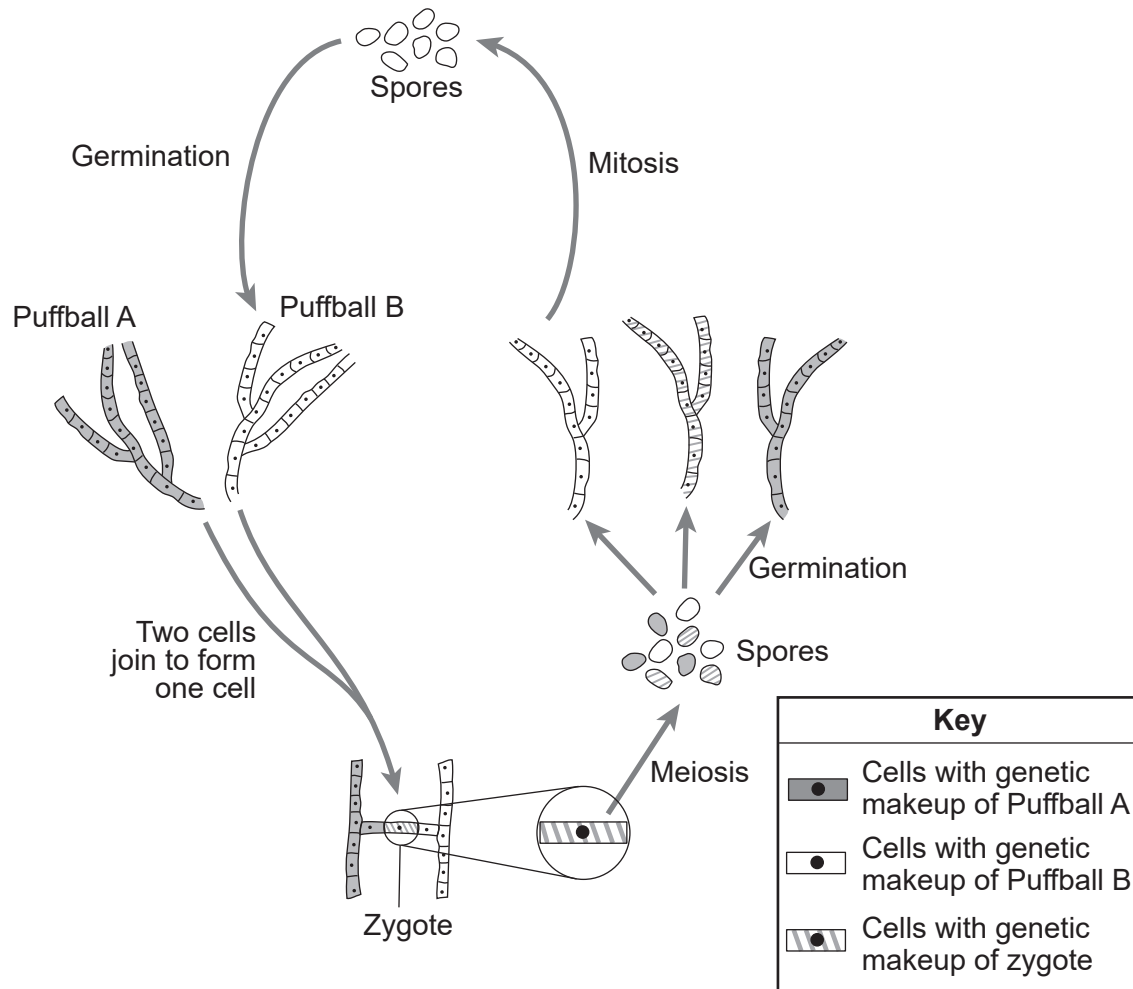
The giant puffball fungus plays an important role in ecosystems. The pyramid diagram below shows the transfer of energy and matter between different trophic levels found in New York State.



- 13** Which claim explains the processes involved in the flow of energy to the giant puffball?
- (1) The giant puffball takes in energy during the process of photosynthesis and converts it into a useable form.
 - (2) The giant puffball can only consume other fungi that are present within the ecosystem to obtain their energy through cellular respiration.
 - (3) The giant puffball obtains energy by using the molecules present from the bodies of organisms to carry out cellular respiration.
 - (4) The giant puffball obtains energy from all levels within the ecosystem as these organisms perform photosynthesis.

Using either mitosis or meiosis, fruiting bodies of puffballs produce and store millions of spores, a type of reproductive cell. When a mature puffball is hit by a raindrop or animal, many spores are released at once in what looks like a puff of smoke. The tiny spores are then spread throughout the area by the wind. The model below shows types of reproduction possible in puffballs.

Reproduction in Puffball Fruiting Bodies



14 Which statement best identifies one result of the process of cellular division in the giant puffball?

- (1) Mitosis produced cells that contain the combined DNA from two different cells of the fruiting body.
- (2) Spores formed from mitosis were genetically identical to the fruiting body cell that produced them.
- (3) Mitosis and meiosis were used by the cells of the fruiting body to produce genetically identical cells.
- (4) Alternating between mitosis and meiosis prevented the occurrence of harmful mutations in spores.

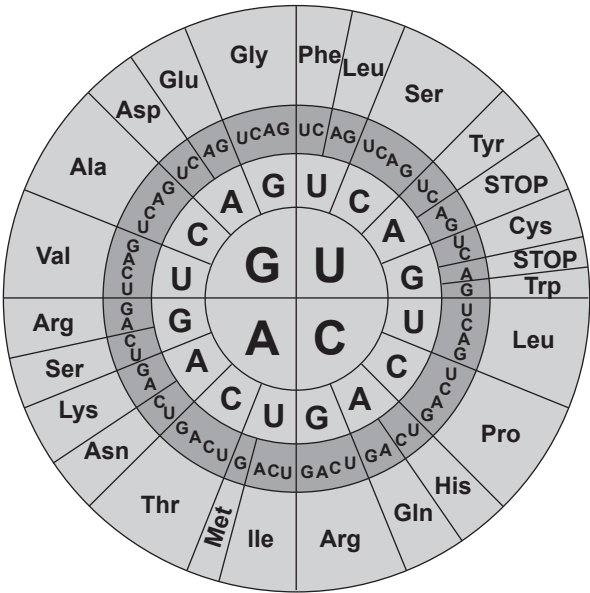
15 Using the evidence provided, defend the claim that a mutation in the giant puffball's DNA could result in inheritable genetic variations. [1]

Scientists designed an experiment to study the regulation of cell division in two types of cells in a fungus. They compared the DNA within Type I cells to the DNA in Type II cells that made up a fruiting body in order to determine if cell division was regulated in the same way in both cell types. The results are summarized below, and a Universal Codon Chart is provided.

Research Results

Cell Type	DNA Sequence of Gene Needed for Cell Division	Able to Regulate Cell Division
I	TAC CCC GTC TGG GTG	Yes
II	TAC CCG GTT TGG GTG	Yes

Universal Codon Chart



16 Based upon the results, the scientists stated that mutations must have occurred to one of the genes that is needed for cell division. Which statement describes the evidence that would support the explanation that the gene mutation has *no* harmful effects on the regulation of cell division in the fungus?

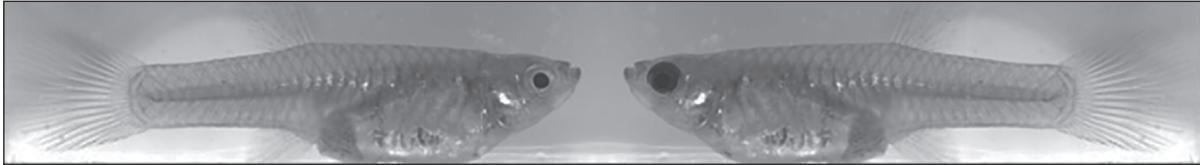
- (1) Type I and II cells have the same number of genetic codes, so each will produce the number of amino acids required to produce proteins that will regulate the process of cell division.
- (2) There are differences in the DNA sequences of Type I and II cells, but they do not change the amino acid that is coded for. The proteins needed to regulate cell division will function correctly in both.
- (3) The changes in the gene sequences of Type I and II cells result in different RNA base sequences. One of the resulting proteins will regulate cell division, the other will not function properly.
- (4) All amino acids have at least four base sequences that code for them, so changing the code rarely interferes with the ability of the resulting protein to regulate cell division in Type I and II cells.

Base your answers to questions 17 through 21 on the information below and on your knowledge of Life Science: Biology.

Colorful Guppies

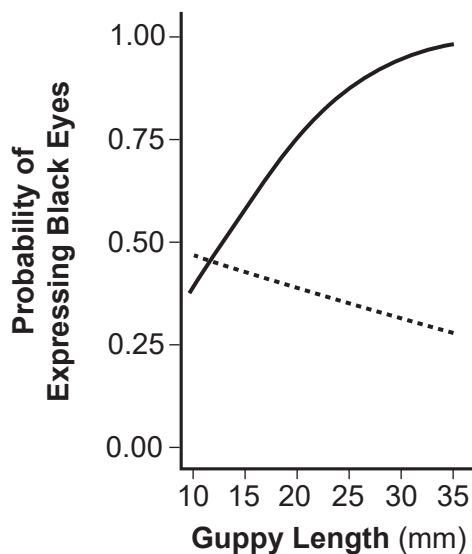
Trinidadian guppies are small freshwater fish that live in pools along mountain streams on the island of Trinidad. The color of their eyes changes from silver to black under certain conditions. Some characteristics of guppies are shown below.

Guppy Eye Color

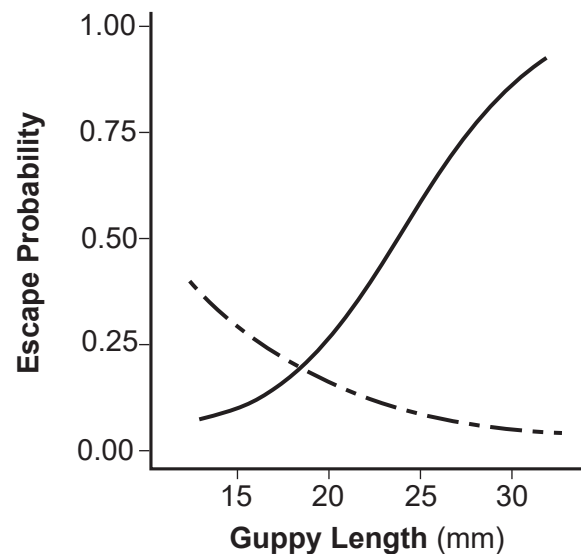


Biologists investigated whether the cause of the differences in eye color seen in the guppies could be related to the presence of predators in their pool. They placed guppies in a tank and exposed them to predators. Their ability to escape predation based on their size and eye color was determined. Some of the researchers' data are included below.

