Notes on the Practice Exam

Introduction

This section provides a description of how the questions in the AP Practice Exam correspond to the components of the curriculum framework included in the *AP Biology Course and Exam Description*. For each of the questions in the AP Practice Exam, the targeted learning objectives, essential knowledge, and science practices from the curriculum framework are indicated.

In addition, the multiple-choice and free-response questions include the following features:

- For multiple-choice questions, the correct response is indicated with a justification for why it is correct. There are additional explanations that address why the other responses are incorrect.
- Free-response questions include scoring guidelines as well as descriptions of student responses that would represent "strong, good, and weak" levels. These scoring guidelines demonstrate how the essential knowledge and application of the science practices are assessed in each free-response question.

The 2013 AP Biology Exam is approximately 3 hours in length. There are two sections, each accounting for 50 percent of the student's AP Exam score.

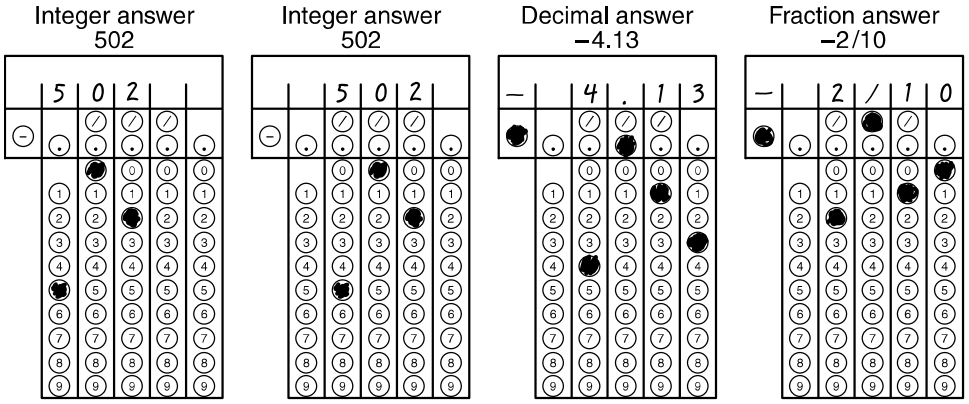
- Section I is 90 minutes long and consists of 63 multiple-choice questions and 6 grid-in questions.
- Section II is 90 minutes long and consists of 2 long free-response questions and 6 short free-response questions. It begins with a 10-minute reading period for students to read the questions and plan their answers. The remaining 80 minutes is for responding to the questions.

Section	Question Type	Number of Questions	Timing
I	Multiple Choice	63	90 minutes
	Grid-In	6	
II	Long Free Response	2	80 minutes + 10-minute Reading Period
	Short Free Response	6	

All of the questions on the exam are designed to measure the student's understanding of the big ideas, enduring understandings, and essential knowledge, and the student's application of this understanding through the science practices.

Multiple-Choice Section

In Section I there are 63 multiple-choice questions. These questions represent the knowledge and skills students should know, understand, and be able to apply. Section I also includes 6 grid-in questions that require the integration of science and mathematical skills. For the grid-in responses, students will need to calculate the answer for each question and enter it in the grid on the answer sheet provided. Note: For this practice exam and publication, the grids included on the answer sheet have been modified. The sample grids below are more representative of what students will actually see on the AP Biology Exam answer sheet.



Information for Multiple-Choice Questions 1–63

Question 1

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.
(A)	This option is incorrect. The presence of organelles will not speed cell reproduction. The need to make new organelles may actually slow the rate of cell division because of the time it takes for the cell to produce them.
(B)	This option is incorrect. Although mitochondria and chloroplasts likely arose from free living prokaryotic cells, this does not explain the advantage for eukaryotic cells to have internal membranes.
(C)	**This option is correct. It demonstrates understanding and provides an explanation of how internal membrane-bound organelles contribute to cell function by providing a favorable local environment for metabolic reactions, and by protecting the cell from potentially damaging metabolic reactions.**
(D)	This option is incorrect. Compartmentalization does not increase mutation rates. Carrying out potentially harmful reactions within membrane-bound organelles may lower mutation rates because it protects DNA from possible damage.

Question 2

Essential Knowledge	1.D.1: There are several hypotheses about the natural origin of life on Earth, each with supporting scientific evidence.
Science Practice	3.3: The student can evaluate scientific questions.
Learning Objective	1.28: The student is able to evaluate scientific questions based on hypotheses about the origin of life on Earth.
(A)	This option is incorrect. The Miller experiment did not model the formation of Earth but rather attempted to model the evolution of biological molecules on Earth.
(B)	This option is incorrect. The Miller experiment did not model the conditions on comets or meteorites but rather attempted to model the evolution of biological molecules on Earth.
(C)	**This option is correct. It demonstrates the ability to evaluate scientific questions about the origin of life on Earth by recognizing that the Miller experiment modeled the presumed early atmospheric conditions and, under laboratory conditions, produced biological molecules, such as amino acids, that were required for early life.**
(D)	This option is incorrect. The molecules formed in the Miller experiment were not proteins.

Question 3

Essential Knowledge	2.A.3: Organisms must exchange matter with the environment to grow, reproduce, and maintain organization.
Science Practice	2.2: The student can apply mathematical routines to quantities that describe natural phenomena.
Learning Objective	2.6: The student is able to use calculated surface area-to-volume ratios to predict which cell(s) might eliminate wastes or procure nutrients faster by diffusion.

(A)	**This option is correct. It demonstrates the ability to calculate surface area-to-volume ratios and predict their effects on a cell's ability to exchange materials with its environment. The cell shown in A has the greatest surface area-to-volume ratio at 0.6:1.**
(B)	This option is incorrect. That cell does not have the greatest surface area-to-volume ratio at 0.3:1.
(C)	This option is incorrect. That cell does not have the greatest surface area-to-volume ratio at 0.2:1.
(D)	This option is incorrect. That cell does not have the greatest surface area-to-volume ratio at 0.1:1.

Question 4

Essential Knowledge	4.B.4: Distribution of local and global ecosystems changes over time.
Science Practice	6.4: The student can make claims and predictions about natural phenomena based on scientific theories and models.
Learning Objective	4.21: The student is able to predict consequences of human actions on both local and global ecosystems.

(A)	**This option is correct. It demonstrates an understanding of the human impact on ecosystems and correctly predicts that the loss of habitat from deforestation likely will lead to a loss of species diversity due to a decrease of available niches.**
(B)	This option is incorrect. Destruction of the tropical rain forest does not increase soil moisture but rather it decreases soil moisture because there is less shade to retain dampness in deforested regions.
(C)	This option is incorrect. Accumulation of carbon dioxide in the atmosphere does not affect ultraviolet penetration but rather contributes to the "greenhouse effect," which absorbs reflected infrared radiation and re-reflects some of it back toward Earth, thus warming the planet.
(D)	This option is incorrect. Deforestation would reduce the amount of available oxygen because there would be less photosynthetic activity to release oxygen in the splitting of water in Photosystem II of the light-dependent reactions.

Question 5

Essential Knowledge	1.B.1: Organisms share many conserved core processes and features that evolved and are widely distributed among organisms today.
Science Practice	6.1: The student can justify claims with evidence.
Learning Objective	1.16: The student is able to justify the scientific claim that organisms share many conserved core processes and features that evolved and are widely distributed among organisms today.

(A)	This option is incorrect. Not all populations of organisms are adapted, or can adapt, to fill vacant ecological roles. The ecological role of an organism depends on biotic and abiotic factors in the environment. For example, a carnivore cannot adapt to fill the role of primary producer, and a prey is unlikely to fill the role of a predator.
(B)	This option is incorrect. Not all organisms utilize oxygen to harness free energy from organic compounds. Fermentation and anaerobic respiration provide a mechanism by which some cells can oxidize organic fuel and generate ATP *without* the use of oxygen. Thus, aerobic respiration is not a universal mechanism for harnessing energy from organic compounds.
(C)	**This option is correct. It demonstrates an understanding that all organisms, both extant and extinct, share a universal genetic code with the justification that the hereditary information encoded in DNA directs the development of biochemical, anatomical, and physiological traits by the fundamental processes of replication, transcription, and translation. Through the process of transformation, genetic information from one organism can change the genotype and phenotype of another organism, thus providing additional evidence for the universality of the genetic code.**
(D)	This option is incorrect. Only eukaryotic cells possess membrane-bound organelles such as mitochondria and chloroplasts. Although mitochondria and chloroplasts likely arose from symbiotic prokaryotic cells, they are not universal to all cells; neither Bacteria nor Archaea possess membrane-bound organelles.

Question 6

Essential Knowledge	3.A.1: DNA, and in some cases RNA, is the primary source of heritable information.
Science Practice	1.2: The student can describe representations and models of natural or man-made phenomena and systems in the domain.
Learning Objective	3.3: The student is able to describe representations and models that illustrate how genetic information is copied for transmission between generations.

