PRACTICE EXAM 11: LIFE SCIENCE: BIOLOGY SIMULATION (50 QUESTIONS)

Instructions: Practice Exam 11 uses a standalone single-question format with an emphasis on scientific inquiry, laboratory technique, biochemistry, molecular biology, and advanced genetics within the New York Living Environment scope. Each question is independent. Select the one best answer for each item.

1. A student observes that bean plants near a sunny window appear to grow taller than bean plants placed in the interior of the same classroom. According to the steps of scientific inquiry, what should the student do next?

A. Begin a full experiment with several different light conditions before any further thinking
B. Publish the original observation in a peer-reviewed scientific journal for review by experts
C. Form a testable hypothesis that predicts a relationship between light and bean plant height
D. Conclude that her observations have already proven a fundamental biological principle

2. In an experiment testing how fertilizer concentration affects plant growth, the independent variable is:

A. The different amounts of fertilizer applied to each of the plants in the experimental groups
B. The final height of each of the plants measured at the end of the study period in centimeters
C. The amount of sunlight that each of the plants receives during the experimental study period
D. The number of plants assigned to serve as control plants for the duration of the experiment

3. The purpose of including a control group in a scientific experiment is to:

A. Increase the total number of test subjects available for statistical analysis of the final results
B. Provide a back-up set of data in case the main experimental treatment fails completely later
C. Test the same independent variable as the experimental group does in every individual trial
D. Serve as a baseline of comparison against the experimental group to evaluate treatment effects

4. Before viewing a slide with a compound light microscope, a student should:

A. Place the slide on the stage and immediately rotate to the highest-power objective lens available
B. Place the slide on the stage and begin viewing with the lowest-power objective lens for focusing
C. Adjust the iris diaphragm to its smallest opening to maximize the contrast in the field of view
D. Apply immersion oil between the slide and every objective lens before any specimen observation

5. A student views a specimen with a 10× ocular lens and a 40× objective lens on a compound light microscope. The total magnification of the specimen as viewed is:

A. 50×, calculated by adding the magnifications of the ocular and the objective lenses together
B. 30×, calculated by subtracting the ocular lens magnification from that of the objective lens
C. 400×, calculated by multiplying the magnifications of the ocular and the objective lenses together
D. 4×, calculated by dividing the objective lens magnification by the ocular lens magnification value

6. Which of the following is a properly written testable hypothesis?

A. If a plant receives more sunlight, then it will grow taller than a plant receiving less sunlight
B. Plants are alive because they have all the basic characteristics that biologists associate with life
C. The sun is the ultimate energy source for nearly every ecosystem found anywhere on the planet
D. Plants near the window appear more attractive to people who walk through the room each day

7. A researcher wants to view the detailed internal structure of a single mitochondrion in a liver cell. The most appropriate instrument to use is:

A. A handheld magnifying lens, which provides about ten-power magnification of small objects
B. An electron microscope, which uses beams of electrons to achieve extremely high magnification
C. A standard compound light microscope at its highest objective lens setting in normal lighting
D. The unaided human eye, particularly under conditions of very bright and direct natural sunlight

8. A biologist uses a dichotomous key in the field primarily to:

A. Map the geographic ranges of related species across multiple continents over many decades
B. Calculate the total amount of energy flowing through each trophic level of a local food web
C. Determine the exact nucleotide sequence of a gene taken from an unknown organism's tissue
D. Identify an unknown organism by following a series of paired, contrasting descriptive choices

9. Which of the following statements is part of the modern cell theory?

A. Cells contain only DNA, proteins, and lipid molecules and lack any other types of molecules
B. All cells are essentially identical in size, shape, and internal molecular composition everywhere
C. All living organisms are composed of cells, and new cells arise from previously existing cells
D. Cells exist only in animals and plants, while bacteria are made of a noncellular substance

10. A key structural difference between a typical eukaryotic cell and a typical prokaryotic cell is that:

A. Eukaryotic cells lack ribosomes entirely, while prokaryotic cells contain many ribosomes inside
B. Eukaryotic cells have a true nucleus and membrane-bound organelles, while prokaryotes do not
C. Prokaryotic cells contain mitochondria, while eukaryotic cells lack mitochondria of any kind
D. Prokaryotic cells are typically much larger than eukaryotic cells in nearly every species studied

