

PRACTICE EXAM 21: LIFE SCIENCE: BIOLOGY SIMULATION (50 QUESTIONS — REQUIRED-LABS, HEALTH, AND BODY SYSTEMS FOCUS)

Instructions: Practice Exam 21 emphasizes the four required NY Regents lab activities, disease and homeostasis disruption, human body systems integration, and applied analysis of figures and data. Each question is independent. Select the one best answer.

1. In the NY Regents "Diffusion Through a Membrane" laboratory, students set up a model "cell" using a piece of dialysis tubing filled with starch and glucose solution and place it in water containing iodine. The dialysis tubing in this model demonstrates which property of real cell membranes?

A. Real cell membranes are made of identical molecules to those that compose dialysis tubing in the lab activity
B. Real cell membranes allow all dissolved substances to pass through them freely without any kind of restriction
C. Real cell membranes are selectively permeable, allowing some substances through while blocking other substances
D. Real cell membranes actively transport every substance into and out of the cell using only ATP energy each time

2. In the NY Regents "Beaks of Finches" lab activity, students use different tools (such as forceps, clothespins, and spoons) to pick up small seeds in competition with other student "finches." This lab activity is most directly designed to model:

A. Natural selection, in which individuals with traits best suited to obtaining food survive and reproduce in greater numbers
B. The carbon cycle, in which carbon moves from plants to animals and back to the environment over time in ecosystems
C. Asexual reproduction, in which a single parent produces offspring that are genetically identical to the parent organism
D. Homeostasis, in which living organisms maintain stable internal conditions despite changes in the external environment

3. In the "Relationships and Biodiversity" lab, students compare a hypothetical endangered plant (*Botana curus*) with three other plant species using several different tests, including a structural comparison, a chemical test for an anti-cancer compound, and a DNA sequence analysis. The most reliable indicator of close evolutionary relationship among species is generally:

A. Similar overall body size and growth habit among the four plant species in the experimental laboratory comparison data B. Similar DNA nucleotide sequences among the species, since DNA sequences directly reflect their common ancestry over time C. The presence of the same identifying anti-cancer compound in each of the four plant species being compared in the lab D. Similar leaf shapes among the four species, since identical leaf shapes always indicate identical common ancestry in plants

4. In the "Making Connections" laboratory, students rapidly squeeze a clothespin repeatedly with one hand while their pulse rate is recorded. As the rate of muscle activity increases, the most likely change observed in the student's pulse rate is:

A. The pulse rate decreases because the body conserves energy during repeated voluntary muscle activity over time B. The pulse rate remains exactly the same since the heart is not directly involved in any voluntary hand movements C. The pulse rate decreases because muscle cells produce ATP independently without requiring oxygen from the bloodstream D. The pulse rate increases because the working muscles require more oxygen and the circulatory system responds accordingly

5. A student observes a cell under high power and notices a large central vacuole, a rigid outer cell wall, and many small green organelles in the cytoplasm. The cell is most likely:

A. A plant leaf cell, since plant cells uniquely have a cell wall, a large central vacuole, and chloroplasts in their cytoplasm B. A red blood cell, since red blood cells contain many small organelles and are surrounded by sturdy outer cell walls C. A human muscle cell, since muscle cells contain many chloroplasts to provide the energy required for contractions D. A bacterial cell, since bacterial cells always contain chloroplasts and central vacuoles within their cytoplasm directly

6. A liver cell that detoxifies harmful chemicals would be expected to contain especially abundant:

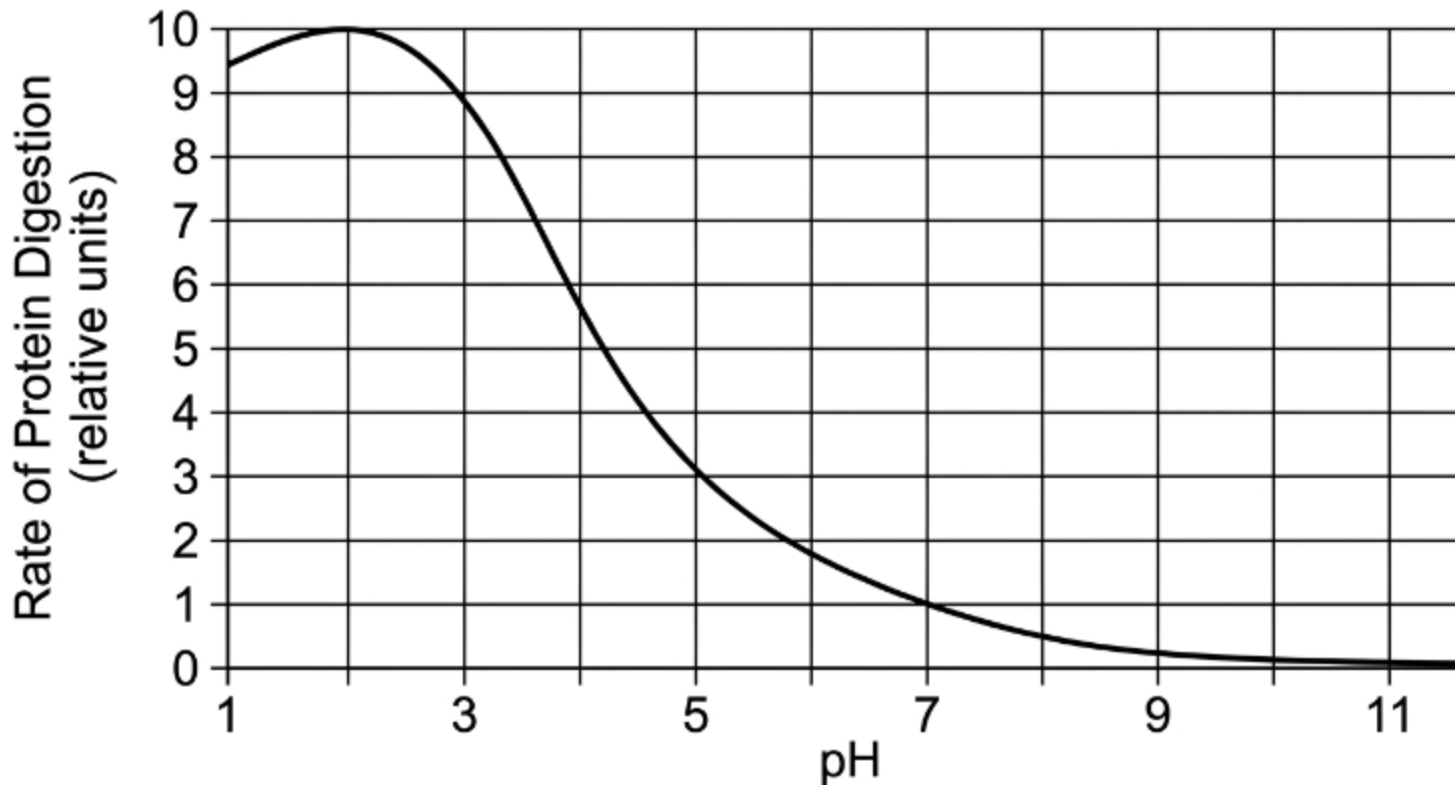
A. Cell walls, which provide additional structural support against the chemical stresses placed on the liver cell each day B. Chloroplasts, which capture light energy needed to power the breakdown of toxic chemicals throughout the human body C. Smooth endoplasmic reticulum, which contains many of the enzymes used in the detoxification of chemicals in the body D. Central vacuoles, which store waste products in plant cells and animal cells in roughly equal quantities in human tissues