Effect of Predation on Guppies



Key	
—	High predation
.....	Low predation

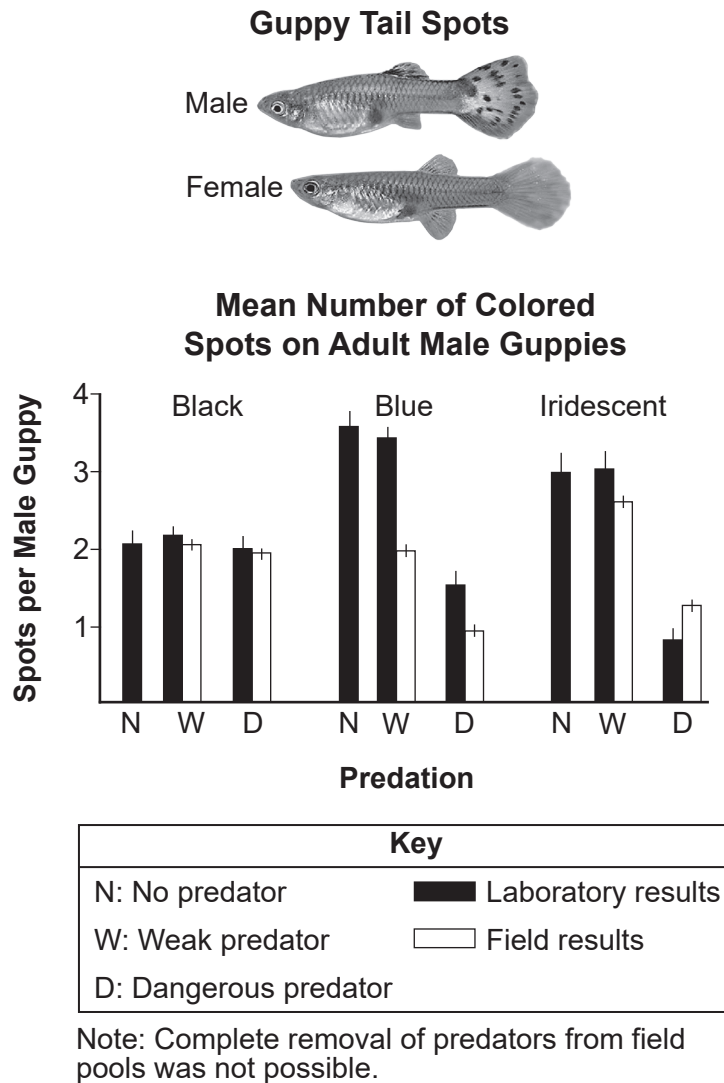


Key	
—	Black eye
- -	Silver eye

- 17** Which question could a scientist ask to clarify the role of DNA in the variation of the ability to change eye color observed in the guppies over several generations?
- (1) Why do guppies with silver eyes have less DNA than guppies with black eyes when they reach adulthood?
 - (2) How does the mutation within the eye color protein affect the expression of the silver eye trait?
 - (3) How does the amino acid sequence of the DNA from the black-eyed guppies compare to the sequence from silver-eyed guppies of previous generations?
 - (4) Why does the presence of predators cause an increase in the function of non-coding DNA sequences that regulate eye color genes over generations?
- 18** Use evidence to construct an explanation for how natural selection resulted in the ability of guppies to change eye color when predators are present in their environment. [1]

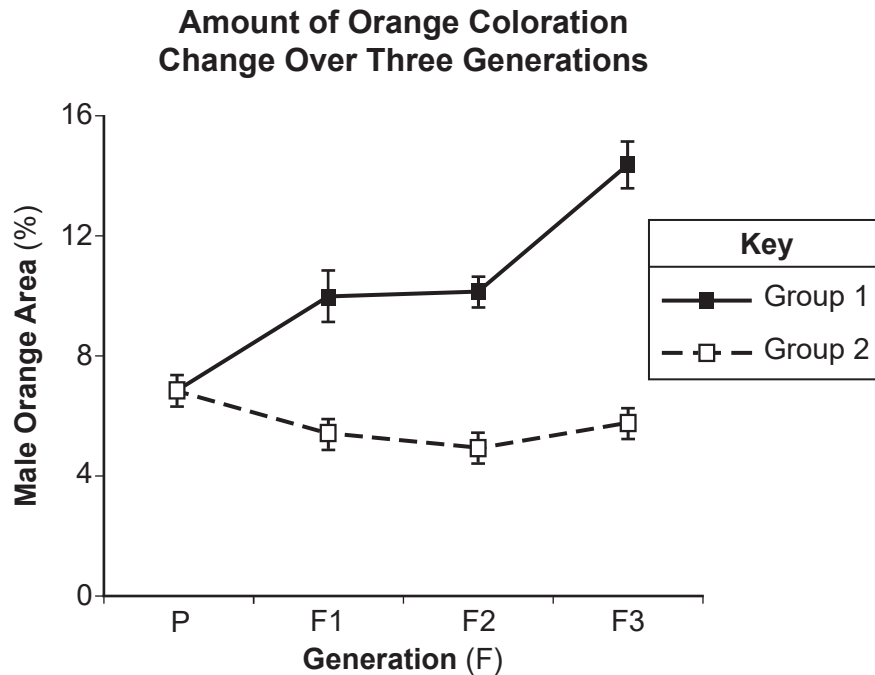
Adult male guppies exhibit great variation in their number and color of spots. Female guppies do not have spots at all. In Trinidad, researchers transferred some guppies from pools in their native environment (field pools) to laboratory pools with either dangerous predators, weak predators, or no predators. After two years and multiple generations of guppies, the researchers recorded the number and color of spots on each male guppy from each pool.

The data below show the results of both the laboratory and field investigations.



- 19 Use the data provided to describe the expected trend in the iridescent-spot trait in the laboratory and field pools if the dangerous predators were removed and the experiment was conducted for an additional two years. [1]

Mate preference in female guppies may be related to the color of the male. Researchers in Japan divided male guppies into two groups. To group 1, they added females who had shown a preference for males with orange colors. To group 2, they added females who had not shown any preference for orange coloration in males. They allowed each group of guppies to breed for multiple generations and calculated the percent of the body covered by orange coloration on males in each generation. The results of their study are shown in the graph below.



- 20** Which evidence supports the explanation that evolution is the result of an inheritable genetic factor?
- (1) Predators are better able to see guppies with orange coloration, which reduces the guppy's chances of survival.
 - (2) The guppies with orange coloration were more likely to produce orange-colored offspring.
 - (3) Females who do not show a preference for orange coloration in males often have offspring with orange coloration.
 - (4) The parents of guppies in Group 1 produced offspring with lower orange coloration than the parents of the guppies in Group 2.

- 21** Using the mathematical representation provided, how does female preference affect the frequency of the orange color trait in male guppies?
- (1) Females with a high preference for orange color can cause the frequency of orange coloration on male guppies in the population to roughly double within a few generations.
 - (2) Females with a low preference for orange color will cause the frequency of orange coloration on male guppies in the population to decrease by more than half within a few generations.
 - (3) Females with low or high preference for orange color in males will cause the frequency of orange coloration on males in the population to remain constant over time.
 - (4) Females with high preference for males with an orange color are less likely to reproduce, reducing the frequency of orange coloration on male guppies in the population.

Base your answers to questions 22 through 25 on the information below and on your knowledge of Life Science: Biology.

A Tale of Two Squirrels

The photographs below show the Kaibab and Abert's squirrels, two forms of the tassel-eared squirrels that live in ponderosa pine forests of the southwestern United States. It is believed that the two different squirrel populations evolved from the same population, which more closely resembled the Abert's squirrel. Scientists believe that about 10,000 years ago, geologic changes and melting ice sheets formed a canyon and river that act as barriers between the two populations.

Some information about these squirrels is shown below.

Kaibab Squirrel



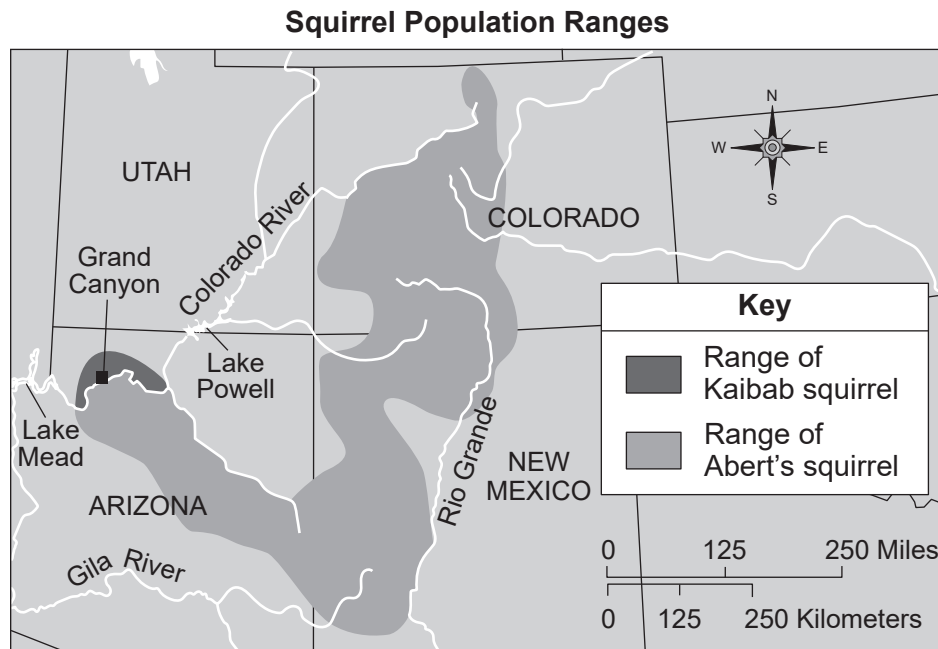
Abert's Squirrel



Comparison of Kaibab vs. Abert's Squirrel Populations

	Kaibab Squirrel	Abert's Squirrel
Physical Characteristics	• Light gray fur • Dark belly • White tail • Slightly smaller	• Light gray fur with dark stripe down their back • White belly • Darker tail • Slightly larger
Climate – relative to each area	• Higher elevation • Higher precipitation, often in the form of snow • Cooler temperature	• Lower elevation • Lower precipitation • Warmer temperature

The map below shows the range of the two squirrel populations.