11. Which organelle is most responsible for breaking down old worn-out cell parts and digesting cellular debris?

A. The lysosome, which contains digestive enzymes that break down damaged organelles and pathogens
B. The mitochondrion, which produces the bulk of the cell's ATP through aerobic cellular respiration
C. The Golgi apparatus, which packages newly made proteins for secretion or use within the cell
D. The endoplasmic reticulum, which transports newly synthesized proteins throughout the cytoplasm

12. The cellular structures most directly responsible for synthesizing proteins from messenger RNA are:

A. Mitochondria, which produce the ATP that is used in many of the cell's metabolic processes
B. Lysosomes, which contain hydrolytic enzymes that break down old cellular structures inside cells
C. Vacuoles, which store water, dissolved waste, and various substances within the plant cell
D. Ribosomes, which read messenger RNA and assemble amino acids into polypeptide chains

13. A pancreatic cell that secretes large quantities of digestive enzymes for export would be expected to contain especially abundant:

A. Lysosomes, which break down cellular waste material and worn-out organelles throughout the cell
B. Nuclear pores, which allow ribosomal subunits to exit the nucleus into the surrounding cytoplasm
C. Rough endoplasmic reticulum, where ribosomes synthesize proteins destined for export from the cell
D. Smooth endoplasmic reticulum, which synthesizes lipid molecules and detoxifies harmful chemicals

14. The structure of the cell membrane is best described as:

A. A phospholipid bilayer with embedded proteins that regulates what enters and leaves the cell
B. A solid sheet of carbohydrate molecules that provides absolute structural support to the cell
C. A continuous layer of DNA molecules that codes for all of the cell's proteins on the surface
D. A single uniform layer of fatty acid molecules without any embedded proteins on its outside

15. A human red blood cell placed in pure distilled water will most likely:

A. Shrink rapidly as water moves out of the cell into the surrounding distilled water in the beaker
B. Maintain its normal biconcave shape because the cell membrane fully prevents water movement
C. Become more crenated as dissolved salts move out of the cell into the surrounding water rapidly
D. Swell and possibly burst as water moves into the cell down its concentration gradient by osmosis

16. A solution that contains a higher concentration of dissolved solute than the cell's cytoplasm is best described as:

A. Isotonic, which produces no net movement of water across the cell membrane in either direction
B. Hypertonic, which causes water to move out of the cell and the cell to lose volume by osmosis
C. Hypotonic, which causes water to move into the cell and the cell to gain volume by osmosis
D. Atomic, which refers to any solution containing single atoms of dissolved minerals or metals

17. As a cell grows larger, its volume increases faster than its surface area. This relationship explains why:

A. Cells generally divide once they reach a certain size rather than continuing to grow much larger
B. All cells must contain a nucleus in order to function effectively within an animal's body daily
C. Larger cells generally produce more energy per unit volume than smaller cells of the same type
D. Cells gradually lose portions of their cell membrane as they grow over the course of their lifetime

18. Which of the following changes would most directly increase the rate of diffusion across a cell membrane?

A. Decreasing the temperature of the environment surrounding the cell by a significant amount
B. Increasing the size of the molecules attempting to cross the cell membrane substantially
C. Increasing the concentration gradient between the two sides of the cell membrane sharply
D. Increasing the thickness of the phospholipid bilayer of the cell membrane substantially

19. The sodium-potassium pump in nerve cell membranes is best described as an example of:

A. Simple diffusion, in which sodium and potassium ions freely move down their concentration gradients
B. Osmosis, in which water moves freely between the inside and outside of the nerve cell as needed
C. Facilitated diffusion, in which carrier proteins move ions across the membrane without using any ATP
D. Active transport, in which ATP is used to move sodium and potassium against their concentration gradients

20. Enzymes in living organisms are best classified as:

A. Proteins that catalyze specific biochemical reactions and accelerate them without being consumed
B. Carbohydrates that serve as long-term energy storage molecules within the body's tissues and cells
C. Lipids that form the structural basis of all cellular membranes in plants, animals, and bacteria
D. Nucleic acids that store the genetic information used to direct cellular protein synthesis activity

21. The shape of an enzyme's active site is critical to its function because:

A. The active site determines the speed at which every biochemical reaction in the body occurs daily
B. Each active site has a specific shape that fits only its particular substrate molecule precisely
C. The active site must be cubic in shape in order to bind any biochemical substrate molecule effectively
D. The active site provides all of the chemical energy needed to drive the reaction forward to completion

