CollegeBoard

AP®

Sample Responses from the Biology Practice Exam

Sample Questions

Scoring Guidelines

Student Responses

Commentaries on the Responses

Effective Fall 2012

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Preface

This publication is designed to help teachers and students understand and prepare for the revised AP® Biology Exam. The publication includes sample free-response questions, scoring guidelines, student responses at various levels of achievement, and reader commentaries. Collectively, these materials accurately reflect the design, composition, and rigor of the revised exam.

The sample questions are those that appear on the AP Biology Practice Exam, and the student responses were collected from actual AP students during a field test of the exam. The students gave permission to have their work reproduced at the time of the field test, and the responses were read and scored by AP Biology Readers in 2011.

Following each free-response question, its scoring guideline, and three student samples, you will find a commentary about each sample. Commentaries include the score that each response would have earned, as well as a brief rationale to support the score.

BIOLOGY
Section II
8 Free-Response Questions
Time—80 minutes

Directions: Questions 1 and 2 are long free-response questions that should require about 20 minutes each to answer. Questions 3 through 8 are short free-response questions that should require about 6 minutes each to answer. Read each question carefully and write your response in the space provided following each question. Only material written in this space will be scored. Answers must be written out. Outline form is not acceptable. It is important that you read each question completely before you begin to write.

1. In a certain prairie community, a dominant prairie grass species has recently been infected with a virus that disrupts one of the electron transport proteins in the chloroplasts of infected cells.

    (a) **Describe** the most likely effects on cellular processes (be specific as to which processes and molecules are most likely to be directly affected).

    (b) **Describe** and **explain** the most likely effects on individual infected plants.

    (c) **Predict** the short-term effects (within a year of infection) on the infected plant populations and their communities. **Justify** your prediction.

    (d) **Predict** the long-term effects (years to decades after infection) on the infected plant populations and their communities. **Justify** your prediction.

Information for Free-Response Question 1

Essential Knowledge	2.A.2: Organisms capture and store free energy for use in biological processes. 4.A.4: Organisms exhibit complex properties due to interactions between their constituent parts. 4.A.5: Communities are composed of populations of organisms that interact in complex ways. 4.A.6: Interactions among living systems and with their environment result in the movement of matter and energy. 4.C.4: The diversity of species within an ecosystem may influence the stability of the ecosystem.
Science Practices	6.2: The student can *construct explanations of phenomena based on evidence* produced through scientific practices. 6.4: The student can *make claims and predictions about natural phenomena* based on scientific theories and models.
Learning Objectives	2.5: The student is able to construct explanations of the mechanisms and structural features of cells that allow organisms to capture, store, or use free energy. 4.9: The student is able to predict the effects of a change in the component(s) of a biological system on the functionality of the organisms(s). 4.13: The student is able to predict the effects of a change in the community's populations on the community. 4.16: The student is able to predict the effect of a change of matter or energy availability on the community. 4.27: The student is able to make scientific claims and predictions about how species diversity within an ecosystem influences ecosystem stability.

Scoring Guidelines for Free-Response Question 1

10 points maximum; 1 point for each specific prediction. A maximum of 3 points can be earned in any one section.

(Part a) 1 point for each reasonable resulting change to a cellular process.
Effects may include:

- Less ATP produced.
- Less NADPH produced.
- Inability to fix carbon via Calvin cycle without products of electron transport chain.
- Decrease in O_2 production.

(Part b) 1 point for each reasonable expected change to an individual plant, with explanation.
Explanations may include:

- Plant cannot produce glucose due to decrease in photosynthetic product (G3P).
- Stunted growth due to lack of energy for building molecules.
- Plant becomes weakened and may die due to lack of ability to capture energy.
- Plant uses up pre-infection energy stores.
- Cannot perform growth/repair/reproduction due to lack of usable energy.

(Part c) 1 point for each reasonable predicted short-term change to the plant population or the prairie community, with justification.
Predictions may include:

- Reduction in population size of affected prairie grass due to death of infected members.
- Decrease in consumer population size as less energy available for the higher trophic levels.
- Smaller herbivore population size due to increased competition for limited resources.
- Unaffected plant species gain resources due to loss of infected plants.
- Uninfected plants have increased offspring due to more available resources.

(Part d) 1 point for each reasonable predicted long-term change to the plant population or the prairie community, with justification.
Predictions may include:

- Plant species becomes locally extinct.
- Reduction in genetic variability due to loss of infected plants.
- Change in allele frequencies for the affected species.
- Loss of consumer species dependent on affected prairie grass species.
- Members of the affected species with a genotype conferring resistance become more common, leading to no long-term effects to the population or community.
- Grass is replaced by other species — community is stabilized, or some changes in members of the food chain.
- Increased erosion due to lack of grass leading to degradation of abiotic environment, further limiting the ability of the environment to support the community.

Sample: 1A

BIOLOGY
Section II
9 Constructed-Response Questions
Time—85 minutes

Directions: Questions 1 and 2 are long constructed-response questions that should require about 20 minutes each to answer. Questions 3 through 9 are short constructed-response questions that should require about five minutes each to answer. Read each question carefully and write your response in the space provided following each question. Only material written in this space will be scored. Answers must be written out. Outline form is not acceptable. It is important that you read each question completely before you begin to write.

1. In a certain prairie community, a dominant prairie grass species has recently been infected with a virus that disrupts one of the electron transport proteins in the chloroplasts of infected cells.
   (a) **Describe** the most likely effects on cellular processes (be specific as to which processes and molecules are most likely to be directly affected).
   (b) **Describe** and **explain** the most likely effects on individual infected plants.
   (c) **Predict** the short-term effects (within a year of infection) on the infected plant populations and their communities. **Justify** your prediction.
   (d) **Predict** the long-term effects (years to decades after infection) on the infected plant populations and their communities. **Justify** your prediction.

1a. Since one of the electron transport proteins has been disrupted, normal electron flow in the light-dependent reactions cannot occur. As a result, the plant may be unable to convert the energy of the sun's photons into the chemical energy of NADPH and ATP. The lack of electron transport proteins disables the plant from using the Calvin Cycle to produce PGAL. Without PGAL, the plant will not have organic compounds to break down for energy.

b. Individuals affected by the virus will be unable to do photosynthesis. When their stored carbohydrates are used up by cellular respiration, they will run out of energy and die.

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c. If many plants in the population die, consumers relying on the prairie grass will have to either switch food sources or die. Since the prairie grass was a dominant grass in the community, their deaths would open up a lot of resources and space for other plants. However, the virus may also transfer to other plants through shared consumers. If this is the case, the entire community could soon die of the virus.

d. The plant population may be forever lowered or wiped out. Other plant species may rise to fill the vacancies left by the prairie grass. If the virus spreads to other species, the area may become barren and over years, the soil may be eroded away. Plant roots hold soil and prevent erosion. If the grasses die, the barren land will suffer from unrestricted erosion.

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Sample: 1B

BIOLOGY
Section II
9 Constructed-Response Questions
Time—85 minutes

Directions: Questions 1 and 2 are long constructed-response questions that should require about 20 minutes each to answer. Questions 3 through 9 are short constructed-response questions that should require about five minutes each to answer. Read each question carefully and write your response in the space provided following each question. Only material written in this space will be scored. Answers must be written out. Outline form is not acceptable. It is important that you read each question completely before you begin to write.

1. In a certain prairie community, a dominant prairie grass species has recently been infected with a virus that disrupts one of the electron transport proteins in the chloroplasts of infected cells.

   (a) **Describe** the most likely effects on cellular processes (be specific as to which processes and molecules are most likely to be directly affected).

   (b) **Describe** and **explain** the most likely effects on individual infected plants.

   (c) **Predict** the short-term effects (within a year of infection) on the infected plant populations and their communities. **Justify** your prediction.

   (d) **Predict** the long-term effects (years to decades after infection) on the infected plant populations and their communities. **Justify** your prediction.

1a. Due to the infection by the virus of the electron transport proteins in ~~the photosynthesis~~ the chloroplast, the rate of photosynthesis will begin to decline, and eventually stop. The light reaction is most directly affected by this infection, because the transport proteins are important components of the thylakoid membrane where light reaction takes place. Transport proteins are responsible for actively pumping the hydrogen ions (from the hydrolysis of water), across the thylakoid membrane. This creates the electrochemical gradient needed to power the synthesis of ATP and the production of electron carriers NADP+. The infection changes the structure and function of the transport protein, which

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would then stop the active transport of Hydrogen ions across the membrane. This will back up the reaction, as there will be no concentration gradient to build ATP. Water will not be split, because the reaction cannot take place. Eventually, the whole process will shut down, and components of the Calvin Cycle in photosynthesis will not be produced.

1b. Individual plants affected by the virus will simply die over time. They cannot produce the sugars needed for cellular respiration because photosynthesis has been inhibited by the viral infection. They become less fit compared to the individuals without the virus.

1c. The short term effect of this infection would be that it will dramatically reduce the population of the praire grass. Sudden environment changes causes a rapid decrease in populations, because they cannot adapt fast enough. However, few praire grass individuals will survive due to a random mutation or another event. They will move on to reproduce.

1d. After ~~years of~~ many years, the population of this grass will begin to increase again, this

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time with resistance to the virus. Those that survived initially contained genes that were adventageous in the sudden environment change. While others are infected and die, they survive to reproduce and pass on these favorable genes. Eventually, the ~~gene po~~ ' allele frequencies will change in the population, thus leading to evolution of ~~plants~~ grass resistant to the virus.