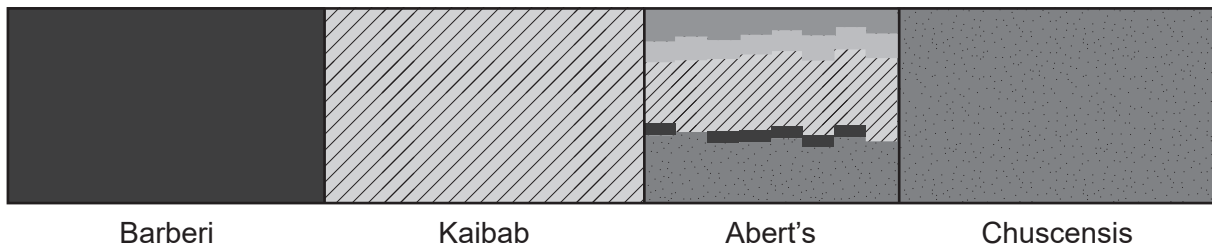


22 Which explanation best supports the claim that differing environmental conditions caused a change in the characteristics of the two populations over time?

- (1) Squirrels living in cooler temperatures evolved to have darker tails for heat absorption.
- (2) The two squirrel populations now live in separate locations that favor a different belly fur color.
- (3) Abert's and Kaibab squirrel populations live at the same elevation, resulting in the same body size.
- (4) Increased snowfall allowed the white-bellied Abert's squirrels to blend in and survive at a higher rate than the dark-bellied Kaibab squirrels.

Scientists claim that Kaibab squirrels are currently classified as a subspecies of the Abert's squirrel, not a separate species. The bar plots below represent gene clusters in four squirrel populations that live in the ponderosa pine region.

Gene Patterns Among Four Squirrel Populations



- 23** Describe the scientific information that is supported by evidence that the Abert's squirrel and Kaibab squirrel share a common ancestry. [1]

- 24** A claim was made that the Kaibab squirrel population is in danger of extinction due to environmental conditions. Which statement could be used to explain how the evidence provided supports this claim?

- (1) The limited range of the Kaibab squirrel can only support a small population, causing low genetic variability and increasing the chance of extinction.
- (2) The environmental conditions are the same so the greater genetic variation of the Abert's squirrel would allow it to outcompete and eliminate the Kaibab squirrel.
- (3) The environment will cause mutations that will result in beneficial traits in both squirrel species, allowing them to eventually interbreed and have more gene clusters in common.
- (4) The small range of the Kaibab squirrel will remain unchanged, decreasing the chance that new, harmful genetic combinations will occur.

The Kaibab squirrel population size has fluctuated dramatically over the years. Their numbers have declined due to human activities. This trend has become a concern to the park staff of the Grand Canyon. Park staff, along with the United States Forest Service and the state of Arizona, have cooperatively agreed to protect the Kaibab squirrel and its habitat. They are seeking solutions to protect the Kaibab squirrel in their environment and avoid possible extinction.

- 25** Place **one** check mark (✓) in the boxes in **each** of the three columns to indicate **one** human activity, **one** matching solution, and **one** refinement for that solution that would **reduce** the impact of the chosen human activities on the environment of the Kaibab squirrel. [1]

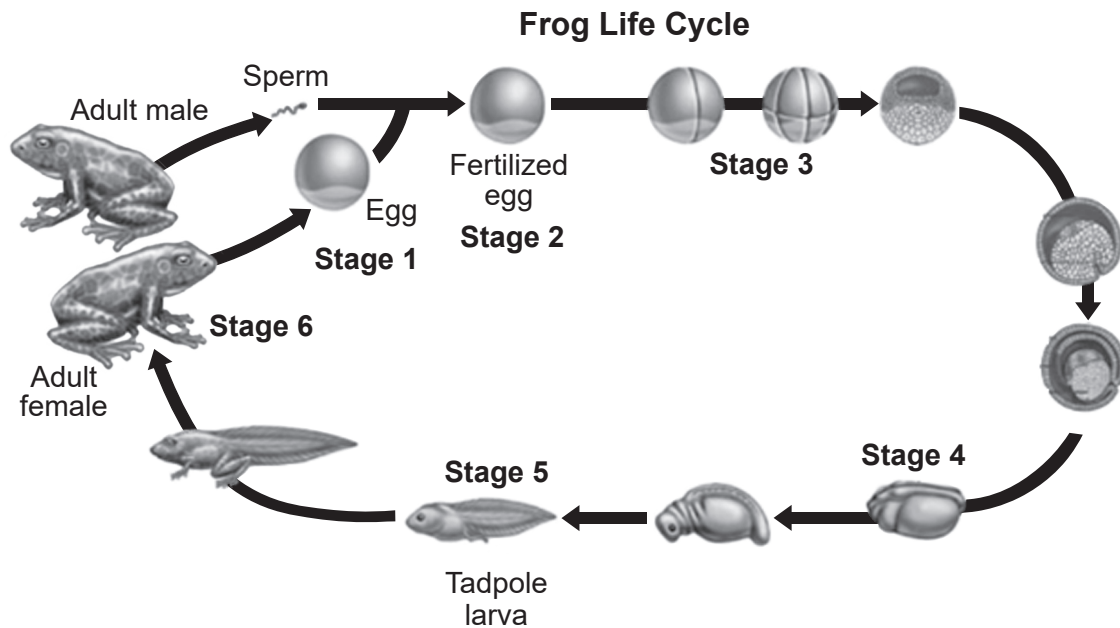
Human Activity	Possible Solution	Refinement
☐ Fires	☐ Designate a preserved area for squirrel habitat and breeding	☐ Charge for permits, which would raise money for park preservation
☐ Deer hunting	☐ Have a schedule that allows for environmental recovery	☐ Use volunteers instead of park staff to keep maintenance cost down
☐ Habitat fragmentation due to human presence	☐ Annual permits that individuals must apply for	☐ Construct wildlife corridors that are safe for squirrels to travel
☐ Logging for profit	☐ Remove leaf litter and dead tree branches	☐ Require replanting of trees

Base your answers to questions 26 through 29 on the information below and on your knowledge of Life Science: Biology.

Frog Development

Frogs are amphibians that undergo a developmental transformation called metamorphosis. There are many processes that need to occur for one cell to become a full-grown frog, capable of jumping large distances. The cells of the amphibian body undergo processes to complete the transformation from aquatic tadpole to terrestrial adult frog.

The model below shows some information about frogs.



- 26** Which process occurs between stage 3 and stage 4 that allows the mass of cells to become a complex organism?
- (1) The process of fertilization occurs, which allows for variation in the cells since they will get half of their information from each parent.
 - (2) The process of mitosis occurs, which allows the number of cells to increase and ensures that each body cell has the same function.
 - (3) The process of differentiation occurs, which enables cells to take on specific tasks within the developing organism.
 - (4) The process of replication occurs, which requires cells to correctly copy the DNA so the cells can increase their genetic information.

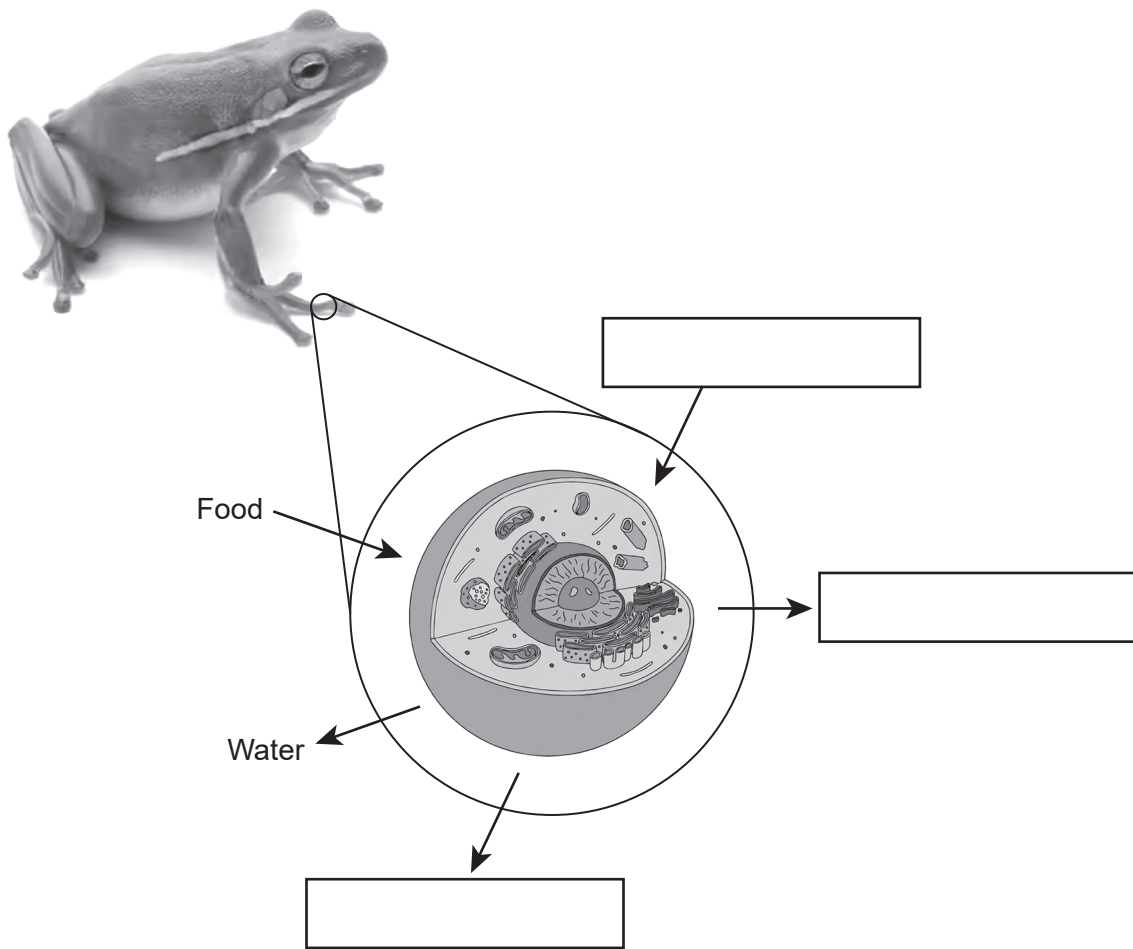
27 Which stage in the model provides evidence to support the claim that inheritable genetic variations result from meiosis?

