

PRACTICE EXAM 38: LIFE SCIENCE: BIOLOGY SIMULATION (50 QUESTIONS — CLASSIC EXPERIMENTS, COMPARATIVE BIOLOGY, CROSS-TOPIC INTEGRATION & ANALYSIS)

Instructions: Practice Exam 38 is organized thematically across five sections: classic experiments and historical biology (Q1–10), comparative biology (Q11–20), cross-topic integration (Q21–30), mechanisms and processes (Q31–40), and application and analysis (Q41–50). Each question is independent. Select the one best answer.

SECTION 1: CLASSIC EXPERIMENTS AND HISTORICAL BIOLOGY (Q1–10)

1. Louis Pasteur's classic 1860s experiment using swan-neck flasks was designed to test the idea of "spontaneous generation," the belief that living organisms could arise from nonliving matter. Pasteur's results most strongly supported the conclusion that:

A. Spontaneous generation does occur, but only under very specific environmental conditions that are difficult to reproduce in a typical laboratory setting today during normal scientific experiments by researchers

B. Bacteria are produced from chemical reactions involving water and air, since the broth in the flasks turned cloudy only when the water and air made direct contact with each other in the laboratory environment each time

C. Living organisms can be created in the laboratory by combining the correct mixture of nonliving chemicals, water, and energy in a sealed glass vessel over the course of time during careful experiments by scientists

D. All living organisms come from preexisting living organisms, since broth in the swan-neck flasks remained clear and free of microbial growth as long as dust and microbes could not enter from the surrounding air

2. Gregor Mendel's experiments crossing pea plants over many generations led him to propose that inherited traits are determined by discrete units (now called genes) that segregate during reproduction. The "law of segregation" specifically states that:

A. All offspring of two homozygous parents are genetically identical to each other and to both of their parents, expressing the same single phenotype throughout their entire lifetime in every generation of the family

B. The two alleles for each gene separate from each other during the formation of gametes, so each gamete contains only one allele for each gene that the parent organism possesses in its cells overall

C. The expression of one gene completely masks the expression of all other genes in the genome, so each organism shows only the dominant phenotype of one of its many genes at any given time during its life

D. All genes are inherited together as a single unit during reproduction, so the offspring receive exactly the same combination of alleles as one of their two parents has in every generation of the family overall

3. The double-helical structure of DNA was first proposed by James Watson and Francis Crick in 1953. Their model relied heavily on X-ray diffraction images obtained by Rosalind Franklin. The X-ray diffraction data was most directly used to determine:

A. The helical shape of the DNA molecule and the distances between repeating structural features such as the spacing between base pairs along the length of the entire molecule of DNA in living cells

B. The exact sequence of nucleotide bases in the DNA molecule for any particular gene, which would later be used to predict the amino acid sequence of the protein product encoded by that gene in cells

C. The total amount of DNA contained within a single human cell on average, expressed in nanograms of DNA per cell of each tissue type studied throughout the body of an adult individual at any age

D. The names of all of the enzymes responsible for replicating DNA during cell division, as well as the specific function of each enzyme during the process of replication in the cells of every organism

4. The Hershey-Chase experiments of 1952 used radioactive isotopes to label the protein and DNA components of bacteriophages (viruses that infect bacteria). The results of these experiments most strongly supported the conclusion that:

A. Both protein and DNA are essential genetic materials in viruses, since the radioactive labels from both molecules ended up inside the bacterial cells after the infection of the host bacteria by the bacteriophages

B. Protein, rather than DNA, is the genetic material of all viruses, since only the radioactive protein label was found inside the bacterial cells after the infection occurred in the experimental setup of the laboratory

C. DNA, rather than protein, is the genetic material of bacteriophages, since the radioactive DNA label entered the bacterial cells while the radioactive protein label remained outside the bacterial cells during infection

D. Neither DNA nor protein is the actual genetic material of viruses, since the radioactive labels from both molecules were found in equal amounts inside and outside of the bacterial cells during the entire experiment

5. The Meselson-Stahl experiment of 1958 used heavy and light nitrogen isotopes to track the replication of DNA in bacterial cells over multiple generations. The results of this elegant experiment most strongly supported which model of DNA replication?

A. Conservative replication, in which the entire parental double helix remains intact and a completely new double helix is synthesized as a separate molecule alongside the original one during DNA replication in the cell

B. Semiconservative replication, in which each new DNA molecule contains one strand from the original parental molecule and one newly synthesized complementary strand made during DNA replication in the cell

C. Dispersive replication, in which the parental DNA is broken into many small fragments that are then mixed with newly synthesized DNA fragments to form the two new DNA molecules during replication in the cell

D. Random replication, in which new DNA molecules are assembled from individual nucleotides without using the parental strands as templates of any kind during the process of replication in the cell

6. Frederick Griffith's 1928 experiments with two strains of *Streptococcus pneumoniae* bacteria (a smooth virulent strain and a rough non-virulent strain) showed that something from the heat-killed virulent strain could change the non-virulent strain into a virulent form. This phenomenon is now known as:

A. Cellular respiration, in which the bacteria break down glucose to produce the ATP needed to power their cellular activities throughout their entire life cycle within the host organism's body during infection

B. Photosynthesis, in which the bacteria convert sunlight into the chemical energy stored in glucose molecules through a series of enzyme-catalyzed reactions in chloroplast-like structures within the bacterial cells

C. Bacterial conjugation, in which two living bacterial cells form a direct physical connection that allows the transfer of genetic material between them during the course of a single bacterial generation in nature

D. Bacterial transformation, in which bacteria take up DNA fragments from their surrounding environment and incorporate the DNA into their own genome, acquiring new heritable traits as a result of the uptake

7. Mary Lyon proposed in 1961 that one of the two X chromosomes in each cell of a female mammal becomes inactivated early in embryonic development. The Lyon hypothesis explains many genetic phenomena, including the:

A. Patchy coloration patterns of calico cats, in which different patches of fur show different X-linked colors depending on which X chromosome was randomly inactivated in the ancestor cells of each patch of skin and fur

B. The fact that male calico cats are extremely common in nature and often exhibit a wider range of fur color patterns than female calico cats do in the same general geographic regions of the species during life

C. The complete absence of any X-linked recessive genetic disorders in human females across all known human populations and ethnic groups around the world during the modern medical era of medicine on Earth

D. The greater susceptibility of female mammals (including humans) to X-linked recessive disorders compared to male mammals of the same species and similar age and overall health status during their daily lives

8. Charles Darwin and Alfred Russel Wallace independently proposed the theory of evolution by natural selection in the 19th century. According to their theory, evolution by natural selection requires which of the following conditions?

A. The conscious effort of individuals within a population to develop new traits in response to changes in their environment over the course of their own lifetimes during their reproductive years on the planet Earth

B. The complete absence of any genetic variation within a population, so that all individuals are genetically identical and respond identically to all environmental pressures over the course of many generations on Earth

C. Heritable variation among individuals in a population, differential survival and reproduction based on that variation, and the inheritance of those variations by offspring of the surviving and reproducing individuals

D. Direct intervention by an external force or designer that selects which individuals in a population will survive and which will not, based on factors unrelated to the physical traits of the individuals affected

9. In the late 1700s, Jan Ingenhousz conducted experiments showing that green plant tissue released oxygen gas only when exposed to sunlight, not when kept in darkness. His results most strongly supported which conclusion about photosynthesis?