(A)	This option is incorrect. The figure shows both template strands of DNA being replicated continuously in a parallel direction. No "lagging" strand with Okazaki fragments is identified. DNA polymerase's structure does not allow it to add nucleotides in the 5' direction.
(B)	This option is incorrect. The figure incorrectly shows Okazaki fragments on the "leading" strand and both new strands being assembled in a parallel direction. DNA polymerase's structure does not allow it to add nucleotides in the 5' direction.
(C)	This option is incorrect. The figure incorrectly shows both strands being replicated continuously, and no Okazaki fragments on the lagging strand are identified. The new strands are shown being assembled in the 3'-to-5' direction, but the limitations of DNA polymerase only allow assembly in the 5'-to-3' direction.
(D)	**This option is correct. It demonstrates an understanding of the structure of DNA and the process of replication. The two strands of the DNA molecule run antiparallel to each other; the 5' end of one strand pairs with the 3' end of the other strand. Replication is semi-conservative, with each strand serving as the template for the creation of new complementary strands. Helicase unzips the DNA molecules between the hydrogen bonds connecting the two strands. DNA polymerase "reads" each template strand in the 3'-to-5' direction and assembles the growing DNA chain in a 5'-to-3' direction. The "leading" strand is produced continuously, but on the "lagging" strand, Okazaki fragments are produced and are connected by ligase to produce the daughter molecule.**

Question 7

Essential Knowledge	1.C.3: Populations of organisms continue to evolve.
Science Practice	5.3: The student can evaluate the evidence provided by data sets in relation to a particular scientific question.
Learning Objective	1.26: The student is able to evaluate given data sets that illustrate evolution as an ongoing process.

(A)	This option is incorrect. Although the drought period was from 1981 to 1987, data were collected only at the beginning and end of the drought period. In addition, the sample was too small to draw conclusions about the correlation between beak size and seed availability during the drought period.
(B)	This option is incorrect. Although the drought period was from 1981 to 1987, measurements of beak size were determined only for 1987, likely too short a time period to observe/measure evolutionary change. Additionally, the measurements were estimations, and the sample size was small.
(C)	**This option is correct. It demonstrates ability to apply the scientific method to evaluate data that illustrate evolution as an ongoing process. Based on observation, the beak sizes of a large number of individuals were measured between the time interval (1981 to 1987) correlating with the period of drought.**
(D)	This option is incorrect. Although the drought period was from 1981 to 1987, beak sizes were measured only in 1981. Measurements of offspring beak sizes were determined, not measurements of beak sizes in the original population; thus, comparisons about changes in beak sizes between generations cannot be accurately determined.

Question 8

Essential Knowledge	1.C.3: Populations of organisms continue to evolve.
Science Practice	5.3: The student can evaluate the evidence provided by data sets in relation to a particular scientific question.
Learning Objective	1.26: The student is able to evaluate given data sets that illustrate evolution as an ongoing process.
(A)	**This option is correct. It demonstrates understanding of evolution through natural selection and explains the relationship between changes in genotype, phenotype, and environment. During the drought period, plants with thick-walled seeds were favored; in turn, finches with larger beaks that could crack the seeds to obtain nourishment were selected for, thus increasing chances for survival.**
(B)	This option is incorrect. There are no data to support this conclusion that draws a correlation between beak size and predatory behavior.
(C)	This option is incorrect. There are no data to support this conclusion that draws a correlation between beak size and flight muscle strength.
(D)	This option is incorrect. Evolution is not explained by Larmack's idea of the inheritance of acquired characters.

Question 9

Essential Knowledge	1.C.3: Populations of organisms continue to evolve.
Science Practice	1.2: The student can describe representations and models of natural or man-made phenomena and systems in the domain.
Learning Objective	1.25: The student is able to describe a model that represents evolution within a population.
(A)	This option is incorrect. The data provide no evidence to support the conclusion that speciation has occurred within the finch population, especially from a single parent species.
(B)	**This option is correct. It demonstrates an understanding of the role of natural selection in evolution. Natural selection acts on phenotypic variations in populations. During the drought period the environment favored plants with thick-walled seeds, and finches with larger beaks had a selective advantage over finches with smaller beaks in using the thick-walled seeds as food. More food led to greater reproductive success for the large-beaked finches. Thus, allele frequencies within the finch population changed, with an increase in alleles conferring the more advantageous phenotype — larger beaks. Changes in allele frequencies in a population provide evidence for evolution.**
(C)	This option is incorrect. The data provide no evidence to support the conclusion that new alleles appeared in the finch population through mutation. Within the population, there was variation in beak size, and changes in the environment (drought) provided a selective pressure favoring finches with larger beaks to crack thick-walled seeds.
(D)	This option is incorrect. The population is not in Hardy-Weinberg equilibrium because of changes in allele frequencies attributed to natural selection. The population is not in equilibrium because beak size is changing.

Question 10

Essential Knowledge	1.C.3: Populations of organisms continue to evolve.
Science Practice	5.3: The student can evaluate the evidence provided by data sets in relation to a particular scientific question.
Learning Objective	1.26: The student is able to evaluate given data sets that illustrate evolution as an ongoing process.
(A)	This option is incorrect. The data provide no evidence to support this conclusion. The return to pre-drought conditions no longer would favor only plants with thick-walled seeds. With an overall increase in the number of plants due to water availability, there would be more variety in the types of seeds available as a food resource for the finches. Thus, the food supply would be expected to increase, not decrease.
(B)	**This option is correct. It demonstrates an ability to evaluate data providing evidence for evolution as an ongoing process. At the end of the drought period, there was a natural return to a variety of seeds available — including a decrease in thick-walled seeds. Thus, allele frequencies shifted to pre-drought numbers because no longer was there selective pressure favoring larger beak sizes.**
(C)	This option is incorrect. The data do not support this conclusion. Had drought conditions increased during the time interval (1988–1993), selected pressure would have favored finches with larger beaks to crack open thick-walled seeds.
(D)	This option is incorrect. The data do not support this conclusion. There is no evidence to support a correlation between finch beak size and predator behavior.

Question 11

Essential Knowledge	4.A.1: The subcomponents of biological molecules and their sequence determine the properties of that molecule.
Science Practice	1.3: The student can refine representations and models of natural or man-made phenomena and systems in the domain.
Learning Objective	4.2: The student is able to refine representations and models to explain how the subcomponents of a biological polymer and their sequence determine the properties of that polymer.
(A)	**This option is correct. It demonstrates an ability to refine and/or interpret a representation to explain the synthesis of a biological polymer. Peptides or proteins are polymers of amino acid monomers arranged in a unique linear sequence. Each of the 20 amino acids consists of a carbon atom surrounded by an amine group (NH_2), a carboxyl group (COOH), a hydrogen, and an R (variable) group. When two amino acids are positioned so that the carboxyl group of one amino acid backbone is adjacent to the amine group of another amino acid backbone, they can join by a dehydration reaction.**
(B)	This option is incorrect. The dipeptide in the figure incorrectly shows a covalent bond between adjacent amine (NH_2) groups, and the "amino acid" shown is not an amino acid because the molecule lacks an amine group.
(C)	This option is incorrect. The dipeptide in the figure incorrectly shows a covalent bond between adjacent carboxyl (COOH) groups between adjacent amino acids, and the "amino acid" shown is not an amino acid because the molecule lacks a carboxyl group.
(D)	This option is incorrect. Although the dipeptide in the figure shows the formation of a peptide bond between the carboxyl (COOH) group of one amino acid and the amine (NH_2) group of the adjacent amino acid, the "amino acid" shown to potentially form a tripeptide is not an amino acid because the molecule lacks an amine group.

Question 12

Essential Knowledge	4.A.6: Interactions among living systems and with their environment result in the movement of matter and energy.
Science Practice	1.4: The student can use representations and models to analyze situations or solve problems qualitatively and quantitatively.
Learning Objective	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.

(A)	This option is incorrect. The quantitative data provided in the scenario do not support this conclusion regarding changes in biomass for coyotes and hawks.
(B)	**This option is correct. It demonstrates an understanding of the components of a food web and interactions between all of the participants. Coyotes prey on deer and rabbits, and if developers remove them, coyotes will lose their primary source of nutrition/energy. With this loss of nutrition/energy they will experience a decrease in reproductive success and therefore a significant decline in their population.**
(C)	This option is incorrect. The data do not provide evidence to support the conclusion that with the removal of deer and rabbits the coyotes will switch to preying on voles and outcompeting hawks for the energy source.
(D)	This option is incorrect. The vole population may not suffer because there is no longer competition from rabbits and deer for the grass. With the removal of rabbits, hawks will lose a source of energy. However, because hawks also prey on voles whereas coyotes do not, hawks still will have a source of energy.

Question 13

Essential Knowledge	4.A.1: The subcomponents of biological molecules and their sequence determine the properties of that molecule.
Science Practice	6.1: The student can justify claims with evidence.
Learning Objective	4.3: The student is able to use models to predict and justify that changes in the subcomponents of a biological polymer affect the functionality of the molecule.