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Sample: 1C

20 min

BIOLOGY
Section II
9 Constructed-Response Questions
Time—85 minutes

Directions: Questions 1 and 2 are long constructed-response questions that should require about 20 minutes each to answer. Questions 3 through 9 are short constructed-response questions that should require about five minutes each to answer. Read each question carefully and write your response in the space provided following each question. Only material written in this space will be scored. Answers must be written out. Outline form is not acceptable. It is important that you read each question completely before you begin to write.

1. In a certain prairie community, a dominant prairie grass species has recently been infected with a virus that disrupts one of the electron transport proteins in the chloroplasts of infected cells.
   - (a) **Describe** the most likely effects on cellular processes (be specific as to which processes and molecules are most likely to be directly affected).
   - (b) **Describe** and **explain** the most likely effects on individual infected plants.
   - (c) **Predict** the short-term effects (within a year of infection) on the infected plant populations and their communities. **Justify** your prediction.
   - (d) **Predict** the long-term effects (years to decades after infection) on the infected plant populations and their communities. **Justify** your prediction.

Ahhh!?

a) electron transport proteins are essential in chloroplasts. Light energy is absorbed by photosystem II & these packets of light, known as photons are used as energy for the process of photosynthesis. If the electron transport proteins are disrupted this will not produce essential molecules like NADP⁺, electron proteins to move the light absorbed from photosystem II → photosystem I. ~~Thep~~

b) the plants will most likely have reduced or stop photosynthesizing because electrons cannot move down the electron transport

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chain without proteins. Then the plant will not be able to produce molecules, like glucose, to provide energy & will most probably die.

c) The short term effects of the virus on the infected plant population will be wide spread death. Because the virus disrupts an essential process. Very few may survive, those who have not yet been infected, which is a small percentage of the population. And if plants are dying, they cannot reproduce & maintain their species. This in turn affects primary consumers, probably herbivores, in this prairie community. They will lose their source of food & either find a different source or may move away from the area. Many may die off. & the secondary consumers & tertiary consumers will have to also move away, find a new source, or begin to die off.

d) Years to decades after the infection of the plants, there will be different effects. After the majority of the grass species have died the virus will be less

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prevalent & the species can begin to repopulate. Because it is a dominant species & a grass species, which are more rugged, it is more likely able to repopulate the area. Then as the population of grass repopulates & stabilizes, it will be able to support more consumers, herbivores, secondary & tertiary consumers & the community can begin to build up again.

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AP® Biology

2012 Practice Exam Scoring Commentary

Note: Student samples are quoted verbatim and may contain grammatical errors.

Free-Response Question 1

Overview

This question provided an opportunity to explain how the free energy requirements in a living system from cells to populations and communities could be impacted by a viral infection in prairie grass. Part (a) provided an opportunity to predict and justify the effect from viral infection on a protein in the electron transport chain in the chloroplast. Part (b) required a description of the effect of viral infection on individual plants, as well as an explanation of the predicted effect(s). Part (c) requested a prediction, with justification, of the short-term effects of viral infection in one species (prairie grass) on the community as a whole. Part (d) requested a prediction, with justification, of the long-term effects of viral infection on the plant population and the prairie community.

Sample: 1A
Score: 7

In part (a), the response earned the maximum 3 points. One point was earned for describing that less ATP will be produced, and 1 point was earned for describing that less NADPH will be produced with the disruption of the electron transport chain in plants by the virus. One point was earned for describing that the virus "disables the plant from using the Calvin cycle to produce PGAL. Without PGAL, the plant will not have organic compounds to break down for energy."

In part (b), 1 point was earned for describing/explaining that "their stored carbohydrates are used up by cellular respiration. They will run out of energy and die."

In part (c), 1 point was earned for predicting that the infected plants would die with justification. That is, when one organism dies, it opens up niches for other species to fill; "their deaths would open up a lot of resources and space for other plants."

In part (d), 2 points were earned. One point was earned for predicting that the infected grass would be replaced by other species, and 1 point for predicting with justification that the death of the plant species would result in increased erosion, thus likely leading to the degradation of the abiotic environment.

Sample: 1B
Score: 6

In part (a), 2 points were earned. One point was earned for describing that there would be "no concentration gradient to build ATP," and 1 point was earned for describing how "eventually, the whole process will shut down, and components of the Calvin cycle in photosynthesis will not be produced."

Free-Response Question 1 (continued)

In part (b), 1 point was earned for describing how the virus causes plants to become weakened and die due to a lack of sugar production, and "cannot produce the sugars needed for cellular respiration because photosynthesis has been inhibited."

In part (c), 1 point was earned for predicting that the virus "will dramatically reduce the population of the prairie grass."

In part (d), 2 points were earned. One point was earned for predicting the survival of resistant plants, and 1 point for predicting that "eventually, the allele frequencies will change in the population" and justifying that the change is due to "grass resistant to the virus."

Sample: 1C
Score: 3

In part (a), 0 points were earned. The response incorrectly states that "this will not produce essential molecules like NADP+." (NADPH is produced in the electron transport chain, not the oxidized form.)

In part (b), 1 point was earned for explaining that infected plants will "not be able to produce molecules, like glucose," and would not produce glucose due to the disruption in the electron transport chain.

In part (c), 2 points were earned. One point was earned for predicting the "wide spread [sic] death" [of the infected population], and 1 point was earned for predicting with justification that a smaller herbivore population size is due to increased competition for limited resources.

In part (d), 0 points were earned. (No reasonable prediction of long-term effects was provided.)

Free-Response Question 2

2. Plants lose water from their aboveground surfaces in the process of transpiration. Most of this water is lost from stomata, microscopic openings in the leaves. Excess water loss can have a negative effect on the growth, development, and reproduction of a plant. Severe water loss can be fatal. Environmental factors have a major impact on the rate of plant transpiration.

TRANSPIRATION RATE VERSUS TEMPERATURE

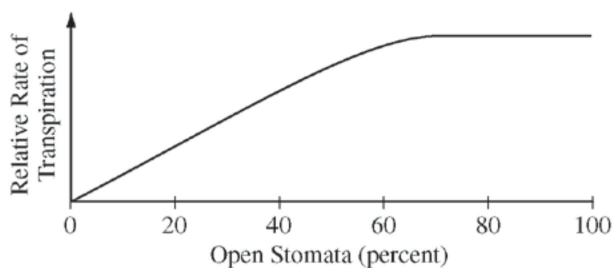
Temperature (°C)	20	23	27	28
Transpiration rate (mmol/m^2•sec)	1.5	3	5	4.5

(a) Using the data above and the axes provided, **draw** a graph showing the effect of temperature change on the rate of transpiration. **Explain** the shape of the curve from 23 degrees to 28 degrees.

(b) Humidity is another environmental factor that affects transpiration rate. Using the axes provided, **draw** a curve that illustrates what you predict would be the rate of transpiration with increasing humidity and constant temperature. **Justify** the shape of the curve based on your prediction.

(c) The curve below illustrates the rate of transpiration related to the percent of open stomata on the leaf of a particular plant. **Explain** why the curve levels off with increasing percentage of open stomata per area of the leaf.

OPEN STOMATA VERSUS RATE OF TRANSPIRATION



(d) The data below show the density of stomata on the leaf surfaces of three different species of plants. **Describe** the environments in which each plant most likely evolved. **Justify** your descriptions.

	Stomata Density (# of stomata/mm^2)	
Plant	In Upper Epidermis	In Lower Epidermis
Anacharis	0	0
Water lily	420	0
Black walnut	0	465

Information for Free-Response Question 2

Essential Knowledge	4.A.6: Interactions among living systems and with their environment result in the movement of matter and energy.
Science Practices	1.4: The student can *use representations and models* to analyze situations or solve problems qualitatively and quantitatively. 2.2: The student can *apply mathematical routines* to quantities that describe natural phenomena.
Learning Objectives	4.14: The student is able to apply mathematical routines to quantities that describe interactions among living systems and their environment, which result in the movement of matter and energy. 4.15: The student is able to use visual representations to analyze situations or solve problems qualitatively to illustrate how interactions among living systems and with their environment result in the movement of matter and energy.

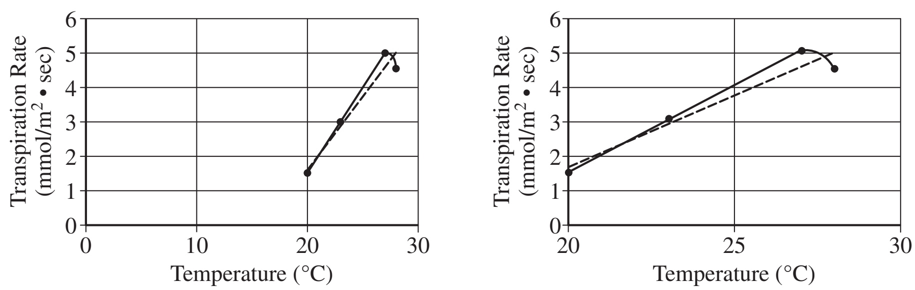
Scoring Guidelines for Free-Response Question 2

10 points maximum; students must earn points in each part of the question to receive all 10 points.

(Part a) Up to 3 points for a properly drawn graph.
One point for each of the following:

- Axes properly labeled and scaled
- Points properly plotted
- Correctly drawing either the curve with connected points or the best-fit line

NOTE: The student may use full scale (0–30), limited scale (20–30), or other legitimate scaling of the x-axis. Two examples are shown. The solid lines indicate the curve with connected points, and the dashed lines indicate the best-fit line.