A. Plants do not perform photosynthesis at any time during their daily life, since the oxygen released by the plant came from the bacteria living on the surface of the plant rather than from the plant itself during the experiment

B. Sunlight is required for the process of photosynthesis, during which plants produce oxygen gas as a byproduct of the light-dependent reactions occurring within the chloroplasts of the plant cells exposed to sunlight

C. Plants release oxygen gas continuously throughout the entire day and night, since photosynthesis is a process that occurs at a constant rate regardless of the amount of sunlight available to the plant during the day

D. Oxygen gas is consumed by plants during the process of photosynthesis, since the carbon dioxide entering the plant is converted into oxygen during the photosynthetic reactions inside the leaf of the plant during daylight

10. Lynn Margulis proposed the "endosymbiotic theory" in the 1960s, which explains the origin of certain eukaryotic organelles. According to this theory:

A. Mitochondria and chloroplasts originated from free-living prokaryotic cells that were engulfed by larger ancestral cells and gradually evolved into the symbiotic organelles found inside modern eukaryotic cells

B. All eukaryotic cells originated from a single ancient prokaryotic cell that gradually developed all of its membrane-bound organelles through internal evolution within a single cellular lineage over very long stretches of time

C. Bacteria and archaea originated from ancient eukaryotic cells that lost their organelles through evolutionary degeneration over the course of many generations of evolution on the planet Earth in the distant past

D. Multicellular organisms originated from single-celled organisms through the process of binary fission, with the daughter cells failing to separate after cell division on multiple successive occasions over time on Earth

SECTION 2: COMPARATIVE BIOLOGY (Q11–20)

11. Mitosis and meiosis are both forms of eukaryotic cell division, but they differ in important ways. Which of the following best describes a difference between mitosis and meiosis?

A. Mitosis produces four haploid daughter cells while meiosis produces two diploid daughter cells, with all of the cells produced being genetically identical to each other and to the original parent cell that produced them

B. Mitosis occurs in gametes (sperm and egg cells) while meiosis occurs in all other body cells, with mitosis playing a critical role in sexual reproduction and meiosis playing a critical role in body growth and tissue repair

C. Mitosis involves crossing over and independent assortment to produce genetic variation, while meiosis produces daughter cells that are genetically identical to the original parent cell and lacks any genetic variation

D. Mitosis produces two diploid daughter cells genetically identical to the parent for growth and tissue repair, while meiosis produces four haploid daughter cells with new genetic combinations for gamete formation

12. Prokaryotic and eukaryotic cells share some features but also differ in important ways. The most important structural difference between prokaryotic and eukaryotic cells is:

A. Prokaryotic cells contain a complex internal membrane system including endoplasmic reticulum, Golgi apparatus, and lysosomes, while eukaryotic cells lack any internal membrane systems of any kind at all in their cytoplasm

B. Prokaryotic cells are typically much larger than eukaryotic cells in terms of overall size and total cellular volume of the cells, with prokaryotic cells often being visible to the naked eye in nature during normal observation

C. Eukaryotic cells contain a membrane-bound nucleus and other membrane-bound organelles, while prokaryotic cells lack a membrane-bound nucleus and most other membrane-bound organelles in their cytoplasm

D. Eukaryotic cells reproduce only through the process of binary fission, while prokaryotic cells reproduce through more complex processes involving mitosis and meiosis with multiple stages of cell division during the year

13. Aerobic and anaerobic cellular respiration both produce ATP, but they differ significantly in their efficiency and products. Which of the following best describes a key difference between them?

A. Aerobic respiration occurs in the absence of oxygen and produces approximately 2 ATP per glucose, while anaerobic respiration requires oxygen and produces approximately 36-38 ATP per glucose molecule each time during cellular respiration

B. Aerobic respiration uses oxygen as the final electron acceptor and produces approximately 36-38 ATP per glucose, while anaerobic respiration does not use oxygen and produces only about 2 ATP per glucose molecule

C. Aerobic and anaerobic respiration produce identical amounts of ATP per glucose molecule, but differ in the temperature at which the chemical reactions occur in the cells of various organisms throughout the body and tissues

D. Aerobic respiration produces lactic acid or ethanol as a byproduct, while anaerobic respiration produces carbon dioxide and water as the only byproducts during the entire process of cellular respiration in the cells

14. DNA and RNA are both nucleic acids, but they differ in important ways. Which of the following correctly identifies a difference between DNA and RNA?

A. DNA contains the sugar deoxyribose and the base thymine and is typically double-stranded, while RNA contains the sugar ribose and the base uracil and is typically single-stranded in the cells of organisms

B. DNA contains the sugar ribose and is single-stranded in nearly all cell types found in nature, while RNA contains the sugar deoxyribose and is typically double-stranded in the cells of most organisms on Earth today

C. DNA contains the base uracil but not thymine, while RNA contains the base thymine but not uracil, and both molecules contain the same sugar (ribose) in the cells of all living organisms on the planet today

D. DNA and RNA are nearly identical molecules that differ only in the type of base they contain, with both molecules being double-stranded structures composed of the same sugar throughout their entire length in nature

15. Innate immunity and adaptive immunity are two major components of the immune system. Which of the following best describes a key difference between them?

A. Innate immunity develops slowly over a period of weeks after infection and produces highly specific antibodies, while adaptive immunity responds within seconds to any pathogen using identical mechanisms regardless of the pathogen type

B. Innate immunity is found only in vertebrate animals such as mammals and birds, while adaptive immunity is found in all major groups of organisms across the entire tree of life on planet Earth today and over the course of time

C. Innate and adaptive immunity respond identically to all pathogens and produce the same types of immune cells regardless of the type of pathogen encountered, with no measurable differences in their response timing

D. Innate immunity is the body's first line of defense and responds rapidly and non-specifically to many pathogens, while adaptive immunity develops over days to weeks and provides pathogen-specific responses with memory

16. Plant cells and animal cells share many features but differ in important structural ways. Which of the following structures is found in plant cells but NOT in animal cells?

A. The plasma membrane, which surrounds the entire cell and controls the movement of substances into and out of the cell through various transport mechanisms in the cell at any given time during the life of the cell

B. The mitochondria, which are responsible for cellular respiration and the production of ATP from the breakdown of glucose during cellular metabolism in the cells of all eukaryotic organisms on Earth during their normal life

C. The cell wall, a rigid outer structure made of cellulose that provides structural support and protection, found in plant cells but not in animal cells throughout the body of either type of organism during life

D. The nucleus, which contains the cell's DNA in the form of chromosomes and serves as the control center for all of the cell's activities throughout its life cycle in any eukaryotic organism on Earth today

17. Endothermic ("warm-blooded") and ectothermic ("cold-blooded") animals regulate body temperature very differently. Which of the following best describes a difference between them?

A. Endothermic animals generate their own body heat through metabolic processes and maintain a relatively constant body temperature, while ectothermic animals rely primarily on environmental heat sources to regulate their body temperature

B. Ectothermic animals generate their own body heat through metabolic processes and maintain a relatively constant body temperature, while endothermic animals rely on environmental heat sources for their body temperature regulation

C. Endothermic and ectothermic animals both produce their body heat in exactly the same way through identical metabolic processes within their tissues, with no significant difference in the source of their body heat during life

D. Endothermic animals have body temperatures that vary widely with the environmental temperature throughout the day, while ectothermic animals maintain perfectly constant body temperatures regardless of the environmental conditions

18. r-selected and K-selected species represent two different reproductive strategies in nature. Which of the following best describes the reproductive strategy of an r-selected species?

A. r-selected species produce a small number of offspring and invest large amounts of parental care in each offspring, ensuring high survival rates for each individual offspring throughout the life cycle of the species each year

B. r-selected species produce many offspring with little parental care and rely on the survival of a few offspring out of the many produced, which is well-suited to unstable environments with high mortality rates each generation

C. r-selected species produce no offspring at all but rather reproduce asexually through the process of binary fission, with each parent organism producing only itself and no other offspring at any time during their lives

D. r-selected species have very long life spans and reproduce only once toward the end of their lives, producing a single large offspring that requires extensive parental care for the entire course of its life on Earth

19. Autotrophs and heterotrophs differ fundamentally in how they obtain energy. Which of the following best describes this difference?