7. A neuron at rest maintains a much higher concentration of sodium ions outside the cell than inside the cell. This electrochemical gradient is most directly maintained by:

A. Simple diffusion of sodium ions through the lipid bilayer of the cell membrane down their normal concentration gradient B. Osmosis of water through the cell membrane, which carries sodium ions along with it across the membrane every minute C. The action of chloroplasts within the neuron, which produce the energy needed to maintain the chemical gradient daily D. The sodium-potassium pump, which uses ATP to actively transport sodium ions out and potassium ions into the cell

8. A student investigates how pH affects the activity of pepsin. The student measures protein digestion rates at pH values of 1, 3, 5, 7, 9, and 11. The data are plotted in the graph below.

Effect of pH on Pepsin Activity



Which conclusion is best supported by the graph?

A. Pepsin activity is highest at pH 7, which matches the normal pH of the human blood and most tissues throughout the body
B. Pepsin activity is highest at low pH (acidic conditions), consistent with its function in the acidic environment of the human stomach
C. Pepsin activity remains essentially constant across all of the pH values tested, showing no clear preference for acidic conditions
D. Pepsin activity is highest at very high pH values (basic conditions), consistent with its function in the small intestine of the body

9. Plant root hairs are tiny extensions of root epidermal cells that greatly increase the surface area of the root system. This increased surface area is most directly beneficial to the plant because it:

A. Increases the rate at which water and dissolved minerals can be absorbed from the soil into the plant's root system
B. Increases the amount of light that reaches the chlorophyll molecules in the plant's root cells located underground
C. Reduces the plant's exposure to soil bacteria and fungi that might decompose the plant's living root tissue underground
D. Provides additional storage capacity for starch and sugars produced during the plant's photosynthesis up in the leaves

10. Marine fish living in salty ocean water must continuously rid themselves of excess salt to maintain their proper internal salt concentration. Specialized cells in their gills move sodium ions from the blood out into the surrounding seawater against the concentration gradient. This process is best classified as:

A. Simple diffusion, in which sodium ions move passively across the gill cell membranes without using any cellular energy B. Osmosis, in which water moves freely across the gill cell membranes in response to differences in solute concentration C. Facilitated diffusion, in which sodium ions cross the membrane through protein channels without any energy cost to the fish D. Active transport, in which energy from ATP is used to move sodium ions against their concentration gradient out of the body

11. A culture of yeast cells is divided between two flasks. Flask 1 is sealed and contains no oxygen, while Flask 2 is open to the air with abundant oxygen. After several hours, which observation would be expected?

A. Both flasks produce equal amounts of ATP, since yeast cells can switch between respiration modes without any change at all B. Flask 1 produces less ATP per glucose molecule than Flask 2, because anaerobic respiration is much less efficient than aerobic C. Flask 1 produces more ATP per glucose molecule than Flask 2, because anaerobic respiration is much more efficient than aerobic D. Neither flask produces any ATP, because yeast cells cannot break down glucose at all without specific external added enzymes

12. In a paper chromatography experiment, an extract of green leaves is separated into several distinct bands of different colors, including yellow, orange, and green. This result best supports which conclusion?

A. The leaves contain only one type of chlorophyll, which produces all of the observed colored bands on the paper at once B. The pigments in the leaves are produced only after the leaves are extracted with solvent during the chromatography process C. Leaves contain multiple different pigments, each absorbing different wavelengths of light during the photosynthesis process D. The various colored bands have no biological function in the leaf and are simply waste products of leaf metabolism each day

13. A couple's first three children all happen to have brown eyes. Both parents are heterozygous for eye color ($Bb \times Bb$), with brown dominant over blue. The probability that their fourth child will have brown eyes is:

A. About 75 percent, the same probability that applies to each individual child of these parents independently of past births B. Less than 75 percent, since the family has already had three brown-eyed children in succession by chance in their household C. Greater than 75 percent, since brown-eyed children tend to be born together in clusters within families due to inheritance D. Exactly 100 percent, since all three of the previous children of this particular couple have already had brown eyes from birth

14. Researchers comparing identical and fraternal twins find that identical twins are much more similar in a particular trait than fraternal twins, even when the twins are raised in different homes. This pattern best suggests that:

A. The trait is determined entirely by the environmental factors of the home each twin grew up in throughout their childhood B. The trait varies completely at random and shows no consistent relationship to either heredity or to the environment at all C. The trait is caused by a single dominant gene with complete penetrance in all individuals within the studied human population D. The trait has a

substantial genetic component, since identical twins share more genetic similarity than fraternal twins ever do

15. The diagram below shows two short sequences of mRNA: the normal sequence and the mutant sequence transcribed from one gene.

Comparison of Normal and Mutant mRNA Sequences.

