PRACTICE EXAM 20 — QUESTIONS 1–50

Instructions: This simulation exam mirrors the format of the New York State Regents Examination in Life Science: Biology. Questions are organized into stimulus-based clusters. Read each cluster's stimulus completely before answering any questions in that set. Select the one best answer for each question.

Base your answers to questions 1 through 5 on the information below and on your knowledge of biology.

A high school student observed cells from a growing onion root tip under a microscope and counted the number of cells in each stage of the cell cycle. The class data are summarized below. The student knew that the amount of time a cell spends in each stage is roughly proportional to the percentage of cells observed in that stage at any given moment.

Stage	Number of Cells Observed
Interphase	154
Prophase	22
Metaphase	8
Anaphase	5
Telophase	11

1. Based on the data, in which stage of the cell cycle do cells spend the most time?

A. Interphase, when the cell grows and the DNA is duplicated before division
B. Prophase, when the chromosomes condense and the nuclear envelope breaks down
C. Metaphase, when the chromosomes line up along the equator of the cell
D. Telophase, when two new nuclei form and the cell prepares to divide fully

2. During which stage of mitosis would you expect to see chromosomes aligned at the center (equator) of the cell?

A. Interphase, when DNA exists as long thin chromatin threads in the cell nucleus
B. Prophase, when chromosomes are first becoming visible and beginning to condense
C. Anaphase, when sister chromatids are pulled apart toward opposite poles of the cell
D. Metaphase, when chromosomes line up along the middle plane of the dividing cell

3. The DNA of each chromosome is duplicated during which phase?

A. Mitosis, when the cell divides into two genetically identical daughter cells
B. Interphase, specifically during the S (synthesis) phase before the cell divides

C. Telophase, when the chromosomes arrive at the two poles of the dividing cell
D. Anaphase, when sister chromatids separate and move toward opposite cell poles

4. The result of one round of mitosis in a body cell is:

A. Four genetically different daughter cells, each containing half the chromosomes of the parent cell
B. One large daughter cell containing twice as many chromosomes as the original parent cell
C. Two genetically identical daughter cells, each containing the same chromosomes as the parent cell
D. Eight daughter cells of varied sizes and shapes formed from one large parent cell at once

5. Cancer is best described biologically as:

A. Uncontrolled cell division resulting from mutations in genes that regulate the cell cycle
B. A bacterial infection that spreads through the body and produces tumors in organs
C. A nutrient deficiency that can be cured by adding specific vitamins to the diet daily
D. A natural process by which old cells are eliminated and replaced with new ones

Base your answers to questions 6 through 10 on the information below and on your knowledge of biology.

Researchers investigated the effect of a chemical inhibitor on the enzyme catalase, which breaks down hydrogen peroxide (H2O2) into water and oxygen. The team prepared a series of test tubes, each containing the same amount of catalase and the same starting concentration of hydrogen peroxide. To different tubes they added increasing concentrations of the inhibitor and measured the resulting rate of oxygen production. The data are shown below.

Inhibitor Concentration (mM)	Rate of O2 Production (mL/min)
0	12
1	9
2	6
5	2
10	0

6. Based on the data, the inhibitor has what overall effect on catalase activity?

A. The inhibitor steadily increases the rate of oxygen production as its concentration rises
B. The inhibitor has no measurable effect on the rate of oxygen production at any level
C. The inhibitor first decreases activity, then suddenly increases it at very high doses
D. The inhibitor decreases the rate of oxygen production as its concentration increases

7. At an inhibitor concentration of 10 mM, no oxygen was produced. The most likely reason is that:

A. All hydrogen peroxide molecules had spontaneously broken down before the test began
B. The inhibitor itself produced extra oxygen that cancelled the catalase reaction's output
C. The inhibitor had bound to or altered every catalase molecule, blocking all enzyme function
D. The temperature dropped below freezing once 10 mM of inhibitor was added to the tube

8. The hydrogen peroxide in this experiment is best classified as the:

A. Enzyme, which is consumed during the reaction it speeds up in living cells
B. Substrate, which is the molecule that the enzyme acts upon during the reaction
C. Product, which is created during the reaction along with water and oxygen
D. Inhibitor, which slows down the reaction by binding to the enzyme active site

9. Enzyme inhibitors are important in medicine because:

A. Many drugs work by inhibiting specific enzymes in disease-causing organisms or in human cells
B. They restore the active sites of enzymes that have been damaged during normal cellular aging
C. They permanently destroy all bacterial cells without affecting any human cells at all
D. They cause enzymes to catalyze new reactions that the enzymes could not catalyze before

10. Which next step would best test whether the inhibitor's effect on catalase is reversible?

A. Adding more hydrogen peroxide to the tubes and observing the rate of oxygen production
B. Raising the temperature of each tube to 90°C and recording the rate of oxygen production
C. Removing the inhibitor by dialysis and then testing whether catalase activity returns
D. Adding additional inhibitor at progressively higher doses to measure further inhibition

Base your answers to questions 11 through 15 on the information below and on your knowledge of biology.