A. Autotrophs and heterotrophs obtain energy in exactly the same way through the process of cellular respiration on glucose molecules, with no measurable difference in their methods of energy acquisition at any time during life

B. Autotrophs obtain energy by consuming other organisms, while heterotrophs make their own energy-rich food molecules using sunlight or chemical energy from the surrounding environment during their daily life cycle on Earth

C. Heterotrophs make their own energy-rich food molecules using sunlight or chemical energy, while autotrophs obtain energy by consuming other organisms in the surrounding environment during their daily activities each day

D. Autotrophs make their own organic food molecules using sunlight (photosynthesis) or chemical energy (chemosynthesis), while heterotrophs obtain energy by consuming other organisms or organic matter as food

20. Sexual and asexual reproduction differ significantly in their outcomes. Which of the following best describes a major advantage of sexual reproduction over asexual reproduction?

A. Sexual reproduction produces genetically identical offspring that are well-suited to the current environmental conditions, ensuring the long-term survival of the parental gene combinations in stable environments over time

B. Sexual reproduction allows organisms to reproduce much more rapidly than asexual reproduction does, with sexually reproducing organisms typically producing many more offspring than asexually reproducing organisms each year

C. Sexual reproduction generates genetic variation among offspring through the combination of alleles from two parents, which increases the population's ability to adapt to environmental changes over many generations

D. Sexual reproduction requires no investment of energy or resources by either parent, since both parents simply combine their alleles without needing to invest in the survival of the resulting offspring after fertilization at all

SECTION 3: CROSS-TOPIC INTEGRATION (Q21–30)

21. Cellular respiration in living organisms plays a critical role in the broader ecosystem energy flow because it:

A. Captures sunlight energy and converts it into chemical energy stored in glucose, which is then made available to organisms higher up in the food chain through the process of consumption and digestion each day in nature

B. Releases energy stored in glucose molecules in a usable form (ATP) for cellular work, while also releasing CO₂ as a byproduct that producers can then reuse during the process of photosynthesis to make new glucose

C. Removes carbon dioxide from the atmosphere and incorporates the carbon into organic molecules that serve as food sources for all of the consumers throughout the entire ecosystem during each year of their lives

D. Produces oxygen as a byproduct that is essential for the survival of all aerobic organisms in the ecosystem, since this oxygen is the only source of atmospheric oxygen available on the planet Earth today during life

22. DNA replication and mitosis are closely linked processes within a single eukaryotic cell. DNA replication must occur before mitosis because:

A. Mitosis produces two daughter cells, each of which must receive a complete copy of all of the cell's genetic information, so the DNA must be duplicated beforehand to provide one complete copy for each daughter cell produced

B. Mitosis destroys the original DNA of the parent cell during the process, so a new copy must be synthesized before the original DNA is destroyed in order to ensure that the genetic information is not lost during division

C. DNA replication produces messenger RNA molecules that are then used to coordinate the events of mitosis within the dividing cell during the various phases of mitosis throughout the entire cell cycle of the cell on Earth

D. DNA replication produces ATP molecules that provide the energy needed to power the events of mitosis within the dividing cell during the various phases of mitosis throughout the entire cell cycle of the cell on Earth

23. Photosynthesis is a critical process in the global carbon cycle because it:

A. Releases large amounts of carbon dioxide into the atmosphere from the bodies of dead plants after their decomposition, contributing to the atmospheric CO₂ pool used by other organisms throughout the world during the year

B. Converts atmospheric oxygen into carbon dioxide through a series of enzyme-catalyzed reactions occurring in the chloroplasts of green plants exposed to direct sunlight during the daylight hours of each and every day

C. Breaks down stored carbon compounds in plant tissues and releases that carbon back to the atmosphere as carbon dioxide, providing an essential supply of CO₂ to the atmosphere for use by other autotrophs each day

D. Removes carbon dioxide from the atmosphere and incorporates the carbon into organic molecules stored in plant tissues, where it can then be transferred to consumers and decomposers in the food chain over time

24. Antibiotic resistance in bacteria provides a striking example of natural selection occurring within the human lifespan. The development of antibiotic resistance in a bacterial population most directly demonstrates that:

A. Bacteria can consciously sense the presence of antibiotics in their environment and respond by developing new resistance mechanisms over the course of just a few hours after the first exposure to antibiotics in their environment

B. The use of antibiotics directly causes bacteria to mutate their DNA into more resistant forms in response to the antibiotic exposure, with all of the antibiotic-exposed bacteria becoming resistant after just one single dose

C. When antibiotics are applied to a bacterial population with pre-existing variation, the resistant bacteria survive and reproduce while the susceptible bacteria die, increasing the frequency of resistance alleles over time

D. The presence of antibiotics in the environment has no effect on the genetic makeup of bacterial populations over time, since the resistance traits are passed only by horizontal gene transfer between unrelated bacteria

25. The cell membrane plays an essential role in maintaining homeostasis throughout the body of any organism. The membrane's contribution to homeostasis is most directly explained by the fact that:

A. The cell membrane is selectively permeable, allowing the cell to control which substances enter and leave the cell and thereby maintain stable internal conditions despite changes in the external environment over time

B. The cell membrane produces all of the enzymes needed for cellular metabolism within the cell at any given time, including the enzymes that catalyze each of the major metabolic pathways within the cell of any organism in nature

C. The cell membrane is freely permeable to all substances, allowing the cell to rapidly equilibrate with its surroundings and ensuring that the internal and external environments of the cell are always identical at any time

D. The cell membrane produces ATP molecules through the process of cellular respiration, providing the energy needed to maintain the cell's various activities throughout its lifetime in the body of any organism on Earth today

26. Genetic variation within a population is fundamentally important to the process of evolution because:

A. Genetic variation has no relationship to the evolution of a population, since all evolutionary change occurs through the random fluctuation of phenotypic traits that have no genetic basis at any time during the life cycle of the organism

B. Genetic variation provides the raw material on which natural selection acts, since different alleles produce different phenotypes that may differ in their survival and reproductive success in a given environment over time

C. Genetic variation always leads directly to the formation of new species within just a few generations of any population, regardless of the environmental conditions or population size during the period of evolutionary change

D. Genetic variation prevents the formation of new species through the process of evolution by natural selection, since the presence of genetic variation in a population always maintains the stability of the species over time

27. Enzymes are critical for normal body function and are also tightly linked to body temperature regulation. The most direct connection between enzymes and body temperature is that:

A. Enzymes are only able to function at temperatures below the freezing point of water (0°C), which is why the body must maintain a temperature below 0°C in order to support normal enzyme function and metabolism in all tissues

B. Enzymes generate heat as a byproduct of their catalytic activity, which is the only source of body heat for endothermic animals such as mammals and birds throughout the day and the night during their lives on Earth

C. Each enzyme has an optimal temperature range, and most human enzymes function best near normal body temperature (37°C); maintaining this temperature through homeostasis preserves normal enzymatic activity in the body

D. Enzymes function identically at any temperature from very cold to very hot, so body temperature has no effect at all on the activity of any enzymes in the body of any organism on the planet during their normal life cycles

28. Meiosis is essential for sexual reproduction and is also a major source of genetic variation in offspring. The two main mechanisms by which meiosis generates genetic variation are:

A. Mitosis and binary fission, which together produce four genetically identical daughter cells from a single parent cell during the process of meiosis in any sexually reproducing organism throughout its life cycle on Earth

B. DNA replication and transcription, which together produce four genetically identical daughter cells from a single parent cell during the process of meiosis in any sexually reproducing organism throughout its life cycle

C. Fertilization and cleavage, which combine the genetic information of two parents into a single new organism during the process of meiosis in any sexually reproducing organism throughout its entire life cycle on Earth

D. Crossing over (recombination) during prophase I and independent assortment of homologous chromosomes during metaphase I, which together produce gametes with many different combinations of parental alleles