22. Exposing a typical enzyme to very high temperatures usually causes the enzyme to:

A. Speed up its reaction rate permanently by gaining additional thermal kinetic energy in solution
B. Replicate itself rapidly and produce many additional functional copies of the same enzyme protein
C. Denature, losing its three-dimensional shape and therefore losing its ability to bind its substrate
D. Convert directly into a fatty acid molecule that can then be used as a long-term energy storage compound

23. The "lock-and-key" model of enzyme function is best illustrated by which of the following statements?

A. An enzyme that randomly binds any substrate molecule present in the bloodstream at the moment
B. The active site of an enzyme that specifically fits one shape of substrate molecule and no others
C. An enzyme that is permanently destroyed every single time it carries out one chemical reaction
D. An enzyme that provides all of the energy required to drive a chemical reaction toward completion

24. The ATP-ADP cycle is essential to cellular activity because it:

A. Stores the genetic information used to direct all of the cell's protein synthesis activities each day
B. Provides the structural framework of the cell's outer membrane and its internal cytoskeleton network
C. Transports oxygen from the lungs to the body's various tissues through the bloodstream of the body
D. Allows energy from food to be stored temporarily and then released as cells need it for daily work

25. The light-dependent reactions of photosynthesis take place in which structure of the chloroplast?

A. The thylakoid membranes, where chlorophyll captures light energy and uses it to make ATP and NADPH
B. The stroma, where carbon dioxide is fixed into a three-carbon sugar through the Calvin cycle reactions
C. The outer membrane of the chloroplast, which simply encloses and isolates the contents of the organelle
D. The mitochondrial matrix, where the citric acid cycle of cellular respiration takes place in eukaryotes

26. During the Calvin cycle (the light-independent reactions of photosynthesis), carbon dioxide is:

A. Released into the atmosphere as a gaseous waste product of the energy production cycle each day
B. Used to produce additional chlorophyll molecules within each of the cell's many chloroplasts daily
C. Fixed into organic molecules and used to build sugars through a series of enzyme-catalyzed reactions
D. Converted directly into oxygen gas, which is then released through the leaf's stomata to the atmosphere

27. Chlorophyll absorbs visible light most strongly in which regions of the spectrum?

A. The yellow and green wavelengths, which is why nearly all healthy plant leaves appear green to humans
B. The red and blue wavelengths, while reflecting the green wavelengths that we perceive in healthy leaves
C. The ultraviolet and infrared wavelengths, neither of which is actually part of the visible light spectrum
D. All wavelengths of light equally, since chlorophyll is not chemically selective about light absorption

28. The fixation of atmospheric carbon dioxide into organic molecules during the Calvin cycle is catalyzed by:

A. RuBisCO, the enzyme that attaches CO_2 to a five-carbon sugar inside the chloroplast stroma
B. ATP synthase, the enzyme that produces ATP from ADP using a proton gradient across a membrane
C. DNA polymerase, the enzyme that copies DNA molecules during the S phase of the cell cycle
D. Pepsin, the digestive enzyme that breaks down dietary proteins inside the human stomach lining

29. The first stage of cellular respiration, called glycolysis, takes place in the:

A. Mitochondrial inner membrane, where the electron transport chain of cellular respiration is also located
B. Nuclear membrane, where the cell's genetic material is enclosed and protected from cytoplasmic enzymes
C. Mitochondrial matrix, where the citric acid cycle takes place during aerobic cellular respiration also
D. Cytoplasm of the cell, where one glucose molecule is broken down into two molecules of pyruvate

30. The Krebs cycle (citric acid cycle) of cellular respiration takes place in which cellular location?

A. The cytoplasm of the cell, where glycolysis also takes place before the rest of cellular respiration
B. The mitochondrial matrix, the inner fluid-filled compartment inside each mitochondrion of the cell
C. The nucleus of the cell, where the cell's genetic material directs all of the cell's daily activities
D. The endoplasmic reticulum, where many of the cell's proteins are synthesized at attached ribosomes

31. During the electron transport chain in aerobic cellular respiration, the final electron acceptor is:

A. Glucose, the six-carbon sugar molecule that originally entered the cellular respiration pathway
B. Carbon dioxide, the waste gas that is exhaled out of the body through the lungs by an animal
C. Oxygen, which combines with hydrogen ions and electrons to form water as a final product
D. Nitrogen, the atmospheric gas that makes up roughly seventy-eight percent of the air we breathe

32. During strenuous exercise, when human muscle cells cannot get enough oxygen, they switch to anaerobic respiration, producing:

