Free-Response Section

Section II, the free-response part of the exam, begins with a mandatory 10-minute reading period. Students should read, review, and begin preliminary planning for their responses. This section contains two types of free-response questions, and the student will have a total of 80 minutes to complete all the questions.

Due to the emphasis on quantitative skills and the application of mathematical methods in the questions on both sections, students will be allowed to use simple four-function calculators (with square root) on the entire exam. Students will also be supplied with a formula list as part of their testing materials.

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.
Characteristics of a STRONG Response	(Part a) The student is able to write a coherent paragraph with appropriate terminology and elaboration to explain how free energy is required for living systems — from cells to populations, communities, and ecosystems — and can predict consequences to these systems if free energy needs are not met. Based on the scenario, the student is able to explain through narrative or diagram with annotation the role of the electron transport chain and its associated proteins with the production of ATP and NADPH in the light-dependent reactions of photosynthesis. The student is able to predict consequences of a viral infection that disrupts the ETS in cells and justifies those predictions *even though the question does not specifically ask for justification*. For example, the student might say that because the light-independent reactions (Calvin cycle) require ATP and NADPH generated in the ETS of the light-dependent reactions, if one of the ETS proteins is disrupted by a virus, production of ATP and/or NADPH decreases and the cells will be unable to fix carbon into G3P. In turn, cellular respiration, which depends on carbohydrate produced in the Calvin cycle, likely decreases. The student is able to make connections between concepts — in this case, the interdependency of the light-dependent and light-independent reactions of photosynthesis, and photosynthesis and cellular respiration.

	(Part b) The student is able to identify, explain, or describe several consequences of viral infection on individual plants and provide justification. Predictions may include, but are not limited to, stunted growth due to lack of energy needed for building molecules; inability to grow, repair tissues, and reproduce due to lack of usable free energy; and likelihood of the plant weakening or dying if energy demands cannot be met once the plant uses up pre-infection energy stores. (Part c) The student is able to explain how a change in one component (e.g., virus, plant species) of a biological system (e.g., plant, prairie community) affects the community as a whole with respect to matter and energy flow. The student is able to predict several potential effects — both negative and positive — of short-term change due to a viral infection on the plant population and prairie community and justify those predictions. For example, the student may explain how a virus that infects a population of producers (i.e., grass species) could result in a decrease in consumer population size as less energy is available for the higher tropic levels. Similarly, the student may explain how the reproductive rate in uninfected plants likely increases due to more available resources with the death of infected plants. (Part d) The student is able to predict several potential effects — both negative and positive — of long-term change due to a viral infection on the plant population and prairie community and justify those predictions. For example, the student may explain how the loss of infected plants reduces genetic variability of the grass species, or may describe how the loss of prairie grass increases erosion, resulting in degradation of the abiotic environment. Similarly, the student may predict with justification how changes in allele frequencies in the infected plants lead to natural selection and evolution or that if the affected grass is replaced by other plant species, the long-term effects can be minimized. Based on considerations, the student is able to explain how populations and communities with species diversity (e.g., a prairie) are more stable and better able to withstand changes to the environment.
Characteristics of a GOOD Response	(Part a) With less elaboration, the student is able to write a coherent paragraph to explain why all organisms require free energy and matter to survive and identifies photosynthesis as an energy-producing strategy associated with plants, including prairie grass. The student is able to explain through narrative or diagram with annotation the general process of the electron transport chain and its associated proteins and its role in the production of energy in light-dependent reactions of photosynthesis. The student identifies ATP and NADPH as energy-carrying molecules. The student is able to predict two to three consequences of a virus that acts by disrupting the ETS. Possible consequences that the student may cite include less ATP and NADPH produced because these energy-carriers are produced in the ETS, and decreased O_2 production if photosynthesis grinds to a halt. Justifications are more limited.