29. Predator-prey cycles in natural populations illustrate important principles of population ecology and carrying capacity. As a predator population grows in response to abundant prey, the prey population eventually decreases because:

A. The increased predation pressure causes prey mortality to exceed the prey birth rate, reducing the size of the prey population and eventually leading to a corresponding decline in the predator population due to food shortage

B. The prey species develops a sudden allergic reaction to being eaten by the predator, causing the entire prey population to undergo rapid mass death within just a few weeks of the first predation event in the population

C. The predator species directly competes with the prey species for the same food resources in the ecosystem, leading to a decline in the prey population due to starvation rather than due to any actual predation by the predator

D. The prey species voluntarily reduces its own birth rate in response to the increasing predator population in the environment, reducing the prey population through conscious behavioral changes in the prey during life

30. The global carbon cycle and climate change are directly linked through the greenhouse effect. Increased atmospheric CO₂ concentrations contribute to climate change because:

A. Carbon dioxide is the only chemical that absorbs visible light from the sun in the Earth's atmosphere, so increased CO₂ levels lead to a corresponding increase in the total amount of visible light reaching the Earth's surface each day

B. Carbon dioxide reflects all incoming solar radiation back into space, so increased CO₂ levels actually cool the Earth's surface by preventing sunlight from reaching the ground in the same way that a mirror reflects light back

C. Carbon dioxide absorbs and re-radiates infrared (heat) energy emitted by the Earth's surface, trapping heat near the surface and causing the Earth's average temperature to rise as atmospheric CO₂ levels increase over time

D. Carbon dioxide directly heats the Earth through chemical reactions occurring within the atmosphere itself, releasing thermal energy that is the primary source of all of the warming observed on Earth over the past century

SECTION 4: MECHANISMS AND PROCESSES (Q31–40)

31. When an enzyme is exposed to a temperature far above its optimum, the enzyme typically loses its ability to catalyze its reaction. The most direct biochemical reason for this loss of function is:

A. The substrate molecules in the surrounding solution are completely destroyed by the high temperature, leaving no substrate available for the enzyme to bind during the course of the reaction at any time during the experiment

B. The high temperature disrupts the weak bonds maintaining the enzyme's three-dimensional shape, causing the active site to lose its specific geometry and thereby preventing the substrate from binding correctly to the enzyme

C. The high temperature causes the enzyme molecules to combine with each other to form larger aggregates, which then prevents the enzymes from interacting with the substrate molecules in the solution during the reaction

D. The high temperature causes the enzyme molecules to dissolve completely in the surrounding solution, leaving no intact enzyme molecules available to catalyze the reaction at any time during the entire experiment

32. Cells are generally limited to small sizes (typically less than 100 micrometers in diameter). The most important biological reason for this size limitation is that:

A. Larger cells would not be able to fit through the narrow openings between the cells of the body's various tissues, preventing them from being able to perform their normal functions within the body of an organism during life

B. Larger cells would not be able to receive enough sunlight to perform photosynthesis effectively, even though all cells (including animal cells) must perform photosynthesis in order to obtain the energy they need for life

C. Larger cells would not be able to be observed under a light microscope by scientists, making it impossible for cell biologists to study the structure and function of cells in the laboratory at any time during research and education

D. As cells grow larger, their volume increases faster than their surface area, making it increasingly difficult for the membrane to supply enough nutrients and remove enough waste to support the entire cell efficiently

33. An action potential propagates along the axon of a neuron through a coordinated sequence of ion movements across the neuronal membrane. The propagation of an action potential most directly involves:

A. The opening and closing of voltage-gated sodium and potassium channels at successive points along the axon, with each segment depolarizing in turn and triggering the depolarization of the next adjacent segment of the axon

B. The continuous secretion of acetylcholine and other neurotransmitters at successive points along the entire length of the axon, with each segment receiving chemical signals from the previous segment of axon during the impulse

C. The movement of red blood cells through capillaries running parallel to the axon, with each capillary supplying oxygen to the corresponding segment of axon to support its electrical activity during each action potential

D. The bending of microscopic hair-like projections from the surface of the axon membrane, which physically push the action potential along the length of the axon during each successive nerve impulse traveling along the axon

34. When a virus infects a host cell, it typically follows a series of stages including attachment, entry, replication, assembly, and release. During the replication stage, a virus most directly:

A. Synthesizes its own ATP using the breakdown of viral proteins as a source of energy for the synthesis of new viral particles within the host cell during the course of the infection of the host cell each time the virus infects it

B. Performs cellular respiration on the glucose molecules within the host cell, generating large amounts of ATP that are used to power the synthesis of new viral particles within the host cell during the entire infection

C. Uses the host cell's enzymes, ribosomes, and nucleotides to make many copies of its own genetic material and proteins, which are then assembled into new viral particles that can infect additional host cells later

D. Performs its own DNA replication, transcription, and translation independently of the host cell using only viral enzymes and viral components that the virus brings with it when it first enters the host cell each time

35. Insulin regulates blood glucose levels through a series of specific molecular and cellular events. When insulin binds to its receptor on the surface of a target cell, the most direct cellular response is:

A. The target cell immediately undergoes apoptosis (programmed cell death), removing itself from the body in order to prevent further uptake of glucose from the bloodstream during periods of high blood glucose in the body

B. The target cell stops all of its metabolic activities and enters a long-term resting phase, halting all cellular processes including the uptake of any nutrients from the bloodstream during the duration of the insulin signal

C. The target cell increases the rate at which it produces and secretes its own insulin into the bloodstream, amplifying the original insulin signal and producing a positive feedback loop of insulin secretion in the body of the patient

D. The target cell increases the number of glucose transporters (GLUT4) in its plasma membrane, allowing more glucose to enter the cell from the bloodstream and lowering blood glucose levels back toward normal values

36. During fertilization in animals, a single sperm cell combines with a single egg cell to form a zygote. The most important event of fertilization is:

A. The activation of the immune system of the female parent in response to the presence of foreign cells (the sperm) in her body, beginning the body's defensive response against the perceived invading cells during pregnancy in the body

B. The combination of the haploid genome of the sperm with the haploid genome of the egg, restoring the diploid chromosome number and creating a new genetically unique individual organism with both parents' alleles

C. The conversion of the egg cell into a sperm cell, transforming its overall structure into one that more closely resembles the structure of the sperm cell as the zygote develops during the early stages of pregnancy in the body

D. The complete separation of the sperm cell from the egg cell into two distinct cells that develop independently into two separate offspring organisms during the development of the embryo over the course of pregnancy each time

37. Muscle contraction occurs through a precisely coordinated molecular mechanism known as the sliding filament theory. During muscle contraction:

A. Myosin heads attach to actin filaments, undergo a power stroke that pulls the actin past the myosin, then detach and reset using ATP, repeating this cycle to shorten the sarcomere of the muscle fiber over the course of contraction

B. The entire actin and myosin filaments physically shorten by reducing the length of each filament during muscle contraction, while the overall sarcomere length remains constant during the entire process of muscle contraction

C. New actin and myosin filaments are rapidly synthesized within the muscle fiber during the contraction, providing the additional protein needed to extend the existing filaments to a greater length during contraction in the body

D. The actin and myosin filaments physically merge together to form a single combined filament during muscle contraction, which then breaks apart again into separate actin and myosin filaments during muscle relaxation each time

38. Translation is the process by which mRNA is decoded by ribosomes to produce a specific protein. During translation:

A. mRNA is synthesized from a DNA template using RNA polymerase within the nucleus of the cell, producing a complementary mRNA strand from each gene during the process of mRNA production in the cell of the body during life

B. DNA is copied to produce two identical daughter DNA molecules through the action of DNA polymerase using the original DNA strand as the template for the synthesis of the new daughter strands during DNA replication