- (1) In stage 1, unique egg and sperm are formed by the parents, so when they join together, new combinations are formed.
- (2) In stage 4, the variation in cells that began to appear in the process during stage 3 caused the differences.
- (3) After stage 3, a hollow ball forms that starts to signal that different cells in various locations will take on different roles.
- (4) In stage 5, some cells have formed and then disappeared, so the variation must have caused these changes to occur.

28 As the frog grows, structural changes occur, as shown by stages 4 through 6 in the model. Which statement best explains why this process might be occurring?

- (1) Adult frogs without tails were adapted to their environment, and this adaptation allowed for reproductive success.
- (2) Tadpoles with tails were less successful at avoiding predators, so their tails disappeared.
- (3) Adult frogs who kept their tails were able to jump more quickly, so they were more likely to survive.
- (4) Tadpoles with shorter tails could not swim at all in water, and they all died before they could successfully reproduce.

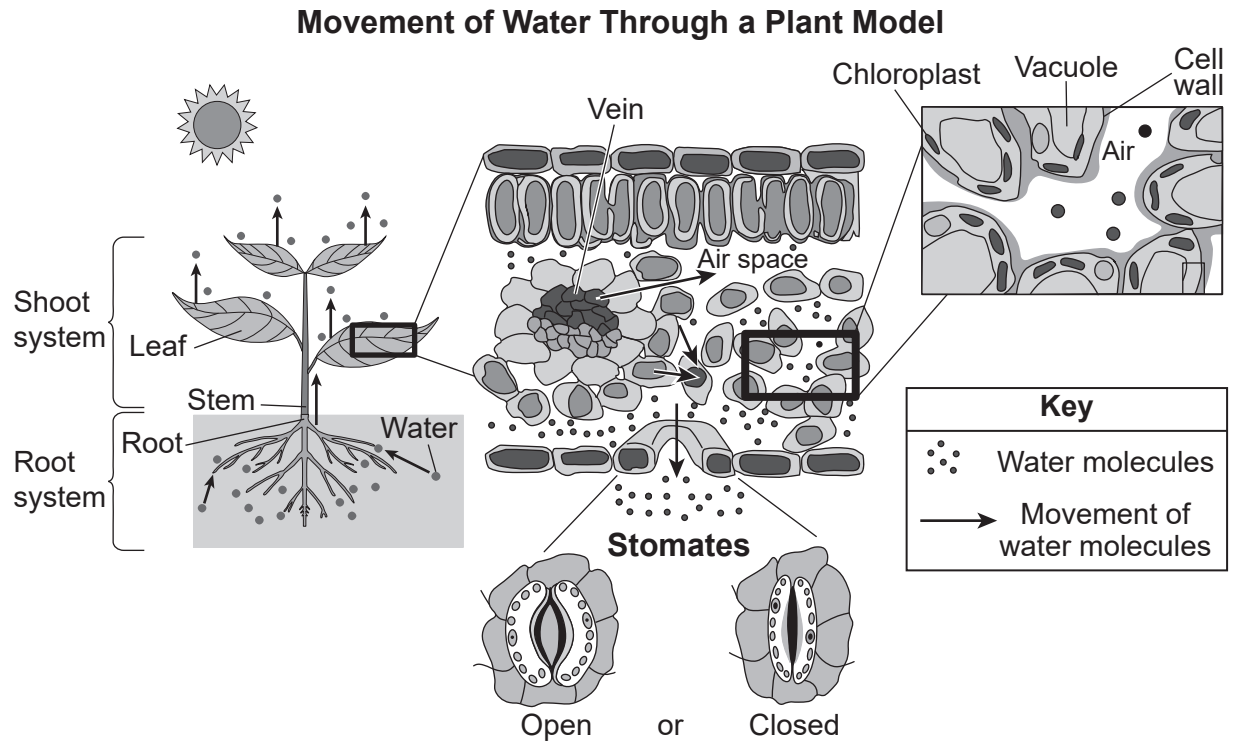
- 29 Complete the model to illustrate the inputs *and* outputs of cellular respiration in the cell of the frog. [1]



Base your answers to questions 30 through 34 on the information below and on your knowledge of Life Science: Biology.

Homeostasis in Plants

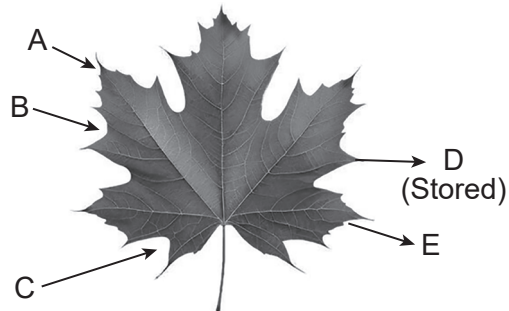
Plants use feedback mechanisms that require the cycling of matter and flow of energy within the organism to stay alive. The model below shows some information about water transport pathways within a leaf.



- 30** Which statement best describes how the root system and shoot system interact to transport water in a plant?
- (1) Closed stomates in the root system transport water to the vacuoles, which will be used in cells by the shoot system.
 - (2) Open stomates in the shoot system take in water, which is transported through the veins to the root system.
 - (3) The shoot system absorbs water, which is transported in veins to the root system and cells that contain chloroplasts.
 - (4) The root system absorbs water, which is transported to the shoot system in veins that deliver water to cells that contain chloroplasts.

Metabolic processes are responsible for maintaining homeostasis in plants. The model below shows some information about a process that results in substance D being stored in leaves.

**Model of Inputs and Outputs
of a Process in Leaves**



- 31 Using the model of the leaf, which row best identifies the inputs and outputs of matter and energy?

Row	Inputs of Matter	Outputs of Matter	Energy
(1)	A: glucose B: oxygen	C: carbon dioxide D: water	E: ATP
(2)	B: carbon dioxide C: water	D: glucose E: oxygen	A: sunlight
(3)	A: water B: carbon dioxide	D: oxygen E: glucose	C: sunlight
(4)	B: oxygen C: glucose	D: carbon dioxide E: water	A: ATP

Students investigated the ability of maple leaves to regulate temperature. Leaves detached from a living tree and leaves that remained attached were exposed to direct sunlight in a surrounding air temperature of 30.5°C. The table below shows some data collected.

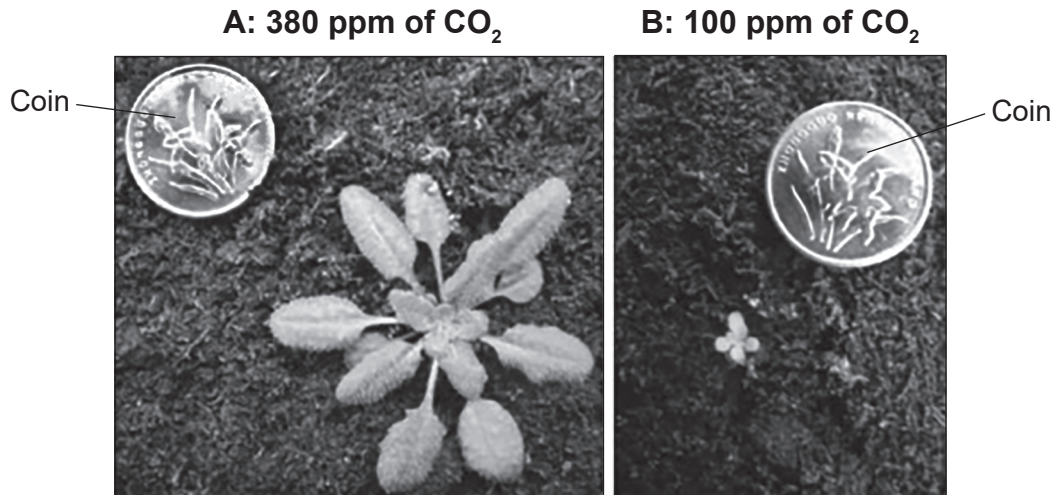
Results of Maple Leaf Investigation

Sample	Temperature of Attached Leaves (°C)		Temperature of Detached Leaves (°C)	
	Initial	Final	Initial	Final
1	31.6	32.2	32.2	39.4
2	32.2	32.7	31.6	38.3
3	31.6	31.6	32.7	38.9
4	32.7	32.2	32.7	37.2
5	33.3	32.7	31.6	40.0
Average	32.3	32.3	32.2	38.8

- 32** Describe the evidence that supports the claim that a feedback mechanism regulates temperature in attached maple leaves but **not** in detached maple leaves. [1]

Students conducted another controlled investigation to determine how plant growth is affected by the availability of CO_2 , which is normally at 380 parts per million (ppm) in the atmosphere. Thale cress, a plant in the mustard family, was exposed to different amounts of CO_2 in two sealed chambers and then compared to a coin for size reference.

The images below show some information about thale cress in each chamber after four weeks of growth.

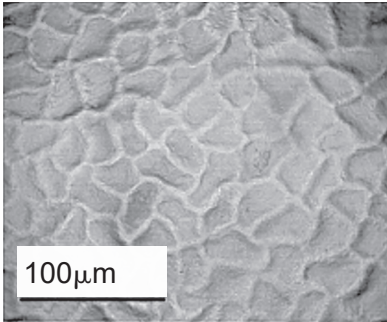
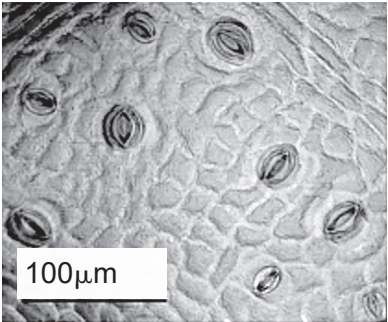


33 Which explanation describes how life processes result in the flow of energy and cycling of matter seen in the results of the investigation?