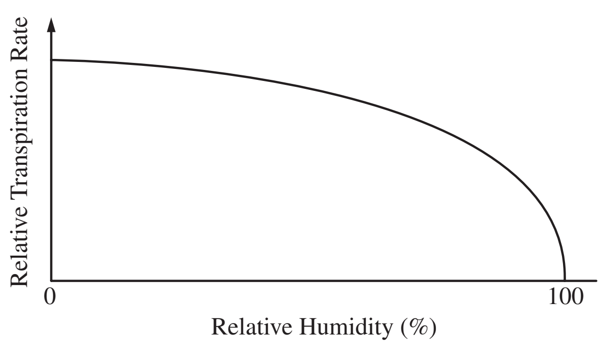
1 point for an appropriate description of the shape of the curve:

- Drawn curve shows increasing rate of transpiration from 20 to 27 degrees and reduction in transpiration rate from 27 to 28 degrees; or
- Best-fit curve shows steady increase in transpiration correlated to increase in temperature.

1 point for appropriate explanation of the change:

- Rate of water evaporation increases with increasing temperature.
- As temperature increases there are more open stomata.
- At the higher temperature stomata begin to close.
- Plants open and close stomata in response to environmental conditions.

(Part b) 1 point for a properly drawn curve, as shown, with correct axes and labels. The curve must have some indication of humidity measure, e.g., 0–100.



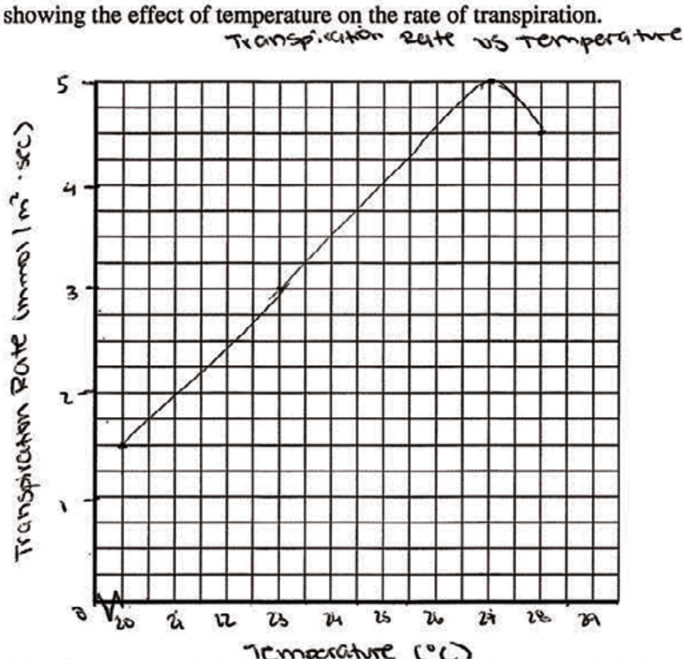
1 point for a correct explanation:

- Increasing humidity leads to reduced evaporation rates due to decreased difference in water vapor pressure (water potential) between leaf and atmosphere.

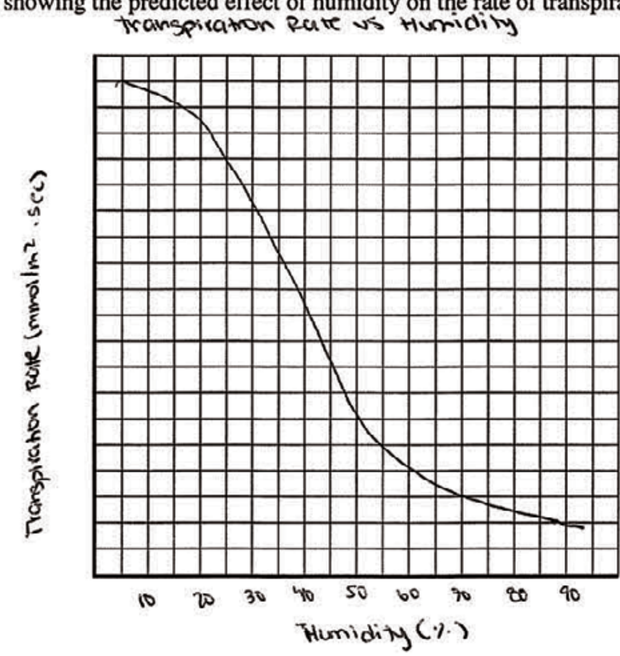
(Part c) 1 point for a correct explanation of the increase in transpiration rate from 0 to 60 percent of open stomata: • From 0 to 60 percent open stomata, there is an increase in gas exchange with more stomata open. • There is higher rate of diffusion between the leaf interior and the environment with more stomata open. **1 point for a correct explanation of the flattening of the curve when more than 60 percent of stomata are open:** • When more than 60 percent of the stomata are open, another factor becomes limiting. • Rate of water movement is now limiting. • Transpiration is now limited by humidity.
(Part d) Up to 3 points for a reasonable description of each environment, with an appropriate justification. Descriptions may include: • Anacharis is adapted to an environment where transpiration does not occur, such as underwater or in 100 percent humidity. There is no need for water vapor *or* it cannot occur via transpiration. • Water lilies are adapted to an environment where only the upper side of the leaf is exposed to air; thus, only one surface can exchange water vapor with the environment. The large number of stomata is not a disadvantage because the plant has easy access to water. • Black walnut is adapted to an environment where the upper surface is exposed to strong sunlight and higher temperatures and/or where water is more limited compared to a watery environment. Stomata located on lower epidermis of leaves are shaded from exposure to direct sunlight and higher temperatures, mitigating excessive water loss.

Sample: 2A

Graph for part (a) showing the effect of temperature on the rate of transpiration.



Graph for part (b) showing the predicted effect of humidity on the rate of transpiration.



a) The graph is increasing in the interval from 23° to 27°. However, it decreases from 27° to 28°. As temperature began to increase the rate of transpiration increased because water began to escape more quickly from the open stomata. The reason the plant's transpiration rate decreased from 27° to 28° is probably that the plant was losing water to fast so the stomata closed.

b) As humidity percentage increased, the transpiration rate should decrease. In this environment, the air has a greater water potential than the leaves, so the plant loses very little water to the environment. The transpiration should decrease gradually when there is little humidity, but when there gets to be about 70% to 80% humidity the transpiration rate should substantially decline because at this point the air has a greater water potential than the leaves.

c) The curve levels off because at this point most of the stomata are open. If water doesn't escape from one part of the plant, it will escape from another, resulting in the maximum traspiration rate ~~[illegible]~~.

d) The Anacharis probably evolved underwater because it has no stomata present at all. The main function of the stomata is to collect CO_2 from the air and ~~[illegible]~~ control water levels. In an aquatic environment, there is no way

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to collect CO_2 from the atmosphere and the plant is surrounded by water so there is no reason to have stomata.

The water lily probably evolved on the surface of a body of water. It ~~develop~~ can't take CO_2 from the water, so it has all its stomata concentrated where the plant has access to air.

The Black walnut probably evolved in an area with intensive sunlight. To have all stomata concentrated on the lower epidermis is probably an adaptation to prevent excessive loss of water from transpiration.

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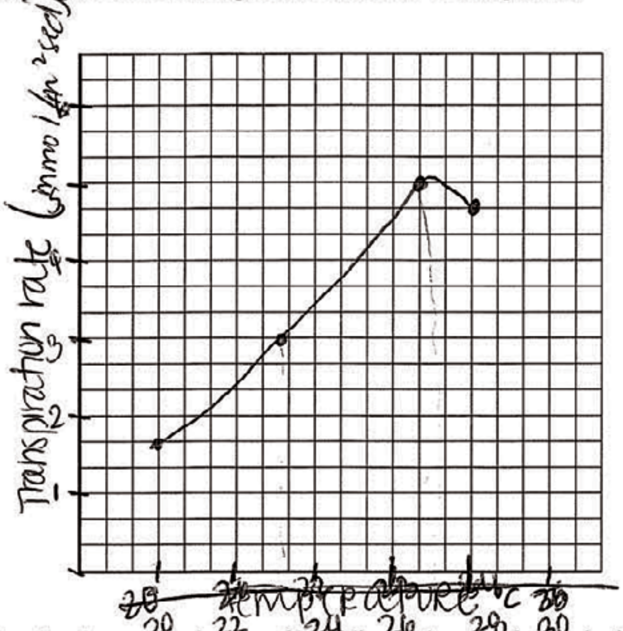
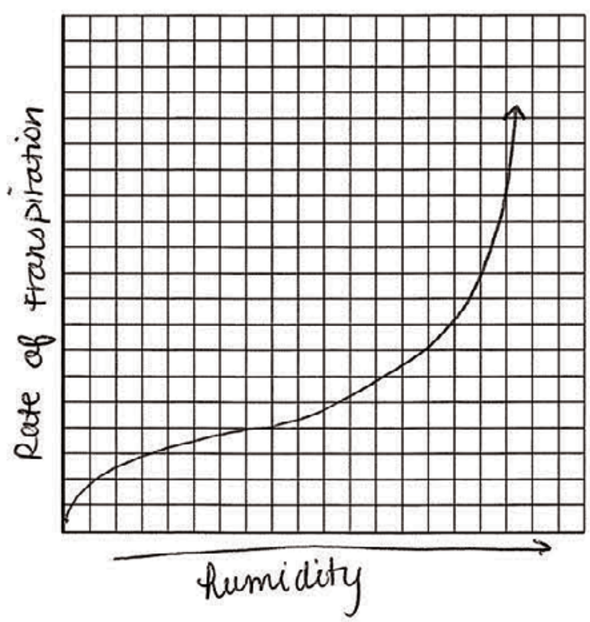
Sample: 2B

Graph for part (a) showing the effect of temperature on the rate of transpiration.