C. tRNA molecules carrying specific amino acids bind to complementary codons on the mRNA at the ribosome, with the ribosome forming peptide bonds between successive amino acids to build the protein chain in sequence

D. Proteins are broken down into individual amino acids by proteolytic enzymes within the lysosomes of the cell, releasing the amino acids back into the cytoplasm for use in building new proteins during the cell's daily life

39. The kidneys filter blood and produce urine through a multi-step process within each nephron. The correct sequence of major events in nephron function is:

A. Filtration of glomerular fluid → secretion of waste products from the tubules into the blood → reabsorption of urine from the bladder back into the kidneys → excretion through the renal artery throughout the day each minute of life

B. Reabsorption of glucose and amino acids from the tubule back into the blood → filtration of plasma at the glomerulus → secretion of waste products into the tubules → excretion of urine through the ureters and the bladder

C. Secretion of waste products from the blood into the tubule → reabsorption of water and solutes from the tubule back into the blood → filtration of plasma at the glomerulus → excretion of urine through the ureters and the bladder

D. Filtration of plasma at the glomerulus into Bowman's capsule → reabsorption of useful substances (glucose, amino acids, water) back into the blood → secretion of waste products into the tubule → excretion of urine

40. Nerve impulses cross synapses between two neurons through a specific mechanism involving neurotransmitter molecules. When an action potential reaches the end of a presynaptic neuron, the most direct sequence of events is:

A. The action potential travels electrically across the synaptic cleft to the postsynaptic neuron, depolarizing the postsynaptic neuron and triggering a new action potential without any chemical messengers involved in the process

B. The action potential triggers voltage-gated Ca^{2+} channels to open, causing synaptic vesicles to release neurotransmitters into the synaptic cleft; these molecules bind receptors on the postsynaptic neuron and alter its membrane potential

C. The action potential causes the presynaptic neuron to physically fuse with the postsynaptic neuron, transferring the electrical signal directly across the cell membranes of the two neurons during the process of nerve transmission

D. The action potential is permanently lost at the synapse and does not continue to the postsynaptic neuron under any circumstances, so signal transmission between neurons does not occur in any nervous system on Earth today

SECTION 5: APPLICATION AND ANALYSIS (Q41–50)

41. A farmer wants to develop a new strain of corn with kernels that are sweeter than any currently available variety. Over several generations, the farmer selects only the sweetest plants for breeding and discards all others. After 10 generations of this selective breeding, the average sweetness of the corn has increased significantly. This outcome most directly illustrates:

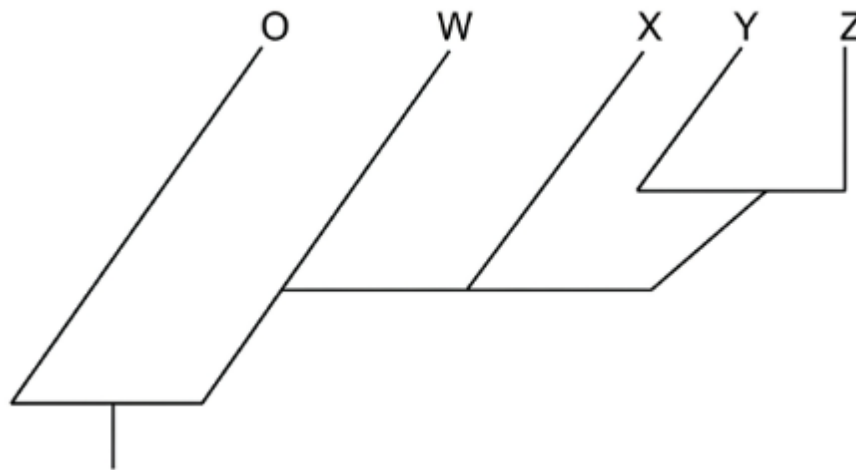
A. The inheritance of acquired characteristics, in which the act of being selected for sweet kernels caused the corn plants to physically develop sweeter kernels over the course of their lifetimes in the farmer's fields each year of work

B. Natural selection occurring without any human involvement, in which environmental factors in the cornfields favor sweeter kernel varieties over less sweet varieties without any direct action by the farmer or by humans in general

C. Artificial selection, in which humans deliberately choose which individuals in a population will reproduce, leading to predictable changes in heritable traits in the population over the course of many generations of selective breeding

D. Convergent evolution, in which two unrelated species independently develop similar traits in response to similar selective pressures in their environments over the course of many generations of evolution by natural selection on Earth

42. The phylogenetic tree below shows the evolutionary relationships among five species (O, W, X, Y, and Z), where O is an outgroup. Based on the tree, which two species are most closely related to each other?



A. Y and Z, because they share the most recent common ancestor on the tree, as shown by the fact that they branch off from each other after all of the other species have already diverged from the main lineage of evolution

B. W and X, because they appear adjacent to each other on the tree at the top, with X being immediately below W on the branching diagram of evolutionary history of the five species on the planet Earth during evolution

C. O and W, because they both branch off from the main lineage near the base of the tree at the earliest possible point, indicating that they must share a recent common ancestor in the past of the species

D. All five species are equally related to one another on the phylogenetic tree, because the tree shows their relationships in a single common ancestor at the base of the tree leading to all five species on the planet today

43. A scientist studies a mutation in a gene that codes for a structural protein. The mutation causes a single base in the DNA to be deleted, resulting in a frameshift mutation in the coding sequence. The most likely effect of this frameshift mutation on the resulting protein is:

A. The protein will have an extra amino acid added to its sequence at the site of the deletion, but the rest of the protein sequence will be completely unchanged from the original protein produced by the normal gene of the cell

B. The protein will have one amino acid replaced with another amino acid at the site of the deletion, but the rest of the protein sequence will be completely unchanged from the original protein produced by the normal gene

C. The protein will be completely identical to the original protein, since the deletion of a single base typically has no measurable effect on the function or structure of the resulting protein in nearly all cases of mutation in the cell

D. The protein will likely have a completely altered amino acid sequence downstream of the deletion site, since all of the codons after the deletion will be shifted by one base, often producing a non-functional protein in the cell

44. The data table below shows the population sizes of three species in a coastal ecosystem before and after the experimental removal of a sea star species that feeds on mussels. Based on the data, the sea stars in this ecosystem are most likely:

Coastal Ecosystem Populations Before and After Sea Star Removal

Species	Population Before Star Removal	Population After Sea Star Removal
Mussels	150	850
Barnacles	200	30
Limpets	180	20

A. An invasive species, since their presence in the ecosystem is associated with smaller populations of native species such as mussels, barnacles, and limpets in the data shown in the table above for the ecosystem each year of study

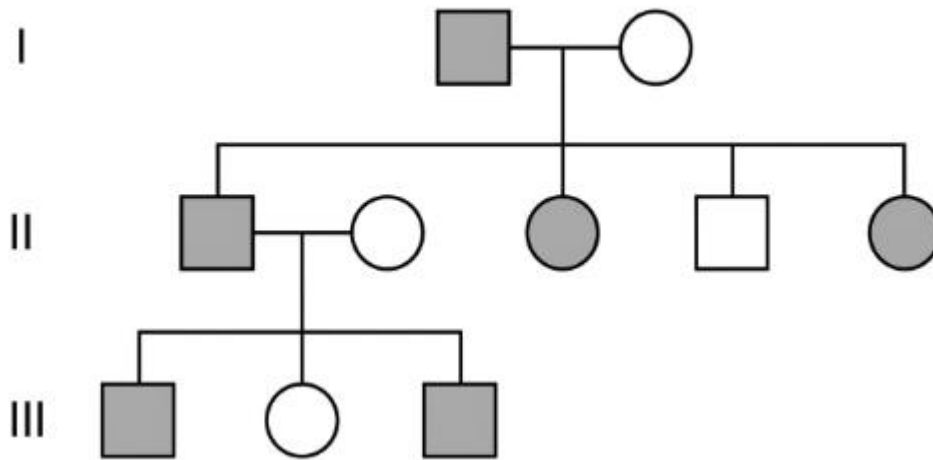
B. A keystone species, since their removal causes the mussel population to expand dramatically and the populations of other species (barnacles and limpets) to decline, indicating a large effect on the entire ecosystem in the area