(A)	This option is incorrect. Although it is true that T (thymine) is a not a component of RNA and is replaced by U (uracil), both DNA Segments 1 and 2 must undergo transcription to produce mRNA.
(B)	This option is incorrect. A nucleotide monomer of DNA consists of a phosphate group, deoxyribose, and a nitrogenous base (A, T, C, or G). Although phosphate groups make DNA polar and therefore soluble in water, because both DNA segments have the same number of nucleotide base pairs (11), they have the same number of phosphate groups. Thus, the influence of phosphate groups on both segments' solubility in water is equal.
(C)	**This option is correct. It demonstrates an understanding of the relationship between structure and function at the molecular level and the ability to make predictions about how change(s) in structure affect functionality. Because G-C base pairs have three hydrogen bonds, they are more stable structurally. Thus, because DNA Segment 2 has more G-C base pairs than DNA Segment 1, Segment 2 is more stable and thus would denature at *higher* temperatures than Segment 1.**
(D)	This option is incorrect. The structure of DNA is universal to all life, both prokaryotes and eukaryotes. DNA from all organisms consists of both A-T and C-G base pairs.

Question 14

Essential Knowledge	2.D.4: Plants and animals have a variety of chemical defenses against infections that affect dynamic homeostasis.
Science Practice	1.2: The student can describe representations and models of natural or man-made phenomena and systems in the domain.
Learning Objective	2.29: The student can create representations and models to describe immune responses.

(A)	This option is incorrect. Ribosomes do not play a direct role in phagocytosis, although they are organelles that carry out protein synthesis.
(B)	This option is incorrect. Antibodies do not play a role in phagocytosis, a nonspecific immune response. Antibodies are involved in *specific* immune responses in the presence of specific antigens. Antibodies do not act intracellularly either.
(C)	**This option is correct. It demonstrates an understanding to interpret representations that describe a nonspecific immune response. In phagocytosis, a cell engulfs a bacterium by wrapping pseudopodia around it and packaging it within a membrane-enclosed vacuole. The bacterium is digested after the vacuole fuses with a lysosome containing hydrolytic enzymes. Digested particles can be exported out of the cell by exocytosis.**
(D)	This option is incorrect. Mitochondria do not play a direct role in cellular digestion. Mitochondria are the sites of cellular respiration, the metabolic process that generates ATP from organic molecules in the presence of oxygen.

Question 15

Essential Knowledge	4.C.4: Diversity of species within an ecosystem may influence the stability of the ecosystem.
Science Practice	6.4: The student can make claims and predictions about natural phenomena based on scientific theories and models.
Learning Objective	4.27: The student is able to make scientific claims and predictions about how species diversity within an ecosystem influences ecosystem stability.

(A)	**This option is correct. The other trees shade out the oak trees. Oak seedlings are relatively intolerant to shade. Oak trees need sunlight for photosynthesis, and although they do survive in poor sunlight, they do not proliferate enough to be the dominant plant in the forest. Some oak species need sunlight for full development.**
(B)	This option is incorrect for two reasons: First, the shrubs disappear in this progression, so there is no evidence that any change would enhance shrub growth. Second, oak trees do not significantly alter the pH of the soil.
(C)	This option is incorrect because shrubs have relatively small root balls and would not out-compete an oak tree with a deep tap root. When the shrubs disappear, the success of the oak tree does not improve.
(D)	This option is incorrect because there is no evidence in this data of environmental pollutants. Although pollutants do affect oak tree growth, oaks are not considered more sensitive to them than other trees.

Question 16

Essential Knowledge	3.B.1: Gene regulation results in differential gene expression, leading to cell specialization.
Science Practice	1.4: The student can use representations and models to analyze situations or solve problems qualitatively and quantitatively.
Learning Objective	3.21: The student can use representations to describe how gene regulation influences cell products and function.

(A)	This option is incorrect because lactose has bonded with the repressor protein, resulting in its release from the operator. This will allow RNA polymerase to transcribe the lac operon because the molecular barrier no longer exists.
(B)	This option is incorrect because if lactose did bind with the repressor protein, then it would result in a conformational change and the repressor protein would no longer bind to the operator portion of the operon. No transcription would occur.
(C)	This option is incorrect because with no repressor in place, the operon would be turned on, and the genes would be transcribed.
(D)	**This option is correct because the lac operon is an inducible operon, which means that the regulatory system is turned off until lactose or its analog turns it on. The mechanism for preventing its transcription is the binding of a repressor protein to the operator region.**

Question 17

Essential Knowledge	2.A.2: Organisms capture and store free energy for use in biological processes. 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	6.2: The student can construct explanations of phenomena based on evidence produced through scientific practices.
Learning Objective	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.

(A)	**This option is correct. There is no change in gas volume measured by the respirometer unless carbon dioxide is removed, because oxygen is consumed at the same rate that carbon dioxide is produced during cellular respiration.**
(B)	This option is incorrect because the production of oxygen by plants is by the process of photosynthesis, which is not the focus of this experiment. The focus of this experiment is the consumption of oxygen during aerobic cellular respiration, not the production of oxygen gas during photosynthesis.
(C)	This option is incorrect because a glucose reserve would have no effect on the measurement of oxygen gas consumption because the oxidation of glucose via aerobic cellular respiration would still consume oxygen gas at the same rate as carbon dioxide production.
(D)	This option is incorrect because the release of excess water would have no effect on the relative volumes of oxygen or carbon dioxide gas. There would not be enough water produced in this experiment to affect gas volume due to differences in solubility.

Question 18

Essential Knowledge	2.A.2: Organisms capture and store free energy for use in biological processes.
Science Practice	6.2: The student can construct explanations of phenomena based on evidence produced through scientific practices.
Learning Objective	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.

(A)	**This option is correct. Mice are endotherms and at cold temperatures will increase their rate of ATP production in order to shiver. This increase in metabolism will produce heat according to the second law of thermodynamics. This heat production will help the mouse maintain a constant internal environment.**
(B)	This option is incorrect because a lower metabolic rate would mean a lower consumption of oxygen. The data do not support this claim. The mouse consumed more oxygen at 10°C than at 25°C.
(C)	This option is incorrect because the data for oxygen consumption were controlled for by mass / weight. All numbers are mL/g.
(D)	This option is incorrect because the data do not support this claim. If the mice were more active at the higher temperature, then they would have consumed more oxygen. More activity would require more ATP, which is produced by aerobic cellular respiration in mice.

Question 19

Essential Knowledge	2.A.1: All living systems require constant input of free energy. 2.A.2: Organisms capture and store free energy for use in biological processes.
Science Practice	6.2: The student can construct explanations of phenomena based on evidence produced through scientific practices.
Learning Objective	2.1: The student is able to explain how biological systems use free energy based on empirical data that all organisms require constant energy input to maintain organization, to grow, and to reproduce.

(A)	This option is incorrect because the rate of oxygen consumption is due to metabolic rates since oxygen is necessary for ATP production. Though size does affect heat gain and loss due to surface area to volume ratios, this physical trait would have the same effect in both organisms, not the opposite.
(B)	This option is incorrect because both crickets and mice are chemoheterotrophs.
(C)	**This option is correct because crickets are ectotherms. Ectotherms have very low metabolic rates, so they depend on the environment to help regulate their internal temperature. Therefore, crickets would have a higher metabolic rate at the higher temperature due to kinetics or more frequent molecular collisions.**
(D)	This option is incorrect because both organisms produce ATP via aerobic cellular respiration when oxygen is not a limiting reactant.

Question 20

Essential Knowledge	1.B.1: Organisms share many conserved core processes and features that evolved and are widely distributed among organisms today.
Science Practice	7.2: The student can connect concepts in and across domain(s) to generalize or extrapolate in and/or across enduring understandings and/or big ideas.
Learning Objective	1.15: The student is able to describe specific examples of conserved core biological processes and features shared by all domains or within one domain of life, and how these shared, conserved core processes and features support the concept of common ancestry for all organisms.

(A)	This option is incorrect because there are no reference organisms described that share this common ancestor. Chloroplasts evolved from endosymbiotic prokaryotes, and this places the evolutionary connection at an earlier pre-eukaryotic stage. The data do not support the claim that FtsZ and tubulin were present in a common ancestor.
(B)	This option is incorrect because microtubules have no direct involvement in photosynthesis. Even if there is some indirect involvement, this claim does not support the relationship between tubulin proteins in eukaryotes and FtsZ proteins in prokaryotes and chloroplasts.
(C)	**This option is correct. The evidence states that the FtsZ gene is present in prokaryotes and in chloroplasts. Chloroplasts evolved from endosymbiotic prokaryotes. The tubulin protein is structurally and functionally similar to FtsZ and is found in eukaryotes, inferring evolutionary descent.**
(D)	This option is incorrect because there is no evidence that the genes encoding FtsZ protein and tubulin are identical. In fact, the data state that the proteins are structurally similar, which implies some variance, which also would require a variance in gene sequences.

Question 21

Essential Knowledge	2.D.2: Homeostatic mechanisms reflect both common ancestry and divergence due to adaptation in different environments.
Science Practice	7.1: The student can connect phenomena and models across spatial and temporal scales.
Learning Objective	2.27: The student is able to connect differences in the environment with the evolution of homeostatic mechanisms.

(A)	This option is incorrect because fish, along with all organisms, consume food containing proteins and nucleic acids — both nitrogenous compounds.
(B)	**This option is correct. There is no need to convert ammonia to urea because it can be excreted often in dilute, nontoxic concentrations. This process requires less energy than the additional step of urea conversion. Dehydration due to water loss is not a problem for freshwater fish because water is plentiful.**
(C)	This option is incorrect because ammonia is not concentrated in tissues for storage; this would be toxic to those cells.
(D)	This option is incorrect because the nitrogen in ammonia is not recycled; it is so toxic that fish need to get rid of it quickly. In addition, animals do not possess the ability to recycle ammonia, most likely due to the lack of enzymes capable of catalyzing this reaction.