A. Carbon dioxide and ethanol, the same products formed in the fermentation pathway of baker's yeast
B. Glucose and oxygen, the same two products that are normally produced through the photosynthesis pathway
C. Pure ATP and water only, with no other byproducts at all formed by the anaerobic metabolic pathway
D. Lactic acid, which can accumulate in the muscle and contribute to muscle fatigue and soreness

33. The cell cycle is regulated by checkpoints that:

A. Ensure that the cell is fully ready to proceed and that its DNA has been correctly replicated first
B. Prevent the cell from making any of the proteins that it needs for normal everyday cellular function
C. Convert the cell from a eukaryotic to a prokaryotic state during the cell division process each time
D. Eliminate all of the cell's mitochondria before the cell is allowed to begin to divide successfully

34. Programmed cell death, called apoptosis, is biologically important because it:

A. Causes the cell to divide rapidly and to produce a large tumor mass from one original parent cell
B. Removes damaged, infected, or unneeded cells in a controlled and orderly biological manner
C. Restores the cell's worn-out internal structures and substantially extends the cell's normal lifespan
D. Converts an injured cell into a healthy stem cell that can continue to divide normally for years

35. Cancer cells are best characterized as cells that:

A. Have stopped dividing entirely and remain in a permanent quiescent resting phase indefinitely
B. Continue performing all of their normal specialized functions within the body's various tissues
C. Respond normally to every one of the body's growth signals and stop dividing as instructed regularly
D. Divide uncontrollably due to a loss of normal regulation over the progression of the cell cycle

36. During DNA replication, the enzyme that adds new nucleotides to a growing DNA strand is:

A. RNA polymerase, the enzyme that synthesizes a strand of RNA from a DNA template during transcription
B. Pepsin, the digestive enzyme that breaks down dietary proteins into smaller peptide fragments in stomach
C. DNA polymerase, the enzyme that catalyzes the addition of nucleotides to the new DNA daughter strand
D. Only DNA ligase, which simply joins together the existing nucleotides already in the DNA backbone

37. DNA replication is described as "semiconservative" because:

A. Each new DNA molecule consists of one original parental strand and one newly synthesized strand
B. Each new DNA molecule contains entirely new strands with none of the original parental DNA at all
C. The original DNA molecule is destroyed and entirely brand-new DNA molecules are built from scratch
D. Half of the cell's chromosomes are replicated, while the other half remain unchanged in the cell

38. In a eukaryotic cell, mRNA transcribed from DNA undergoes processing before it leaves the nucleus. This processing includes:

A. Combining several different mRNA strands together into one long polypeptide chain in the nucleus
B. Converting the messenger RNA molecule back into a strand of DNA before it leaves the nucleus
C. Removing the noncoding intron sequences and splicing together the exon sequences that code for protein
D. Attaching multiple ribosomes to the mRNA molecule before it can be exported to the cytoplasm

39. Transfer RNA (tRNA) molecules play which role during the process of protein synthesis?

A. Reading the DNA template strand directly and copying its base sequence into a new RNA strand
B. Delivering specific amino acids to the ribosome based on the codon present on the mRNA strand
C. Forming a major structural component of the ribosome along with several other large RNA molecules
D. Permanently storing the genetic information of the cell within the nucleus across the cell's lifetime

40. The genetic code is described as "degenerate" because:

A. The genetic code routinely produces nonfunctional proteins that the cell then must destroy rapidly
B. The genetic code becomes less accurate as an organism ages over the course of its lifetime overall
C. Each codon in the genetic code can specify multiple different amino acids at the same time of translation
D. Most amino acids are specified by more than one different codon in the standard genetic code

41. In bacterial cells, a group of related genes that is regulated together as one unit is best called:

A. An operon, a cluster of related genes regulated together by a single promoter region in bacteria
B. A chromosome, which is a single linear DNA molecule found only in the cells of eukaryotic organisms
C. A nucleotide, which is one single subunit of DNA consisting of a sugar, a phosphate group, and a base
D. A protein, which is a long chain of amino acids folded into a specific three-dimensional functional shape

42. A point mutation that changes a single codon from GGA to GGG without altering the amino acid that the codon specifies is best classified as a:

A. Nonsense mutation, which converts an ordinary amino-acid codon into a stop codon prematurely
B. Silent mutation, which produces no change in the resulting protein's amino acid sequence at all
C. Frameshift mutation, which shifts the reading frame of every codon downstream in the gene
D. Missense mutation, which changes the codon so that it specifies a different amino acid in the protein