	(Part b) The student is able to identify, explain, or describe two to three consequences of viral infection on individual plants and justify the predictions. However, justifications are more limited. Predictions may include, but are not limited to, stunted growth due to lack of energy needed for building molecules; the inability to grow, repair tissues, and reproduce due to lack of usable free energy; and plant death if energy demands cannot be met. (Part c) The student is able to explain how a change in the plant population due to infection affects the prairie community as a whole with respect to energy flow/dynamics. The student is able to predict two to three consequences of short-term change due to a viral infection on the plant population and prairie community and justify the predictions. However, justifications are more limited. For example, the student may describe how the population size decreased due to death of infected members, or that the herbivore population could decrease due to increased competition for resources. Similarly, the student may describe how unaffected plant species gain resources because the loss of infected plants leads to more available resources. (Part d) The student is able to predict two to three potential effects — both negative and positive — of long-term change due to a viral infection on the plant population and prairie community and justify those predictions. However, justifications are more limited. For example, the student may describe how plant species become locally extinct due to increased death rate attributed to infection. Similarly, the student could predict a change in allele frequency when naturally resistant phenotypes are selected for. Based on the considerations, the student is able to explain how populations and communities with species diversity (e.g., a prairie) are better able to withstand change to the environment.
Characteristics of a WEAK Response	(Part a) The student's narrative is less coherent and often lacks correct terminology. The student is able to state that organisms require free energy to survive but is limited in ability to explain *why* free energy is necessary. The student identifies photosynthesis as an energy-producing process in plants and can list ATP (and possibly NADPH) as an energy-carrying molecule(s) produced in photosynthesis. However, the student's explanation of how the electron transport chain produces energy in the form of ATP (and/or NADPH) is limited and reflects little conceptual understanding on the molecular level. The student is able to predict one to two consequences of a virus that acts by disrupting the ETS but cannot elaborate on the reasons (justifications) for the disruption(s). (Part b) The student is able to describe one to two consequences of viral infection on individual plants but cannot justify the predictions. For example, the student states that the infected plant can die but does not give a reason for the consequence.

	(Part c) The student is able to explain how a decrease in the amount of grass due to infection affects the energy dynamics of the prairie community; that is, a change in the producer trophic level affects the consumer level(s). The student is able to describe 1–2 adverse consequences of short-term change due to infection on the plant population and prairie community but provides limited or no justification for the predictions. The student likely does not consider possible positive effects to the prairie community. (Part d) The student is able to predict one to two adverse consequences of long-term change due to infection on the plant population and prairie community but provides limited or no justification for the predictions. The student likely does not consider possible positive effects on the community and is unable to explain with much coherence why populations and communities with species diversity (e.g., a prairie) are better able to withstand change to the environment.

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.

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.
Characteristics of a STRONG Response	The student is capable of demonstrating understanding that interactions among living systems and with their environment result in the movement of matter and energy. (Part a) The student is able to draw a graph showing the effect of temperature change on the rate of transpiration that possesses properly labeled and scaled axes with points accurately plotted. The student may either connect the points or construct an accurate best-fit line. The student is able to write a coherent paragraph with appropriate terminology and elaboration to explain that the shape of the curve from 23–28 degrees demonstrates that the rate of evaporation increases with increasing temperature and/or that at higher temperatures there are more open stomata. The student also recognizes the leveling off of the line and is able to explain that as the temperature rises too high the plant begins to close its stomata to prevent excessive water loss. (Part b) The student is able to draw a curve that possesses properly labeled and scaled axes indicating a measure of humidity. The student then explains this decreasing curve to the fact that increasing humidity leads to reduced evaporation rates due to a decreased difference in water vapor pressure between the leaf and the atmosphere. (Part c) The student can use the graph, a representation of the effect of increasing percentage of open stomata per area of leaf on the rate of transpiration. The student recognizes and is able to articulate an understanding of the difference in rates of transpiration from 0–60 percent open stomata compared to 60 percent–100 percent open stomata. The student articulates understanding that as the number of open stomata increases, the rate of diffusion between the leaf interior and the environment will increase, and therefore the transpiration rate also increases. The student is then able to recognize that above 60 percent open stomata there must be another limiting factor, such as no difference in vapor pressure between the leaf interior and the environment. Transpiration is now limited by humidity.