Question 22

Essential Knowledge	3.C.3: Viral replication results in genetic variation, and viral infection can introduce genetic variation into the hosts.
Science Practice	1.4: The student can use representations and models to analyze situations or solve problems qualitatively and quantitatively.
Learning Objective	3.30: The student is able to use representations and appropriate models to describe how viral replication introduces genetic variation in the viral population.

(A)	This option is incorrect because the virus particle does not get damaged during the infection stage. Although the viral envelope fuses with the host cell membrane, the virus particle is not damaged during the process of infection.
(B)	**This option is correct. The process of reverse transcription does not involve proofreading.**
(C)	This option is incorrect. The host cell provides the nucleotides for making viral nucleic acids, as well as enzymes, ribosomes, tRNAs, amino acids, ATP, polymerases, and other components needed for synthesizing viral proteins. Thus, using host machinery, viral DNA is translated effectively.
(D)	This option is incorrect. Retroviral genes are incorporated into the host cell's DNA and are transcribed into RNA molecules, which serve as genomes for the next viral generation and as mRNAs for translation into viral protein. The integrated viral DNA remains part of the host's genome.

Question 23

Essential Knowledge	2.B.2: Growth and dynamic homeostasis are maintained by the constant movement of molecules across membranes.
Science Practice	1.4: The student can use representations and models to analyze situations or solve problems qualitatively and quantitatively.
Learning Objective	2.12: The student is able to use representations and models to analyze situations or solve problems qualitatively and quantitatively to investigate whether dynamic homeostasis is maintained by the active movement of molecules across membranes.

(A)	This option is incorrect because the cells would shrink in a hypertonic solution, not a physiological saline solution, which means the solution is isotonic to a normal RBC.
(B)	This option is incorrect because RBCs do not have the ability to pump water out. Red blood cells lack internal membrane-bound organelles.
(C)	**This option is correct. The saline solution is isotonic relative to the RBC's cytoplasm. This will result in a dynamic equilibrium. View 2 shows a RBC in an isotonic environment because it would shrink in a hypertonic solution and swell in a hypotonic solution.**
(D)	This option is incorrect because the sodium potassium pump actually pumps out more sodium than potassium, which would make the internal environment of the RBC hypotonic and thus lose water and shrink, not gain water and swell. In addition, sodium potassium pumps do not play a role in osmosis across cell membranes.

Question 24

Essential Knowledge	2.A.1: All living systems require constant input of free energy.
Science Practice	6.1: The student can justify claims with evidence.
Learning Objective	2.2: The student is able to justify a scientific claim that free energy is required for living systems to maintain organization, to grow, or to reproduce, but that multiple strategies exist in different living systems.

(A)	This option is incorrect despite being a correct statement. These strategies help the different organisms to survive cold periods but are not metabolic strategies for meeting their energy needs.
(B)	This option is incorrect because this fact comparing bacterial and eukaryotic genomes and the presence of introns has nothing to do with these organisms meeting their energy needs by varying metabolic strategies.
(C)	This option is incorrect. Metabolism is defined as the totality of an organism's chemical reactions. The type of teeth organisms have would not be considered a metabolic strategy but rather a structural strategy.
(D)	**This option is correct. Starch, glycogen, and fat are all molecules used for energy storage, yet plants have evolved to use starch while animals have evolved to use fat for long-term energy storage and glycogen for short-term energy storage.**

Question 25

Essential Knowledge	2.B.2: Growth and dynamic homeostasis are maintained by the constant movement of molecules across membranes.
Science Practice	1.4: The student can use representations and models to analyze situations or solve problems qualitatively and quantitatively.
Learning Objective	2.12: The student is able to use representations and models to analyze situations or solve problems qualitatively and quantitatively to investigate whether dynamic homeostasis is maintained by the active movement of molecules across membranes.

(A)	This option is incorrect because the paramecium's plasma membrane is not permeable to charged ions, so no salt will enter. If salt could enter the paramecium, then water would follow by osmosis and actually result in increasing contractions of the contractile vacuole.
(B)	**This option is correct. The lower the concentration of solute, the larger the gradient between the paramecium and the solution. When the paramecium is hypertonic to the low concentration solution, water will enter the paramecium by osmosis. If the paramecium does not pump excess water back out, it will burst. As the solution gradient decreases, less water will enter, and, therefore, there will be a decreased need to pump excess water out.**
(C)	This option is incorrect because the external concentration of salt has no direct relationship with internal ATP production by cellular respiration. As long as the paramecium's internal environment is not altered, then cellular respiration should be unaffected, and therefore the contractile vacuole will have sufficient energy.
(D)	This option is incorrect because even at isosmotic concentrations water still diffuses, but in dynamic equilibrium.

Question 26

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 possible patterns and relationships between a biotic or abiotic factor and a biological system (cells, organisms, populations, communities, or ecosystems).

(A)	**This option is correct. Dish B, which was uncovered, had 20 seeds germinate, while the covered dish A had only 12 seeds germinate in the first week.**
(B)	This option is incorrect because the only variable was light intensity, and dish B did have more seeds germinate when exposed to light versus only 12 seeds in dish A, which was not exposed to light.
(C)	This option is incorrect because both dishes had paper towels — the paper towels were a controlled variable.
(D)	This option is incorrect. Germination occurred more rapidly in the yellow-leaved seedlings in dish A and at the same rate in dish B, so the data do not support the claim that germination was accelerated in green-leaved seedlings.

Question 27

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 possible patterns and relationships between a biotic or abiotic factor and a biological system (cells, organisms, populations, communities, or ecosystems).

(A)	This option is incorrect. Shortening of cells in response to a lack of light would result in slower growth, but this claim is not supported by the data.
(B)	**This option is correct. In response to the lack of light, the plant elongates cells in an attempt to reach light necessary for photosynthesis at the expense of leaf development.**
(C)	This option is incorrect. In the seeds that were exposed to light, the plants actually grew more slowly, so enhancement of stem elongation is not supported by the data.
(D)	This option is incorrect because genetic differences were accounted for by using 20 seeds each from the same species.

Question 28

Essential Knowledge	3.C.1: Changes in genotype can result in changes in phenotype.
Science Practice	7.2: The student can connect concepts in and across domain(s) to generalize or extrapolate in and/or across enduring understandings and/or big ideas.
Learning Objective	3.26: The student is able to explain the connection between genetic variations in organisms and phenotypic variations in populations.

(A)	This option is incorrect because the leaves in dish A could have been yellow because they had not been exposed to light yet and could have changed to green in response to light, which would not be a genetic difference. Some yellow leaves did change to green when exposed to light.
(B)	This option is incorrect because the only variable in this experiment was light. If genes responsible for leaf color also had an impact on germination rate, then germination should have been similar in each dish, which is not supported.
(C)	This option is incorrect because according to the data, no seedlings died.
(D)	**This option is correct because both colors of leaves existed after 14 days and essentially in the same numbers. If the green color resulted from a response to light, then the yellow leaves would have changed to green by 14 days.**

Question 29

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	7.2: The student can connect concepts in and across domain(s) to generalize or extrapolate in and/or across enduring understandings and/or big ideas.
Learning Objective	2.23: The student is able to design a plan for collecting data to show that all biological systems (cells, organisms, populations, communities, and ecosystems) are affected by complex biotic and abiotic interactions.

(A)	This option is incorrect because there is no evidence that yellow seedlings were unable to absorb water between days 14–21. In addition, because the seedlings were capable of doing so during the first 14 days, there is no evidence to support this claim that they could not absorb water *after* day 14.
(B)	This option is incorrect because there is no evidence that green seedlings were taller.
(C)	**This option is correct. The only difference between the two plants after day 14 was the leaf color. Without chlorophyll, the yellow seedlings could not absorb enough light energy to convert to chemical energy to sustain growth. Therefore, no yellow seedlings were found alive in either dish after day 21.**
(D)	This option is incorrect because there are no data supporting a higher rate of respiration in yellow seedlings compared to green seedlings.

Question 30

Essential Knowledge	4.C.2: Environmental factors influence the expression of the genotype in an organism.
Science Practice	6.2: The student can construct explanations of phenomena based on evidence produced through scientific practices.
Learning Objective	4.23: The student is able to construct explanations of the influence of environmental factors on the phenotype of an organism.

(A)	**This option is correct. It demonstrates the ability to explain the influence of environmental factors on the phenotype of an organism. When the genes of the arctic fox that produce the dark coat are blocked by cold temperatures, a white coat results. In the summer these genes are not blocked, and a darker coat results.**
(B)	This option is incorrect. The diet of the foxes in the summer or winter, regardless of whether it lacks a particular nutrient, would not cause a coat color change. In addition, the diet of the foxes in the summer is more likely to be better in terms of nutrients than in the winter.
(C)	This option is incorrect. Competition for mates and the increase in camouflage in the spring are not responsible for the seasonal change in coat color. Competition for mates generally involves being noticed, not camouflaged.
(D)	This option is incorrect. Cold temperatures do not denature pigment molecules.