C. A decomposer species, since their main ecological role is to break down dead organic matter and recycle nutrients back into the soil of the surrounding ecosystem during the course of the year and the season on the coast

D. A pioneer species, since their presence allows other species to colonize the ecosystem and start the long process of primary succession in the area during the season after a major disturbance event in the area on the coast

45. The pedigree below shows the inheritance of a genetic trait through three generations of a family. Affected individuals are shaded; unaffected individuals are unshaded. Based on the pedigree, the trait is most likely inherited as:

Figure PQ-3



A. X-linked recessive, since the trait appears predominantly in males of the family and is passed through unaffected carrier females to their affected sons over the course of multiple generations of the family overall during the time

B. Autosomal recessive, since the trait appears only in homozygous individuals and is most often inherited from two unaffected carrier parents who are both heterozygous for the recessive allele in the same family during the time

C. Autosomal dominant, since the trait appears in every generation, both males and females are affected at roughly equal rates, and affected parents pass the trait to about half of their offspring of either sex each generation

D. Y-linked, since the trait is passed from affected fathers directly to all of their sons but never to any of their daughters during the course of multiple generations of the family across all of the family members each year

46. A rare tropical butterfly species is threatened by climate change, which is causing its rainforest habitat to become hotter and drier over time. Conservation biologists predict that this butterfly will be most negatively affected if:

A. The butterfly has a narrow tolerance range for temperature and humidity, low genetic variation within the population, and limited ability to migrate to other suitable habitats outside of its current range in nature during the year

B. The butterfly has a broad tolerance range for temperature and humidity, high genetic variation within the population, and a strong ability to migrate to other suitable habitats outside of its current range in nature during the year

C. The butterfly has a short generation time of just a few weeks, a large population size of many millions of individuals, and a strong ability to disperse over long distances throughout its current geographic range each year

D. The butterfly is an invasive species that has been introduced to the rainforest from another continent, where it originated and where it might still be able to find suitable habitat conditions during the climate change each year

47. The data table below shows the rates of photosynthesis (measured in $\mu\text{mol CO}_2/\text{m}^2/\text{sec}$) for a plant exposed to varying light intensities at three different temperatures. Based on the data, the highest rate of photosynthesis would be expected at which combination of light intensity and temperature?

Figure PQ-4: Rate of Photosynthesis ($\mu\text{mol CO}_2/\text{m}^2/\text{sec}$) at Different Light Intensities and Temperatures

Light Intensity ($\mu\text{mol}/\text{m}^2/\text{sec}$)	10°C	25°C	35°C
200	3	5	4
500	5	12	8
1000	6	18	10

A. Low light intensity (200 $\mu\text{mol}/\text{m}^2/\text{sec}$) at the lowest temperature (10°C), since cool temperatures and low light are the most efficient conditions for the process of photosynthesis in any green plant species on Earth today during the year

B. Medium light intensity (500 $\mu\text{mol}/\text{m}^2/\text{sec}$) at the highest temperature (35°C), since this combination of conditions produces the most rapid breakdown of glucose during photosynthesis in any green plant species on Earth today

C. Low light intensity ($200 \mu\text{mol}/\text{m}^2/\text{sec}$) at the highest temperature (35°C), since this combination provides the right balance between the available light energy and the rate of the photosynthetic enzyme reactions

D. High light intensity ($1000 \mu\text{mol}/\text{m}^2/\text{sec}$) at the moderate temperature (25°C), since the data table shows a rate of $18 \mu\text{mol CO}_2/\text{m}^2/\text{sec}$ at this combination of conditions, which is the highest value shown in the entire table

48. In humans, free earlobes (E) are dominant over attached earlobes (e). If a heterozygous father (Ee) has children with a homozygous recessive mother (ee), the expected ratio of children with free earlobes to children with attached earlobes is:

A. 3:1, with three out of every four children expected to have free earlobes and one out of every four expected to have attached earlobes during the course of the family's reproductive years and beyond throughout the family's life

B. 1:1, with approximately half of the children expected to have free earlobes and approximately half expected to have attached earlobes during the course of the family's reproductive years and beyond throughout the family

C. 9:3:3:1, with the ratio reflecting the inheritance of two different genes simultaneously rather than just a single gene during the course of the family's reproductive years and beyond in the history of the family

D. 1:0, with all of the children expected to have free earlobes and none of the children expected to have attached earlobes during the course of the family's reproductive years and beyond throughout the entire family

49. A patient comes to the doctor reporting frequent thirst, excessive urination, and unexplained weight loss over the past several months. Lab tests reveal that the patient's blood glucose levels are extremely high, both fasting and after meals. The most likely diagnosis is:

A. Diabetes mellitus, a disease in which the body either fails to produce enough insulin or fails to respond properly to the insulin that is produced, leading to chronically elevated blood glucose levels in the body of the patient

B. Hyperthyroidism, a disease in which the thyroid gland produces too much thyroid hormone, leading to elevated metabolic rate and a wide range of symptoms throughout the body of the affected patient during each day of life

C. Asthma, a disease in which the airways of the lungs become inflamed and constricted, leading to difficulty breathing and other respiratory symptoms during the course of the patient's daily life and activities each day in the body

D. Anemia, a disease in which the body has fewer red blood cells than normal, leading to fatigue and other symptoms related to inadequate oxygen delivery to the body's tissues during the patient's daily life each day of life

50. A large area of continuous forest is divided by a new highway into several smaller forest patches. Over the next several decades, the biodiversity of the smaller patches declines significantly compared to the original forest. The most likely explanation for this decline is:

A. The new highway has caused all of the forest trees in the patches to die off rapidly, eliminating the habitat for forest-dwelling animal species in the patches during the years following the construction of the highway each year

B. The new highway has dramatically increased the amount of solar radiation reaching the forest floor in the patches, leading to overheating of the forest ecosystem and a corresponding decline in biodiversity over time in the patches

C. Habitat fragmentation has reduced effective population sizes, restricted gene flow between forest patches, and limited resources within each patch, all of which contribute to declines in species diversity over time in the patches

D. The new highway has introduced large numbers of new species into the forest patches from outside the area, leading to overpopulation and a corresponding decline in biodiversity within each forest patch over time in the area

Practice Exam 38: Life Science: Biology Simulation – Answer Key with Explanations

1. D — Pasteur showed that broth in flasks open only to dust-trapping swan necks remained sterile, while broth in tilted swan-neck flasks (exposing the broth to settled dust) developed microbial growth. This demonstrated that microorganisms come from preexisting microbes carried in dust, not from the broth itself. The experiment definitively disproved spontaneous generation and is one of the foundations of modern microbiology.

2. B — Mendel's law of segregation states that during gamete formation, the two alleles for each gene separate so that each gamete carries only one. This explains why an Aa parent produces both A and a gametes in equal proportions. The principle was confirmed by the predictable 3:1 phenotype ratios Mendel observed in his pea-plant monohybrid crosses.

3. A — Franklin's famous "Photo 51" showed an X-shaped diffraction pattern characteristic of a helix and revealed key spatial measurements such as the 3.4 Å spacing between base pairs and the 10-base-pair pitch of the helix. These dimensions allowed Watson and Crick to build the correct double-helix model. The technique did not provide specific base sequences, only structural parameters of the molecule.