A class performed paper chromatography to separate the pigments in spinach leaves. Students ground spinach leaves with a small amount of solvent, applied a drop of the green extract near the bottom of a strip of chromatography paper, and placed the paper into a beaker containing a different solvent. As the solvent traveled up the paper by capillary action, it carried the pigments with it. After 30 minutes, four colored bands appeared on the paper, summarized below.

Distance from Origin (cm)	Color	Pigment Identified
1.0	Yellow-green	Chlorophyll b
2.3	Blue-green	Chlorophyll a
5.8	Yellow	Xanthophyll
8.5	Orange	Carotene

11. The presence of four different pigments in the spinach leaf extract suggests that:

A. Only chlorophyll a is involved in photosynthesis in the leaves of spinach plants
B. The leaf produces different pigments depending on the time of day during photosynthesis
C. Spinach leaves contain only one type of light-absorbing pigment overall in the chloroplasts
D. Spinach leaves use multiple pigments to absorb a broader range of light wavelengths

12. Chlorophyll a appears blue-green because it:

A. Absorbs green light and reflects red and blue wavelengths back to the observer
B. Absorbs red and blue light strongly while reflecting blue-green wavelengths
C. Absorbs all visible wavelengths of light equally without reflecting any color
D. Reflects all visible wavelengths of light equally to produce a neutral appearance

13. The accessory pigments (chlorophyll b, xanthophyll, and carotene) function in photosynthesis primarily by:

A. Absorbing light at wavelengths that chlorophyll a cannot absorb efficiently
B. Producing the oxygen released as a byproduct during the light-independent reactions
C. Splitting the carbon dioxide molecules to release usable carbon for the plant
D. Storing the glucose produced during photosynthesis for later use by other cells

14. The pigments separated on the paper during chromatography because:

A. Each pigment evaporated at a different rate when exposed to the solvent in the beaker
B. The solvent reacted chemically with each pigment to produce different colored bands
C. Each pigment has a different solubility in the solvent and adherence to the paper fibers
D. The pigments were originally arranged in horizontal bands inside the spinach leaves

15. The color of a leaf in autumn often changes from green to yellow or orange because:

A. The leaf begins producing new yellow and orange pigments not present during summer
B. The leaf absorbs different wavelengths of light during the shorter autumn days
C. The leaf's chloroplasts are physically destroyed by the cold autumn air temperatures
D. Chlorophyll breaks down faster than other pigments, revealing the underlying colors

Base your answers to questions 16 through 19 on the information below and on your knowledge of biology.

Students set up two identical bottles, each containing a mixture of yeast, water, and glucose. Bottle A was left open to the air, so oxygen could reach the yeast. Bottle B was sealed with a stopper so that no additional oxygen could enter. Both bottles were placed in a warm location and observed for 24 hours.

After 24 hours, students measured the amount of carbon dioxide produced in each bottle and tested the liquid in each bottle for the presence of ethanol (alcohol). The results are summarized below.

Bottle	Conditions	CO2 Produced	Ethanol Detected?
A	Open to air (aerobic)	Large amount	No
B	Sealed (anaerobic)	Smaller amount	Yes

16. The presence of ethanol in Bottle B indicates that the yeast in that bottle performed:

A. Aerobic cellular respiration, which produces water as its primary metabolic byproduct
B. Anaerobic fermentation, which converts glucose into ethanol and carbon dioxide
C. Photosynthesis, which converts the carbon dioxide in the bottle into glucose molecules
D. Active transport, which moves dissolved sugar across the yeast cell's plasma membrane

17. The yeast in Bottle A (with oxygen) produced more carbon dioxide than the yeast in Bottle B because:

A. Aerobic respiration completely breaks down glucose, releasing more CO2 per glucose molecule
B. The open bottle allowed extra CO2 from the air to enter and add to the measured amount
C. Anaerobic yeast produces only water and no carbon dioxide as a fermentation byproduct
D. The yeast in Bottle A reproduced more rapidly because oxygen kills yeast cells in Bottle B