Question 31

Essential Knowledge	2.C.1: Organisms use negative feedback mechanisms to maintain their internal environments and respond to external environmental changes.
Science Practice	7.2: The student can connect concepts in and across domain(s) to generalize or extrapolate in and/or across enduring understandings and/or big ideas.
Learning Objective	2.16: The student is able to connect how organisms use negative feedback to maintain their internal environments.

(A)	This option is incorrect. The onset of labor is an example of a positive feedback mechanism, not a negative feedback mechanism.
(B)	**This option is correct. The decrease of blood glucose levels as a result of insulin production is an example of how the endocrine system is involved in negative feedback, allowing organisms to maintain their internal environments.**
(C)	This option is incorrect. Respiration rates would increase, not decrease, in response to low oxygen levels.
(D)	This option is incorrect. Transcription factors are not part of the endocrine system.

Question 32

Essential Knowledge	1.B.2: Phylogenetic trees and cladograms are graphical representations (models) of evolutionary history that can be tested.
Science Practice	1.1: The student can create representations and models of natural or man-made phenomena and systems in the domain.
Learning Objective	1.19: The student is able create a phylogenetic tree or simple cladogram that correctly represents evolutionary history and speciation from a provided data set.

(A)	This option is incorrect. The nucleotide differences between species 5 and 1 in the data set are high and do not represent a close relationship.
(B)	This option is incorrect. Even though the nucleotide differences between species 5 and 3 in the data set show a close relationship, species 3 and 4 have fewer differences and thus are closer in their evolutionary history.
(C)	**This option is correct. It demonstrates the ability to select the phylogenetic tree that correctly represents evolutionary history and speciation from the data set. The data indicate that species 5 is not closely related to the others and that 3 and 4 are very closely related. This cladogram incorporates those differences as well as the close relationship between 1 and 2.**
(D)	This option is incorrect. The nucleotide differences in species 2 are closer to species 1, and this representation indicates they are linked evolutionarily to all the other species.

Question 33

Essential Knowledge	3.D.4: Changes in signal transduction pathways can alter cellular response.
Science Practice	6.1: The student can justify claims with evidence.
Learning Objective	3.37: The student is able to justify claims based on scientific evidence that changes in signal transduction pathways can alter cellular response.

(A)	This option is incorrect. The absorption of a mineral is not part of a signal transduction pathway.
(B)	**This option is correct. The student is asked to justify the claim that changes in signal transduction pathways can alter cellular response. Second messengers are involved in signal transduction pathways, and if the second messenger is not present, the pathway is blocked.**
(C)	This option is incorrect. A mutagen would cause a change in the DNA, not the signal transduction pathway.
(D)	This option is incorrect. Transcription of ribosomal RNA is not part of a signal transduction pathway.

Question 34

Essential Knowledge	2.E.1: Timing and coordination of specific events are necessary for the normal development of an organism, and these events are regulated by a variety of mechanisms.
Science Practice	1.4: The student can use representations and models to analyze situations or solve problems qualitatively and quantitatively.
Learning Objective	2.32: The student is able to use a graph or diagram to analyze situations or solve problems (quantitatively or qualitatively) that involve timing and coordination of events necessary for normal development in an organism.

(A)	**This option is correct. The second indicates that, after fertilization, the concentration of the bicoid protein decreases as the concentration of the caudal protein increases. Inhibition of the translation of caudal protein by bicoid protein is a logical hypothesis about the interaction of these two proteins and supports the concept that both the coordination and timing of these two proteins are necessary for the normal development in a *Drosophila* egg.**
(B)	This option is incorrect. There is no indication that the bicoid protein stabilizes caudal DNA. The first graph shows the relative concentrations of mRNA for the two proteins; the second shows the relative concentration of the proteins.
(C)	This option is incorrect. There are not enough data to support that translation of bicoid mRNA produces caudal protein.
(D)	This option is incorrect. The second graph shows that caudal protein stimulates the development of posterior structures, not anterior structures, as indicated in the graph.

Question 35

Essential Knowledge	3.C.2: Biological systems have multiple processes that increase genetic variation.
Science Practice	7.2: The student can connect concepts in and across domain(s) to generalize or extrapolate in and/or across enduring understandings and/or big ideas.
Learning Objective	3.27: The student is able to compare and contrast processes by which genetic variation is produced and maintained in organisms from multiple domains.

(A)	This option is incorrect. Crossing over would not lead to a change in the genetic information within a strain.
(B)	This option is incorrect. Viruses do not contain genes for synthesis pathways.
(C)	This option is incorrect. Random assortment of chromosomes does not lead to genetic variation in the population.
(D)	**This option is correct. The most likely source of genetic variation found in the tryptophan synthesis pathways of both species would have occurred primarily with the imperfect nature of DNA replication, which could have led to an increase in genetic variation in both species.**

Question 36

Essential Knowledge	4.A.1: The subcomponents of biological molecules and their sequence determine the properties of that molecule.
Science Practice	7.1: The student can connect phenomena and models across spatial and temporal scales.
Learning Objective	4.1: The student is able to explain the connection between the sequence and subcomponents of a biological polymer and its properties.

(A)	**This option is correct. The mutation results in the replacement of an amino acid, which alters the properties of the R-group both structurally and functionally; thus, the interactions between adjacent hemoglobin molecules would also be altered. In this case, hemoglobin molecules would tend to stick together as a result of hydrophobic interactions between amino acids on the surface.**
(B)	This option is incorrect. A point mutation, which causes the replacement of an amino acid with another amino acid, has already occurred in the DNA. The replacement of one amino acid would not alter the hydrogen bonding between nitrogenous bases in the structure of DNA.
(C)	This option is incorrect. A point mutation, which causes the replacement of a hydrophilic amino acid R-group with another amino acid that has a hydrophobic R-group, would not alter a fatty acid.
(D)	This option is incorrect. A mutation is not likely to alter the secondary structure of a protein. The secondary structure of proteins is due to hydrogen bonding between the carboxyl and amine residues in the chain, not interactions between R-groups.

Question 37

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

(A)	This option is incorrect. The population of beetles after pollution would not have shifted to a more light-colored beetle as indicated in diagram I because the tree trunks would have been darker, and the lighter colored beetles would have been eaten by predators more easily since they were light and the trees were dark. The suggestion that the predators would find the darker tree trunks more easily is irrelevant.
(B)	This option is incorrect. After the pollution the coloration could not have split into two groups because the lighter colored beetles would not have been able to hide on the darker tree trunks and thus would have been preyed upon.
(C)	This option is incorrect. The coloration range after pollution would not have become narrower, as in diagram III, because predators were selecting those light-colored beetles that were distinguishable on the darker tree trunks.
(D)	**This option is correct because it illustrates the change in the population that would occur with selection against the lighter colored beetles. The student is asked to justify and explain the process of biological evolution in this question. A change in coloration of the beetle population after pollution is shown in diagram IV because the original beetles (lighter colored beetles) were eaten by predators, and the darker colored beetles would have survived.**

Question 38

Essential Knowledge	4.C.2: Environmental factors influence the expression of the genotype in an organism.
Science Practice	6.2: The student can construct explanations of phenomena based on evidence produced through scientific practices.
Learning Objective	4.23: The student is able to construct explanations of the influence of environmental factors on the phenotype of an organism.

(A)	This option is incorrect. Environmental contamination in Lake Apopka had a negative effect on the enzyme in females by decreasing the activity, not increasing the activity, as in Lake Woodruff, which was not contaminated.
(B)	**This option is correct. In Lake Woodruff, the lake that is relatively pristine, females had high levels of oxido-reductase enzyme activity, but in Lake Apopka, where environmental contamination conditions were severe, the enzyme activity was low, indicating that environmental factors had an influence on the organism.**
(C)	This option is incorrect. Environmental contamination in both lakes did not seem to influence the enzyme for activity for males.
(D)	This option is incorrect. Environmental contamination in both lakes did not seem to influence the enzyme for activity for males.

Question 39

Essential Knowledge	2.D.4: Plants and animals have a variety of chemical defenses against infections that affect dynamic homeostasis.
Science Practice	1.2: The student can describe representations and models of natural or man-made phenomena and systems in the domain.
Learning Objective	2.29: The student can create representations and models to describe immune responses.

(A)	**This option is correct. The graph correctly represents the humoral immune response of an organism to the same antigen more than once. Memory cells created after the first exposure result in a more rapid response in subsequent exposures with a greater amount of the antibody.**
(B)	This option is incorrect. The graph shows that the amount of antibody during the first exposure is twice as much as the second exposure, whereas the second exposure to the antigen should show results that have a rapid increase in the amount of antibody.
(C)	This option is incorrect. The graph shows that during the first antigen exposure the antibody increased and remained at a high level, which is not what happens in an individual's humoral response.
(D)	This option is incorrect. The graph shows that during the first antigen exposure the antibody increased and then remained at a high level. Increasing further after the second exposure is not what we would predict with an individual's humoral response.

Question 40

Essential Knowledge	3.C.2: Biological systems have multiple processes that increase genetic variation.
Science Practice	6.2: The student can construct explanations of phenomena based on evidence produced through scientific practices.
Learning Objective	3.28: The student is able to construct an explanation of the multiple processes that increase variation within a population.