Normal mRNA

AUG — GCA — UUU — CCG — UAA

Mutant mRNA

AUG — GCA — UAU — CCG — UAA

Start | Ala | (variable:
Phe / Tyr) | Pro | Stop

Based on the diagram, the mutation has changed:

A. The start codon, so that protein synthesis cannot begin at all on the mutant mRNA sequence in the cell anymore
B. The total number of codons present in the mutant mRNA, leading to a frameshift downstream of the change point
C. A single codon (UUU to UAU), which changes one amino acid (phenylalanine to tyrosine) in the resulting protein chain
D. The stop codon, so that translation continues far beyond its normal endpoint in the mutant mRNA sequence each time

16. DNA fingerprints from a crime scene and from three different suspects are compared using gel electrophoresis. The band pattern of suspect #2 exactly matches the band pattern from the crime scene sample. This result indicates that:

A. The crime scene sample was contaminated, and the test cannot reliably identify any individual suspect involved in the crime
B. The crime scene DNA most likely came from suspect #2, since the band patterns are an exact match for that individual person
C. None of the three suspects could be the actual source of the crime scene DNA, since DNA fingerprints are never identical at all
D. The crime scene DNA came equally from all three suspects, since DNA from different individuals always produces similar patterns

17. A population of mice contains alleles for black fur (B, dominant) and brown fur (b, recessive). Of 1,000 mice, 90 have brown fur (homozygous recessive). Assuming Hardy-Weinberg equilibrium, the frequency of the recessive allele (q) in this population is approximately:

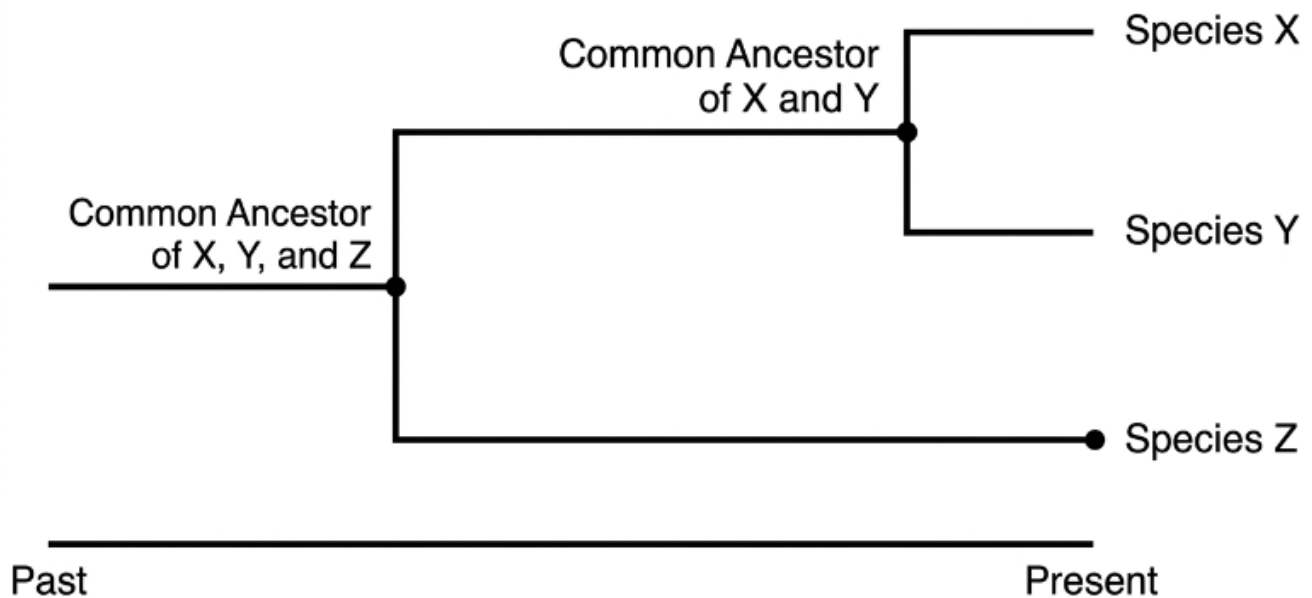
A. 0.09, calculated directly from the proportion of brown-furred mice in this particular mouse population in the study
 B. 0.91, calculated directly from the proportion of black-furred mice in this particular mouse population in the study
 C. 0.81, calculated as the square of the proportion of brown-furred mice in the population in the same study setup
 D. 0.30, calculated as the square root of the proportion of brown-furred mice in the population in the same study

18. Modern dog breeds such as the Chihuahua, Great Dane, and Poodle were all developed from a common ancestor (the gray wolf) through deliberate breeding choices made by humans over many generations. This process is best classified as:

A. Artificial selection, in which humans deliberately choose which individuals reproduce in order to produce desired traits
 B. Natural selection, in which the natural environment determines which individuals survive and reproduce most successfully
 C. Convergent evolution, in which unrelated species independently evolve similar traits under similar selective pressures over time
 D. Spontaneous generation, in which living organisms arise from nonliving material under specific environmental conditions

19. A phylogenetic tree shows three species: X, Y, and Z. The tree is drawn below.

Phylogenetic Tree of Species X, Y, and Z



Which conclusion is best supported by this tree?

A. Species X is the direct ancestor of species Y and Z, since species X appears first on the time axis of this phylogenetic tree
 B. Species Z is more closely related to species Y than to species X, since Z is drawn directly below the X-Y branch on the tree
 C. Species X and Y are more closely related to each other than to species Z

other than either is to species Z based on the most recent common ancestor D. All three of these species are equally closely related to one another, since they all appear at the same point in time today

20. A pyramid of energy in a freshwater pond ecosystem shows producers at the base containing 50,000 kcal of energy, primary consumers at the next level containing 5,000 kcal of energy, and secondary consumers at the next level containing 500 kcal of energy. This pyramid is best explained by which biological principle?

A. Energy is created and destroyed at each level of the ecological pyramid in proportion to the trophic level of each group B. Approximately 90 percent of the energy at each trophic level is lost as heat through metabolic activities of the organisms C. Predators at the higher trophic levels generally have access to more total energy than the producers at the base of the pyramid D. Each trophic level contains a greater total number of individual organisms than the trophic level just below it in the pyramid

21. Approximately what percentage of the energy at one trophic level is generally transferred to the next higher trophic level in a typical food web?

A. About 100 percent, since energy is conserved as it flows from one trophic level up to the next higher trophic level continuously B. About 50 percent, since roughly half of the energy at each level is incorporated directly into the predator's body tissue each time C. About 25 percent, since one-fourth of the energy at each trophic level passes upward to the next level in standard food chains D. About 10 percent, since most of the energy at each trophic level is lost as heat through cellular respiration each day in animals

22. The widespread decline of honeybees and other pollinators in recent decades poses a serious threat to humans primarily because:

A. Many of the food crops humans depend on require pollination by bees or other insects to produce fruit and seeds each year B. Honeybees are the primary source of dietary protein in the daily diets of most people across the world's various continents C. Without honeybees, there would be no source of pure oxygen available in Earth's atmosphere for the breathing of humans D. Honeybees produce the only form of fresh water that can be safely consumed by humans during long droughts each year today

23. The Burmese python, native to Southeast Asia, was introduced into the Florida Everglades by accidental and deliberate releases. The python population has grown rapidly and has caused dramatic declines in native mammal populations. This situation is best described as a problem caused by:

A. Natural selection, in which the python evolved new traits specifically suited for life in the Everglades environment of Florida B. Habitat destruction, in which direct human activity has eliminated the native species' habitat throughout the Florida Everglades C. An invasive species, a non-native species whose introduction causes ecological or economic harm in the new region it enters D. Genetic drift, in which random changes in allele frequencies caused the native mammal populations to disappear from the area

24. After an oil spill on a coastline, scientists use specific bacterial strains capable of breaking down crude oil components in order to help clean the affected beaches and shorelines. This use of living organisms to clean up environmental pollutants is best called:

A. Bioaccumulation, in which pollutants build up in the tissues of organisms over many generations of repeated consumption B. Bioremediation, the use of living organisms to remove or neutralize pollutants from a contaminated environmental setting C. Biomagnification, in which pollutant concentrations increase at each higher level of the food chain over a period of time D. Eutrophication, the process by which excess nutrients enter water and trigger major algal blooms in lakes and rivers

25. Polar bears at the top of the Arctic food chain often have very high levels of certain industrial chemicals in their body fat — far higher than the levels in the ocean water or in the small organisms at the base of the food chain. This pattern is best classified as:

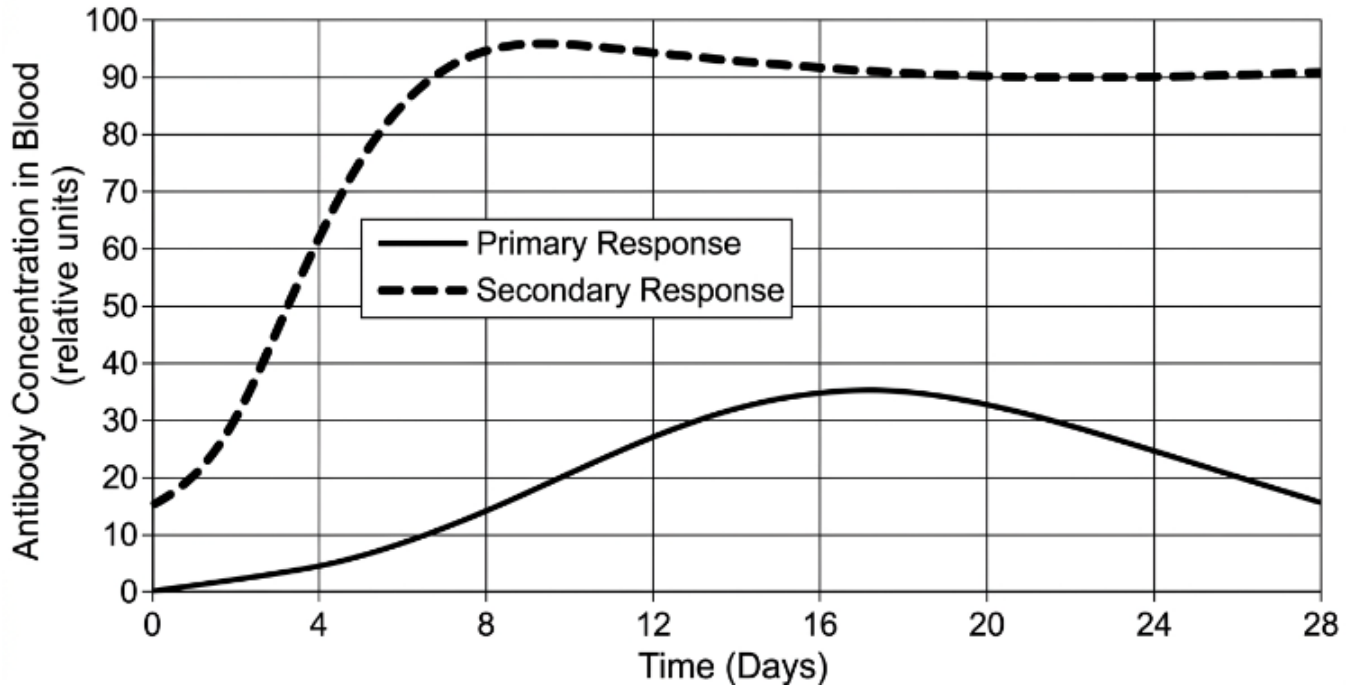
A. Eutrophication, the buildup of excess plant nutrients in a body of water leading to algal blooms over a period of time B. Habitat fragmentation, the breaking apart of a single continuous habitat into smaller isolated patches over a period of time C. Bioremediation, the use of living organisms to clean up pollutants from a contaminated environmental area in many regions D. Biomagnification, the increasing concentration of certain pollutants at each higher trophic level of the food chain over time

26. In a hospital, a graph shows the percentage of bacterial samples resistant to a particular antibiotic increasing year over year despite no change in the antibiotic being used in patients. This increase in resistance is best explained by:

A. Bacteria intentionally evolving resistance by deliberately responding to the presence of the antibiotic in the hospital settings B. Bacteria losing all of their genetic material and then regenerating it in a new form that happens to resist antibiotic action well C. Natural selection, in which bacteria carrying resistance alleles survived antibiotic exposure and reproduced more successfully D. Random environmental changes inside the hospital that affected bacteria but had nothing at all to do with the antibiotic exposure

27. A graph below compares the antibody response in a person's blood after a first exposure to a particular pathogen (primary response) and after a later second exposure to the same pathogen (secondary response).

Primary vs. Secondary Antibody Response



Which conclusion is best supported by the graph?

A. The secondary response produces antibodies much more rapidly and at higher concentration levels than the primary response does
B. The primary response produces antibodies more rapidly and at higher concentration levels than the secondary response does each time
C. The primary and secondary antibody responses produce identical antibody levels and reach exactly the same peak in each case shown
D. Antibody production stops completely after a person's very first exposure to a particular pathogen during their entire life on Earth

28. The human immunodeficiency virus (HIV) attacks and destroys helper T cells (CD4 cells) in the immune system. A person whose helper T cell count drops very low as a result of HIV infection will most likely:

A. Have a stronger than normal immune system, because the absence of helper T cells allows other immune cells to multiply rapidly
B. Become highly vulnerable to many infections that a person with a normal immune system could easily fight off in the same situation
C. Develop natural resistance to all bacterial and viral infections because of dramatic changes in the body's immune system structure
D. Become completely immune to every viral infection except for the specific HIV strain that initially caused the destruction of T cells

29. A patient's thyroid gland produces excessive amounts of the hormone thyroxine. The most likely set of symptoms the patient will experience is:

A. Decreased heart rate, increased weight gain, and increased sensitivity to cold temperatures throughout the patient's body each day
B. No noticeable symptoms at all, since the body's hormones do not

significantly affect any of the major physiological processes C. Increased blood glucose levels and increased urination, very similar to the most common symptoms of type 1 diabetes patients D. Increased heart rate, weight loss, and increased sensitivity to heat, all reflecting elevated metabolic activity in the patient's body

30. Type 1 and type 2 diabetes both result in elevated blood glucose levels, but they differ in their underlying causes. In type 1 diabetes, the most common underlying cause is:

A. The immune system destroys insulin-producing beta cells in the pancreas, leaving the body unable to make its own insulin B. The body's cells become resistant to insulin even though the pancreas continues to produce normal levels of insulin each day C. The liver produces too much glucose during the night, leading to elevated glucose levels in the morning hours of each day D. The kidneys allow excessive amounts of glucose to leak into the urine even though insulin levels remain completely normal

31. Which of the following lifestyle changes would most directly reduce a person's long-term risk of cardiovascular disease?