18. Yeast fermentation is used in baking because:

A. The ethanol produced gives bread its characteristic flavor and improves the texture
B. The fermentation process generates the heat that bakes the bread within the oven
C. The carbon dioxide produced causes bread dough to rise during the baking process
D. The yeast cells multiply and become the principal source of protein in the baked bread

19. In humans, a process similar to yeast fermentation can occur during intense exercise. In human muscle cells, this process produces:

A. Ethanol, which is the same alcohol product that yeast fermentation produces
B. Lactic acid, which can accumulate and contribute to muscle fatigue and soreness
C. Pyruvate, which is the final product of the fermentation pathway in muscle cells
D. Methane gas, which is then exhaled through the lungs during heavy breathing

Base your answers to questions 20 through 24 on the information below and on your knowledge of biology.

Once a messenger RNA (mRNA) molecule is made from a DNA template in the nucleus, the mRNA travels to a ribosome in the cytoplasm. At the ribosome, the mRNA is "read" three nucleotides at a time. Each three-nucleotide unit (codon) on the mRNA specifies one amino acid. Transfer RNA (tRNA) molecules deliver amino acids to the ribosome. Each tRNA has an anticodon at one end and carries a specific amino acid at the other end. The anticodon pairs with a complementary codon on the mRNA, ensuring that the correct amino acid is added to the growing protein chain.

20. The process described in the stimulus is called:

A. Replication, which copies the DNA of a cell before the cell divides into two daughter cells
B. Transcription, in which an RNA copy of a gene is synthesized from DNA in the nucleus
C. Mutation, in which a change is introduced into the DNA of a cell during replication
D. Translation, in which the genetic code carried by the mRNA is used to synthesize a protein

21. An mRNA codon reads 5′-AUG-3′. The complementary anticodon on the tRNA that recognizes this codon is:

A. 5′-AUG-3′, which is identical to the codon and binds with perfect compatibility
B. 5′-TAC-3′, which would use thymine in place of uracil at the second position
C. 3′-UAC-5′, in which each base pairs with its complement on the messenger RNA codon
D. 5′-GUA-3′, in which the bases are reversed but not complementary to the codon

22. If a single nucleotide is added to the middle of an mRNA molecule, the most likely effect on the resulting protein is:

A. A frameshift that alters the reading frame, changing many amino acids from that point onward
B. A single amino acid change at the location of the insertion, with no other effects on the protein
C. No effect at all on the protein, because the ribosome simply skips the extra nucleotide
D. An increase in the rate of protein synthesis because the mRNA molecule is now longer

23. The function of a transfer RNA (tRNA) molecule is to:

A. Carry the genetic message from the DNA in the nucleus to the ribosome in the cytoplasm
B. Catalyze the formation of peptide bonds between amino acids during protein synthesis
C. Provide the energy required to assemble amino acids into long polypeptide protein chains
D. Bring specific amino acids to the ribosome and pair its anticodon with the mRNA codon

24. The cellular structure where translation takes place is the:

A. Nucleus, which contains the DNA template that encodes each cellular protein
B. Ribosome, which assembles amino acids into proteins based on the mRNA sequence
C. Mitochondrion, which provides the ATP needed for active transport across membranes
D. Endoplasmic reticulum, which is involved only in lipid synthesis in animal cells

Base your answers to questions 25 through 29 on the information below and on your knowledge of biology.

In snapdragon flowers, the gene for flower color is inherited with incomplete dominance. The allele R produces red pigment, and the allele R′ produces no pigment (white). A snapdragon with genotype RR has red flowers, R′R′ has white flowers, and RR′ has pink flowers — an intermediate blended color. A breeder crosses a pink-flowered snapdragon with another pink-flowered snapdragon.

25. What phenotypic ratio is expected in the offspring of the RR′ × RR′ cross?

A. All offspring will have pink flowers, identical in color to both of the parents
B. Three red-flowered offspring for every one white-flowered offspring in the cross
C. One red : two pink : one white among the offspring of this cross
D. All offspring will have red flowers because R is dominant to R′ in this gene

26. The pink color of an RR′ snapdragon demonstrates which inheritance pattern?

A. Incomplete dominance, in which the heterozygous phenotype is a blend of the two homozygous phenotypes
B. Codominance, in which both alleles are fully and independently expressed in the heterozygote
C. Complete dominance, in which one allele completely masks the expression of the other allele
D. Sex linkage, in which the gene for flower color is located on a sex chromosome only

27. A breeder wants to produce a generation in which all of the offspring have pink flowers. Which cross would best achieve this goal?