	(Part d) The student is able to articulate the understanding that an adaptation is a trait that an organism possesses that increases its fitness within its niche. The student demonstrates an understanding of structure and function by correctly connecting the organism to its environment. The student justifies that Anacharis must be adapted to an environment where transpiration does not occur, such as underwater or in 100 percent humidity because in either environment there would be no need for stomata. The student successfully connects all stomata on the upper epidermis to the water lily and justifies this to the water lilies' environment on the surface of water. The student justifies the large number of stomata as the plant's increasing its ability for gas exchange with no danger of excess water loss due to its environment. Lastly, the student connects the presence of stomata, limited to the lower leaf surface, to an understanding that 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 an aquatic environment. Stomata located on the lower epidermis of leaves are shaded from exposure to direct sunlight and higher temperatures, mitigating excessive water loss.
Characteristics of a GOOD Response	(Part a) The student is able to draw a graph showing the effect of temperature change on the rate of transpiration that possesses properly labeled and scaled axes with points accurately plotted. The student may either connect the points or construct an accurate best-fit line. The student is able to write a coherent paragraph with appropriate terminology and elaboration to explain that the shape of the curve from 23–28 degrees demonstrates that the rate of evaporation increases with increasing temperature and/or that at higher temperatures there are more open stomata. The student also recognizes the leveling off of the line and is able to explain that as the temperature rises too high, the plant begins to close its stomata to prevent excessive water loss. (Part b) The student is able to properly draw a curve that possesses properly labeled and scaled axes indicating a measure of humidity. The student is unable to explain that the decreasing curve is due to the fact that increasing humidity leads to reduced evaporation rates due to a decreased difference in water vapor pressure between the leaf and the atmosphere but can explain generically that water does not evaporate as readily in high humidity.

	(Part c) The student can use the graph, a representation of the effect of increasing percentage of open stomata per area of leaf on the rate of transpiration. The student recognizes and is able to articulate an understanding of the difference in rates of transpiration from 0–60 percent open stomata compared to 60 percent–100 percent open stomata. The student articulates the understanding that as the number of open stomata increases, the rate of diffusion between the leaf interior and the environment will increase, and therefore the transpiration rate also increases. The student is unable to recognize that above 60 percent open stomata there must be another limiting factor, such as no difference in vapor pressure between the leaf interior and the environment. (Part d) The student is able to articulate the understanding that an adaptation is a trait that an organism possesses that increases its fitness within its niche. The student demonstrates an understanding of structure and function by correctly connecting the organism to its environment but has difficulty with justifications.
Characteristics of a WEAK Response	(Part a) The student is able to draw a graph showing the effect of temperature change on the rate of transpiration that possesses properly labeled and scaled axes with points accurately plotted. The student may either connect the points or construct an accurate best-fit line. The student is able to write a coherent paragraph with appropriate terminology to explain that the shape of the curve from 23–28 degrees demonstrates that the rate of evaporation increases with increasing temperature and/or that at higher temperatures there are more open stomata. (Part b) The student is able to properly draw a curve that possesses properly labeled and scaled axes indicating a measure of humidity. The student is unable to explain the decreasing curve to the fact that increasing humidity leads to reduced evaporation rates due to a decreased difference in water vapor pressure between the leaf and the atmosphere. (Part c) The student can read the graph, a representation of the effect of increasing percentage of open stomata per area of leaf on the rate of transpiration. The student recognizes but is unable to articulate an understanding of the difference in rates of transpiration from 0–60 percent open stomata compared to 60 percent–100 percent open stomata. The student articulates the understanding that as the number of open stomata increases, the rate of transpiration increases but does not demonstrate the understanding that the rate of diffusion between the leaf interior and the environment will increase, and therefore the transpiration rate increases. The student is unable to recognize that above 60 percent open stomata there must be another limiting factor, such as no difference in vapor pressure between the leaf interior and the environment. (Part d) The student is able to connect one of the organisms to an environment, such as water lilies to a body of water but is unable to justify the decision or is very general in the justifications.