(A)	This option is incorrect. Plate I shows an extensive growth of bacteria, which is normal when wild-type *E. coli* is grown without ampicillin. There was no selection for ampicillin resistance; thus, this plate served as a control.
(B)	This option is incorrect. Plate III shows *E. coli* and the ampicillin-resistant plasmid growing extensively when no ampicillin is present. Indication of which bacteria took up the naked DNA with the *amp*^{r} gene is undetermined.
(C)	**This option is correct. Plate IV shows that only *E. coli* with the plasmid containing the gene for ampicillin-resistant plasmid grew individual colonies with ampicillin in the agar, thus showing the competent cells that transformed successfully.**
(D)	This option is incorrect. Plate II shows that there is no bacterial growth when ampicillin is present; thus, there are no ampicillin-resistant bacteria.

Question 41

Essential Knowledge	3.C.2: Biological systems have multiple processes that increase genetic variation.
Science Practice	6.2: The student can construct explanations of phenomena based on evidence produced through scientific practices.
Learning Objective	3.28: The student is able to construct an explanation of the multiple processes that increase variation within a population.

(A)	**This option is correct. The initial wild-type *E. coli* did not contain the plasmid containing the gene for resistance to the ampicillin (*amp*^{r}) and, when exposed to ampicillin, did not grow on Plate II.**
(B)	This option is incorrect. In a typical transformation experiment, if all procedures were followed as in this experiment, it is unlikely for a procedure to kill the bacteria. Plate IV indicates that the transformation procedure did not kill the bacteria.
(C)	This option is incorrect. Nutrient agar promotes *E. coli* growth.
(D)	This option is incorrect. The bacteria in Plate II were not exposed to the plasmid and thus could not have been transformed.

Question 42

Essential Knowledge	3.C.2: Biological systems have multiple processes that increase genetic variation.
Science Practice	6.2: The student can construct explanations of phenomena based on evidence produced through scientific practices.
Learning Objective	3.28: The student is able to construct an explanation of the multiple processes that increase variation within a population.

(A)	**This option is correct. Both Plates I and III had extensive *E. coli* growth, showing that the cells were viable before and after the transformation procedure.**
(B)	This option is incorrect. Plates I and III would not have provided information on whether the plasmid could lose its *amp*^{r} gene, and there was no way of knowing this with the data from these two plates.
(C)	This option is incorrect. The bacteria in Plate I were not exposed to the plasmid.
(D)	This option is incorrect. The bacteria were plated after the transformation; thus, plating could not have prepared them for transformation.

Question 43

Essential Knowledge	3.C.2: Biological systems have multiple processes that increase genetic variation.
Science Practice	6.2: The student can construct explanations of phenomena based on evidence produced through scientific practices.
Learning Objective	3.28: The student is able to construct an explanation of the multiple processes that increase variation within a population.

(A)	This option is incorrect. Plate I is the positive control, showing that the bacteria were viable before the transformation procedure.
(B)	**This option is correct. Only the *E. coli* that have been transformed and contain the *amp*^{r} gene will grow and produce colonies.**
(C)	This option is incorrect. The transformation experiment did not determine whether *E. coli* bacteria could mutate or not.
(D)	This option is incorrect. Both plates with plasmids showed growth while the plate with ampicillin and no plasmids showed no growth, indicating that plasmids did not inhibit growth.

Question 44

Essential Knowledge	3.C.2: Biological systems have multiple processes that increase genetic variation.
Science Practice	6.2: The student can construct explanations of phenomena based on evidence produced through scientific practices.
Learning Objective	3.28: The student is able to construct an explanation of the multiple processes that increase variation within a population.

(A)	This option is incorrect. The bacteria in Plate I were not exposed to the plasmid.
(B)	This option is incorrect. Plate III does not distinguish which bacteria took up the plasmid. Bacteria with and without the plasmid grow, but the percentage of those with the ability to produce insulin is much lower than in Plate IV.
(C)	**This option is correct. In Plate IV the colonies of *E. coli* were successfully transformed and expressed the *amp*^{r} gene; adding another gene to the plasmid would express the human insulin gene the same way.**
(D)	This option is incorrect. The bacteria on Plate I were not exposed to the plasmid and so could not have taken up the insulin gene, thus eliminating this choice.

Question 45

Essential Knowledge	1.B.1: Organisms share many conserved core processes and features that evolved and are widely distributed among organisms today.
Science Practice	7.2: The student can connect concepts in and across domain(s) to generalize or extrapolate in and/or across enduring understandings and/or big ideas.
Learning Objective	1.15: The student is able to describe specific examples of conserved core biological processes and features shared by all domains or within one domain of life, and how these shared, conserved core processes and features support the concept of common ancestry for all organisms.

(A)	This option is incorrect. Glycolysis does not occur in the mitochondria. Archaea and Bacteria do not contain mitochondria.
(B)	**This option is correct because it demonstrates understanding of the processes of evolution and glycolysis, which is common to both aerobic and anaerobic respiration.**
(C)	This option is incorrect. Many organisms rely on aerobic respiration for ATP production.
(D)	This option is incorrect. There is no evidence for any other energy-producing process that substitutes for and predates glycolysis.

Question 46

Essential Knowledge	2.E.1: Timing and coordination of specific events are necessary for the normal development of an organism, and these events are regulated by a variety of mechanisms.
Science Practice	7.1: The student can connect phenomena and models across spatial and temporal scales.
Learning Objective	2.34: The student is able to describe the role of programmed cell death in development and differentiation, the reuse of molecules, and the maintenance of dynamic homeostasis.

(A)	**This option is correct. It demonstrates understanding of dynamic homeostasis in the reuse of nutrients by the body in development.**
(B)	This option is incorrect. Shedding the tail in this stage of development is not necessary to conserve energy.
(C)	This option is incorrect. The tail does not divide bilaterally during development.
(D)	This option is incorrect. There is no evidence that cells of the tail migrate to gonads.

Question 47

Essential Knowledge	1.A.2: Natural selection acts on phenotypic variations in populations.
Science Practice	7.1: The student can connect phenomena and models across spatial and temporal scales.
Learning Objective	1.5: The student is able to connect evolutionary changes in a population over time to a change in the environment.

(A)	This option is incorrect. It implies that evolution occurs according to "need," or in order to cause a certain outcome.
(B)	This option is incorrect because it is contrary to fact; the plasmid does not confer resistance to the new antibiotic.
(C)	**This option is correct. It demonstrates an understanding that the plasmid would remain in the population even though it is not favored by selection and because it is not being selected against.**
(D)	This option is incorrect because the methicillin-resistance plasmid does not confer any resistance to the new antibiotic in bacteria.

Question 48

Essential Knowledge	3.D.3: Signal transduction pathways link signal reception with cellular response.
Science Practice	1.5: The student can re-express key elements of natural phenomena across multiple representations in the domain.
Learning Objective	3.36: The student is able to describe a model that expresses the key elements of signal transduction pathways by which a signal is converted to a cellular response.

(A)	This option is incorrect. ADH stimulates the production of aquaporins. Inhibition of ADH would result in fewer aquaporins.
(B)	This option is incorrect because inhibition of ADH causes more water to be excreted from the body, thus triggering thirst rather than decreasing it.
(C)	This option is incorrect because filtration of the blood in the kidney is independent of ADH.
(D)	**This option is correct because it links the signal (ADH) with the response (reabsorption of water). Because ADH increases reabsorption of water, its lack would result in less water reabsorbed, more excreted, and thus a more dilute urine.**

Question 49

Essential Knowledge	2.E.1: Timing and coordination of specific events are necessary for the normal development of an organism, and these events are regulated by a variety of mechanisms.
Science Practice	1.4: The student can use representations and models to analyze situations or solve problems qualitatively and quantitatively.
Learning Objective	2.32: The student is able to use a graph or diagram to analyze situations or solve problems (quantitatively or qualitatively) that involve timing and coordination of events necessary for normal development in an organism.

(A)	**This option is correct. The stem of the question indicates that cell 4 and cell 3 must be touching in order for cell 3 to induce formation of the intestine. This is the mechanism by which the correct timing of this developmental event occurs.**
(B)	This option is incorrect because there is no indication that microvilli are formed.
(C)	This option is incorrect because there is no evidence of an electrical signal.
(D)	This option is incorrect because there is no indication that genetic material is transferred from cell 4 to cell 3, resulting in the development of intestinal cells.

Question 50

Essential Knowledge	3.A.2: In eukaryotes, heritable information is passed to the next generation via processes that include the cell cycle, mitosis, or meiosis plus fertilization.
Science Practice	5.3: The student can evaluate the evidence provided by data sets in relation to a particular scientific question.
Learning Objective	3.11: The student is able to evaluate evidence provided by data sets to support the claim that heritable information is passed from one generation to another generation through mitosis, or meiosis followed by fertilization.