A. Crossing two pink-flowered (RR′ × RR′) snapdragons, since this always produces pink offspring
B. Crossing a red-flowered (RR) snapdragon with a white-flowered (R′R′) snapdragon
C. Crossing two red-flowered (RR × RR) snapdragons would produce all pink-flowered offspring
D. Crossing a pink-flowered (RR′) snapdragon with a red-flowered (RR) snapdragon only

28. What is the probability that any single offspring of an RR′ × RR′ cross will be homozygous for either allele?

A. 0%, because all offspring of two heterozygous parents are also heterozygous
B. 25%, because only one of every four offspring carries two identical alleles
C. 75%, because three of every four offspring will be homozygous for one allele
D. 50%, because half of all offspring (the RR and R′R′ groups together) are homozygous

29. Incomplete dominance differs from codominance in that:

A. Incomplete dominance occurs only in plants, while codominance occurs only in animals
B. Codominance produces a fully blended phenotype, while incomplete dominance does not
C. In incomplete dominance the heterozygote shows a blended intermediate phenotype; in codominance both alleles are fully expressed at the same time
D. Incomplete dominance and codominance are different names for exactly the same inheritance pattern

Base your answers to questions 30 through 36 on the information below and on your knowledge of biology.

Methicillin-resistant *Staphylococcus aureus* (MRSA) is a bacterium that has evolved resistance to many common antibiotics, including methicillin, penicillin, and amoxicillin. MRSA causes serious infections in hospitals and communities. Decades ago, *S. aureus* could be easily killed by penicillin and similar drugs. Over time, due to widespread use of these antibiotics, populations of *S. aureus* changed: bacteria carrying resistance genes survived antibiotic treatment, reproduced, and passed those genes on to their offspring. Today, MRSA strains are resistant to many drugs, and physicians must use newer or stronger antibiotics — to which the bacteria are also beginning to develop resistance.

30. The development of MRSA from earlier antibiotic-sensitive *S. aureus* populations is best classified as an example of:

A. Evolution by natural selection acting on heritable variation in bacterial populations
B. Acquired resistance that individual bacteria developed during their own lifetimes
C. Spontaneous generation of new bacterial species from non-living chemical materials
D. Sexual reproduction between different bacterial species in the hospital environment

31. Resistance to methicillin in MRSA originally arose through:

A. Bacteria deliberately altering their own DNA in response to the presence of the antibiotic
B. Bacteria learning from their parents which chemicals to avoid in the hospital environment
C. The doctor giving the bacteria immunity by exposing them to small doses of the antibiotic
D. Random mutations in bacterial DNA that produced new variants resistant to the antibiotic

32. When antibiotics are given, sensitive bacteria die while resistant bacteria survive. The resistant bacteria then reproduce, increasing the percentage of resistant cells in the population. This selective pressure illustrates:

A. Genetic drift, in which allele frequencies change due to random sampling effects in small populations
B. Natural selection, in which environmental pressures favor the reproduction of certain heritable variants
C. Sexual selection, in which mate choice drives changes in physical traits of one sex over generations
D. Convergent evolution, in which unrelated species independently develop similar physical traits

33. Why is incomplete antibiotic treatment (stopping medication early when symptoms improve) particularly dangerous?

A. Partially treated patients become permanent carriers of the antibiotic at toxic doses
B. Patients become physically dependent on the antibiotic and require lifetime doses
C. The most resistant bacteria are left alive to reproduce, accelerating the evolution of resistance
D. The bacteria's DNA fuses with the patient's DNA, producing new genetic combinations

34. Bacteria reproduce rapidly, often dividing every 20 to 30 minutes under good conditions. How does this rapid reproduction rate affect the evolution of antibiotic resistance?