- (1) Plant growth in the chamber with 100 ppm of CO_2 was limited by a chemical input required for photosynthesis.
- (2) Plant growth in the chamber with 100 ppm of CO_2 was limited by a chemical input required for cellular respiration.
- (3) Plant growth in the chamber with 380 ppm of CO_2 was supported by a greater energy input required for photosynthesis.
- (4) Plant growth in the chamber with 380 ppm of CO_2 was supported by a greater energy input required for cellular respiration.

Scientists investigated the number of stomates on the lower surface of two types of cottonwood trees. Although these trees are found in different regions, they are both exposed to similar atmospheric CO₂ conditions. The table below shows some information about cottonwood trees and the environmental conditions in which they grow.

Stomates in Cottonwood Trees

Tree Name	Black Cottonwood	Eastern Cottonwood
Location	Western North America	Eastern North America
Leaf Shape		
Magnified Image of Lower Leaf Epidermis		
Environmental Conditions	• summer temperature range of 15-24°C • high annual precipitation • full sunlight to partial shade • elevation of sea level to mountains	• summer temperature range of 24-30°C • moderate annual precipitation • full sunlight • lowland areas near rivers

- 34** Write a research question for an investigation about the role stomates play in feedback mechanisms that maintain homeostasis in cottonwood trees. The question must include *both* an independent and dependent variable and be testable. Then, identify **two** factors that would need to be kept constant during this investigation. [1]

Research question: _____

Factor 1: _____

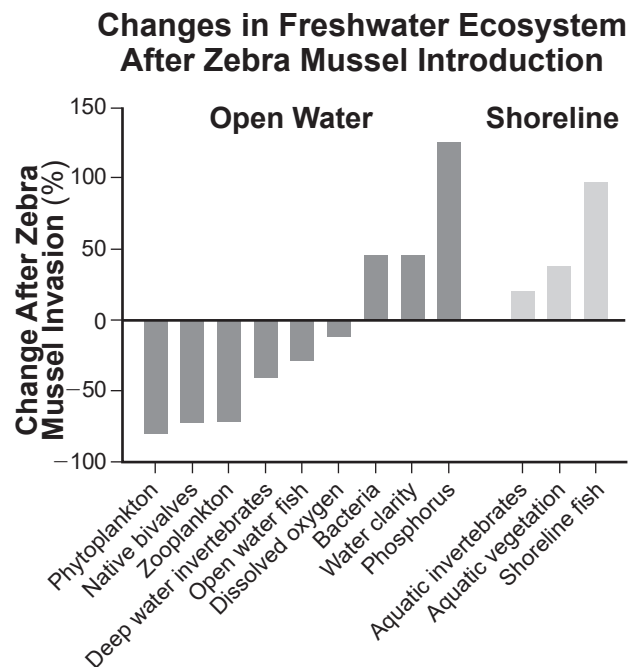
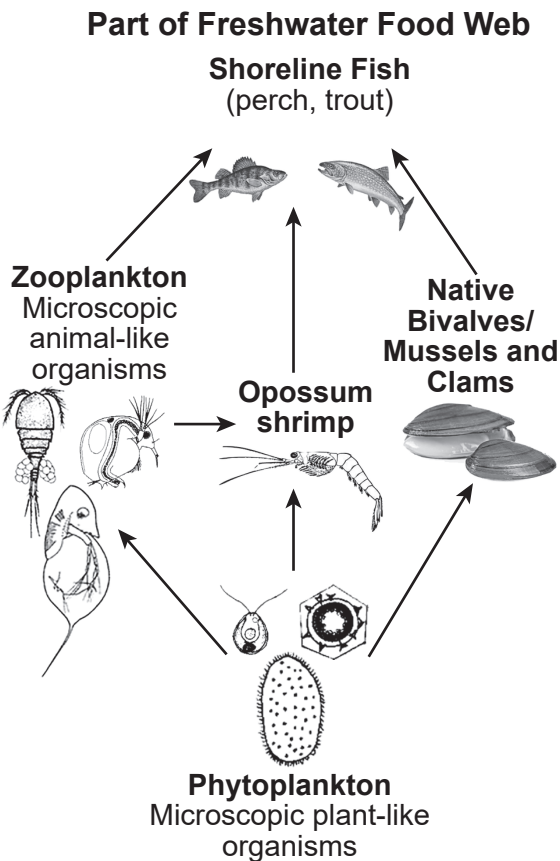
Factor 2: _____

Base your answers to questions 35 through 39 on the information below and on your knowledge of Life Science: Biology.

Invasive Mussels

The disruption of ecosystems by invasive species, such as the zebra mussel, is a growing problem. Zebra mussels are filter feeders that eat microscopic organisms and organic matter floating in the water. They are native to some waterways of eastern Europe and western Asia. Zebra mussels were first discovered in the United States in 1988 when they were found in Lake St. Clair, part of the Great Lakes system.

The information below summarizes some biotic and abiotic factors and how these factors changed after the introduction of zebra mussels into a freshwater ecosystem.

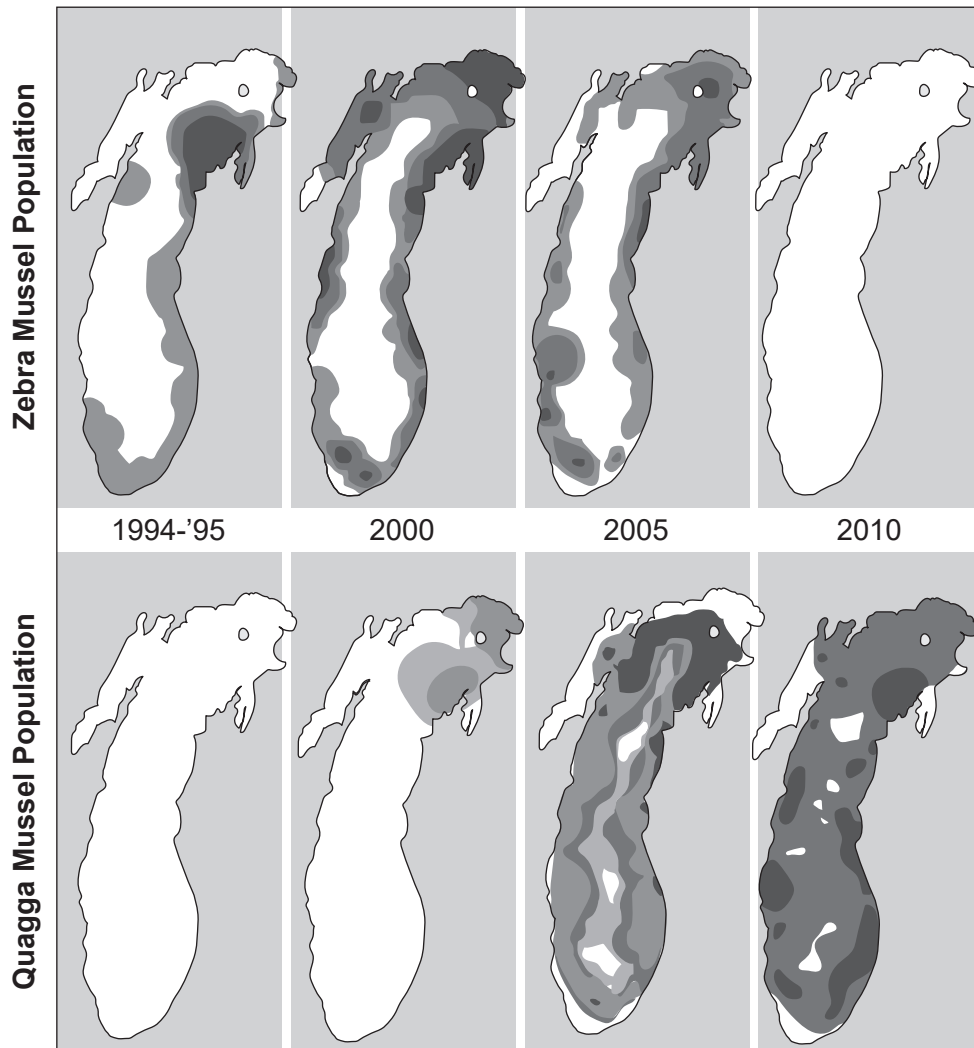


35 Which response correctly uses a mathematical representation to support the explanation that the introduction of zebra mussels caused the change in population of the trout?

- (1) The dissolved oxygen in the lake decreased more than 50% after the introduction of the zebra mussels, increasing the bacteria that prey upon the trout.
- (2) The water clarity of the lake increased by about 80%, allowing more sunlight to reach the aquatic vegetation, increasing the food available for the trout.
- (3) The trout eat opossum shrimp, a type of aquatic invertebrate that increased by about 25% after the introduction of zebra mussels, increasing the trout population.
- (4) The number of native bivalves decreased by about 75%, which decreased competition for food among the trout, decreasing the trout population as well.

Shortly after zebra mussels were first found in the Great Lakes, quagga mussels (a larger bivalve) were accidentally introduced into Lake Michigan. Researchers studying the lake measured changes in the size (density per square meter) of both populations over several years. Their data are represented in the diagram below.

Changing Mussel Density in Lake Michigan



Key			
Density per Square Meter:			
	10-100		1,000-10,000
	100-1,000		10,000-100,000

36 Based upon the mathematical representation provided, which statement best explains the differences in population density between the quagga and zebra mussels from 1994 to 2010?

- (1) The depth of the water in the middle of Lake Michigan made it possible for the zebra mussels to reach their carrying capacity of 1000 per square meter, and they maintained that population during this time.
- (2) The amount of sunlight at the southern end of Lake Michigan allowed the quagga mussels to effectively carry out photosynthesis and exceed their carrying capacity.
- (3) The quagga mussels were able to limit their own carrying capacity based upon available resources in Lake Michigan during different times of the year, never exceeding 10,000 per square meter.
- (4) The zebra mussels colonized the shallow, rocky areas of Lake Michigan but could not expand their habitat into the deep-water areas because water depth limits their carrying capacity.