Graph for part (b) showing the predicted effect of humidity on the rate of transpiration.



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Transpiration rate is a factor that depends on both temperature, humidity as well as light and darkness. When temperature increases, the rate of transpiration increases as well. In the graph of rate of transpiration based on temperature, the rate of transpiration steadily increases, until around 27°, where it begins to level off. This is because of the closing of the stomata due to high temperature, to minimize water loss, therefore ~~minimizing~~ lowering the rate of transpiration slightly. ~~It~~ is still transpiring, but some stomata have begun to close.

Humidity also effects the rate of transpiration. When more water is available in humid environments, like a rainforest, the plants use that water and then release it through transpiration. The stomata remain open and because the temperature remains constant, does not close the stomata.

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As rate of transpiration increases, the opening of the stomata increases to enable a higher rate of transpiration. It begins to level out at around 60-100%, because enough stomata are open that the rate of respiration does not increase. When the stomata had fewer percent open, the plant needed to work harder to transpire more.

Lastly, different plant species have different stomata in different locations. The Anarchis does not have any stomata, because it probably evolved in dry conditions where water is needed to be retained and cannot lose through stomata. The water Lily has stomata on the upper epidermis because the lower epidermis is resting on water and cannot have stomata to release water. The walnut must have evolved in conditions where the upper epidermis was not able to hold stomata, like a humid temperate environment. The side not exposed to the sun, the lower epidermis, must have evolved to contain all of the stomata.

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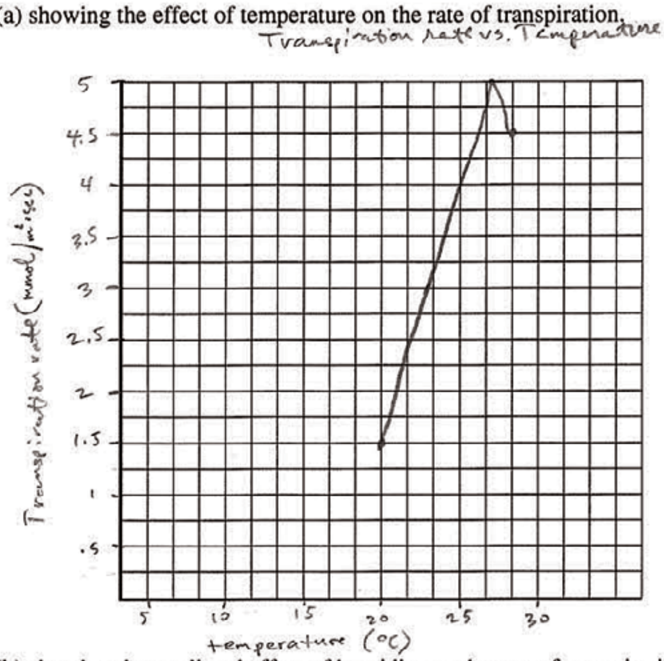
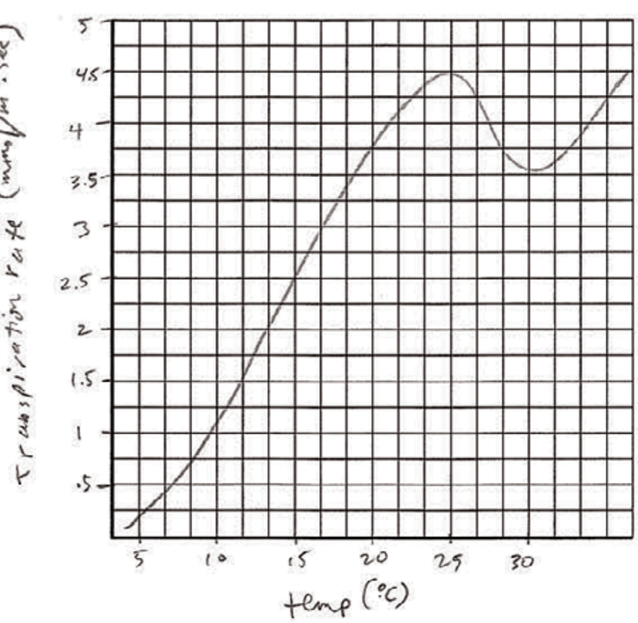
Sample: 2C

Graph for part (a) showing the effect of temperature on the rate of transpiration.



Graph for part (b) showing the predicted effect of humidity on the rate of transpiration.



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The transpiration rate increases until twenty-seven degrees Celsius, but then decreases at twenty-eight degrees Celsius. The more opened the stomata is the higher its transpiration rate and once it reaches about seventy percent it levels off because the stomata is basically fully opened and won't effect the plant when it reaches one hundred percent. The anacharis didn't evolve and therefore has zero stomata/mm². The water lily evolves at the bottom of the ocean/river. The black walnut evolved from the land instead of from water like the water lily.

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Free-Response Question 2

Overview

This question provided an opportunity to demonstrate an understanding of how the interactions among living systems and with their environment result in the movement of matter and energy.

Part (a) provided data on transpiration rate versus temperature, and required the construction of a graph to show the effect of temperature change on the rate of transpiration, as well as an explanation of a portion of the graph. Part (b) required drawing an additional curve predicting the rate of transpiration with increasing humidity and constant temperature, with justification. Part (c) required interpretation and explanation of a graph depicting the rate of transpiration related to the number of open stomata. Part (d) provided an opportunity to describe, with justification, the environments in which three (3) plant species most likely evolved.

Sample: 2A
Score: 9

In part (a), the maximum of 5 points was earned. Three points were earned for creating a graph with the axes correctly labeled and scaled, data points plotted, and data points connected. One point was earned for appropriately describing the shape of the curve as "increasing in the interval from 23 to 27 degrees. However, it decreases from 27 to 28 degrees." One point was earned for explaining that the observed change is likely due to the closing of stomata.

In part (b), 1 point was earned. (No points were earned for the graph because the predicted shape of the graph was inaccurate; however, the axes and labels were correct, and there was an indication of humidity measure.) One point was earned for explaining that the water potential between the leaf and the atmosphere correlates to a decrease in transpiration rate: "As humidity percentage increased, the transpiration rate should decrease … but when there gets to be about 70% to 80% humidity the transpiration rate should substantially decline because at this point the air has a greater water potential than the leaves."

In part (c), 0 points were earned. (No correct explanations for the relationship between the number of open stomata and transpiration rate were provided.)

In part (d), the maximum of 3 points was earned. One point was earned for describing that because *Anarcharis* is an aquatic plant, "there is no way to collect carbon dioxide from the atmosphere and the plant is surrounded by water so there is no reason to have stomata." One point was earned for explaining that the water lily has stomata only on its upper surface " so it has all its stomata concentrated where the plant has access to air." One point was earned for explaining with justification that the black walnut is adapted to "an area with intensive sunlight" and that "all stomata concentrated on the lower epidermis is probably an adaptation to prevent excessive loss of water from transpiration."

Sample: 2B
Score: 6

In part (a), the maximum of 5 points was earned. Three points were earned for creating a graph with axes correctly labeled and scaled, data points plotted, and data points connected. One point was earned for describing that "the rate of transpiration steadily increases until around 27 degrees, where it begins

Free-Response Question 2 (continued)

to level off." One point was earned for justifying that this observation is "because of the closing of the stomata due to high temperature to minimize water loss."

In part (b), 0 points were earned. (The graph did not accurately depict the relationship between transpiration rate and humidity, nor did the response provide an appropriate explanation for the shape of the constructed graph.)

In part (c), 0 points were earned. (No correct explanation for the relationship between the number of open stomata and transpiration rate was provided.)

In part (d), 1 point was earned for explaining with justification that "the water lily has stomata on the upper epidermis because the lower epidermis is resting on water."

Sample: 2C
Score: 3

In part (a), 3 points were earned for creating a graph with the axes correctly labeled and scaled, data points plotted, and data points connected. (No points were earned for describing the shape or the curve, or for explaining the change in its shape.)

In part (b), 0 points were earned. (The graph did not accurately depict the relationship between transpiration rate and humidity, nor did the response provide an appropriate explanation for the shape of the constructed graph.)

In part (c), 0 points were earned. (No correct explanation for the relationship between the number of open stomata and transpiration rate was provided.)

In part (d), 0 points were earned. (No reasonable descriptions of the relationship/adaptation between the number and position of stomata and environmental were provided. The response also reveals misconceptions about evolution, natural selection, and adaptation, such as "The anacharis [*sic*] didn't evolve" and, "The water lily evolves at the bottom of the ocean/river.")

Free-Response Question 3

3. In fruit flies (*Drosophila melanogaster*), straight wing shape is dominant to curly wing shape. A particular population of fruit flies is in Hardy-Weinberg equilibrium with respect to the alleles for wing shape.

   The Hardy-Weinberg equation, given below, is useful in understanding population genetics:

   $$p^2 + 2pq + q^2 = 1$$

   (a) **Explain** what the terms (p^2, $2pq$, and q^2) represent in the population of fruit flies.