A. Rapid reproduction generates many generations quickly, allowing resistant traits to spread faster
B. Rapid reproduction slows the spread of resistance by exhausting the bacterial food supplies
C. Rapid reproduction prevents mutations from occurring because reproduction must be exact
D. Rapid reproduction has no effect on the speed of evolution within bacterial populations

35. For bacteria to become resistant to a new antibiotic, the resistance trait must be:

A. Learned by individual bacteria during their own lifetime through exposure to the antibiotic
B. Heritable, encoded in DNA, so that it can be passed to daughter cells through reproduction
C. Acquired by the bacteria from chemicals in the patient's body during the course of treatment
D. Identical in every bacterial cell at the moment when the antibiotic treatment first begins

36. One important strategy to slow the evolution of antibiotic resistance is to:

A. Encourage patients to stop taking antibiotics as soon as the symptoms start to improve
B. Add small doses of antibiotics to all foods and beverages consumed by healthy people daily
C. Treat all viral infections, including the common cold, with broad-spectrum antibiotics
D. Use antibiotics only when truly needed and complete the full prescribed course every time

Base your answers to questions 37 through 41 on the information below and on your knowledge of biology.

In the 1950s and 1960s, the pesticide DDT was widely used in the United States to control mosquitoes and crop pests. DDT does not break down quickly in the environment and is fat-soluble, so it accumulates in the body tissues of living organisms over time. When small organisms with DDT in their tissues are eaten by larger predators, the predators accumulate the DDT from many prey individuals at once, leading to much higher concentrations at higher trophic levels. This process is known as biomagnification. By the 1960s, populations of bald eagles and other top predators had declined sharply due to DDT poisoning, which thinned their eggshells and caused widespread reproductive failure.

37. Which group of organisms in a food chain typically has the highest concentration of DDT in its body tissues?

A. The producers, such as algae and phytoplankton at the very base of the food chain
B. The primary consumers, such as small herbivores that eat the producers directly
C. The top predators, such as bald eagles at the highest trophic level of the food chain
D. The decomposers, such as bacteria and fungi that break down dead organisms in soils

38. Biomagnification of DDT occurs because:

A. DDT is fat-soluble and persists in tissues, so each predator accumulates DDT from many prey
B. Top predators deliberately consume more DDT than other organisms in the food chain
C. DDT enters the air and falls in greater concentrations on top predators directly from above
D. Smaller organisms can rapidly break down DDT, while larger organisms cannot do so

39. The thinning of bald eagle eggshells caused by DDT exposure led to:

A. Increased eagle population growth in the affected regions of the country
B. Improved reproductive success because the chicks could hatch more easily from the eggs
C. Stronger eggs that resisted predation by other birds and mammals near eagle nests
D. Reproductive failure because the eggs cracked under the weight of the incubating bird

40. After DDT was banned in the United States in 1972, populations of bald eagles and other top predators:

A. Continued to decline because of the DDT permanently stored in soil and water systems
B. Gradually recovered over several decades as DDT levels in the environment decreased
C. Immediately rebounded to their pre-DDT population levels within just one or two years
D. Have remained at the same low population numbers as during the peak of DDT use

41. The story of DDT illustrates an important biological principle: chemicals introduced into the environment can:

A. Have only short-term effects that disappear as soon as their use is stopped
B. Be safely used at any concentration if applied carefully by professional pesticide workers
C. Have long-lasting, far-reaching consequences for ecosystems at all trophic levels
D. Always benefit ecosystems by removing harmful pest species from natural food chains

Base your answers to questions 42 through 45 on the information below and on your knowledge of biology.

The water cycle (hydrologic cycle) describes how water moves between the atmosphere, the land, the oceans, and living organisms on Earth. Water evaporates from oceans, lakes, and other water bodies into the atmosphere as water vapor. Plants release water vapor through their leaves in a process called transpiration. Water vapor in the atmosphere cools and condenses into clouds, and eventually falls back to Earth's surface as precipitation (rain, snow, sleet, or hail). Some precipitation soaks into the ground (infiltration) and replenishes groundwater, while the rest flows over the surface (runoff) into streams, rivers, and ultimately the oceans, completing the cycle.

42. The process by which liquid water becomes water vapor and enters the atmosphere is called:

A. Evaporation, which occurs at the surfaces of lakes, oceans, and other water bodies
B. Condensation, which occurs when water vapor cools and forms tiny liquid droplets
C. Precipitation, which occurs when water falls back to Earth as rain or snow from clouds
D. Infiltration, which occurs when water soaks into the soil after a rainfall or snowmelt

43. Plants release water vapor into the atmosphere through small pores in their leaves. This process is called:

A. Photosynthesis, which uses sunlight to make glucose from carbon dioxide and water
B. Transpiration, which releases water vapor from the leaves of plants into the atmosphere
C. Respiration, which produces water as a byproduct of glucose breakdown inside cells
D. Germination, which is the early growth of a seed into a young plant after watering