43. A single nucleotide insertion or deletion in the middle of a protein-coding gene is most likely to produce:

A. A silent mutation that produces no observable change at all in the resulting protein product
B. A small change in the protein structure that does not affect its biological function over time
C. A frameshift mutation that alters every codon downstream and usually produces a nonfunctional protein
D. The creation of a brand-new gene that codes for an entirely new and biologically useful function

44. Down syndrome is caused by the presence of three copies of chromosome 21 instead of the normal two. This condition is best classified as an example of:

A. A frameshift mutation in a single gene that codes for one particular protein within the body's cells
B. A point mutation involving the substitution of one nucleotide for another nucleotide in the DNA sequence
C. A silent mutation that does not produce any visible effect on the phenotype of the affected individual
D. A chromosomal mutation that results from nondisjunction during meiosis in one of the two parents

45. In snapdragons, crossing a red-flowered plant (RR) with a white-flowered plant (WW) produces all pink-flowered offspring (RW). This inheritance pattern is best described as:

A. Codominance, in which both alleles in the heterozygote are expressed equally and independently
B. Incomplete dominance, in which the heterozygous phenotype is intermediate between the two homozygotes
C. Complete dominance, in which one allele completely masks the expression of the other allele entirely
D. Polygenic inheritance, in which two or more different genes together contribute to one observable trait

46. In humans with type AB blood, both the A antigen and the B antigen are fully expressed on the red blood cells. This inheritance pattern is best described as:

A. Codominance, in which both alleles present in the heterozygote are fully expressed in the phenotype
B. Incomplete dominance, in which the heterozygote shows a phenotype that blends the two homozygotes
C. Complete dominance, in which one allele completely masks the expression of the other allele entirely
D. Sex-linked inheritance, in which the trait is carried on either the X or the Y sex chromosome

47. Human ABO blood type is determined by three different alleles (I^A, I^B, and i) at a single gene locus. This pattern is best described as an example of:

A. Sex-linked inheritance, in which the gene is carried on the X chromosome and is expressed more in males
B. Polygenic inheritance, in which several separate genes together contribute to one observable phenotype
C. Multiple alleles, in which more than two alleles exist for a single gene within the larger population
D. Environmental influence, in which the surrounding environment alone determines the observable phenotype

48. Human skin color and adult height are influenced by multiple genes acting together, producing a continuous range of phenotypes rather than discrete categories. This is best described as:

A. Codominance, in which both alleles of one single gene are expressed in the heterozygous individual
B. Polygenic inheritance, in which two or more different genes together contribute to one observable trait
C. Complete dominance, in which one allele of a single gene completely masks the other allele in heterozygotes
D. Sex-linked inheritance, in which a trait is carried on either the X or Y chromosome and is expressed accordingly

49. Identical twins raised in different environments often show some differences in traits such as body weight, despite sharing the same DNA sequence. This observation illustrates that:

A. Identical twins do not actually share the same DNA sequence as has been commonly believed for decades
B. Environmental factors have absolutely no effect on the observable physical traits of human individuals
C. The phenotype of every individual is determined entirely by the genes alone with no other

contributing factors
D. Both genes and the environment contribute to an organism's observable phenotype throughout its lifetime

50. When a single gene affects multiple, seemingly unrelated traits in an organism — for example, the single mutation in sickle-cell disease that affects red blood cells, organ function, and growth — this phenomenon is best described as:

A. Pleiotropy, in which a single gene affects multiple different traits in the organism's overall phenotype
B. Polygenic inheritance, in which many separate genes together contribute to one single observable trait
C. Codominance, in which both alleles of a gene are expressed equally in the heterozygous individual
D. Environmental variation, in which different environments produce different phenotypes from a single gene

Practice Exam 11: Life Science: Biology Simulation — Answer Key with Explanations

1. C — Form a testable hypothesis that predicts a relationship between light and bean plant height. The scientific method moves from observation to question to hypothesis before experimentation begins. A testable hypothesis is required because it gives the experiment a specific prediction to evaluate.

2. A — The different amounts of fertilizer applied to each of the plants in the experimental groups. The independent variable is the factor that the researcher deliberately changes between groups. Plant height in this design is the dependent (responding) variable, not the independent variable.