37 Place a check mark (✓) in *either* the Valid *or* Not valid box to evaluate the claim that the complex interactions of the zebra and quagga mussels distinctly changed the Lake Michigan ecosystem between 1994 and 2010. Use the evidence provided in your evaluation. [1]

☐

Valid

☐

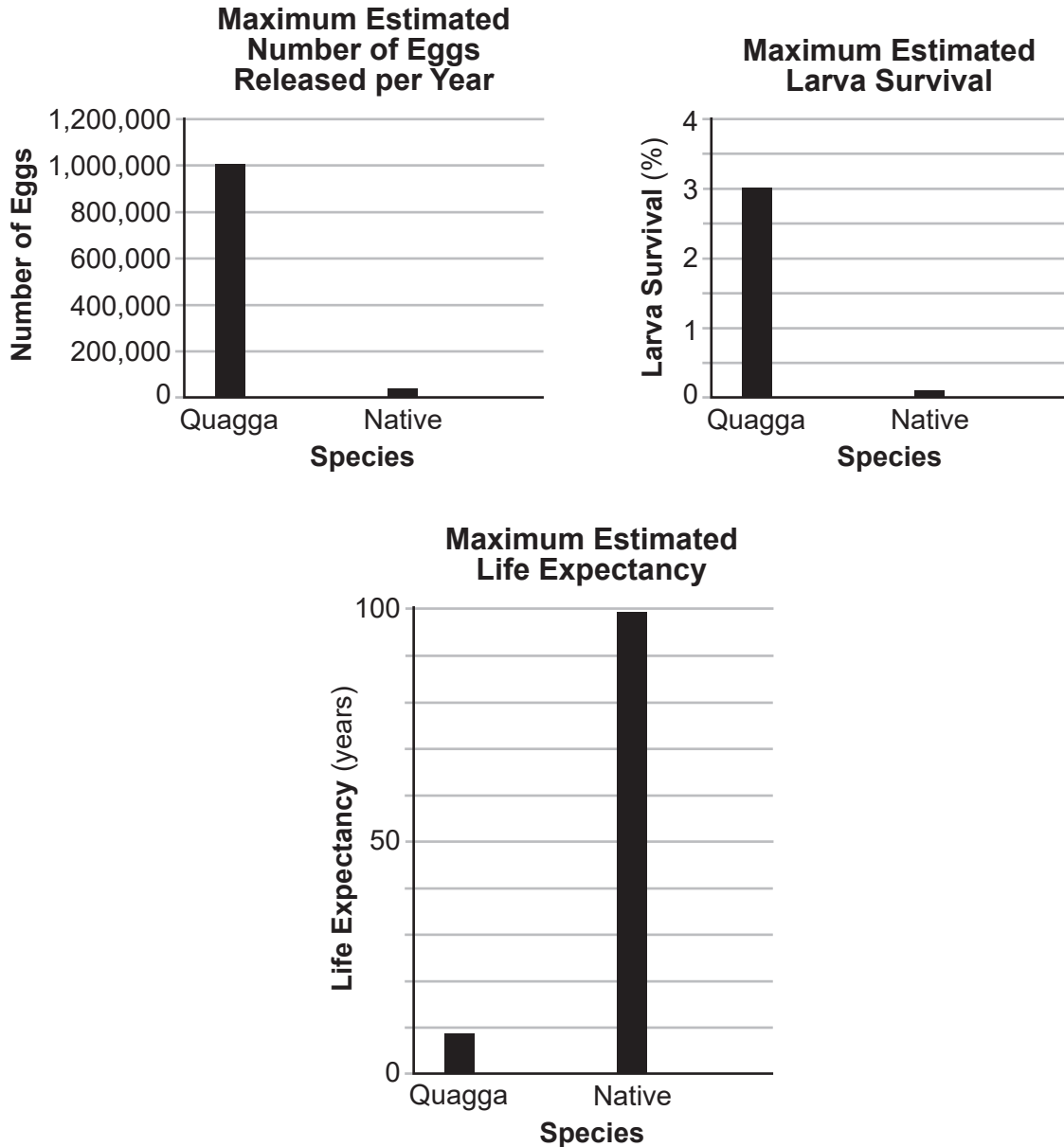
Not valid

Evidence: _____

A female quagga mussel releases eggs into the open water, where fertilization occurs. Larvae develop and drift on the water currents for three to four weeks until they settle into the sediment.

Native mussels also release eggs into the water, where fertilization occurs. The larvae formed attach to the gills of fish, where they obtain nutrients until they are large enough to drop off into the sediment and complete their life cycle.

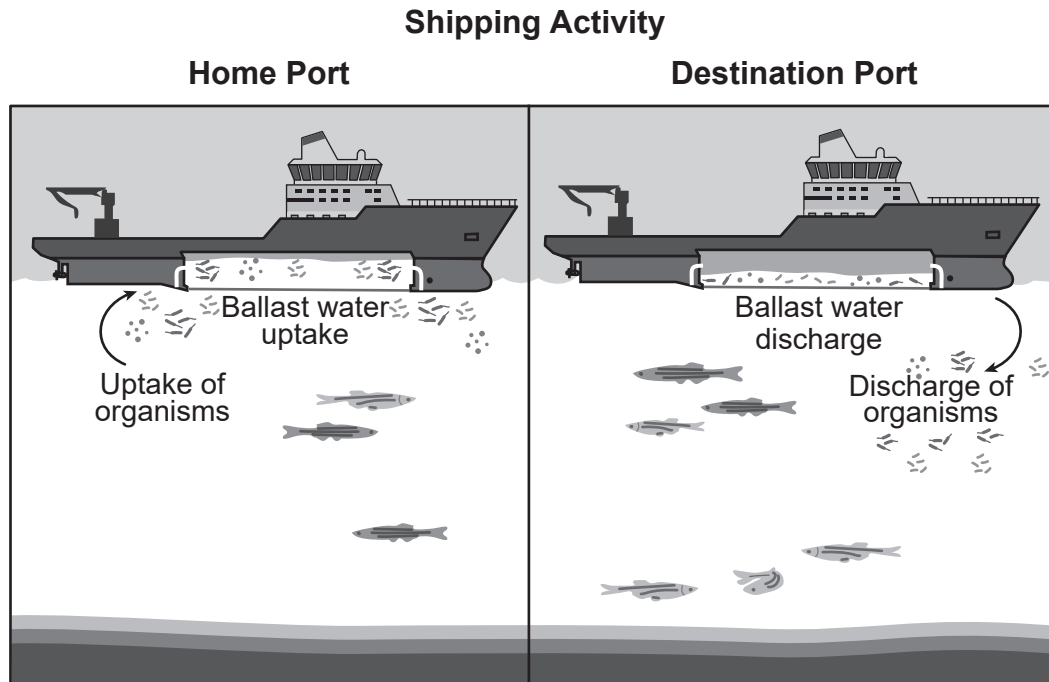
The graphs below compare life cycle data for the two mussel species in a year.



- 38** Researcher A claims that invasive quagga mussels can take over freshwater ecosystems and affect native bivalve populations because their reproductive strategy is more effective than the strategy used by native mussels. Researcher B claims that native mussels will be able to produce more offspring throughout their lifetime. Select *one* researcher's explanation and identify evidence that can be used to support that researcher's claim. [1]

Researcher: _____

The introduction of the quagga and zebra mussels has been linked to the shipping industry. These mussels can attach to the hulls (bottom) of shipping vessels and recreational boats, surviving for 3–5 days out of water. Water (ballast) from the ship's home port is often used to fill tanks within the vessel prior to departure to stabilize the ship. When the ship arrives at its destination it discharges (empties) the ballast water. The diagram below shows the exchange of ballast water.



- 39** Describe a potential solution that could be engineered to solve the problem of ships spreading invasive organisms into aquatic ecosystems in different locations in the world. Be sure to include at least *one* trade-off that would need to be considered in the proposed solution. [1]

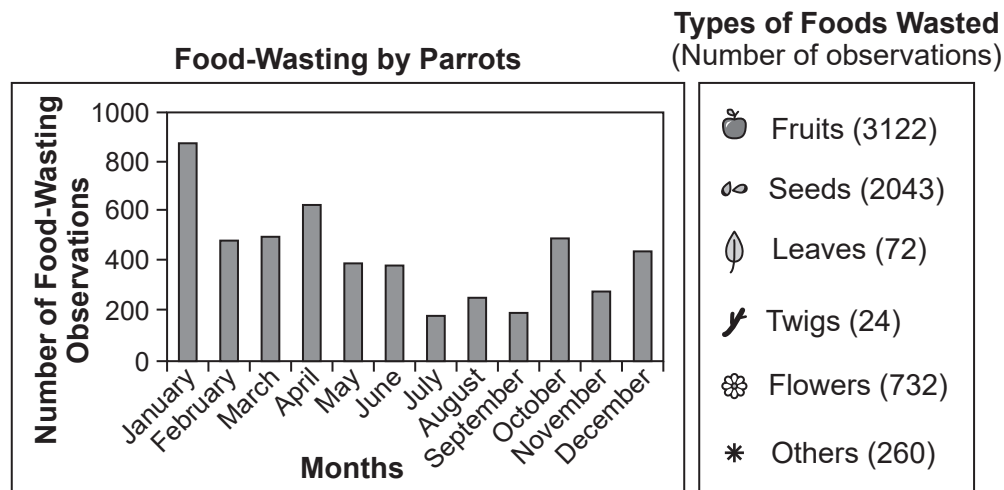
Base your answers to questions 40 through 44 on the information below and on your knowledge of Life Science: Biology.

Parrots and Biodiversity

Parrots are a group of over 400 bird species that live mainly in tropical and subtropical regions of the world. Many parrots live in trees and primarily feed on plant matter. As part of the pet trade, some parrots are removed from their natural habitats and relocated.

Food-wasting is one behavior of parrots that impacts the ecosystem. This occurs when parrots drop food before it is fully consumed. Scientists have studied this behavior and its effects on the ecosystem in areas with high parrot populations.