44. Water vapor in the atmosphere returns to Earth's surface as precipitation only after it has undergone:

A. Evaporation, in which liquid water becomes water vapor and rises into the air
B. Decomposition, in which water molecules are broken down into hydrogen and oxygen
C. Photosynthesis, in which water is used to build glucose in green plant cells
D. Condensation, in which water vapor cools and forms liquid droplets that grow into clouds

45. The water cycle is important to ecosystems because it:

A. Removes harmful chemicals from the soil by binding them within water molecules
B. Provides the oxygen that all living organisms need to perform cellular respiration
C. Distributes fresh water across Earth, supporting plants, animals, and entire ecosystems
D. Generates most of the heat energy required to warm Earth's surface for organisms

Base your answers to questions 46 through 50 on the information below and on your knowledge of biology.

The human immune system protects the body against harmful microorganisms (pathogens) such as bacteria, viruses, fungi, and parasites. When a pathogen enters the body, specialized white blood cells recognize molecules on the pathogen's surface (called antigens). Some white blood cells produce proteins called antibodies, which bind specifically to those antigens and help destroy the pathogen. After an infection, the immune system retains a "memory" of the pathogen, so future encounters with the same pathogen are met with a faster, stronger response. Vaccines work by introducing weakened or inactivated antigens that train the immune system without causing disease.

46. The molecules on the surface of a pathogen that are recognized by the immune system are called:

A. Antigens, which trigger the immune system to produce a specific defensive response
B. Antibodies, which are produced by white blood cells to attack invading pathogens
C. Enzymes, which catalyze the chemical reactions of the host's immune response
D. Hormones, which carry signals between cells of the body during an active infection

47. Antibodies are best classified as which type of biological molecule?

A. Lipids, which form the cell membranes of all cells in the human body
B. Carbohydrates, which serve as the primary source of energy for human cells
C. Nucleic acids, which carry genetic information from parents to their offspring
D. Proteins, which are folded into specific shapes that allow them to bind antigens

48. Vaccines work by:

A. Killing all pathogens directly upon contact with the bloodstream after a single injection
B. Exposing the immune system to a weakened or inactivated form of a pathogen to train it
C. Replacing infected cells with healthy cells synthesized in a laboratory and then injected
D. Producing the antibiotics that the patient's body will need to fight a future infection

49. A person who has recovered from chickenpox typically does not get chickenpox again because:

A. The chickenpox virus is destroyed permanently by the body's stomach acid after exposure
B. The chickenpox virus mutates so rapidly that it cannot infect the same person twice
C. The immune system retains memory cells that respond quickly to a second exposure
D. The skin develops a permanent rash that physically blocks the virus from reentering

50. A person infected with HIV (the virus that causes AIDS) gradually loses the ability to fight off other infections because:

A. HIV attacks and destroys certain white blood cells that are central to the immune response
B. HIV produces a chemical that prevents the bone marrow from making any new blood cells
C. HIV makes the body produce antibodies against the patient's own healthy organ tissues
D. HIV physically blocks the airways, preventing oxygen from reaching the immune system

PRACTICE EXAM 20 – EXPLAINED ANSWER KEY (Q1–Q50)

1. A — The data show 154 of 200 observed cells in interphase, a much larger fraction than any other stage. Since time spent in a stage is proportional to the percentage of cells seen in it, interphase is by far the longest stage. Cells spend the bulk of their cycle growing and replicating DNA in preparation for division.

2. D — Metaphase is defined by the alignment of condensed chromosomes along the equatorial plane (metaphase plate) of the cell. Spindle fibers attach to centromeres and balance forces from opposite poles, holding chromosomes at the midline. This alignment ensures that sister chromatids will be separated equally during anaphase.

3. B — DNA replication occurs during the S (synthesis) phase of interphase, before the cell enters mitosis. This step doubles the genetic material so that each daughter cell can receive a complete copy. Errors during S phase produce mutations that may be passed on through subsequent cell divisions.

4. C — Mitosis produces two daughter cells that are genetically identical to each other and to the parent cell. The original chromosome set is duplicated during S phase and then divided equally during mitosis. This is the basis of growth and tissue repair in multicellular organisms.

5. A — Cancer arises when mutations disrupt the genes that normally control cell division, causing cells to divide without regulation and form tumors. This uncontrolled growth is the defining hallmark of cancer. Many cancer treatments target rapidly dividing cells precisely because of this loss of control.