A. Spending more hours sitting at work and during leisure activities throughout the typical week of daily routines and habits B. Eating a diet very high in saturated fats, trans fats, salt, and added sugars throughout each day of the week regularly C. Engaging in regular aerobic exercise and eating a diet rich in fruits, vegetables, whole grains, and lean sources of protein D. Increasing daily consumption of tobacco products in combination with regular and substantial consumption of alcoholic beverages

32. During an asthma attack, the smooth muscles surrounding the airways (bronchi and bronchioles) contract, the airway lining becomes inflamed, and excess mucus is produced. These changes most directly cause:

A. Increased flow of air into and out of the lungs, since narrower airways increase the speed of air movement during each breath B. Reduced flow of air into and out of the lungs, since the narrowed and obstructed airways resist airflow during normal breathing C. Increased exchange of oxygen and carbon dioxide at the alveolar walls during each breath taken by the affected patient quickly D. Faster digestion of food in the stomach and the small intestine due to the increased airflow through the entire digestive tract

33. A myocardial infarction (heart attack) most commonly occurs when:

A. A blood clot blocks a coronary artery, depriving part of the heart muscle of oxygen and causing tissue damage to the heart B. The heart's electrical system shuts down completely, immediately preventing any further contractions of the heart muscle at all C. The heart muscle becomes overly relaxed, allowing blood to pool in the chambers without ever being pumped out to the body D. The pulmonary artery becomes blocked, preventing oxygen-rich blood from reaching the brain through the heart and arteries

34. Long-term cigarette smoking damages the respiratory system in several ways. One major effect is the destruction of the walls of the alveoli, leading to a condition called emphysema. Emphysema reduces lung function primarily by:

A. Increasing the total amount of blood available for gas exchange across the lung's alveolar surface area each minute of breathing B. Increasing the heart rate so dramatically that the lungs can no longer keep up with the higher oxygen demand throughout the body C. Causing the diaphragm muscle to contract much more strongly during each breath taken by the patient over the entire course of a day D. Reducing the total surface area available for the diffusion of oxygen and carbon dioxide across the alveolar walls of the lung tissue

35. Compared to normal body cells, cancer cells generally show all of the following characteristics EXCEPT:

A. The ability to continue dividing indefinitely without the usual cellular controls limiting the total number of divisions in a lifetime B. The ability to invade nearby tissues and to spread to distant organs through the bloodstream in a process called metastasis later C. The ability to respond normally to all of the body's growth signals and to stop dividing when adequate tissue growth has occurred D. The accumulation of multiple mutations in genes that control the cell cycle, programmed cell death, and the repair of damaged DNA

36. A scientist observes that fish in a particular polluted river are noticeably smaller than fish of the same species living in a nearby clean river. Which of the following is a properly formed testable hypothesis based on this observation?

A. The fish in the polluted river are clearly smaller because the polluted river is dirtier than the clean river that was also observed B. If fish are exposed to pollutants in their water, then they will grow to a smaller adult body size than fish living in clean water C. Polluted rivers exist throughout much of the modern world due to ongoing human industrial activity and agricultural waste runoff D. Fish are remarkable organisms that have evolved many different adaptations over millions of years of evolutionary history on Earth

37. In an experiment testing whether different brands of fertilizer affect plant growth, the type of fertilizer used is best classified as the:

A. Independent variable, the factor deliberately manipulated by the researcher to test its effect on the dependent measure of growth B. Dependent variable, the factor measured by the researcher at the end of the experimental study period in centimeters of growth C. Controlled variable, the factor kept constant across every experimental group to avoid confounding the results of the experiment D. Confounding variable, a factor that varies unexpectedly during the experiment and significantly biases the experimental results

38. A student studying the effect of caffeine on heart rate in adult volunteers gives the experimental group a cup of coffee containing caffeine and gives the control group a cup of decaffeinated coffee that looks and tastes the same. Including this control group allows the student to:

A. Demonstrate that decaffeinated coffee has no calories at all, since the controls drink nothing else during the entire study period B. Increase the total number of subjects who actually receive the caffeine treatment during the entire course of the experimental study C. Provide the experimental group with extra fluids during the study to keep all of the participants comfortable while being tested daily D.

Distinguish the effects of caffeine itself from the effects of drinking a warm liquid or simply being a participant in a study

39. During a biology lab in which students are dissecting a preserved frog, the most important safety precautions for students to follow include:

A. Tasting the preservative solution to verify that the preserved specimen has been preserved properly before beginning any dissection B. Wearing safety goggles, using sharp instruments carefully, and washing hands thoroughly when the dissection has been completed C. Touching the preserved tissue freely with bare hands so that the texture of each organ can be felt very accurately by every student D. Eating snacks at the lab bench during the dissection in order to maintain the energy levels of the students throughout the day's work

40. Recent advances in CRISPR-Cas9 gene-editing technology raise important bioethical questions, especially when applied to human embryos. Among the most widely debated concerns is:

A. The financial cost of the laboratory equipment used for CRISPR experiments at major universities and major research institutions today B. The difficulty of finding scientific personnel willing to learn modern CRISPR techniques in laboratories spread around the entire world C. The possibility of making heritable changes to the human genome that would then be passed to all future generations of descendants D. The lack of any potential medical benefit at all from any of the CRISPR-based gene-editing techniques currently being developed today

41. The sequence of stages in the early development of a human embryo, from earliest to latest, is best described as:

A. Zygote → cleavage → blastula → gastrula → embryo with three germ layers and the beginning of organ formation in the embryo B. Embryo with organs → gastrula → blastula → cleavage → zygote, in reverse order of human embryonic development from late to early C. Blastula → zygote → gastrula → cleavage → embryo, in the order followed by normal human embryonic development in utero today D. Gastrula → blastula → zygote → cleavage → embryo, in the order shown in human embryonic development during the first week