(A)	This option is incorrect because if the environment determined the flower color, then the occasional white and pink flower would not be seen in the original environment.
(B)	This option is incorrect because there is no indication of the stages of flower development, and the 3:1 ratios in the first two crosses would not be seen if the stage of flower development were the controlling factor.
(C)	This option is incorrect because the crosses of blue and white and blue and pink do fit expected phenotypic ratios. Vegetative propagation would not result in the ratios indicated by the data.
(D)	**This option is correct. The student is asked to evaluate the data given. The crosses between blue / white and blue / pink show expected 3:1 ratios in the F_1 generation. The appearance of a majority of blue flowers in the F_1 cross between pink and white indicate that there is another gene product affecting the outcome.**

Question 51

Essential Knowledge	4.B.1: Interactions between molecules affect their structure and function.
Science Practice	5.1: The student can analyze data to identify patterns or relationships.
Learning Objective	4.17: The student is able to analyze data to identify how molecular interactions affect structure and function.

(A)	This option is incorrect. The graph shows that myoglobin does bind oxygen at 10 mm Hg partial pressure.
(B)	This option is incorrect. At 20 mm Hg partial pressure myoglobin is nearly saturated with oxygen, whereas hemoglobin is only about 10 percent saturated.
(C)	**This option is correct. The question tests whether the student can read the graph to analyze the data. The graph indicates that at 40 mm Hg pressure, myoglobin binds a greater amount of oxygen than hemoglobin.**
(D)	This option is incorrect because the saturation of both hemoglobin and myoglobin with oxygen is nearly equal.

Question 52

Essential Knowledge	4.B.1: Interactions between molecules affect their structure and function.
Science Practice	5.1: The student can analyze data to identify patterns or relationships.
Learning Objective	4.17: The student is able to analyze data to identify how molecular interactions affect structure and function.

(A)	**This option is correct. If the curve shifts to the right, both hemoglobin and myoglobin are less saturated at a given partial pressure of oxygen, thus indicating that the oxygen has been unloaded. This answer reflects the claim that the student can analyze the data to identify how molecular interactions (H^+ and myoglobin) affect function (binding of O_2).**
(B)	This option is incorrect because an increase in binding sites would increase, not decrease, binding.
(C)	This option is incorrect because the capture of more oxygen would increase, not decrease, binding. The curve would not be shifted to the right.
(D)	This option is incorrect because the capture of more oxygen would increase, not decrease, binding. The curve would not be shifted to the right.

Question 53

Essential Knowledge	4.B.1: Interactions between molecules affect their structure and function.
Science Practice	5.1: The student can analyze data to identify patterns or relationships.
Learning Objective	4.17: The student is able to analyze data to identify how molecular interactions affect structure and function.

(A)	This option is incorrect. The higher affinity of myoglobin for oxygen would not prevent oxygen from being taken from the blood.
(B)	This option is incorrect. The fact that myoglobin has a high affinity for oxygen retards anaerobic respiration in the muscles.
(C)	This option is incorrect. The increased availability of oxygen allows the use of glucose for energy following breakdown of glycogen by other pathways.
(D)	**This option is correct. Because myoglobin has a higher affinity for oxygen than hemoglobin, it takes oxygen from the blood into the muscles. This answer reflects the claim that the student can analyze the data to identify how molecular interactions (hemoglobin and myoglobin with O_2) affect function (binding of O_2).**

Question 54

Essential Knowledge	3.B.1: Gene regulation results in differential gene expression, leading to cell specialization.
Science Practice	7.1: The student can connect phenomena and models across spatial and temporal scales.
Learning Objective	3.18: The student is able to describe the connection between the regulation of gene expression and observed differences between different kinds of organisms.

(A)	**This option is correct. Arabinose will bind with the repressor protein allowing expression of the genes controlled by the *ara* regulatory sequences. Because the genes for ampicillin resistance and GFP were inserted downstream of the regulatory sequences, these genes will be expressed and the products will cause the resultant colonies to be green under UV light. This answer indicates that the student is able to describe the connection between the regulation of gene expression and observed differences between different kinds of organisms.**
(B)	This option is incorrect because the presence of ampicillin in the agar would not allow growth of bacteria without the plasmid, but those with the plasmid would not have increased GFP.
(C)	This option is incorrect because without arabinose the gene sequences downstream from the *ara* regulatory sequence would not be expressed.
(D)	This option is incorrect because ampicillin prevents colony growth in cells without the plasmid.

Question 55

Essential Knowledge	2.A.3: Organisms must exchange matter with the environment to grow, reproduce, and maintain organization.
Science Practice	4.1: The student can justify the selection of the kind of data needed to answer a particular scientific question.
Learning Objective	2.8: The student is able to justify the selection of data regarding the types of molecules that an animal, plant, or bacterium will take up as necessary building blocks and excrete as waste products.

(A)	This option is incorrect because carbon dioxide fixation is not part of the light-dependent reactions.
(B)	**This option is correct. This choice correctly describes the events of the light-dependent reactions and indicates that the student can justify the selection of data regarding the types of molecules that an organism will take up as necessary building blocks.**
(C)	This option is incorrect because water is not split in the Calvin cycle.
(D)	This option is incorrect because water is not split in the Calvin cycle.

Question 56

Essential Knowledge	2.A.3: Organisms must exchange matter with the environment to grow, reproduce, and maintain organization.
Science Practice	1.1: The student can create representations and models of natural or man-made phenomena and systems in the domain.
Learning Objective	2.9: The student is able to represent graphically or model quantitatively the exchange of molecules between an organism and its environment, and the subsequent use of these molecules to build new molecules that facilitate dynamic homeostasis, growth, and reproduction.

(A)	This option is incorrect because it indicates that protein is being synthesized in the absence of nitrogen before and after several weeks.
(B)	**This option is correct. Without a source of nitrogen, the *Spirogyra* cannot synthesize proteins or nucleic acids, both of which contain nitrogen. This answer reflects that the student is able to represent graphically the exchange of molecules between an organism and its environment and the use of these molecules in synthesis.**
(C)	This option is incorrect because it shows protein being synthesized at the same level as at the beginning of the experiment, and it shows an increase in the amount of nucleic acids.
(D)	This option is incorrect because it shows a significant increase in the amount of protein, which cannot be synthesized without a nitrogen source.

Question 57

Essential Knowledge	3.E.2: Animals have nervous systems that detect external and internal signals, transmit and integrate information, and produce responses.
Science Practice	1.1: The student can create representations and models of natural or man-made phenomena and systems in the domain.
Learning Objective	3.47: The student is able to create a visual representation of complex nervous systems to describe/explain how these systems detect external and internal signals, transmit and integrate information, and produce responses.

(A)	This option is incorrect because the action potentials would not increase due to interference from the antibody.
(B)	**This option is correct because the antibody binds to the acetylcholine receptors, thus making fewer receptors on the postsynaptic neuron available for acetylcholine stimulation. This answer indicates that the student is able to interpret a visual representation of the nervous system to describe how this system integrates information to produce a response.**
(C)	This option is incorrect. The number of sodium-gated channels in the muscle does not change.
(D)	This option is incorrect. Acetylcholine must bind to the receptor in order to have an effect. Unbound acetylcholine in the junction has no effect.

Question 58

Essential Knowledge	1.C.1: Speciation and extinction have occurred throughout the Earth's history.
Science Practice	4.2: The student can design a plan for collecting data to answer a particular scientific question.
Learning Objective	1.21: The student is able to design a plan for collecting data to investigate the scientific claim that speciation and extinction have occurred throughout Earth's history.

(A)	This option is incorrect because the number of fossils is not directly related to any period.
(B)	**This option is correct because it indicates that a student is able to design a plan for collecting data concerning speciation and extinction throughout the Earth's history. The Devonian period prior to the Permian period did not contain vertebrates, which evolved later. Thus, an area prior to the Permian that contains a few early vertebrates would indicate the Devonian/Permian boundary, which would be an appropriate place for students to collect fossil data.**
(C)	This option is incorrect because trilobites existed in the Permian, not the Devonian, period.
(D)	This option is incorrect because the rate of speciation is not related to the location of Devonian fossils.

Question 59

Essential Knowledge	4.A.3: Interactions between external stimuli and regulated gene expression result in specialization of cells, tissues, and organs.
Science Practice	1.3: The student can refine representations and models of natural or man-made phenomena and systems in the domain.
Learning Objective	4.7: The student is able to refine representations to illustrate how interactions between external stimuli and gene expression result in specialization of cells, tissues, and organs.

(A)	**This option is correct because free calcium is needed for heterocyst formation. Binding the calcium will prevent cyst formation. This answer demonstrates that the student is able to refine representations to illustrate how interactions between external stimuli and gene expression result in specialization of cells.**
(B)	This option is incorrect because the *patS* gene inhibits heterocyst formation, so fewer would be produced.
(C)	This option is incorrect because in an environment with abundant fixed nitrogen, heterocysts are not an advantage to the organism in that the anaerobic nitrogen-fixing enzymes are not needed.
(D)	This option is incorrect because loss of the *hetR* gene would prevent, not induce, heterocyst formation.

Question 60

Essential Knowledge	3.C.3: Viral replication results in genetic variation, and viral infection can introduce genetic variation into the hosts.
Science Practice	1.4: The student can use representations and models to analyze situations or solve problems qualitatively and quantitatively.
Learning Objective	3.30: The student is able to use representations and appropriate models to describe how viral replication introduces genetic variation in the viral population.