6. D — As the inhibitor concentration rises from 0 to 10 mM, the rate of oxygen production falls steadily from 12 mL/min to 0 mL/min. This monotonic decline establishes that higher inhibitor concentrations slow catalase activity. Dose-response relationships of this kind are central to understanding enzyme inhibitors.

7. C — At 10 mM, every catalase active site is presumably either occupied or chemically altered by the inhibitor, leaving no enzyme available to break down hydrogen peroxide. With no functional enzyme, no oxygen is produced. This complete shutdown indicates that the inhibitor concentration was high enough to overwhelm the available enzyme.

8. B — The substrate of an enzyme is the molecule the enzyme acts upon. Catalase binds hydrogen peroxide at its active site and converts it into water and oxygen, so H2O2 is the substrate. Identifying substrate, enzyme, and product clearly is fundamental to understanding any enzyme-catalyzed reaction.

9. A — Many therapeutic drugs work by selectively inhibiting enzymes — antibiotics inhibit bacterial enzymes, statins inhibit a liver enzyme, and aspirin inhibits cyclooxygenase. By blocking key enzymes in disease processes, these drugs can stop or slow harmful reactions. Enzyme inhibition is therefore a foundational principle in pharmacology.

10. C — Reversibility is tested by removing the inhibitor and checking whether enzyme activity returns. If activity is restored after dialysis, the inhibition is reversible; if not, the inhibitor has permanently modified the enzyme. The other options do not separate the inhibitor from the enzyme and so cannot answer the question.

11. D — Different pigments absorb light most strongly at different wavelengths. By using multiple pigments together, a leaf can capture a much wider portion of the visible spectrum than chlorophyll a alone could. This broadens the range of light that can power photosynthesis.

12. B — Chlorophyll a has absorption peaks in the red and blue regions of the visible spectrum, with minimal absorption in the blue-green to green range. The wavelengths it does not absorb are reflected back to our eyes, producing its characteristic blue-green color. The visible color of any pigment is the light it does not absorb.

13. A — Chlorophyll b, xanthophyll, and carotene capture wavelengths (some green, yellow, and additional blue) that chlorophyll a does not absorb efficiently. They then transfer the captured energy to chlorophyll a, the reaction-center pigment. This broadens the light-harvesting capacity of the chloroplast.

14. C — In paper chromatography, pigments separate based on their relative solubility in the moving solvent and their tendency to stick to the paper fibers. More soluble pigments travel farther up the paper; less soluble pigments lag behind. This is why the four pigments produce distinct bands at characteristic distances from the origin.

15. D — Chlorophyll is less stable than the accessory pigments (xanthophyll and carotene) and is broken down more rapidly as leaves prepare for winter. As chlorophyll fades, the yellow and orange pigments that were present all along become visible. The autumn colors were already in the leaf — they were simply masked by the dominant green of chlorophyll.

16. B — Yeast carry out anaerobic fermentation when oxygen is unavailable, converting glucose into ethanol plus CO2. Detecting ethanol in Bottle B is the diagnostic sign that fermentation occurred. This is the same biochemical process that humans exploit in brewing and winemaking.

17. A — Aerobic respiration completely oxidizes glucose to 6 CO2 + 6 H2O per glucose molecule, releasing far more CO2 (and far more ATP) than fermentation, which produces only 2 CO2 per glucose. With oxygen available, Bottle A's yeast extracted maximum energy and released maximum CO2. This explains the much larger CO2 yield in the aerobic bottle.

18. C — In bread dough, yeast cells ferment sugars and release CO2 gas, which is trapped in the gluten network and causes the dough to rise. The ethanol produced largely evaporates during baking. The leavening effect is therefore due to the CO2, not the alcohol.

19. B — When muscle cells run short of oxygen during intense exercise, they switch to anaerobic fermentation. Unlike yeast, human muscle produces lactic acid (not ethanol) as the end product. Buildup of lactic acid contributes to the muscle fatigue and burning sensation associated with strenuous effort.

20. D — Translation is the process by which the mRNA sequence is decoded at a ribosome and used to assemble a protein. The other options describe different molecular processes (DNA copying, RNA synthesis, sequence change). Translation is the second major step of gene expression after transcription.

21. C — Codon and anticodon pair in antiparallel fashion, with A-U and G-C base pairing. The codon 5′-AUG-3′ therefore pairs with the anticodon 3′-UAC-5′. This base-pairing rule ensures that the correct tRNA — and therefore the correct amino acid — is delivered to the ribosome for each codon.