42. The pancreas plays important roles in both the digestive and the endocrine systems. As an endocrine gland, the pancreas:

A. Produces digestive enzymes that are released into the small intestine to break down starches, proteins, and fats during digestion each day B. Produces bile, which emulsifies dietary fats so that they can be more easily broken down by lipase enzymes in the small intestine C. Filters waste products out of the blood and produces concentrated urine for excretion through the urinary system of the human body D. Produces the hormones insulin and glucagon, which regulate blood glucose levels by signaling cells throughout the body to act

43. Signals travel along myelinated neurons much faster than along unmyelinated neurons of comparable size. The most likely reason for this difference is that:

A. Myelinated neurons are much larger in diameter than unmyelinated neurons in all parts of the human nervous system overall B. The myelin sheath allows the nerve impulse to "jump" between gaps in the sheath, greatly speeding up transmission along the axon C. Myelinated neurons are surrounded by additional sensory receptors that detect signals before the unmyelinated neurons can do so D. Myelin sheaths produce action potentials directly through metabolic activity in the cytoplasm of the neuron's cell body each second

44. Which of the following structures is NOT part of the reflex arc that causes a person to rapidly pull away from a hot object?

A. The sensory neuron, which carries information from the sensory receptors in the skin toward the spinal cord during the reflex B. The motor neuron, which carries the signal from the spinal cord out to the muscle that pulls the hand away from the heat source C. The cerebral cortex, which must consciously process the painful information before the protective reflex movement can be initiated D. The interneuron located in the spinal cord, which connects the sensory neuron to the motor neuron during the reflex response

45. During muscle contraction, the protein filaments actin and myosin slide past each other within each muscle fiber. The energy required for this sliding-filament process comes directly from:

A. ATP hydrolysis, which provides the energy needed for the myosin heads to pull on the actin filaments repeatedly during contraction B. The direct conversion of dietary glucose into ATP within each muscle fiber at the precise moment of each muscular contraction C. The breakdown of the muscle fiber's own cell membrane in order to release stored chemical energy for the muscle contraction D. The conversion of sunlight directly into chemical energy through photosynthesis within each muscle cell during periods of exercise

46. Bones in the human body are described as "living tissue" because they:

A. Are made entirely of nonliving calcium minerals deposited in a hard structure without any living cells inside them at all B. Are made entirely of soft cartilage tissue throughout the body and contain no minerals or hard materials at all in the structure C. Are merely placeholders that hold up the body's organs but do not have any biological activity at all in any living humans today D. Contain living cells (osteocytes and osteoblasts) that continuously remodel, repair, and respond to mechanical stress on the bone

47. The skin is the largest organ of the human body and performs many essential functions in daily life. Which of the following is one of the most important biological functions of the skin?

A. Producing all of the body's red blood cells, which are then used to carry oxygen from the lungs to the body's various tissues each minute B. Filtering waste products from the blood and producing concentrated urine for excretion from the body through the urinary system every day C. Protecting the body from pathogens and physical damage and helping to regulate body temperature through sweating and circulation control D. Producing the digestive enzymes needed to break down complex food molecules in the small intestine of the body shortly after each meal

48. The kidneys remove urea from the bloodstream during the production of urine. Urea is best classified as:

A. An undigested food molecule that enters the bloodstream from the small intestine after a particularly heavy meal of dietary protein
B. A nitrogen-containing waste product produced by the liver when amino acids are broken down for energy use throughout the body
C. A type of hormone that signals body cells to take up glucose from the bloodstream after meals during the process of digestion each day
D. An enzyme that breaks down complex proteins into individual amino acids during the early stages of digestion in the human body

49. Different digestive enzymes act on different types of macromolecules in the human digestive system. The enzyme amylase is best described as an enzyme that:

A. Breaks down starch into smaller sugar molecules, beginning in the mouth where amylase is found in the saliva of humans
B. Breaks down proteins into smaller amino acid units, beginning in the stomach where pepsin is most active in human digestion
C. Breaks down fats into fatty acids and glycerol, beginning in the small intestine where lipase enzymes are released after each meal
D. Breaks down nucleic acids such as DNA and RNA into smaller nucleotide units, beginning in the pancreas of the human digestive system

50. The human liver performs many essential functions in the body. Which of the following is NOT a major function of the liver?

A. Producing bile, which helps emulsify dietary fats and aids in their digestion in the small intestine after meals each day in humans
B. Detoxifying harmful substances such as alcohol and many drugs that enter the bloodstream from the digestive system of the body
C. Storing excess glucose as glycogen and converting that glycogen back into glucose when blood glucose levels fall too low for the body
D. Producing the hormone insulin that signals the body's cells to absorb glucose from the bloodstream after each meal eaten during the day

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1. C — Real cell membranes are selectively permeable, allowing some substances through while blocking other substances. Dialysis tubing models this property because it allows small molecules such as glucose and iodine to pass through its pores while blocking larger molecules such as starch. This selective permeability is the defining functional feature of all living cell membranes.

2. A — Natural selection, in which individuals with traits best suited to obtaining food survive and reproduce. The lab simulates differential success at acquiring food among finches with different beak shapes, paralleling Darwin's observations on the Galapagos. Students who model "finches" with the best-suited tools collect more seeds and "survive" to the next round.

3. B — Similar DNA nucleotide sequences among the species, since DNA sequences directly reflect their common ancestry over time. DNA is the most reliable molecular evidence because shared sequences result from inheritance from a common ancestor and are minimally influenced by environmental factors. Morphological features can converge in unrelated species, but DNA sequence similarities track true ancestry.

4. D — The pulse rate increases because the working muscles require more oxygen and the circulatory system responds accordingly. Muscle activity raises ATP demand, increasing the need for oxygen and the removal of CO₂. The cardiovascular and respiratory systems coordinate to meet this demand by speeding up heart rate and breathing rate.

5. A — A plant leaf cell, since plant cells uniquely have a cell wall, a large central vacuole, and chloroplasts in their cytoplasm. These three features together — rigid cell wall, central vacuole, and chloroplasts — are diagnostic of a photosynthetic plant cell. Animal, red blood, and bacterial cells lack at least one of these structures.

6. C — Smooth endoplasmic reticulum, which contains many of the enzymes used in the detoxification of chemicals in the body. Liver hepatocytes are especially rich in smooth ER because that is where cytochrome P450 and related drug-metabolizing enzymes reside. Damage to this system, as in liver disease, impairs the body's ability to clear medications and toxins.