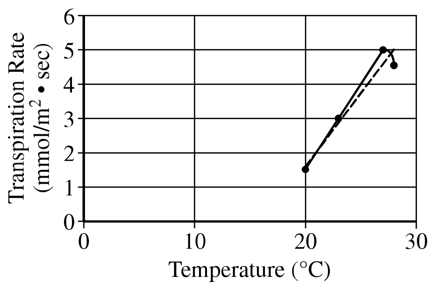
10 points maximum; students must earn points in each part of the question to receive all 10 points.

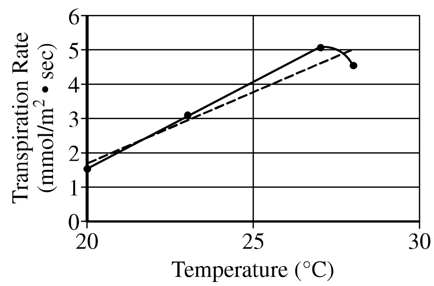
(Part a) Up to 3 points for a properly drawn graph.

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.





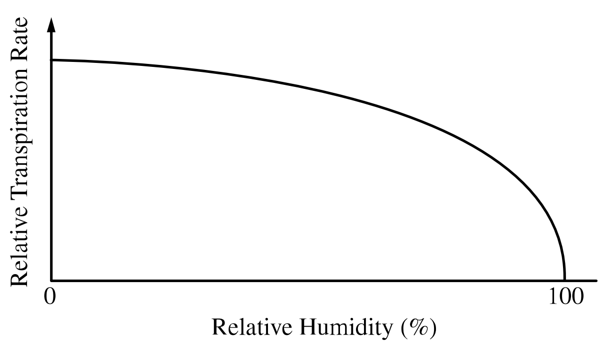
1 point for an appropriate description of the shape of the curve:

- 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.

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.
Characteristics of a STRONG Response	(Part a) The student is able write a coherent paragraph with appropriate terminology to correctly explain that p^2 represents the frequency (proportion, percent) of the homozygous straight-wing individuals and that each has two copies of the dominant allele. The student also can correctly explain that q^2 represents the frequency (proportion, percent) of the homozygous curly-wing individuals and that each has two copies of the recessive allele. Finally, the student can correctly explain that $2pq$ represents the frequency (proportion, percent) of the heterozygous straight-wing flies and that each has one copy of the dominant allele and one copy of the recessive allele. (Part b) The student is able write a coherent paragraph with appropriate terminology to correctly describe one of the following conditions: large population size, no selection, no mutation, no migration, random mating. Descriptions show an understanding that: • Large populations decrease the role of chance fluctuations in allele frequencies that occur more often in smaller populations. This is referred to as genetic drift. • No natural selection ensures no differential survival or reproductive success of individuals carrying different genotypes that would alter allele frequencies. • No mutations ensures no introduction or removal of genes from chromosomes or changes to the genes and thus the gene pool. • No migration or gene flow ensures no transfers of alleles between populations that would alter allele frequencies. • Random mating ensures random mixing of the gametes and no preference to certain genotypes.
Characteristics of a GOOD Response	(Part a) The student is able write a coherent paragraph with appropriate terminology to correctly explain two out of the three terms. (Part b) The student is able write a coherent paragraph with appropriate terminology to correctly describe one of the following conditions: large population size, no selection, no mutation, no migration, random mating.

Characteristics of a WEAK Response	(Part a) The student is able write a coherent paragraph with appropriate terminology to correctly explain one of the terms. (Part b) The student is able write a coherent paragraph with appropriate terminology to correctly describe one of the following conditions: large population size, no selection, no mutation, no migration, random mating.

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. • $2pq$ 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.