   (b) **Describe** one condition that is necessary for the population to be in equilibrium.

Information for Free-Response Question 3

Essential Knowledge	1.A.4: Biological evolution is supported by scientific evidence from many disciplines, including mathematics.
Science Practices	1.1: The student can *create representations and models* of natural or man-made phenomena and systems in the domain. 2.1: The student can *justify the selection of a mathematical routine* to solve problems.
Learning Objectives	1.13: The student is able to construct and/or justify mathematical models, diagrams, or simulations that represent processes of biological evolution.

Scoring Guidelines for Free-Response Question 3

4 points maximum.
(Part a) Up to 3 points for the following correct explanations: • p_2 represents the frequency (proportion, percent) of the homozygous straight-wing individuals; each has two copies of the dominant allele. • 2*pq* represents the frequency (proportion, percent) of the heterozygous straight-wing flies; each has one copy of the dominant allele and one copy of the recessive allele. • q_2 represents the frequency (proportion, percent) of the homozygous curly-wing individuals; each has two copies of the recessive allele.
(Part b) 1 point for a correct description of a condition: • Correct descriptions of a condition include: large population size, no selection, no mutation, no migration, and random mating.

Sample: 3A

3. In fruit flies (*Drosophila melanogaster*), straight wing shape is dominant to curly wing shape. A particular population of fruit flies is in Hardy-Weinberg equilibrium with respect to the alleles for wing shape.

The Hardy-Weinberg equation, given below, is useful in understanding population genetics:

$$p^2 + 2pq + q^2 = 1$$

(a) **Explain** what the terms (p^2, $2pq$, and q^2) represent in the population of fruit flies.

(b) **Describe** one condition that is necessary for the population to be in equilibrium.

a) The term p^2 is used to describe the frequency of the population who are homozygous dominant for the given alleles or in this case those who only possess the alleles for the straight wing shape. 2pq represents the frequency of the population who are heterozygous for this gene, thus meaning they possess one of each allele type in their genome but still possess the straight wings. q^2 represents the frequency that is homozygous recessive for this trait, meaning they only possess the alleles for the curly wing shape.

b) One condition for equilibrium is the population must have random mating. There must not be any choice of mate & must be selected completely at random or the frequency could fluctuate meaning its not at equilibrium

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Sample: 3B

3. In fruit flies (*Drosophila melanogaster*), straight wing shape is dominant to curly wing shape. A particular population of fruit flies is in Hardy-Weinberg equilibrium with respect to the alleles for wing shape.

The Hardy-Weinberg equation, given below, is useful in understanding population genetics:

$$p^2 + 2pq + q^2 = 1$$

(a) **Explain** what the terms (p^2, $2pq$, and q^2) represent in the population of fruit flies.

(b) **Describe** one condition that is necessary for the population to be in equilibrium.

a) p^2 represents the ~~number~~ percentage of organisms homozygous dominant for the trait (that is, they have 2 dominant alleles coding for straight wings).

2pq represents the percentage of organisms Heterozygous for the trait (that is they have 1 allele of the Dominant gene and one allele of the Recessive Gene. These fruit flies would be phenotypically indistinguishable from the p^2 (Homozygous dominant) fruit flies, in that both p^2 and 2pq fruit flies would exhibit the dominant phenotype of straight wings.

q^2 represents the percentage of organisms Homozygous recessive for the trait. (that is, they have 2 recessive alleles coding for curly wings, and phenotypically exhibit this recessive trait).

b) The population would be in equillibrium if the gene is not sexually selected for and is ~~equal~~ represented on many levels ~~off~~ offspring.

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Sample: 3C

3. In fruit flies (*Drosophila melanogaster*), straight wing shape is dominant to curly wing shape. A particular population of fruit flies is in Hardy-Weinberg equilibrium with respect to the alleles for wing shape.

The Hardy-Weinberg equation, given below, is useful in understanding population genetics:

$$p^2 + 2pq + q^2 = 1$$

(a) **Explain** what the terms (p^2, $2pq$, and q^2) represent in the population of fruit flies.

(b) **Describe** one condition that is necessary for the population to be in equilibrium.

In these fruit flies p^2 represents the dominant alleles (straight wing shape) and q^2 represents recessive alleles (curly wing shape). The 2pq would represent the heterozygous individuals for straight wing shape.
One condition necessary for the population to be in equilibrium is that no mutations occur.

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Free-Response Question 3

Overview

This question provided an opportunity to demonstrate an understanding of the Hardy-Weinberg equation and its usefulness in population genetics. In part (a) an explanation of the terms representing the three genotype frequencies (p^2, $2pg$, q^2) was required. Part (b) provided an opportunity to demonstrate knowledge of one of the five conditions (large population, no natural selection, no mutations, no migration or gene flow, random mating) required for a population to be in equilibrium.

Sample: 3A
Score: 4

In part (a), 3 points were earned. One point was earned for explaining p^2 as the "frequency of the population who are homozygous dominant for the given alleles or in this case those who only possess the alleles for the straight wing shape." One point was earned for explaining "$2pq$ represents the frequency of the population who are heterozygous." The statement "q^2 represents the frequency that is homozygous recessive for this trait, meaning they only possess the alleles for the curly wing shape" earned 1 point.

In part (b), describing how random mating is a condition for the population to be in Hardy-Weinberg equilibrium earned 1 point.

Sample: 3B
Score: 3

In part (a), 3 points were earned. One point was earned for explaining that "p^2 represents the percentage of organisms homozygous dominant for the trait (that is, they have 2 dominant alleles coding for straight wings)." One point was earned for explaining $2pq$, and 1 point was earned for explaining that "q^2 represents the percentage of organisms homozygous recessive for the trait, (that is, they have 2 recessive alleles coding for curly-wings, and phenotypically exhibit this recessive trait)."

Part (b) earned 0 points. (No accurate condition for a population to be in Hardy-Weinberg equilibrium was provided.)

Sample: 3C
Score: 2

In part (a), 1 point was earned for describing "the $2pq$ would represent the heterozygous individuals for straight wing shape." In part (b), 1 point was earned for describing "that no mutations occur" for the population to be in Hardy-Weinberg equilibrium.

Free-Response Question 4

4. Populations of a plant species have been found growing in the mountains at altitudes above 2,500 meters. Populations of a plant that appears similar, with slight differences, have been found in the same mountains at altitudes below 2,300 meters.

   (a) **Describe** TWO kinds of data that could be collected to provide a direct answer to the question, do the populations growing above 2,500 meters and the populations growing below 2,300 meters represent a single species?

   (b) **Explain** how the data you suggested in part (a) would provide a direct answer to the question.

Information for Free-Response Question 4

Essential Knowledge	1.C.2: Speciation may occur when two populations become reproductively isolated from each other.
Science Practices	4.1: The student can *justify the selection of the kind of data* needed to answer a particular scientific question.
Learning Objectives	1.23: The student is able to justify the selection of data that address questions related to reproductive isolation and speciation.

Scoring Guidelines for Free-Response Question 4

4 points maximum.

Description of the appropriate kind of data and the appropriately linked explanation of its selection may include:

Description of kind of data (1 point each)	Explanation (1 point each)
Ability to produce viable seeds/offspring in nature	Consistent with definition of biological species
Ability to cross-pollinate	Consistent with definition of biological species
Production of fertile offspring	Consistent with definition of biological species
Comparison of sequence of DNA or structures of other conserved molecules	Sufficient similarity supports single species
Comparison of chromosome number and/ or structure	Similarity supports single species
Fertile hybrid populations found living between the two other populations of plants	Consistent with definition of biological species

Sample: 4A

4. Populations of a plant species have been found growing in the mountains at altitudes above 2,500 meters. Populations of a plant that appears similar, with slight differences, have been found in the same mountains at altitudes below 2,300 meters.

   (a) **Describe** TWO kinds of data that could be collected to provide a direct answer to the question, "Do the populations growing above 2,500 meters and the populations growing below 2,300 meters represent a single species?"

   (b) **Explain** how the data you suggested in part (a) would provide a direct answer to the question.

a. One kind of data that can be obtained is by attempting to ~~[illegible]~~ breed the two species. If the resultant offspring can reproduce and continue the generation, then these two plants communities are from the same species. Another test that can be performed is if the DNA ~~of each~~ karotypes of each species is compared. If they have the same number of chromosomes then they are of the same species.

b. Breeding will give a direct answer because if two similar but different species bred, they will produce a sterile offspring that will be unable to produce more children. The karotype will also give a direct answer because the number of chromosomes of a species is unique and can be used to ~~identify~~ distinguish between different or same species.

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Sample: 4B

4. Populations of a plant species have been found growing in the mountains at altitudes above 2,500 meters. Populations of a plant that appears similar, with slight differences, have been found in the same mountains at altitudes below 2,300 meters.

(a) **Describe** TWO kinds of data that could be collected to provide a direct answer to the question, "Do the populations growing above 2,500 meters and the populations growing below 2,300 meters represent a single species?"

(b) **Explain** how the data you suggested in part (a) would provide a direct answer to the question.

a) Molecular data could be collected from the two ~~pp~~ groups of populations, specifically DNA, to analyze whether or not ~~they~~ their genes are similar enough to be classified as one species.
Phylogenic data could also be collected from the two groups of populations to determine whether or not the two are able to reproduce with one another successfully (meaning their offspring survive and can also reproduce ~~~~ among themselves ~~~~ (the "hybrids"), or with either of the parent populations.
b) If ~~the~~ the genes of the two groups of populations differ enough to be classified as different species, then the populations growing above 2500 m & below 2300 m are different species. If the two groups of populations cannot ~~reproduces~~ reproduce successfully, they are different ~~~~ species.