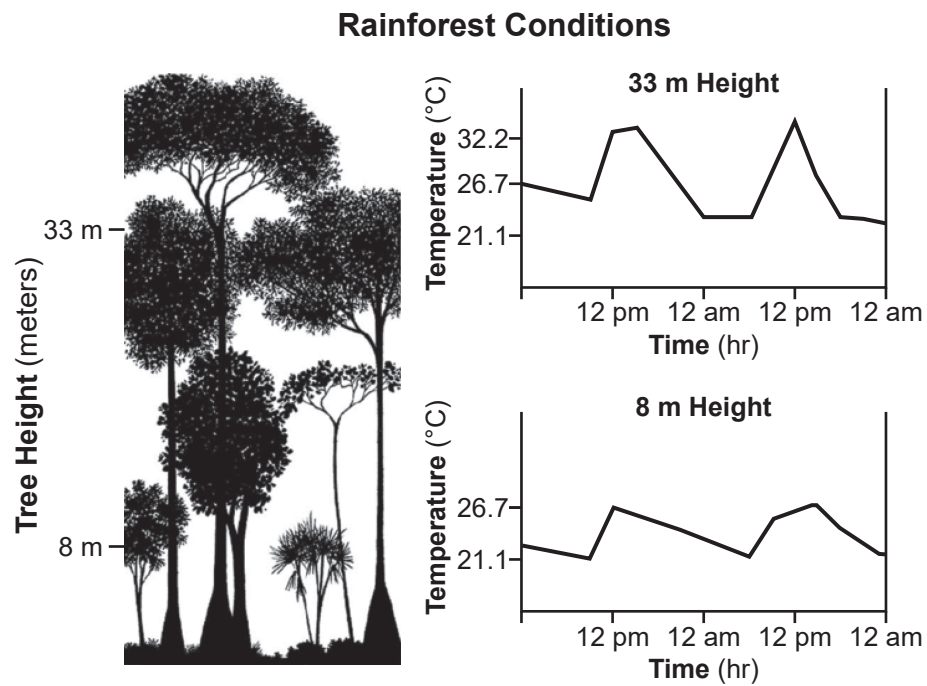
Some information about parrots in their natural habitat is shown below.



- 40 Which evidence-based claim best describes how the complex interactions resulting from the parrot behavior of food-wasting contributes to the survival of other organisms in the ecosystem?
- (1) Food-wasting of leaves and twigs has the least impact, decreasing the amount of food available for other ground-dwelling organisms.
 - (2) Maximum food-wasting occurs in July, August, and September, which makes more food available to other animals in the winter months of the Southern Hemisphere.
 - (3) Food-wasting helps to increase biodiversity due to seed dispersal, which would also provide food for other ground-dwelling organisms.
 - (4) Less food-wasting occurs from January through April, which increases the ability of ground-dwelling organisms to disperse seeds.

Parrots exhibit some other interesting behaviors. At night, the birds flock together in the dense foliage of trees, huddling right next to each other.

The information below shows some environmental data collected over two days at different tree heights.

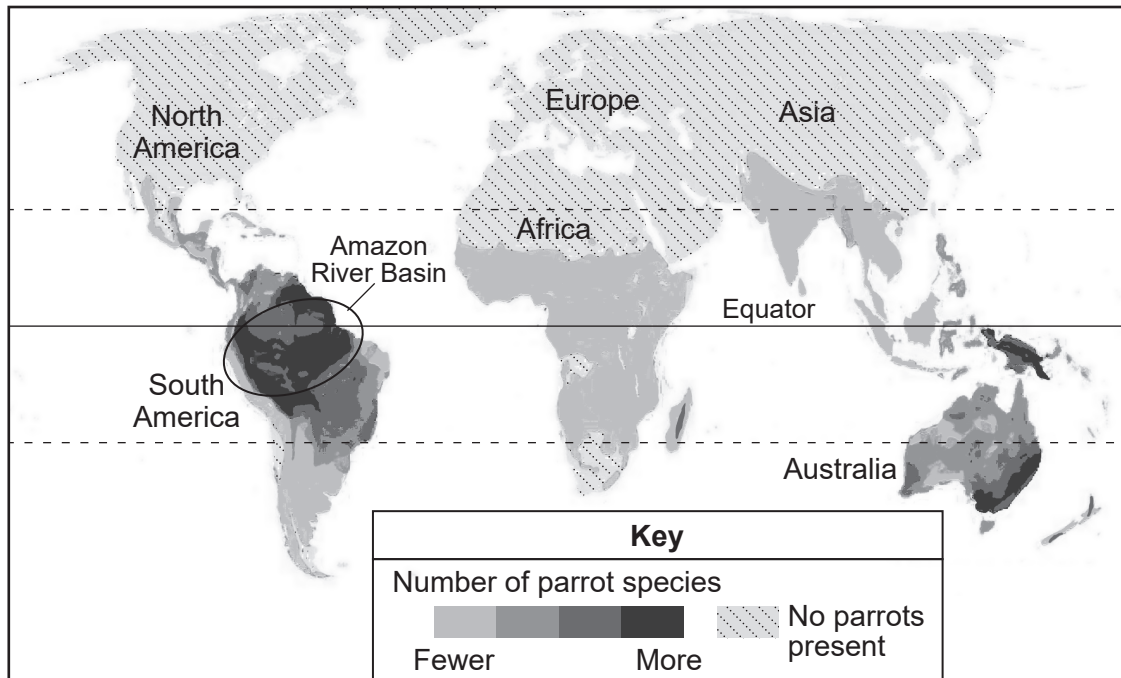


- 41 Based on the evidence, describe how the group behavior of huddling at night increases the parrot species' chances to survive and reproduce. [1]

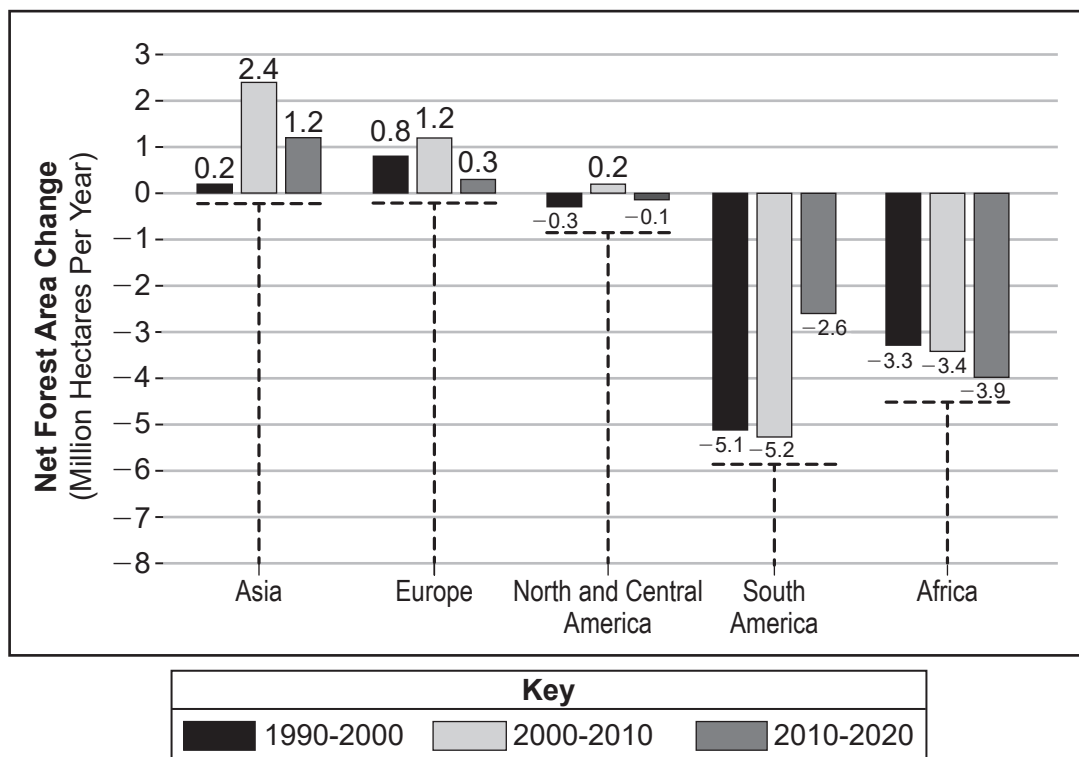
The native habitats of parrots can be found throughout the world. Human behaviors are changing these habitats.

The map and data below show some information about where parrots are found and how their habitat is changing.

Global Parrot Diversity



Net Change in Forest Acres by Region and Decade



42 Using the evidence provided, which explanation best describes how a biotic factor may affect the carrying capacity for parrots?

- (1) The reduction of trees as habitat in Asia will decrease the carrying capacity, and the increase of trees in Africa will decrease the carrying capacity.
- (2) Deforestation in Asia has slowed, therefore fewer trees are being cut down and the carrying capacity increased during the 1990–2020 time period.
- (3) The net loss of trees in North and South America will increase the carrying capacity because many hectares of trees are still available.
- (4) The deforestation occurs in South America at a slower rate during the 2010–2020 time period, resulting in a continued reduction in carrying capacity.

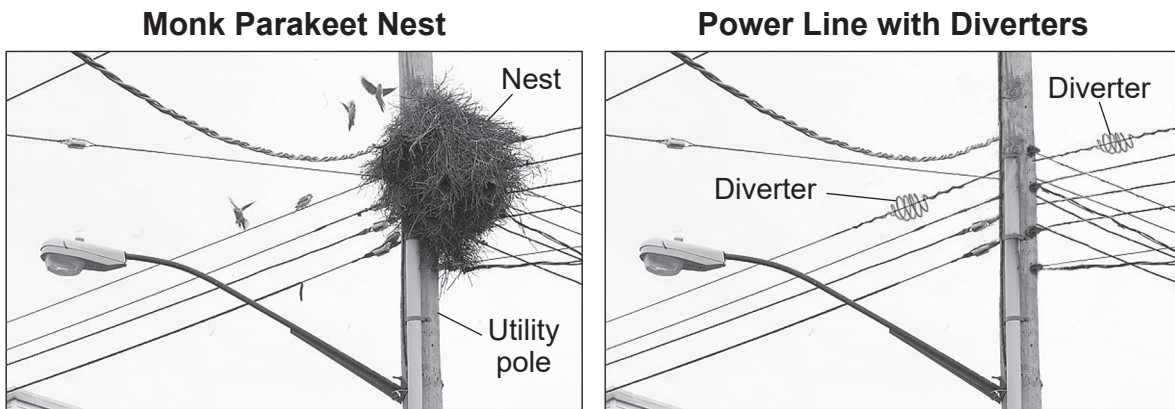
43 Which statement provides evidence that explains how deforestation in a region of South America known as the Amazon River Basin would impact the biodiversity of organisms?

- (1) There are fewer parrot species in the Amazon Basin, so there would be limited impact on biodiversity.
- (2) The even distribution of parrot species in South America would mean that deforestation would not impact biodiversity.
- (3) Loss of habitat in the Amazon Basin would decrease biodiversity when parrot species are displaced.
- (4) There is a greater number of parrot species in the Amazon Basin, so biodiversity may decrease.