7. D — The sodium-potassium pump, which uses ATP to actively transport sodium ions out and potassium ions into the cell. This pump moves three Na⁺ out and two K⁺ in per ATP hydrolyzed, establishing the electrochemical gradient that underlies the resting membrane potential. Without it, action potentials in neurons could not occur.

8. B — Pepsin activity is highest at low pH (acidic conditions), consistent with its function in the acidic environment of the human stomach. The graph peaks sharply near pH 2, matching pepsin's natural environment in stomach acid. As pH rises into the neutral and basic range, the enzyme denatures and loses activity.

9. A — Increases the rate at which water and dissolved minerals can be absorbed from the soil into the plant's root system. Greater surface area means more contact with the soil solution, allowing faster uptake of water and dissolved nutrients. This is the same general principle that explains why villi increase intestinal absorption and alveoli increase gas exchange.

10. D — Active transport, in which energy from ATP is used to move sodium ions against their concentration gradient out of the body. Marine fish must constantly expend ATP to move salt outward, because ocean water has higher solute concentration than their tissues. Without active salt excretion, marine fish would dehydrate by osmosis.

11. B — Flask 1 produces less ATP per glucose molecule than Flask 2, because anaerobic respiration is much less efficient than aerobic. Without oxygen, yeast must rely on fermentation, which yields only about 2 ATP per glucose compared to roughly 36–38 ATP under aerobic conditions. The electron transport chain — the major ATP producer — cannot operate without oxygen.

12. C — Leaves contain multiple different pigments, each absorbing different wavelengths of light during the photosynthesis process. Chromatography separates these pigments — chlorophyll a, chlorophyll b, carotenes, and xanthophylls — based on their different solubilities. Having multiple accessory pigments allows plants to capture a broader range of light wavelengths.

13. A — About 75 percent, the same probability that applies to each individual child of these parents independently of past births. Each child of a $Bb \times Bb$ cross has an independent $3/4$ chance of inheriting at least one dominant allele and showing the brown-eyed phenotype. Past outcomes do not change future probabilities — a classic application of the independence of meiotic events.

14. D — The trait has a substantial genetic component, since identical twins share more genetic similarity than fraternal twins ever do. Greater similarity among identical twins than fraternal twins, even when raised apart, points to a heritable basis for the trait. This twin-study design is a standard tool for partitioning genetic versus environmental contributions to a trait.

15. C — A single codon (UUU to UAU), which changes one amino acid (phenylalanine to tyrosine) in the resulting protein chain. The middle base of the third codon changes from U to A, producing a missense point mutation that swaps phenylalanine for tyrosine. The other codons remain intact, so the reading frame is preserved and the protein length is unchanged.

16. B — The crime scene DNA most likely came from suspect #2, since the band patterns are an exact match for that individual person. DNA fingerprints (STR or RFLP patterns) are essentially unique to each individual, so a band-for-band match is strong evidence of identity. This is the principle that has revolutionized forensic identification since the late 1980s.

17. D — 0.30, calculated as the square root of the proportion of brown-furred mice in the population in the same study. Under Hardy-Weinberg, q^2 equals the homozygous recessive frequency: $90/1,000 = 0.09$, so $q = \sqrt{0.09} = 0.30$. This same formula is used routinely to estimate allele frequencies from phenotype data.

18. A — Artificial selection, in which humans deliberately choose which individuals reproduce in order to produce desired traits. Selective breeding is the defining feature of artificial selection, where human preference replaces natural environmental pressure as the agent of selection. Darwin used examples like pigeon breeding to argue by analogy for natural selection in wild populations.

19. C — Species X and Y are more closely related to each other than either is to species Z based on the most recent common ancestor. The X-Y node is more recent than the X-Y-Z node, indicating X and Y share a closer ancestry. This is the fundamental rule for reading evolutionary relatedness from a phylogenetic tree.

20. B — Approximately 90 percent of the energy at each trophic level is lost as heat through metabolic activities of the organisms. The energy values drop by a factor of ten between each level ($50,000 \rightarrow 5,000 \rightarrow 500$), consistent with the well-known 10% rule. The lost energy is dissipated as heat during cellular respiration or remains in undigested waste.

- 21. D** — About 10 percent, since most of the energy at each trophic level is lost as heat through cellular respiration each day in animals. Roughly 90% of energy is dissipated as heat, with another portion lost in undigested wastes and uneaten biomass. This inefficiency is why food chains rarely exceed four or five trophic levels in nature.
- 22. A** — Many of the food crops humans depend on require pollination by bees or other insects to produce fruit and seeds each year. Apples, almonds, blueberries, squash, and dozens of other crops depend on insect pollinators. Severe pollinator declines therefore threaten global agriculture and food security, not just wild biodiversity.
- 23. C** — An invasive species, a non-native species whose introduction causes ecological or economic harm in the new region it enters. Burmese pythons have no natural predators in the Everglades and few co-evolved defenses limit them, allowing rapid population growth and severe ecosystem disruption. This is a hallmark scenario of invasive species impact.
- 24. B** — Bioremediation, the use of living organisms to remove or neutralize pollutants from a contaminated environmental setting. Oil-degrading bacteria such as *Alcanivorax* break down hydrocarbons into less harmful compounds. Bioremediation was used extensively after the Exxon Valdez and Deepwater Horizon spills to accelerate cleanup.
- 25. D** — Biomagnification, the increasing concentration of certain pollutants at each higher trophic level of the food chain over time. Persistent, fat-soluble pollutants such as PCBs and DDT accumulate in body tissues and concentrate as predators consume prey. Top predators such as polar bears, eagles, and large fish therefore carry the highest body burdens.
- 26. C** — Natural selection, in which bacteria carrying resistance alleles survived antibiotic exposure and reproduced more successfully. The antibiotic does not create resistance — it selects in favor of any bacteria that already happen to carry resistance alleles. Repeated antibiotic use therefore drives up the frequency of resistance over time, which is why antibiotic stewardship matters.
- 27. A** — The secondary response produces antibodies much more rapidly and at higher concentration levels than the primary response does. After first exposure, memory B and T cells persist; on re-exposure, they respond within days and produce far higher antibody titers. This is the immunological basis for how vaccines provide long-lasting protection.
- 28. B** — Become highly vulnerable to many infections that a person with a normal immune system could easily fight off in the same situation. Helper T cells coordinate both antibody production and cell-mediated immunity, so their loss disables much of the adaptive immune response. This vulnerability to opportunistic infections defines progression from HIV infection to AIDS.
- 29. D** — Increased heart rate, weight loss, and increased sensitivity to heat, all reflecting elevated metabolic activity in the patient's body. Excess thyroxine accelerates the basal metabolic rate, producing the classic signs of hyperthyroidism (Graves disease). Hypothyroidism, by contrast, causes the opposite symptom pattern with weight gain, fatigue, and cold intolerance.