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Sample: 4C

4. Populations of a plant species have been found growing in the mountains at altitudes above 2,500 meters. Populations of a plant that appears similar, with slight differences, have been found in the same mountains at altitudes below 2,300 meters.

   (a) **Describe** TWO kinds of data that could be collected to provide a direct answer to the question, "Do the populations growing above 2,500 meters and the populations growing below 2,300 meters represent a single species?"

   (b) **Explain** how the data you suggested in part (a) would provide a direct answer to the question.

A.) 1.) Breed the two kinds of plants and track if the two produce fertile offspring.
2.) Track both of plants natural predators

B.) 1.) Based on the biological species concept, two organisms are the same species if they can produce fertile offspring.
2.) Based on the ecological species concept, two organisms are the same species if they fill the same niche in an environment. Both plants are autotrophs, but a list of their natural predators would reveal where their biomass travels and the niche they fill in the environment.

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Free-Response Question 4

Overview

This question provided an opportunity to demonstrate knowledge of how speciation may occur when two populations become reproductively isolated from each other. Part (a) required the description of two kinds of data that could be collected in order to determine if the population growing above 2,500 meters and the population growing below 2,300 meters represent a single species. Part (b) required justification of how the choice of data supports the biological species concept.

Sample: 4A
Score: 4

Part (a) earned 2 points. One point was earned for the ability to produce viable offspring "by attempting to breed the two species" and 1 point for comparison of chromosome number.

Part (b) earned 2 points. One point was earned for the definition of a biological species stated in part (a) "If the resultant offspring can reproduce and continue the generation, then these two plant communities are from the same species," as well as a statement in part (b) that "if two similar but different species bred, they will produce a sterile offspring that will be unable to produce more children." One point was earned for the statement that the karyotype supports a single species, "because the number of chromosomes of a species is unique and can be used to distinguish between different or same species."

Sample: 4B
Score: 3

In part (a), 2 points were earned. One point was earned for describing molecular comparison, "specifically DNA, to analyze whether or not their genes are similar enough to be classified as one species" and 1 point for "their offspring survive and can also reproduce among themselves" as two kinds of data to determine if the two populations of plants represent a single species.

In part (b), 1 point was earned for "if the genes of the two groups of populations differ enough to be classified as different species" as an explanation for the answer to the question whether or not the two populations of plants represent a single species.

Sample: 4C
Score: 2

In part (a), 1 point was earned for describing fertile offspring as a type of data to determine if the two populations of plants represent a single species.

In part (b), 1 point was earned for explaining the biological species concept as "two organisms are the same species if they can produce fertile offspring."

Free-Response Question 5

5. In eukaryotic cells, ribosomes are found both free in the cytosol and attached to the endoplasmic reticulum (ER). Proteins produced on the attached ribosomes are delivered to the ER, while proteins produced on free ribosomes are delivered to the cytosol. **Briefly explain** in one or two sentences the two processes in terms of the following:

   - ONE ultimate destination of a protein produced on an attached ribosome, and ONE general function of the protein (You do not need to identify the specific protein.)
   - ONE ultimate destination of a protein produced on a free ribosome, and ONE general function of the protein (You do not need to identify the specific protein.)

Information for Free-Response Question 5

Essential Knowledge	2.B.3: Eukaryotic cells maintain internal membranes that partition the cell into specialized regions.
Science Practices	6.2: The student can *construct explanations of phenomena based on evidence* produced through scientific practices.
Learning Objectives	2.13: The student is able to explain how internal membranes and organelles contribute to cell functions

Scoring Guidelines for Free-Response Question 5

4 points maximum.

Possible explanations for attached ribosomes include:

Ultimate Destination (1 point maximum)	**General Function (1 point maximum)**
Excreted from cell	• An intercellular messenger/hormone/signaling molecule • Extracellular matrix protein
Integrated into the cell membrane	• Surface receptor • Transmembrane transport
Inside an organelle such as a lysosome	• Enzyme that hydrolyzes old molecules • Digestive enzyme
Inside a Golgi apparatus	• Packaged into a lipoprotein or glycoprotein • Immature extracellular matrix protein

Possible explanations for attached ribosomes include:

Ultimate Destination (1 point maximum)	**General Function (1 point maximum)**
In cytosol	• Structural protein in cell, such as cytoskeleton and motor proteins • Enzyme that mediates cell process • Second messenger
In a vacuole	Enzyme that mediates cell process
In nucleus	• Transcription factor

Sample: 5A

5. In eukaryotic cells, ribosomes are found both free in the cytosol and attached to the endoplasmic reticulum (ER). Proteins produced on the attached ribosomes are delivered to the ER, while proteins produced on free ribosomes are delivered to the cytosol. **Describe** the two processes in terms of the following:

- ONE ultimate destination of a protein produced on an attached ribosome, and ONE general function of the protein (you do not need to identify the specific protein).
- ONE ultimate destination of a protein produced on a free ribosome, and ONE general function of the protein (you do not need to identify the specific protein).

• Proteins made by ~~ribosomes found~~ attached ribosomes are delivered to the ER, where they are processed and shipped to the Golgi, which sends it to its final destination. This protein could potentially leave the cell or become a protein on the cell membrane. As such, it could function as a cell "identifyer."

• Proteins made by free ribosomes tend to stay in the cytosol of the cell. There, they can function as enzymes that breakdown un-needed organic material.

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Sample: 5B

5. In eukaryotic cells, ribosomes are found both free in the cytosol and attached to the endoplasmic reticulum (ER). Proteins produced on the attached ribosomes are delivered to the ER, while proteins produced on free ribosomes are delivered to the cytosol. **Describe** the two processes in terms of the following:
   - ONE ultimate destination of a protein produced on an attached ribosome, and ONE general function of the protein (you do not need to identify the specific protein).
   - ONE ultimate destination of a protein produced on a free ribosome, and ONE general function of the protein (you do not need to identify the specific protein).

• A protein produced on an attached ribosome would be hydrophobic. It would then be transported outside of the cell, possibly to be used in the membrane.

• A protein produced on a free ribosome would stay in the cytosol of the cell where it could be used as a transport protein. or as a protein for signaling and interactions between cells.

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Sample: 5C

5. In eukaryotic cells, ribosomes are found both free in the cytosol and attached to the endoplasmic reticulum (ER). Proteins produced on the attached ribosomes are delivered to the ER, while proteins produced on free ribosomes are delivered to the cytosol. **Describe** the two processes in terms of the following:

- ONE ultimate destination of a protein produced on an attached ribosome, and ONE general function of the protein (you do not need to identify the specific protein).
- ONE ultimate destination of a protein produced on a free ribosome, and ONE general function of the protein (you do not need to identify the specific protein).

In Eukaryotic cells, ribosomes are found both free in the Cytosol and attached to the endoplasmic reticulum. Proteins produced on the attached ribosomes are delivered to the ER, while proteins produced on free ribosomes are delivered to the cytosol. The two processes in terms of an ultimate destination of a protein produced on an attached ribosome, and One general function of the protein. Another ultimate destination of a protein produced on a free ribosome, and a general function of the protein.

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Free-Response Question 5

Overview

This question provided an opportunity to explain how internal membranes and organelles contribute to cell functions. An explanation of the destination of a protein produced on an attached ribosome, for instance, excreted from the cell, embedded in the cell membrane, processed in the Golgi, and the function of that protein, was required. An explanation of the destination of a protein produced on a free ribosome, and the function of that protein, was required. For example, the protein's destination would be in the cytosol or a vacuole as a structural protein in the cytoskeleton or as a motor protein.

Sample: 5A
Score: 4

First bullet, 1 point was earned for identifying a possible destination of a protein produced on an attached ribosome with the description, "This protein could potentially leave the cell or become a protein on the cell membrane." One point was earned for describing the general function of the protein "as a cell 'identifyer' [sic]."

Second bullet, 1 point was earned for identifying a possible destination of a protein produced on a free ribosome with the description, "...tend to stay in the cytosol of the cell" although this information was provided in the question's stem. One point was earned for describing the general function of the protein as "enzyme that breakdown un-needed organic material."

Sample: 5B
Score: 3

First bullet, 1 point was earned for identifying a possible destination of a protein produced on an attached ribosome with the description, "It would then be transported outside of the cell." One point was earned for describing that the protein could act "as a protein for signaling and interactions between cells."

Second bullet, 1 point was earned for describing a possible destination of a protein produced on a free ribosome as" [it] would stay in the cytosol of the cell."

Sample: 5C
Score: 1

First bullet, no points were earned for a protein from an attached ribosome.

Second bullet, 1 point was earned for the ultimate destination for proteins from free ribosomes, "while proteins produced on free ribosomes are delivered to the cytosol."

Free-Response Question 6

6. Fruit flies (*Drosophila melanogaster*) with a wild-type phenotype have gray bodies and red eyes. Certain mutations can cause changes to these traits. Mutant flies may have a black body and/or cinnabar eyes. To study the genetics of these traits, a researcher crossed a true-breeding wild-type male fly (with gray body and red eyes) with a true-breeding female fly with a black body and cinnabar eyes. All of the F_1 progeny displayed a wild-type phenotype.