3. D — Serve as a baseline of comparison against the experimental group to evaluate treatment effects. Without an untreated control, any change in the experimental group cannot be reliably attributed to the variable being tested. The control isolates the effect of the independent variable from background influences.

4. B — Place the slide on the stage and begin viewing with the lowest-power objective lens for focusing. Low power offers a wider field of view, making it easier to locate the specimen, and prevents the higher-power lens from crushing the slide. Once the specimen is centered and roughly focused, the user can rotate to higher magnification.

5. C — 400×, calculated by multiplying the magnifications of the ocular and the objective lenses together. Total magnification of a compound light microscope is the product of the ocular and objective lens powers: $10 \times 40 = 400\times$. This is the standard convention for reporting microscope magnification.

6. A — If a plant receives more sunlight, then it will grow taller than a plant receiving less sunlight. A proper hypothesis is a testable, falsifiable "if-then" prediction relating an independent variable to a dependent variable. The other choices are observations, factual claims, or subjective opinions that cannot be experimentally tested.

7. B — An electron microscope, which uses beams of electrons to achieve extremely high magnification. Electron microscopes provide the resolution needed to see organelle ultrastructure, such as the cristae of mitochondria, which light microscopes cannot resolve. Magnifying glasses and the unaided eye are far below the resolution limit needed.

8. D — Identify an unknown organism by following a series of paired, contrasting descriptive choices. A dichotomous key presents two opposing statements at each step, leading the user through a branching path until the organism is identified. This tool is widely used in field biology and taxonomy.

9. C — All living organisms are composed of cells, and new cells arise from previously existing cells. These statements, along with "the cell is the basic unit of life," form the three central tenets of the modern cell theory. The other options misstate or directly contradict the theory.

10. B — Eukaryotic cells have a true nucleus and membrane-bound organelles, while prokaryotes do not. Prokaryotic DNA floats in the cytoplasm in a region called the nucleoid, and prokaryotes lack mitochondria, ER, Golgi, and other organelles. This is the most fundamental structural distinction between the two cell types.

11. A — The lysosome, which contains digestive enzymes that break down damaged organelles and pathogens. Lysosomes function as the cell's recycling and disposal system, using hydrolytic enzymes that work best at acidic pH. Defects in lysosomal function underlie a number of storage diseases.

12. D — Ribosomes, which read messenger RNA and assemble amino acids into polypeptide chains. Ribosomes are the universal sites of translation, found free in the cytoplasm and bound to the rough endoplasmic reticulum. They are present in both prokaryotic and eukaryotic cells.

13. C — Rough endoplasmic reticulum, where ribosomes synthesize proteins destined for export from the cell. Cells that export large amounts of protein, such as pancreatic acinar cells, have abundant rough ER studded with ribosomes. Proteins synthesized there enter the ER lumen for folding and modification before being packaged by the Golgi for secretion.

14. A — A phospholipid bilayer with embedded proteins that regulates what enters and leaves the cell. The fluid mosaic model describes the membrane as a flexible bilayer with embedded transport, receptor, and recognition proteins. This structure underlies the membrane's role in selective permeability and cell signaling.

15. D — Swell and possibly burst as water moves into the cell down its concentration gradient by osmosis. Distilled water is hypotonic relative to the red blood cell's cytoplasm, so water moves into the cell by osmosis. Without a cell wall to resist the pressure, the red blood cell undergoes hemolysis (cytolysis).

16. B — Hypertonic, which causes water to move out of the cell and the cell to lose volume by osmosis. "Hyper-" means above or greater, so a hypertonic solution has greater solute concentration than the cell. Water moves down its concentration gradient out of the cell, causing it to shrink — the basis of crenation in red blood cells.

17. A — Cells generally divide once they reach a certain size rather than continuing to grow much larger. As volume increases by the cube and surface area by the square, the membrane cannot exchange enough material to support the cell's interior. This surface-area-to-volume constraint is a fundamental reason cells stay small and divide.

18. C — Increasing the concentration gradient between the two sides of the cell membrane sharply. A steeper concentration gradient drives faster net movement of molecules by diffusion. Thicker membranes, larger molecules, and lower temperatures all slow diffusion, while a stronger gradient accelerates it.

19. D — Active transport, in which ATP is used to move sodium and potassium against their concentration gradients. The Na^+/K^+ pump moves three Na^+ out and two K^+ in per ATP hydrolyzed, establishing the electrochemical gradient essential for nerve impulse conduction. This expenditure of ATP defines it as active rather than passive transport.