4. C — Hershey and Chase labeled phage DNA with radioactive ^{32}P and phage protein with radioactive ^{35}S , then infected bacteria and tracked where each label went. Only the ^{32}P (DNA) ended up inside the infected bacteria, while the ^{35}S (protein) stayed outside in the empty phage coats. This was the decisive demonstration that DNA, not protein, carries the genetic information.

5. B — Bacteria grown in heavy ^{15}N medium and then switched to light ^{14}N produced one generation of intermediate-density DNA and a second generation of half intermediate and half light DNA. This pattern is uniquely predicted by semiconservative replication, in which each daughter molecule contains one parental strand and one newly synthesized strand. The conservative and dispersive models predicted entirely different banding patterns and were ruled out.

6. D — Griffith's results showed that a "transforming principle" from the dead virulent strain could permanently change the live non-virulent strain into a virulent form. Avery, MacLeod, and McCarty later identified this transforming principle as DNA. Bacterial transformation is now a foundational technique in molecular biology and a major route of horizontal gene transfer between bacteria.

7. A — Random X-inactivation occurs early in embryonic development, with each cell silencing one of its two X chromosomes; all descendants of that cell inherit the same inactivation. In a heterozygous female ($X^B X^o$), patches of skin trace back to single cells with different active X chromosomes, producing the patchy orange-and-black calico coat. Male calicoes are extremely rare because they require an XXY karyotype to display both color alleles.

8. C — Natural selection has three requirements: heritable variation among individuals, differential survival or reproductive success based on that variation, and inheritance of the favored variants by the

next generation. Without all three present, evolutionary change by selection cannot occur. These conditions are the logical core of Darwin and Wallace's joint 1858 paper to the Linnean Society.

9. B — Ingenhousz demonstrated that the production of oxygen-rich gas by aquatic plants required sunlight, with no production in darkness. This isolated light as a necessary factor for photosynthesis. His work, building on Joseph Priestley's earlier findings, helped establish the modern understanding that the light-dependent reactions split water and release O₂.

10. A — Margulis's endosymbiotic theory proposes that mitochondria and chloroplasts arose when ancestral eukaryotic cells engulfed free-living aerobic bacteria and cyanobacteria, respectively, that then became permanent symbionts. Evidence supporting the theory includes the organelles' own circular DNA, their 70S (bacterial-type) ribosomes, and their double membranes. The theory is now mainstream cell biology.

11. D — Mitosis is one division producing two diploid genetically identical cells, used for growth and tissue repair. Meiosis is two divisions producing four haploid genetically variable cells, used for gamete formation in sexual reproduction. The genetic variability comes from crossing over and independent assortment, processes unique to meiosis.

12. C — The defining structural feature separating prokaryotes from eukaryotes is the membrane-bound nucleus that houses DNA in eukaryotic cells. Eukaryotes also possess other membrane-bound organelles (mitochondria, ER, Golgi) that prokaryotes lack entirely. The word "eukaryote" literally means "true nucleus" in Greek.

13. B — Aerobic respiration uses O₂ as the final electron acceptor in the electron transport chain, allowing complete oxidation of glucose to CO₂ and water and yielding ~36–38 ATP per glucose. Anaerobic fermentation produces only 2 ATP per glucose because oxidation stops after glycolysis. This enormous efficiency difference is why aerobic organisms dominate environments where oxygen is available.

14. A — DNA's sugar is deoxyribose, its pyrimidine bases are cytosine and thymine, and it is typically double-stranded as a double helix. RNA's sugar is ribose, it uses uracil in place of thymine, and it is typically single-stranded. These structural differences underlie the very different roles of DNA (stable information storage) and RNA (versatile message and catalysis) in cells.

15. D — Innate immunity (barriers, phagocytes, complement, inflammation) is fast, non-specific, and lacks immunological memory. Adaptive immunity (B and T lymphocytes) is slower to develop, pathogen-specific, and produces long-lasting memory cells that confer protection after exposure. Vaccination harnesses the memory of the adaptive system to prevent disease.

16. C — Plant cells have a rigid cellulose cell wall outside the plasma membrane, providing mechanical support and resisting turgor pressure. Animal cells lack a cell wall entirely. Plant cells also typically have chloroplasts and a large central vacuole that animal cells lack, but only the cell wall is offered as a choice here.

17. A — Endothermic animals generate body heat through internal metabolic processes such as muscle activity and brown-fat thermogenesis, allowing them to maintain a relatively stable internal temperature regardless of external conditions. Ectothermic animals rely on external heat sources (basking, behavioral thermoregulation) and have body temperatures that vary with the environment. Each strategy carries different metabolic trade-offs.

18. B — r-selected species produce many offspring with little parental investment, rely on the high reproductive rate rather than the survival of any single offspring, and thrive in unstable or unpredictable environments. Oysters, dandelions, and many insects are classic examples. K-selected species, in contrast, produce few offspring with extensive parental care and are suited to stable habitats near carrying capacity.

19. D — Autotrophs synthesize their own organic molecules from inorganic precursors using an external energy source — sunlight (photoautotrophs) or chemical energy (chemoautotrophs). Heterotrophs cannot synthesize organic molecules from inorganic precursors and must obtain organic matter by consuming other organisms. Together, autotrophs and heterotrophs form the producer-consumer architecture of every food web.

20. C — Sexual reproduction shuffles alleles from two parents through meiosis and fertilization, producing offspring with new combinations not present in either parent. This genetic variation is the raw material on which natural selection acts and allows populations to adapt to changing environments over generations. Asexual reproduction is faster and energetically cheaper but produces genetically uniform offspring that are vulnerable to environmental change.

21. B — Cellular respiration breaks down glucose to release energy as ATP and produces CO₂ as a waste product. The CO₂ released enters the atmosphere, where it can be captured by producers during photosynthesis to make new glucose. This reciprocal relationship between respiration and photosynthesis is the foundation of the carbon cycle and ecosystem energy flow.

22. A — Mitosis produces two daughter cells, each of which must receive a complete copy of all chromosomes. DNA is therefore replicated during S phase, doubling the cell's chromosomal content before division. Mitosis then separates the duplicated chromatids into two complete sets, restoring the original chromosome count in each daughter cell.

23. D — Photosynthesis fixes atmospheric CO₂ into glucose during the Calvin cycle, removing carbon from the atmosphere and incorporating it into living biomass. The carbon then moves through the food web as consumers eat producers and into the soil and atmosphere again through respiration, decomposition, and combustion. This loop is the heart of the global carbon cycle.

24. C — Antibiotic resistance evolves through the standard mechanism of natural selection: random pre-existing mutations confer resistance in a small fraction of bacteria, antibiotic exposure kills susceptible cells, and the surviving resistant bacteria reproduce and pass on their alleles. The antibiotic does not create resistance; it merely selects for variants that were already present in the population. This is one of the most clinically important demonstrations of evolution in action.

25. A — Selective permeability allows the cell membrane to regulate the entry of nutrients and exit of wastes while excluding harmful substances. This selectivity preserves the unique internal chemistry needed for life despite external fluctuations. Membrane-spanning channels, carriers, and pumps each contribute different specificities to this overall control of homeostasis.

26. B — Without heritable variation, natural selection has nothing to act on because all individuals would respond identically to any environmental pressure. Mutation, recombination, and gene flow continually generate the variation that selection then sorts. The amount of standing genetic variation in a population strongly affects how rapidly that population can evolve in response to new pressures.

27. C — Each enzyme has a temperature range within which its three-dimensional shape is stable and its active site functional. Human enzymes have generally evolved a peak near 37°C, and temperatures more than a few degrees outside this range slow them dramatically. Homeostatic mechanisms (sweating,

shivering, vasodilation) maintain core temperature near 37°C precisely to keep enzymes operating at their optimum.