30. A — The immune system destroys insulin-producing beta cells in the pancreas, leaving the body unable to make its own insulin. Type 1 diabetes is an autoimmune disease that typically appears in childhood or adolescence and requires lifelong insulin therapy. Type 2 diabetes, in contrast, is characterized by insulin resistance rather than insulin destruction.

31. C — Engaging in regular aerobic exercise and eating a diet rich in fruits, vegetables, whole grains, and lean sources of protein. These behaviors lower blood pressure, improve cholesterol profiles, reduce inflammation, and help maintain healthy body weight — all factors that reduce cardiovascular risk. They are the foundation of nearly every cardiovascular prevention guideline.

32. B — Reduced flow of air into and out of the lungs, since the narrowed and obstructed airways resist airflow during normal breathing. Bronchoconstriction, inflammation, and mucus all reduce the cross-section of the airways and make it harder to move air, especially during exhalation. Inhaled bronchodilators reverse the smooth muscle contraction and relieve the obstruction.

33. A — A blood clot blocks a coronary artery, depriving part of the heart muscle of oxygen and causing tissue damage to the heart. Coronary thrombosis — typically caused by rupture of an atherosclerotic plaque — interrupts blood flow to a region of the myocardium, leading to ischemia and tissue death. Rapid restoration of blood flow with clot-dissolving drugs or stents minimizes the damage.

34. D — Reducing the total surface area available for the diffusion of oxygen and carbon dioxide across the alveolar walls of the lung tissue. Destruction of alveolar walls merges many small alveoli into fewer, larger air spaces, drastically reducing the surface area for gas exchange. Patients experience progressive shortness of breath because their lungs cannot oxygenate the blood efficiently.

35. C — The ability to respond normally to all of the body's growth signals and to stop dividing when adequate tissue growth has occurred. Cancer cells are defined precisely by their failure to respond to these regulatory signals, allowing uncontrolled proliferation. The other options listed are all characteristic features of cancer cells.

36. B — If fish are exposed to pollutants in their water, then they will grow to a smaller adult body size than fish living in clean water. A testable hypothesis takes an if-then form, relating an independent variable (pollution exposure) to a dependent variable (body size) in a way that can be experimentally tested. The other options are observations, general facts, or opinions rather than testable predictions.

37. A — Independent variable, the factor deliberately manipulated by the researcher to test its effect on the dependent measure of growth. The researcher chooses which brand of fertilizer to apply to each group, making fertilizer type the manipulated factor. Plant growth would be the dependent variable measured at the end.

38. D — Distinguish the effects of caffeine itself from the effects of drinking a warm liquid or simply being a participant in a study. A well-designed control receives the same experience as the experimental group except for the variable being tested, isolating the effect of that single factor. This design also helps control for placebo effects in human subjects.

39. B — Wearing safety goggles, using sharp instruments carefully, and washing hands thoroughly when the dissection has been completed. These standard precautions protect against splashes of preservative, accidental cuts from scalpels, and contamination of the body or food with biological material. They are the universal core of biology laboratory safety practice.

40. C — The possibility of making heritable changes to the human genome that would then be passed to all future generations of descendants. Germline edits in embryos affect every cell of the resulting person and are inherited by all descendants, raising profound ethical, safety, and consent concerns. This is why most countries currently prohibit clinical germline gene editing.

41. A — Zygote → cleavage → blastula → gastrula → embryo with three germ layers and the beginning of organ formation in the embryo. Fertilization produces the zygote, which undergoes rapid cleavage divisions to form a hollow blastula, then folds in during gastrulation to form three germ layers (ectoderm, mesoderm, endoderm). These germ layers then develop into specific organ systems through organogenesis.

42. D — Produces the hormones insulin and glucagon, which regulate blood glucose levels by signaling cells throughout the body to act. Insulin from beta cells lowers blood glucose by promoting cellular uptake, while glucagon from alpha cells raises blood glucose by stimulating glycogen breakdown. These hormones are secreted from islets of Langerhans, the endocrine portion of the pancreas.

43. B — The myelin sheath allows the nerve impulse to "jump" between gaps in the sheath, greatly speeding up transmission along the axon. This process is called saltatory conduction: action potentials regenerate only at the unmyelinated Nodes of Ranvier, effectively leaping along the axon. Demyelinating diseases such as multiple sclerosis slow or block nerve conduction precisely because they disrupt this mechanism.

44. C — The cerebral cortex, which must consciously process the painful information before the protective reflex movement can be initiated. A reflex arc bypasses the cerebral cortex by routing the signal through the spinal cord, which is why the hand moves before pain is consciously felt. The cortex is informed afterward, allowing the person to perceive what just happened.

45. A — ATP hydrolysis, which provides the energy needed for the myosin heads to pull on the actin filaments repeatedly during contraction. Each cycle of myosin attachment, power stroke, and release requires the hydrolysis of one ATP molecule. This is why rigor mortis occurs after death: without ATP, myosin cannot detach from actin, locking the muscles in contraction.

46. D — Contain living cells (osteocytes and osteoblasts) that continuously remodel, repair, and respond to mechanical stress on the bone. Osteoblasts deposit new bone matrix, osteoclasts resorb old bone, and osteocytes sense mechanical loads — together making bone a dynamic, metabolically active tissue. This explains why bones heal after fractures and why bone density responds to exercise.

47. C — Protecting the body from pathogens and physical damage and helping to regulate body temperature through sweating and circulation control. The skin acts as a physical and chemical barrier, contributes to immune defense, regulates body temperature through sweat and blood-vessel dilation, and senses the external environment. It is the body's largest organ and one of its most multifunctional.

48. B — A nitrogen-containing waste product produced by the liver when amino acids are broken down for energy use throughout the body. Excess amino acids are deaminated in the liver, producing ammonia, which is then converted into the less toxic urea via the urea cycle. Urea is carried in the blood to the kidneys, which filter it out into the urine.

49. A — Breaks down starch into smaller sugar molecules, beginning in the mouth where amylase is found in the saliva of humans. Salivary amylase begins starch digestion before food even reaches the stomach, and pancreatic amylase continues the process in the small intestine. The end result is shorter sugar fragments such as maltose that can be further broken down for absorption.

50. D — Producing the hormone insulin that signals the body's cells to absorb glucose from the bloodstream after each meal eaten during the day. Insulin is produced by the beta cells of the pancreatic islets, not by the liver. The liver does store glucose as glycogen in response to insulin signaling, but it does not produce the hormone itself.