20. A — Proteins that catalyze specific biochemical reactions and accelerate them without being consumed. Enzymes are globular proteins whose three-dimensional shape creates an active site complementary to a particular substrate. Their catalytic activity is the foundation of virtually every metabolic pathway in the cell.

21. B — Each active site has a specific shape that fits only its particular substrate molecule precisely. Enzyme specificity arises from the precise three-dimensional fit between active site and substrate, often described as a lock-and-key or induced-fit interaction. Loss of the proper shape — through heat or pH change — destroys this specificity.

22. C — Denature, losing its three-dimensional shape and therefore losing its ability to bind its substrate. High temperatures disrupt the hydrogen bonds and other weak interactions that maintain a protein's tertiary structure. Once denatured, the active site no longer fits the substrate, and enzyme activity is lost.

23. B — The active site of an enzyme that specifically fits one shape of substrate molecule and no others. The lock-and-key model emphasizes the precise complementary shape between substrate (key) and active site (lock). Although the induced-fit model is more current, the lock-and-key analogy remains the standard description of enzyme specificity.

24. D — Allows energy from food to be stored temporarily and then released as cells need it for daily work. Energy released from glucose breakdown is captured by adding a phosphate to ADP, forming ATP; hydrolyzing ATP back to ADP releases energy to drive cellular work. This rapid, reversible cycle is the cell's universal energy currency system.

25. A — The thylakoid membranes, where chlorophyll captures light energy and uses it to make ATP and NADPH. Light absorption, water splitting, and electron transport all occur in the thylakoid membranes. The ATP and NADPH produced there are then used in the stroma to drive the Calvin cycle.

26. C — Fixed into organic molecules and used to build sugars through a series of enzyme-catalyzed reactions. In the Calvin cycle, CO_2 is attached to RuBP and processed through multiple steps to form glucose precursors, using ATP and NADPH from the light reactions. The result is conversion of inorganic carbon into organic compounds.

27. B — The red and blue wavelengths, while reflecting the green wavelengths that we perceive in healthy leaves. Chlorophyll a and b have strong absorption peaks in the red (~660 nm) and blue (~430 nm) regions of the spectrum. Green light is largely reflected, which is why most healthy plant tissue appears green.

28. A — RuBisCO, the enzyme that attaches CO_2 to a five-carbon sugar inside the chloroplast stroma. RuBisCO (ribulose-1,5-bisphosphate carboxylase/oxygenase) catalyzes the first major step of the Calvin cycle by combining CO_2 with RuBP. It is the most abundant protein on Earth and is essential to nearly all carbon fixation in the biosphere.

29. D — Cytoplasm of the cell, where one glucose molecule is broken down into two molecules of pyruvate. Glycolysis is anaerobic, requires no organelles, and occurs in the cytosol of all cells, prokaryotic and eukaryotic. It produces a small net yield of ATP and NADH and is the universal first stage of cellular respiration.

30. B — The mitochondrial matrix, the inner fluid-filled compartment inside each mitochondrion of the cell. Pyruvate from glycolysis enters the matrix, where it is decarboxylated and fed into the Krebs cycle enzymes. CO_2, NADH, and $FADH_2$ produced here feed the electron transport chain on the inner membrane.

31. C — Oxygen, which combines with hydrogen ions and electrons to form water as a final product. Oxygen's role as the final electron acceptor is what makes respiration "aerobic" and allows the electron transport chain to keep operating. Without oxygen, the chain backs up and ATP production collapses to glycolysis alone.

32. D — Lactic acid, which can accumulate in the muscle and contribute to muscle fatigue and soreness. Lactic acid fermentation regenerates NAD^+ so that glycolysis can keep producing small amounts of ATP when oxygen is insufficient. Yeasts, not human muscle cells, produce ethanol and CO_2 instead.

33. A — Ensure that the cell is fully ready to proceed and that its DNA has been correctly replicated first. Cell cycle checkpoints monitor cell size, nutrient availability, DNA integrity, and chromosome attachment to the spindle. When checkpoints detect problems, they halt the cycle to prevent passing on damaged DNA to daughter cells.

34. B — Removes damaged, infected, or unneeded cells in a controlled and orderly biological manner. Apoptosis sculpts developing tissues (such as fingers from paddle-shaped hands), eliminates virus-infected cells, and discards cells with severe DNA damage. Failure of apoptosis is a hallmark of many cancers and autoimmune diseases.