28. D — Crossing over during prophase I exchanges segments between paired homologous chromosomes, recombining alleles within each chromosome. Independent assortment during metaphase I randomly orients each homologous pair, generating $2^{23} \approx 8.4$ million combinations of parental chromosomes for human gametes. Together with random fertilization, these two meiotic mechanisms explain the enormous genetic uniqueness of every sexually produced offspring.

29. A — As predators become abundant, they kill more prey, raising the prey death rate above the prey birth rate and shrinking the prey population. Predators then face food shortage and their own population declines, eventually allowing the prey to recover. This negative-feedback dynamic produces the classic lagged predator-prey oscillations seen in the lynx-hare fur-trade data.

30. C — Carbon dioxide is a greenhouse gas because it strongly absorbs and re-emits infrared (heat) radiation that the Earth's surface would otherwise radiate to space. Adding CO₂ to the atmosphere therefore traps more heat in the lower atmosphere, raising the planet's mean temperature. This effect, well-established by both physics and paleoclimate data, is the central mechanism of anthropogenic climate change.

31. B — Enzyme three-dimensional structure is maintained by weak interactions (hydrogen bonds, ionic interactions, hydrophobic packing) that are easily disrupted by excess heat. Once the active site loses its precise shape, the substrate can no longer bind productively, and the enzyme is denatured. This denaturation is usually irreversible, which is why fevers above ~42°C become life-threatening.

32. D — Cell function depends on the surface-area-to-volume ratio: a cell exchanges nutrients and wastes only across its membrane (surface area), while metabolism scales with the cell's volume. As a sphere grows, volume increases as r^3 while surface area increases only as r^2 , so the ratio drops. Once the ratio becomes too low, the membrane cannot keep up with metabolic demand and the cell must either divide or die.

33. A — Action potentials propagate through sequential opening of voltage-gated Na⁺ channels, which depolarize each membrane patch and trigger depolarization of the adjacent patch. Voltage-gated K⁺

channels then open to repolarize the membrane behind the moving impulse. In myelinated axons, this process is accelerated by saltatory conduction at the nodes of Ranvier between myelin segments.

34. C — Viruses are obligate intracellular parasites because they lack the enzymes, ribosomes, and metabolic machinery needed for independent replication. They hijack the host cell's biochemistry to copy viral genomes and synthesize viral proteins, which are then assembled into new viral particles. This dependence is why antiviral drugs must target steps unique to the viral life cycle without harming host cells.

35. D — Insulin binding to its receptor on muscle and fat cells triggers an intracellular signaling cascade that translocates GLUT4 glucose transporters from internal vesicles to the plasma membrane. The added transporters dramatically increase glucose uptake into the cell, lowering blood glucose. This is the central mechanism by which insulin reduces post-meal hyperglycemia.

36. B — Fertilization combines the haploid sperm nucleus ($n = 23$ in humans) with the haploid egg nucleus ($n = 23$), restoring the diploid chromosome number ($2n = 46$) in the zygote. The combined genome is also genetically unique because of recombination and independent assortment in the two gametes. Fertilization is therefore both a chromosome-restoring and a variation-generating event.

37. A — Myosin heads bind actin filaments, undergo a power stroke that slides actin past myosin toward the center of the sarcomere, release using ATP, and re-cock for another stroke. Repeated cycles draw the Z-discs of each sarcomere closer together, shortening the muscle. Calcium release from the sarcoplasmic reticulum exposes the myosin-binding sites on actin to initiate the contraction cycle.

38. C — During translation, tRNA molecules with three-base anticodons match complementary codons on the mRNA, each tRNA delivering its specific amino acid to the ribosome. The ribosome's peptidyl transferase activity forms peptide bonds between successive amino acids, building the polypeptide chain from N-terminus to C-terminus. The ribosome moves codon by codon along the mRNA until a stop codon terminates translation.

39. D — Urine formation begins with filtration of plasma at the glomerulus into Bowman's capsule, driven by blood pressure. Useful substances (glucose, amino acids, much of the water and ions) are then reabsorbed into peritubular capillaries along the tubule, while additional wastes are secreted into the tubule. The final modified filtrate is excreted as urine through the ureters, bladder, and urethra.

40. B — Action potentials arriving at the axon terminal open voltage-gated Ca^{2+} channels; Ca^{2+} influx triggers synaptic vesicles to fuse with the presynaptic membrane and release neurotransmitter into the synaptic cleft. The neurotransmitter diffuses across, binds receptors on the postsynaptic membrane, and changes its permeability to specific ions. This chemical relay is how electrical signals jump between neurons that do not actually touch.

41. C — Artificial selection (selective breeding) is the deliberate human choice of which individuals reproduce, based on traits valued by the breeder. Generations of selecting only the sweetest corn for breeding shift the allele frequencies toward sweetness alleles, just as natural selection does, but with humans rather than the environment doing the selecting. Darwin used artificial selection in pigeons and other domestic species to introduce the logic of natural selection in *On the Origin of Species*.

42. A — Y and Z share the most recent common ancestor on the tree, branching from a single node after all other species have already diverged. This makes them sister taxa and the most closely related pair shown on the tree. Branching closer to the tips of a phylogenetic tree consistently indicates more recent shared ancestry.

43. D — A single base deletion shifts the reading frame for all downstream codons, so every amino acid after the deletion site is potentially different from the original. The result is usually a non-functional protein, often truncated by a premature stop codon arising from the shifted frame. This is why frameshift mutations tend to be far more damaging than simple base substitutions.

44. B — A keystone species exerts an ecological effect disproportionate to its abundance, and its removal causes cascading changes throughout the community. Removing the sea star released mussels from predation, allowing them to overgrow and competitively exclude barnacles and limpets — the original Robert Paine experiment that defined the keystone species concept in the 1960s. The table's dramatic post-removal shifts are the signature of keystone effects.

45. C — Autosomal dominant inheritance shows the trait in every generation, affects males and females roughly equally, and is transmitted from affected parents to about half of their offspring of either sex. All three of these patterns are visible in the pedigree shown. Huntington disease and Marfan syndrome follow this classic transmission pattern.

46. A — A species with a narrow physiological tolerance is poorly equipped to handle changing conditions; low genetic variation reduces its evolutionary potential; and limited dispersal prevents it from tracking suitable habitat as conditions shift. Together, these three factors define maximum extinction risk under climate change. Conservation biologists prioritize such species — often endemic to mountain or island habitats — for active intervention.

47. D — Scanning the table, the largest value ($18 \mu\text{mol CO}_2/\text{m}^2/\text{sec}$) appears at $1000 \mu\text{mol}/\text{m}^2/\text{sec}$ light and 25°C . This combination provides ample light to saturate the light-dependent reactions and a temperature near the optimum for the Calvin cycle enzymes. At 35°C , enzymes begin to denature; at 10°C , all reactions slow down because of reduced kinetic energy.

48. B — A monohybrid cross between Ee (heterozygous) and ee (homozygous recessive) is a classic test cross. The Ee parent produces $\frac{1}{2}$ E and $\frac{1}{2}$ e gametes; the ee parent produces only e gametes. The offspring are therefore $\frac{1}{2}$ Ee (free earlobes) and $\frac{1}{2}$ ee (attached earlobes), giving a 1:1 phenotype ratio.

49. A — Polyuria, polydipsia, weight loss, and persistent hyperglycemia are the classic clinical tetrad of diabetes mellitus, caused by either inadequate insulin production (Type 1) or insulin resistance (Type 2). The high blood glucose overwhelms the kidney's reabsorptive capacity, drawing water along osmotically into the urine and triggering compensatory thirst. Diagnosis is confirmed by fasting glucose, HbA1c, or oral glucose tolerance testing.

50. C — Habitat fragmentation cuts a single large continuous population into several smaller, partially isolated ones. The smaller populations have less genetic diversity, more inbreeding, smaller resource bases, and reduced opportunity for gene flow between patches. All of these factors raise extinction risk for many species, particularly those with large home ranges or specialized habitat needs.