Information for Free-Response Question 4

Essential Knowledge	1.C.2: Speciation may occur when two populations become reproductively isolated from each other.
Science Practice	4.1: The student can *justify the selection of the kind of data* needed to answer a particular scientific question.
Learning Objective	1.23: The student is able to justify the selection of data that address questions related to reproductive isolation and speciation.
Characteristics of a STRONG Response	(Parts a and b are combined.) The student is able write a coherent paragraph with appropriate terminology to correctly identify two kinds of data that could be collected. For each of the data, the student explains with justification how the selection of the data addresses the question of whether the populations growing above 2,500 meters and the populations growing below 2,300 meters represent a single species. Given the scenario, the student is able to identify that the plant populations have the potential to interbreed in nature and produce viable and/or fertile offspring. The student is also able to identify that the two plant populations may have the ability to cross-pollinate and/or germinate seeds, as another appropriate type of data. For any of these data sets, the student then validates his or her choice of the data by stating that the biological species concept supports these data. The student may also be able to identify that when comparing the DNA or conserved proteins, a sufficient number of similarities between the two plant species may justify that the two populations may be the same species.
Characteristics of a GOOD Response	The student is able to describe two kinds of data but may be able to justify the selection of only one as answering the question of whether the two populations are the same species. Such an answer would indicate understanding of the biological definition of species.
Characteristics of a WEAK Response	The student may be able to describe two kinds of data without justification, or may be able to correctly describe and justify only one kind of data. This student would indicate limited knowledge of the biological definition of a species.

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

Information for Free-Response Question 5

Essential Knowledge	2.B.3: Eukaryotic cells maintain internal membranes that partition the cell into specialized regions.
Science Practice	6.2: The student can *construct explanations of phenomena based on evidence* produced through scientific practices.
Learning Objective	2.13: The student is able to explain how internal membranes and organelles contribute to cell functions.
Characteristics of a STRONG Response	Attached ribosome (location and function): The student is able to write a coherent paragraph with appropriate terminology and elaboration to explain how a protein produced on the attached ribosome may ultimately end up as a secretory protein excreted from the cell for further use by another cell for cell signaling, signal transduction, or a particular type of metabolic action. Students may also say that the protein may end up embedded into the cell membrane as an integral protein or peripheral protein. The student could then elaborate on how this receptor protein can help in membrane signaling or as an enzyme in a metabolic reaction. The student may mention that the secretory proteins may also be found in transport vesicles for further processing in the Golgi apparatus or to other components of the endomembrane system. The student may mention that proteins end up inside a vacuole or as a digestive enzyme or are stored for later use in seed plants. Another possible description is that the proteins end up inside the Golgi apparatus. The protein will eventually be packed and excreted as a transmembrane protein within the cell. Free ribosome (location and function): The student is able to write a coherent paragraph with appropriate terminology and elaboration to explain how a protein produced on the free ribosome may ultimately end up in the cytosol or a vacuole as a structural protein to function in the cytoskeleton or as a motor protein in the cell. The student may also mention that the proteins in the vacuole function as an enzyme that mediates cell processes or as a second messenger in a cell signal transduction mechanism. Another explanation of the location of a protein is in the nucleus. The student would elaborate that the protein would function as a transcription factor or in DNA packaging in chromosomes.