35. D — Divide uncontrollably due to a loss of normal regulation over the progression of the cell cycle. Mutations in tumor suppressor genes (such as p53) and proto-oncogenes (such as Ras) disable the checkpoints that normally limit cell division. The result is unrestrained proliferation, the defining feature of cancer.

36. C — DNA polymerase, the enzyme that catalyzes the addition of nucleotides to the new DNA daughter strand. DNA polymerase reads the template strand and adds complementary nucleotides one at a time in the 5'→3' direction. RNA polymerase has a different role (transcription), and ligase only seals nicks between fragments after they form.

37. A — Each new DNA molecule consists of one original parental strand and one newly synthesized strand. The two strands of the parental double helix separate, and each serves as a template for a new complementary strand. The Meselson–Stahl experiment confirmed this mechanism in the late 1950s.

38. C — Removing the noncoding intron sequences and splicing together the exon sequences that code for protein. Pre-mRNA processing in eukaryotes also includes addition of a 5' cap and a 3' poly-A tail before export to the cytoplasm. Splicing is what allows a single gene to produce multiple protein variants through alternative exon combinations.

39. B — Delivering specific amino acids to the ribosome based on the codon present on the mRNA strand. Each tRNA carries one specific amino acid and bears an anticodon that base-pairs with the corresponding mRNA codon. This codon-anticodon recognition is how the genetic message is converted into the correct amino acid sequence.

40. D — Most amino acids are specified by more than one different codon in the standard genetic code. With 64 codons coding for only 20 amino acids (plus stop signals), there are multiple synonymous codons for most amino acids. This redundancy buffers many single-base mutations against changing the protein sequence.

41. A — An operon, a cluster of related genes regulated together by a single promoter region in bacteria. The lac operon and trp operon of E. coli are classic examples, allowing the bacterium to coordinate the expression of enzymes for a single metabolic pathway. This regulatory arrangement is found in prokaryotes but not in eukaryotic genomes.

42. B — Silent mutation, which produces no change in the resulting protein's amino acid sequence at all. Both GGA and GGG code for the amino acid glycine, so the codon change is "silent" with respect to the protein. Silent mutations exploit the degeneracy of the genetic code.

43. C — Frameshift mutation that alters every codon downstream and usually produces a nonfunctional protein. Insertions or deletions of a single nucleotide shift the reading frame, so every codon after the mutation is misread. The resulting protein is almost always nonfunctional and often truncated by a premature stop codon.

44. D — A chromosomal mutation that results from nondisjunction during meiosis in one of the two parents. When a chromosome pair fails to separate properly during meiosis, a gamete may receive two copies of chromosome 21, producing trisomy 21 at fertilization. This is a large-scale chromosomal change rather than a point mutation in DNA sequence.

45. B — Incomplete dominance, in which the heterozygous phenotype is intermediate between the two homozygotes. Heterozygous RW plants produce an intermediate amount of red pigment, resulting in a pink color rather than red or white. This contrasts with codominance, in which both phenotypes appear simultaneously rather than blending.

46. A — Codominance, in which both alleles present in the heterozygote are fully expressed in the phenotype. In AB blood, both I^A and I^B alleles produce their own antigen on the red blood cell surface — neither dominates the other. This differs from incomplete dominance, where the heterozygote shows a blended intermediate trait.

47. C — Multiple alleles, in which more than two alleles exist for a single gene within the larger population. The ABO blood-type locus has three alleles (I^A, I^B, and i) in the population, even though each individual can carry only two. ABO inheritance combines this multiple-allele system with codominance between I^A and I^B.

48. B — Polygenic inheritance, in which two or more different genes together contribute to one observable trait. When many genes each contribute a small effect to the same trait, the result is a smooth continuous distribution of phenotypes rather than a few discrete categories. Human height, skin color, and weight are classic polygenic traits.

49. D — Both genes and the environment contribute to an organism's observable phenotype throughout its lifetime. Identical twins share DNA but encounter different diets, activity levels, stresses, and exposures, producing measurable phenotypic differences. This shows that phenotype = genotype + environmental influence for most traits.

50. A — Pleiotropy, in which a single gene affects multiple different traits in the organism's overall phenotype. The sickle-cell mutation alters hemoglobin, which in turn affects red blood cell shape, oxygen transport, organ blood flow, immune response, and growth. One gene with multiple downstream effects on the phenotype is the defining feature of pleiotropy.