   Female flies from the F_1 generation were crossed with true-breeding male flies with black bodies and cinnabar eyes. The table below represents the predicted outcome and the data obtained from the cross. **Explain** the difference between the expected data and the actual numbers observed.

F_2 Generation Phenotypes			
Body Color	Eye Color	Number Predicted	Number Observed
Gray	Red	244	455
Black	Cinnabar	244	432
Gray	Cinnabar	244	42
Black	Red	244	47

Information for Free-Response Question 6

Essential Knowledge	3.A.3: The chromosomal basis of inheritance provides an understanding of the pattern of passage (transmission) of genes from parent to offspring.
Science Practices	2.2: The student can apply mathematical routines to quantities that describe natural phenomena.
Learning Objectives	3.14: The student is able to apply mathematical routines to determine Mendelian patterns of inheritance provided by data.

Scoring Guidelines for Free-Response Question 6

4 points maximum.
Student explanations include the following: • Prediction of a 1:1:1:1 ratio with correct phenotypes based on independent assortment. • Support for prediction with a diagram of the cross of *BbEe* x *bbee*. • Correct application of chi-square analysis to show that observed results do not conform to expected Mendelian frequencies. • Identification of body color and eye color as linked genes/loci. • Use of ratios to show linkage and independent assortment of wing type versus linked traits. • Identification of the bottom two phenotypes as products of crossing over (recombinant chromosome). • Mentioning that crossover rate is approximately 9–10 percent.

Sample: 6A

6. Fruit flies (*Drosophila melanogaster*) with a wild-type phenotype have gray bodies and red eyes. Certain mutations can cause changes to these traits. Mutant flies may have a black body and/or cinnabar eyes. To study the genetics of these traits, a researcher crossed a true-breeding wild-type male fly (with gray body and red eyes) with a true-breeding female fly with a black body and cinnabar eyes. All of the F_1 progeny displayed a wild-type phenotype.

Female flies from the F_1 generation were crossed with true-breeding male flies with black bodies and cinnabar eyes. The table below represents the predicted outcome and the data obtained from the cross. **Explain** the difference between the expected data and the actual numbers observed.

F_2 Generation Phenotypes			
Body Color	Eye Color	Number Predicted	Number Observed
Gray	Red	244	455
Black	Cinnabar	244	432
Gray	Cinnabar	244	42
Black	Red	244	47

The difference between the expected and actual data could be accounted for ~~it~~ by hypothesizing that the two traits being ~~studied~~ studied are linked, ~~that is~~ they are both on the same chromosome. This invalidates the theory of independent assortment, as the two traits are mostly passed down together. However, the two traits ~~can be~~ are rarely separated by a process known as genetic recombination, which involves the exchanging of genes amongst sister chromatids during meiosis. This explains why all of the flies are not either gray and red or black and cinnabar.

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Sample: 6B

6. Fruit flies (*Drosophila melanogaster*) with a wild-type phenotype have gray bodies and red eyes. Certain mutations can cause changes to these traits. Mutant flies may have a black body and/or cinnabar eyes. To study the genetics of these traits, a researcher crossed a true-breeding wild-type male fly (with gray body and red eyes) with a true-breeding female fly with a black body and cinnabar eyes. All of the F_1 progeny displayed a wild-type phenotype.

   Female flies from the F_1 generation were crossed with true-breeding male flies with black bodies and cinnabar eyes. The table below represents the predicted outcome and the data obtained from the cross. **Explain** the difference between the expected data and the actual numbers observed.

F_2 Generation Phenotypes			
Body Color	Eye Color	Number Predicted	Number Observed
Gray	Red	244	455
Black	Cinnabar	244	432
Gray	Cinnabar	244	42
Black	Red	244	47

Equal numbers of all varieties were expected, however, because the genes were linked, ~~the~~ two phenotypes were more frequent than the others. ~~Because they were linked, the only~~ Because the Gray & Red were linked, and the Black & Cinnabar, the only mixes between the two were produced by random crossing over, thus, the Gray cinnabar & Black Red combinations are less frequent

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Sample: 6C

6. Fruit flies (*Drosophila melanogaster*) with a wild-type phenotype have gray bodies and red eyes. Certain mutations can cause changes to these traits. Mutant flies may have a black body and/or cinnabar eyes. To study the genetics of these traits, a researcher crossed a true-breeding wild-type male fly (with gray body and red eyes) with a true-breeding female fly with a black body and cinnabar eyes. All of the F_1 progeny displayed a wild-type phenotype.

Female flies from the F_1 generation were crossed with true-breeding male flies with black bodies and cinnabar eyes. The table below represents the predicted outcome and the data obtained from the cross. **Explain** the difference between the expected data and the actual numbers observed.

F_2 Generation Phenotypes			
Body Color	Eye Color	Number Predicted	Number Observed
Gray	Red	244	455
Black	Cinnabar	244	432
Gray	Cinnabar	244	42
Black	Red	244	47

The difference of the number predicted and the number observed is that the genes may be linked, or be close in location. Because of their closeness, the recombination frequencies when genes cross over is reduced. The farther apart the genes, the more likely that will be crossed with another gene allowing genetic recombination. Because their recombination of the two genes is very small, they are likely to be passed together = gray and red, or black and cinnabar

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Free-Response Question 6

Overview

This question provided an opportunity to demonstrate an understanding of the chromosomal basis of inheritance and how it provides an explanation of the pattern or passage (transmission) of genes from parent to offspring. Using phenotype data from the F_2 generation, an explanation for the difference between expected data and actual observed data was required. The explanation of these different data could be explained by independent assortment, linkage, and recombination. Prediction of a 1:1:1:1 ratio could be supported by a diagram or Punnett square. The use of a chi-square analysis to show that the results do not support the 1:1:1:1 prediction and an explanation of linked genes provide evidence of the ability to apply mathematical analysis of data.

Sample: 6A
Score: 3

One point was earned for identifying gene linkage as an explanation for the differences between observed and expected phenotypic ratios for body and eye color in *Drosophila*.

One point was earned for explaining that linkage "invalidates the theory of independent assortment as the two traits are mostly passed down together." One point was awarded for explaining that the bottom two phenotypes (gray/cinnabar and black/red) result from crossing over, i.e., that "genetic recombination … involves the exchanging of genes amongst sister chromatids during meiosis." (The response could have earned an additional 1 point if the student had used a mathematical application such as Punnett square or chi-square analysis to support a 1:1:1:1 expected phenotypic ratio.)

Sample: 6B
Score: 2

One point was earned for stating that the "genes were linked" as an explanation for the differences between observed and expected phenotypic ratios.

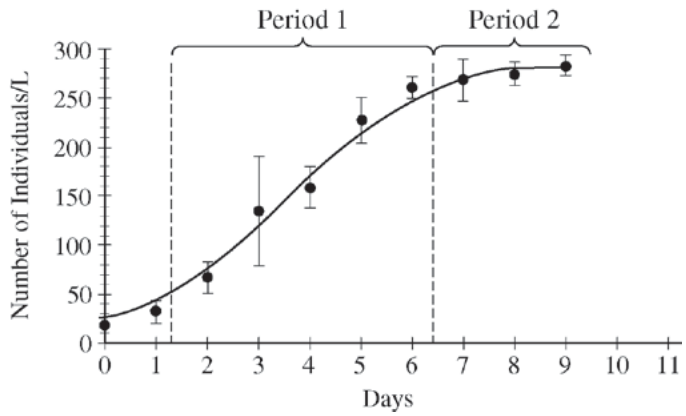
One point was earned for identifying the bottom two phenotypes (gray/cinnabar and black/red) as products of crossing over. (No mathematical applications such as Punnett square or chi-square analysis were used to support the explanation.)

Sample: 6C
Score: 1

One point was earned for explaining that the genes for body color and eye color are linked. (No mathematical applications such as Punnett square or chi-square analysis were used to support the explanation. The response did not distinguish between independent assortment, linkage, and recombination/crossing-over.)

Free-Response Question 7

7. A population of microscopic eukaryotic organisms growing in a large flask had the growth pattern shown.



In one paragraph, **explain** the biological factors that determine the shape of the growth pattern shown above in both period 1 and period 2.

Information for Free-Response Question 7

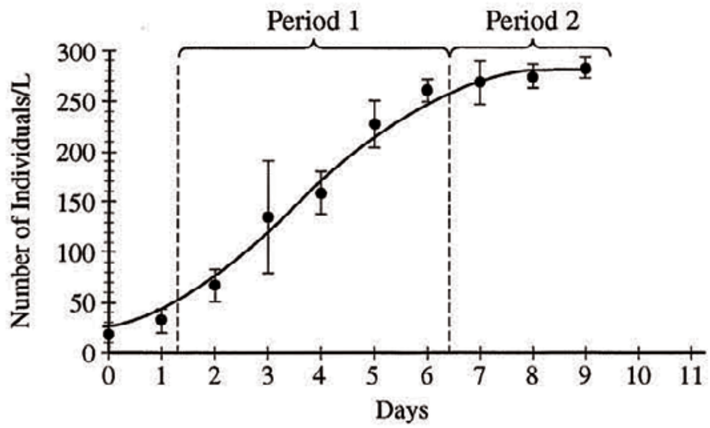
Essential Knowledge	2.D.1: All biological systems from cells and organisms to populations, communities, and ecosystems are affected by complex biotic and abiotic interactions involving exchange of matter and free energy
Science Practices	5.1: The student can analyze data to identify patterns or relationships.
Learning Objectives	2.24: The student is able to analyze data to identify patterns and relationships between a biotic or abiotic factor and a biological system (cells, organisms, populations, communities, or ecosystems).