Characteristics of a GOOD Response	Attached ribosome (location and function): The student is able to explain in a paragraph how a protein produced on the attached ribosome may ultimately end up as a secretory protein excreted from the cell for further use by another cell; however, the student will not go into further details. The student may also say that the protein may end up embedded in the cell membrane as an integral protein or as a peripheral protein. The student states that this receptor protein contributes to the structure of the cell membrane but will not provide additional details. The student may mention that the secretory proteins may also be found in transport vesicles for further processing in the Golgi apparatus or to other components of the endomembrane system. The student may mention that proteins end up inside a vacuole for storage but not explain further details of how they function for the plant being in the vacuole. Free ribosome (location and function): The student is able to write a paragraph to explain how a protein produced on the free ribosome may ultimately end up in the cytosol or a vacuole as a structural protein to function in the cytoskeleton or as a motor protein in the cell. The student may also mention that the proteins in the vacuole function as an enzyme. Also included in the explanation could be how the location of the protein in the nucleus can function as a transcription factor or with DNA.
Characteristics of a WEAK Response	The student may mention the location but not the function or vice versa, and the identifications and explanations will be brief. Attached ribosome (location and function): The student is able to explain how a protein produced on the attached ribosome may end up as a protein excreted from the cell. The student may also say that the protein may end up embedded into the cell membrane. The student may not be able to elaborate on the functions. The student may mention that the proteins are found in transport vesicles for further processing in the Golgi apparatus. The student may mention that proteins end up inside a vacuole but may not mention their function. Free ribosome (location and function): The student is able to explain how a protein produced on the free ribosome may end up in the cytosol or a vacuole. The explanation may also include factors surrounding the location of a protein in the nucleus. The student may mention that the protein has something to do with DNA but not elaborate further.

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 free 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

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 Practice	2.2: The student can apply mathematical routines to quantities that describe natural phenomena.
Learning Objective	3.14: The student is able to apply mathematical routines to determine Mendelian patterns of inheritance provided by data.
Characteristics of a STRONG Response	The student is able to write a coherent paragraph that shows an understanding of independent assortment, linkage, and recombination in the transmission of genes from parent to offspring. A prediction of a 1:1:1:1 ratio will be supported by a diagram or Punnett square. The student will be able to use a chi-square analysis to show that the results of the cross do not fit the expected 1:1:1:1 ratio predicted by independent assortment and will be able to explain that the genes for body color and eye color are linked on the same chromosome. A strong student may also predict the relative location of the genes on the chromosome based on the data.
Characteristics of a GOOD Response	The student is able to write a coherent paragraph that indicates an understanding of independent assortment and linkage in the transmission of genes from parent to offspring. The student will be able to use a diagram of the cross to support a 1:1:1:1 ratio predicted by independent assortment and will be able to recognize that the eye color and body color genes are linked with some recombination. The student will be able to predict the relative location of the genes on the chromosome by recognizing the recombinant phenotypes and calculating the ratio.
Characteristics of a WEAK Response	The student is able to predict a 1:1:1:1 ratio based on independent assortment. The student may support this prediction with a Punnett square or diagram, or may recognize that the genes for eye color and body color are linked on the same chromosome.

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.

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 Practice	5.1: The student can analyze data to identify patterns or relationships.
Learning Objective	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).
Characteristics of a STRONG Response	The student is able to explain three possible factors that influence the shape of the growth pattern. The student will correctly identify and explain the logarithmic pattern of period 1 and the slowing of the growth rate in period 2 and will relate each specific biological factor to the change in growth rate of the system.
Characteristics of a GOOD Response	The student is able to explain two factors that influence the shape of the growth pattern, correctly explaining the logarithmic growth in period 1 and how each factor causes a slowing of the growth rate in period 2.
Characteristics of a WEAK Response	The student is able to relate one possible factor to the shape of the growth pattern, correctly explaining the logarithmic growth in period 1 and how that factor causes a slowing of the growth in period 2.

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.

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.
Characteristics of a STRONG Response	A strong student will be able to identify a microbe as photosynthetic if it had evidence of photosynthetic pigments or a photosynthetic membrane within the cell. The student will also indicate that the presence of oxides or oxygen gas in the surrounding rock provides such evidence. Conversely, the student may state that the lack of photosynthetic structures or evidence of oxygen would suggest this microbe was not photosynthetic.
Characteristics of a GOOD Response	A good student would be able to cite one piece of evidence indicating whether or not the microbe was photosynthetic, such as the presence of photosynthetic pigments or membrane. The student may instead choose to use evidence of oxygen or oxides in the surrounding rock or to state that their absence indicates that the organism was not photosynthetic.

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

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