Monk parakeets are an invasive parrot species in New York City. One explanation for the parakeets' presence is that owners may have released the birds into the wild. These parakeets build large, multi-family nests on utility poles, making maintenance difficult, and interfere with supplying power to communities. When nests are removed, the parakeets rebuild.

Scientists have studied the nest-building process for monk parakeets to determine a solution to this problem. They observed that monk parakeets must land on the power line first, then walk to where the line meets the pole. Scientists proposed a device to prevent the parakeets from walking the last 30 cm to the pole, which will prevent the building of nests.

The pictures below show the utility pole and the solution (diverter).



- 44 Place **one** check mark (✓) in a box to indicate *one* criterion *or* constraint that should be considered when building diverters to help **reduce** the effect of monk parakeets walking directly to the pole. Describe how this selection is needed to meet societal needs and wants. [1]

Criteria	Constraints
☐ Budget is followed	☐ Budget amount per device
☐ Device keeps birds from building a nest on the wires	☐ Device cannot harm the birds

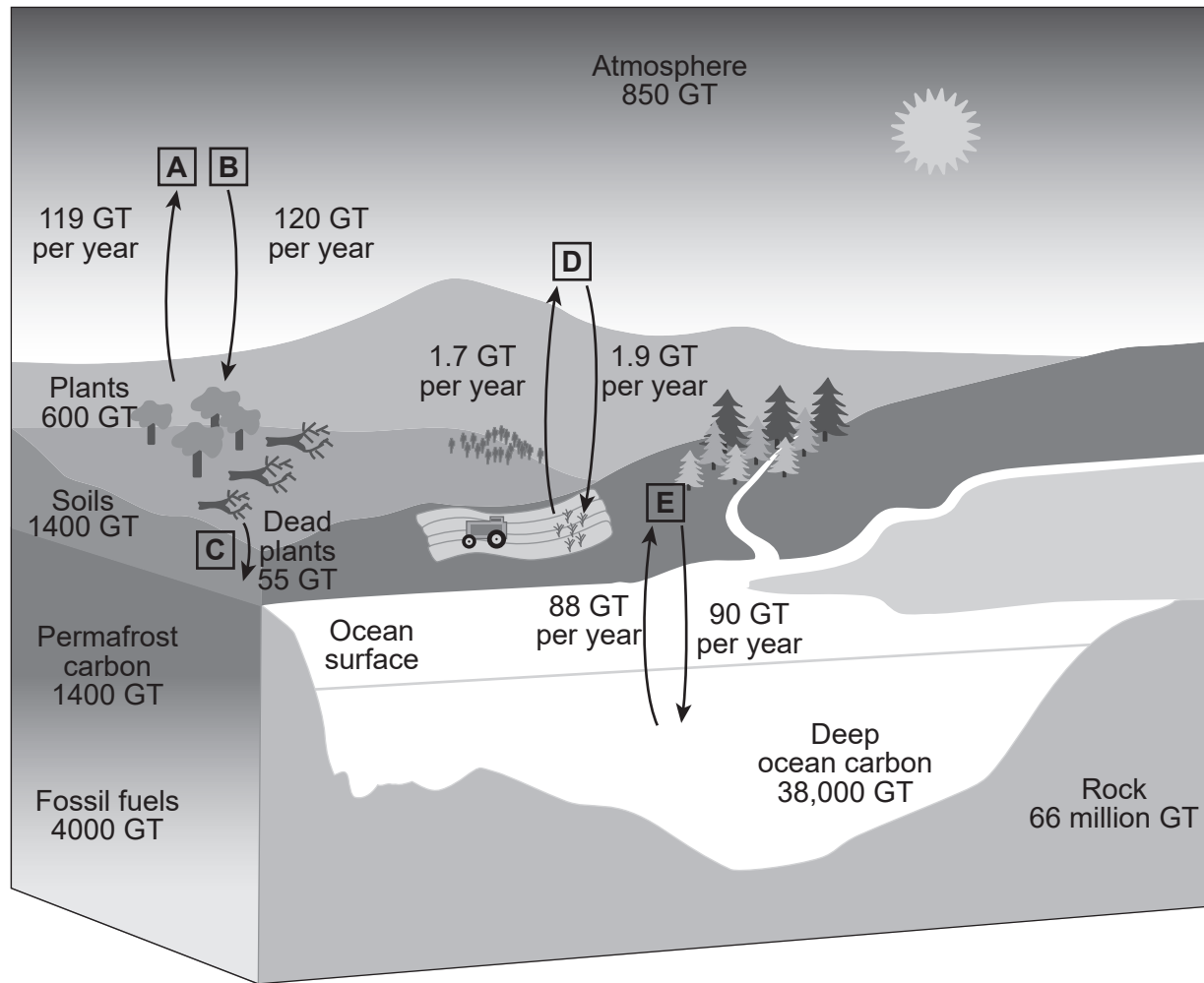
Description: _____

Base your answers to questions 45 through 48 on the information below and on your knowledge of Life Science: Biology.

The Permafrost Problem

Permafrost is a frozen layer of soil that is present in Arctic and sub-Arctic regions. Permafrost is vital to the stability of the Arctic ecosystem because of its ability to store carbon. Scientists have determined that about one-third of the regions with permafrost are now melting. More carbon is being released to the atmosphere in the form of carbon dioxide (CO_2) and methane (CH_4). These gases are measured in gigatons (GT), as shown in the model below.

Processes in the Arctic and Sub-Arctic Regions

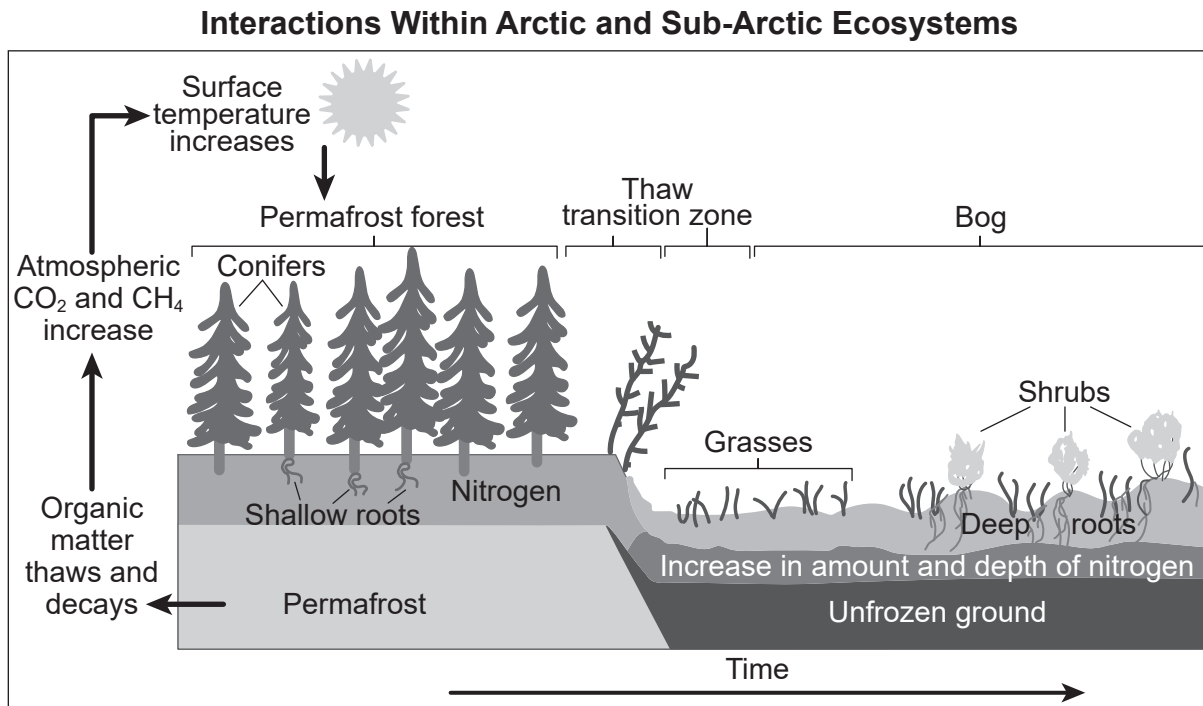


- 45 Which numbered row uses the model to describe the process occurring at the labeled location *and* describes its role in the cycling of carbon between two of Earth's spheres?

Row	Location	Process Name	Moves Carbon From	Moves Carbon To
(1)	A	respiration	biosphere	atmosphere
(2)	B	decomposition	biosphere	geosphere
(3)	C	photosynthesis	geosphere	biosphere
(4)	D	combustion	geosphere	hydrosphere

- 46 Scientists are concerned about the potential environmental impact of melting permafrost in an already fragile ecosystem. Use numerical information from the model to describe how the melting of the permafrost would affect the cycling of carbon between the geosphere *and* the atmosphere. [1]

The cycling of carbon in Arctic and sub-Arctic ecosystems is regulated by feedback mechanisms. The feedback mechanisms are critical as humans face the global challenge of temperature regulation. The model below summarizes some of the interactions that occur in these ecosystems.



47 Which statement includes evidence that supports the argument that melting permafrost is having an impact on feedback mechanisms within this ecosystem?

- (1) Melting permafrost decreases nitrogen availability in permafrost forests, which decreases the growth of trees through a negative feedback mechanism.
- (2) Melting permafrost increases the concentration of CO₂ and CH₄ in the atmosphere, increasing the temperature, which accelerates permafrost melting through a positive feedback mechanism that impacts plants.
- (3) Due to melting permafrost, plants will absorb more CO₂, adding it back to the soil, which maintains the amount of permafrost in the ecosystem through a positive feedback mechanism.
- (4) Due to melting permafrost, organic matter decays at a higher rate, which decreases the availability of nitrogen to bog plants through a negative feedback mechanism.

- 48 Which statement uses information from both models to describe quantitative criteria that must be met by the solution of global reforestation in order to maintain the permafrost in affected areas?
- (1) The reforestation solution must maintain atmospheric carbon levels below 850 GT in the Arctic for the surface temperature to decrease.
 - (2) The reforestation solution must result in an increase in carbon stored in soil above 1400 GT in order to supply the additional carbon required to thaw the ground.
 - (3) Global reforestation must result in 600 GT of carbon that trees and other plants will release, resulting in a lower surface temperature.
 - (4) Global reforestation must maintain a total of 55 GT of carbon in order to reverse the change in nitrogen levels.