(A)	This option is incorrect because bacterial DNA, not protein, is transferred by the phage.
(B)	This option is incorrect because the recipient does not incorporate (add) the transduced DNA into its chromosome. The transduced DNA must recombine with the recipient DNA in order to become part of the chromosome.
(C)	This option is incorrect because recombinant DNA does not cause point mutations.
(D)	**This option is correct. Transduction is the transfer of bacterial genes from one bacterium to another by bacteriophages.**

Question 61

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	3.2: The student can refine scientific questions.
Learning Objective	2.22: The student is able to refine scientific models and questions about the effect of complex biotic and abiotic interactions on all biological systems from cells and organisms to populations, communities, and ecosystems.

(A)	This option is incorrect because the phosphate is limiting; thus, additional nutrients would have no effect.
(B)	This option is incorrect because the addition of nitrogen, an essential plant nutrient, would not decrease the algal growth.
(C)	**This option is correct because the limiting nutrient is phosphate, not nitrogen.**
(D)	This option is incorrect because adding nitrogen, an essential plant nutrient, would not increase then decrease the algal growth.

Question 62

Essential Knowledge	2.A.2: Organisms capture and store free energy for use in biological processes.
Science Practice	3.1: The student can pose scientific questions.
Learning Objective	2.4: The student is able to use representations to pose scientific questions about what mechanisms and structural features allow organisms to capture, store, and use free energy.

(A)	**This option is correct because both diagrams indicate that hydrogen ions are flowing back down their gradient through a channel in the transmembrane protein (ATP synthase) to phosphorylate ADP, forming ATP.**
(B)	This option is incorrect because neither diagram shows the changes of energy to drive the electron transport chain in both processes.
(C)	This option is incorrect because neither diagram indicates temperature data needed to pose this scientific question.
(D)	This option is incorrect because neither diagram indicates data regarding evolutionary relationships needed to pose this scientific question.

Question 63

Essential Knowledge	3.B.2: A variety of intercellular and intracellular signal transmissions mediate gene expression.
Science Practice	1.4: The student can use representations and models to analyze situations or solve problems qualitatively and quantitatively.
Learning Objective	3.23: The student can use representations to describe mechanisms of the regulation of gene expression.

(A)	This option is incorrect because creating a molecule similar to the Hedgehog protein and activating Ptc will amplify the signaling pathway, possibly creating more pancreatic cancer cells.
(B)	This option is incorrect because there is no indication or data in the information provided that embryonic cells can be used to bind to other cancer cells, which will alter the Hedgehog signaling pathway.
(C)	**This option is correct because inactivating Smo will modify the Hedgehog signaling pathway, thus reducing the risk of developing pancreatic cancer cells.**
(D)	This option is incorrect because inducing Ci for gene transcription may cause more cancer cells to appear.

Information for Grid-In Questions 1–6

Question 1

Essential Knowledge	1.A.1: Natural selection is a major mechanism of evolution.
Science Practice	2.2: The student can apply mathematical routines to quantities that describe natural phenomena.
Learning Objective	1.3: The student is able to apply mathematical methods to data from a real or simulated population to predict what will happen to the population in the future.

The correct answer is 340–360. The graph depicts a logistic growth curve for a population. The formula to calculate the per capita rate increase between days 3 and 5 is $\Delta N/\Delta T$, where ΔN=change in population size and ΔT=time interval. In other words, $\Delta N/\Delta T$ = 900 individuals-200 individuals/2 days=700 individuals/2 days. However, the mean rate of population growth is for 1 day, or 350 individuals/day.

Question 2

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.

The correct answer is 5.3–5.4. If the purple-flowered parent was heterozygous for the trait (*Pp*) and the other parent had yellow flowers (*pp*), the EXPECTED ratios for the cross *Pp* x *pp* is 1 purple-flowered: 1 yellow-flowered. From 146 offspring, 73 would be expected to have purple flowers (*Pp*), and 73 would be expected to have yellow flowers (*pp*). However, the OBSERVED offspring values from the cross were 87 purple (*Pp*) and 59 yellow (*pp*). These values can be put in a chart as follows:

Phenotype	Observed (o)	Expected (e)	(o-e)	$(o-e)^2$	$(o-e)^2/e$
Purple flowers	87	73	(87-73=14)	$(14)^2=196$	196/73=2.68
Yellow flowers	59	73	(59-73=-14)	$(-14)^2=196$	196/72=2.68

The chi-square formula is $X^2 = \sum (o-e)^2/e$, or, for this cross, 2.68 + 2.68 = 5.36 for the null hypothesis. The critical value for p=0.05 with one degree of freedom is 3.84. Since 5.36 is greater than 3.84, the null hypothesis that the purple parent was heterozygous for the flower-color gene is rejected.

Question 3

Essential Knowledge	4.A.6: Interactions among living systems and with their environment result in the movement of matter and energy.
Science Practice	2.2: The student can apply mathematical routines to quantities that describe natural phenomena.
Learning Objective	4.14: The student is able to apply mathematical routines to quantities that describe interactions among living systems and their environment that result in the movement of matter and energy.

The correct answer is 26 or 25. The problem is an application of the first law of thermodynamics, not the "10 percent rule" of energy transformation. To work this problem, all numbers should be converted to the same KJ/m^2. There are TWO possible ways to arrive at the correct answer.

First, 14,100 KJ/m^2 is 74.3 percent of the total accumulated biomass, so the shrubs would possess 25.7 percent of the total biomass.

A more complex pathway to the same answer is as follows: Energy accumulated as biomass is 1.9×10^4 KJ/m^2 or 19,000 KJ/m^2 and is distributed among the tree layer, shrub layer, and herb layer. The energy accumulated as biomass in the tree layer is 1.3×10^4 KJ/m^2 or 13,000 KJ/m^2, and the energy accumulated as biomass in the herb layer is 1.1×10^3 KJ/m^2 or 1,100 KJ/m^2. Together, the energy accumulated as biomass in the tree and herb layers is 13,000 + 1,100 KJ/m^2. Subtracting this amount from the total of 19,000 KJ/m^2 leaves 4,900 KJ/m^2 energy accumulated as biomass ("tied up") in the shrub layer. This percentage of the total can be calculated as 4,900 KJ/m^2 /19,000 KJ/m^2 = .257 or 25.7 percent.

Question 4

Essential Knowledge	1.A.1: Natural selection is a major mechanism of evolution.
Science Practice	2.2: The student can apply mathematical routines to quantities that describe natural phenomena.
Learning Objective	1.1: The student is able to convert a data set from a table of numbers that reflects a change in the genetic makeup of a population over time and apply mathematical methods and conceptual understandings to investigate the cause(s) and effect(s) of this change.

The correct answer for the frequency of the green allele is 0.34–0.35. After the drought, the frequency of the recessive phenotype, q^2, was 0.12. Since the population is now in Hardy-Weinberg equilibrium, the frequency of alleles will not change, so q is the square root of 0.12, or 0.35.

Question 5

Essential Knowledge	4.A.5: Communities are composed of populations of organisms that interact in complex ways.
Science Practice	2.2: The student can apply mathematical routines to quantities that describe natural phenomena.
Learning Objective	4.12: The student is able to apply mathematical routines to quantities that describe communities composed of populations of organisms that interact in complex ways.
The correct answer could be any value from 1.4–1.7 months. Note: The data are reflective of actual data. To calculate the lag time in months between the change in the densities of the prey and the predator populations, calculate the differences between the prey and predator peaks or valleys. The first peak of oscillation is the prey at 4.8 months; the predator hits the first peak at approximately 6.5 months. The first valley of oscillation is the prey at 8.5 with the second at 10. When calculating the difference between lag time, subtract 8.5 from 10 to obtain 1.5 months.	

Question 6

Essential Knowledge	4.A.6: Interactions among living systems and with their environment result in the movement of matter and energy.
Science Practice	2.2: The student can apply mathematical routines to quantities that describe natural phenomena.
Learning Objective	4.14: The student is able to apply mathematical routines to quantities that describe interactions among living systems and their environment that result in the movement of matter and energy.
The correct answer is 60. The herbivores receive 125 g/m^2 from the grass. 60 g/m^2 is lost to decomposers, and 5 g/m^2 is lost to predators. 125 – 60 – 5 = 60 g/m^2 left for the herbivores to use in metabolic activity.	

Answers to Multiple-Choice Questions

1 – C	17 – A	33 – B	49 – A
2 – C	18 – A	34 – A	50 – D
3 – A	19 – C	35 – D	51 – C
4 – A	20 – C	36 – A	52 – A
5 – C	21 – B	37 – D	53 – D
6 – D	22 – B	38 – B	54 – A
7 – C	23 – C	39 – A	55 – B
8 – A	24 – D	40 – C	56 – B
9 – B	25 – B	41 – A	57 – B
10 – B	26 – A	42 – A	58 – B
11 – A	27 – B	43 – B	59 – A
12 – B	28 – D	44 – C	60 – D
13 – C	29 – C	45 – B	61 – C
14 – C	30 – A	46 – A	62 – A
15 – A	31 – B	47 – C	63 – C
16 – D	32 – C	48 – D	

Answers to Grid-In Questions

1 – 340–360	4 – 0.34–0.35
2 – 5.3–5.4	5 – 1.4–1.7
3 – 26 or 25	6 – 60