Scoring Guidelines for Free-Response Question 7

3 points maximum. 1 point for each correct explanation of the pattern or relationship between the environmental factor and the biological system.
Possible explanations include the following: • Recognition of exponential growth due to lack of limiting factors; reproductive/growth rate far exceeds death rate. • Slowing of reproductive/growth rate due to the influence of density-dependent limiting factors. • Death rate beginning to approach reproductive/growth rate in transition from period 1 to period 2. • Accumulation of toxic wastes increases death rate and decreases reproductive rate. • Population at carrying capacity stabilizes as the reproductive rate equals the death rate.

Sample: 7A

7. A population of microscopic organisms growing in a large flask had the growth pattern shown.



In one paragraph, **explain** the biological factors that determine the shape of the growth pattern shown above in both period 1 and period 2.

During period 1, the bacteria had a wide availability of food and growing room. With virtually no competition, the bacteria were able to grow rapidly; during this period, the bacteria population experienced exponential growth. In period 2, however, resources were becoming limited as the population approached carrying capacity; the growth of the population slowed dramatically as bacteria were forced to compete for limited resources. In the end, the growth rate of the population approached zero as the population attained equilibrium.

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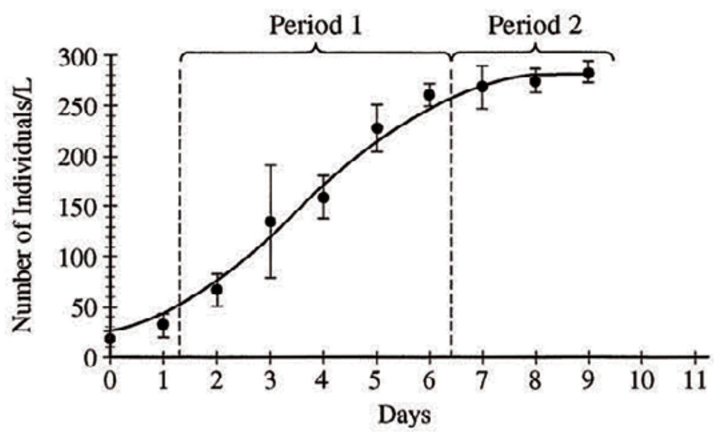
Sample: 7B

7. A population of microscopic organisms growing in a large flask had the growth pattern shown.



In one paragraph, **explain** the biological factors that determine the shape of the growth pattern shown above in both period 1 and period 2.

The organisms began growing (period 1) exponentially because they had more resources than they needed at the time. The reproduction rate reduced over time (in period 2) and leveled off when ~~they~~ the population approached carrying capacity, the maximum amount of individuals that can be sustained by the environment.

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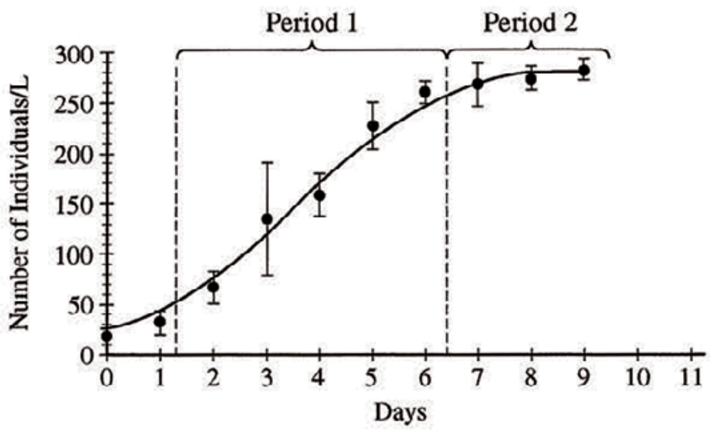
Sample: 7C

7. A population of microscopic organisms growing in a large flask had the growth pattern shown.



In one paragraph, **explain** the biological factors that determine the shape of the growth pattern shown above in both period 1 and period 2.

Biological factors that determine the growth pattern in part one have to do with nutrients available as well as the space alotted within the flask for growth. In this case ~~it~~ the growth pattern increased readily until period 2. ~~At~~ At this point the microorganisms ~~had~~ seem to cap off in number because of the conditions in the flask, over population, and depleting food levels.

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Free-Response Question 7

Overview

This question provided an opportunity to demonstrate an understanding of the biological factors that determine the shape of a growth pattern graph of microscopic eukaryotic organisms growing in a large flask. The ability to analyze data to identify patterns and relationships between a biotic or abiotic factor and a biological system was required. The analysis of two different periods (segments) of the graph was expected.

Sample: 7A
Score: 3

The maximum of 3 points were earned. One point was earned for explaining that the shape of the graph during period 1 could be attributed to the lack of limiting factors: "With virtually no competition, the bacteria were able to grow rapidly … experienced exponential growth." One point was earned for explaining the slowing of the productive rate during period 2 as "bacteria were forced to compete for limited resources." One point was earned for explaining that "as the population approached carrying capacity … the growth rate of the population approached zero."

Sample: 7B
Score: 2

One point was earned for explaining that the shape of the curve illustrated in period 1 indicates that the population of organisms was "growing exponentially because they had more resources than they needed." One point was earned for explaining that the "reproduction rate reduced over time (in period 2) and leveled off when the population approached carrying capacity." (The response did not describe factors that could slow population growth such as limiting factors and differences between death and birth rate.)

Sample: 7C
Score: 1

One point was earned for explaining that the slowing of the reproductive/growth rate was due to "overpopulation and depleting food levels." (The response did not describe the changes in the shape of the graph during period 1 and period 2 nor did it provide explanations for the changes, e.g., exponential v. density-dependent growth rate, carrying capacity, death v. birth rate.)

Free-Response Question 8

8. Fossils of a microscopic organism are found in rocks determined to be over 3.5 billion years old. **Identify** TWO types of evidence that would help answer the question of whether the organism was photosynthetic.

Information for Free-Response Question 8

Essential Knowledge	1.D.1: There are several hypotheses about the natural origin of life on Earth, each with supporting scientific evidence. 2.A.2: Organisms capture and store free energy for use in biological processes.
Science Practices	3.3: The student can *evaluate scientific questions*. 6.2: The student can *construct explanations of phenomena based on evidence* produced through scientific practices.
Learning Objectives	1.28: The student is able to evaluate scientific questions based on hypotheses about the origin of life on Earth. 2.5: The student is able to construct explanations of the mechanisms and structural features of cells that allow organisms to capture, store, or use free energy.

Scoring Guidelines for Free-Response Question 8

2 points maximum.

Possible evidence that the organism was photosynthetic:

- Internal presence of photosynthetic membrane or chloroplast
- High levels of oxygen gas or oxides in the surrounding rock
- Evidence of photosynthetic pigments in cell
- Chemical analysis of the fossil shows the presence of molecules associated with the photosynthetic process

Possible evidence that the organism was not photosynthetic:

- Lack of photosynthetic membrane or chloroplast
- Surrounding rock suggests anaerobic environment

Sample: 8A

9. Fossils of a microscopic organism are found in rocks determined to be over 3.5 billion years old. **Identify** TWO types of evidence that would help answer the question of whether the organism was photosynthetic.

One of the main evidences to determining if an organism was photosynthetic would be to check if the organism has a chloroplast. The chloroplast is the main organelle for carrying out the process of photosynthesis. Another aspect that can determine if an organism is photosynthetic would be by seeing if there are any signs of trapped O_2 in the fossil, because one of the bi-products of the process of photosynthesis is O_2 as well as $C_6H_{12}O_6$.

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Sample: 8B

9. Fossils of a microscopic organism are found in rocks determined to be over 3.5 billion years old. **Identify** TWO types of evidence that would help answer the question of whether the organism was photosynthetic.

~~if~~ Chloroplasts survive for a very long time even though a cell may have died. If the fossil were ~~still~~ completely in tact, the chloroplast may still be visible. Finding a chloroplast would prove that the organism was ~~photosynthetic~~ photosynthetic. Another organelle that could be located to prove the organism to be photosynthetic is the mitochondria. The mitochondria is beleived to also be ~~an~~ photosynthetic organelle that evolved over a long period of time.

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Free-Response Question 8

Overview

This question provided an opportunity to demonstrate the ability to evaluate scientific questions based on hypotheses about the origin of life on Earth and to construct an explanation of the mechanisms and structural features of cells that allow organisms to capture, store, or use free energy. The ability to identify a microbe as photosynthetic and to describe its characteristics, as well as evidence of its presence, was required.

Sample: 8A
Score: 2

The maximum of 2 points was earned. One point was earned for identifying the presence of a chloroplast as evidence for determining whether the fossilized organism was photosynthetic. One point was earned for "seeing if there are any signs of trapped O_2 in the fossil" as another clue for identifying the organism as photosynthetic and explaining "one of the bi-products [*sic*] of the process of photosynthesis is O_2 as well as $C_6H_{12}O_6$."

Sample: 8B
Score: 1

One point was earned for stating, "Finding a chloroplast would prove that the organisms was photosynthetic." (No additional supporting evidence was cited. The response contained several misconceptions about cellular origins, including, "The mitochondria is believed [*sic*] to also be a photosynthetic organelle" and, "Chloroplasts survive for a very long time even through a cell may have died.")

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