22. A — Because the genetic code is read in groups of three nucleotides, inserting a single base shifts the reading frame for every codon downstream of the insertion. This frameshift typically scrambles the amino acid sequence of the rest of the protein, often producing a nonfunctional product. Frameshift mutations are usually far more damaging than single-base substitutions.

23. D — Transfer RNA molecules act as adapters: each tRNA carries a specific amino acid on one end and recognizes the mRNA codon for that amino acid via its anticodon on the other end. By matching the right anticodon to the right codon, tRNA ensures that amino acids are added to the protein in the correct order. Other molecules carry the message (mRNA) or catalyze peptide bonds (ribosome).

24. B — The ribosome is the cellular machine where translation takes place: it reads the mRNA codon by codon and links amino acids delivered by tRNAs into a polypeptide chain. Ribosomes consist of rRNA and proteins and are found free in the cytoplasm or attached to the rough endoplasmic reticulum. Without ribosomes, no proteins could be produced.

25. C — A Punnett square of RR′ × RR′ produces 1 RR : 2 RR′ : 1 R′R′. Because each genotype expresses a distinct flower color under incomplete dominance, the phenotypic ratio matches the genotypic ratio at 1 red : 2 pink : 1 white. This contrasts with complete dominance, where these same genotypes would give a 3:1 phenotypic ratio.

26. A — In incomplete dominance, the heterozygous phenotype appears as a blend between the two homozygous phenotypes. The pink color of RR′ snapdragons is intermediate between the red RR and white R′R′ extremes, fitting this definition precisely. Codominance, in contrast, would produce a flower with separate red and white patches.

27. B — Crossing homozygous red (RR) with homozygous white (R′R′) produces only RR′ heterozygotes, all of which are pink. This is the most reliable way to obtain a uniformly pink generation. The other crosses produce a mixture of phenotypes or no pink offspring at all.

28. D — Among the four equally likely outcomes of RR′ × RR′, two (1 RR + 1 R′R′) are homozygous and two (2 RR′) are heterozygous. The probability of being homozygous is therefore 2/4 = 50%. This even split is characteristic of crosses between two heterozygotes.

29. C — In incomplete dominance, the heterozygote shows a blended intermediate phenotype (such as pink from red and white). In codominance, both alleles are expressed simultaneously and fully (as in human AB blood type, where both A and B antigens appear). The two patterns are genuinely distinct, even though both produce heterozygous phenotypes different from either homozygote.

30. A — The MRSA story is a textbook example of natural selection: heritable variation in antibiotic resistance, environmental pressure from antibiotic use, and differential reproduction of the resistant variants leading to a shifted population. Each generation makes resistance more common. This shows that evolution can occur observably within human time frames.

31. D — Antibiotic resistance arises from random mutations in bacterial DNA, not from a directed response to the drug. Such mutations occur continually in large bacterial populations regardless of antibiotic presence. The antibiotic does not cause the mutation — it merely selects for bacteria that already happen to carry resistance alleles.

32. B — Natural selection occurs when an environmental factor (here, the antibiotic) causes differential survival and reproduction among variants in a population. Resistant bacteria reproduce while sensitive ones die, increasing resistance frequency over generations. This is exactly the mechanism Darwin proposed, observed in real time in a clinical setting.

33. C — When patients stop antibiotics early, the most resistant bacteria — the ones that survived the longest — are left alive to reproduce. These selected survivors then dominate the population, accelerating the evolution of resistance. Completing the full course aims to eliminate even the toughest bacteria before they can multiply.

34. A — Rapid bacterial generation times mean that selection acts on many generations within a short period. Each generation provides another chance for resistant variants to outreproduce sensitive ones, so resistance can spread through a population in days rather than centuries. This is one reason bacterial evolution is so easy to observe directly.

35. B — Natural selection can only act on traits that are encoded in DNA and inherited by daughter cells. Antibiotic resistance must therefore be a heritable, gene-based trait — not learned, acquired, or temporarily induced. The resistance genes are then passed on each time a bacterium divides.

36. D — Reducing unnecessary antibiotic use limits the selection pressure that drives resistance, and completing prescribed courses ensures that surviving partially resistant bacteria are eliminated before they can reproduce. Together these practices slow the evolution of resistance. Public health programs worldwide emphasize this dual strategy.

37. C — Because DDT is fat-soluble and not readily excreted, each organism keeps the DDT it has consumed in its tissues. Predators accumulate the DDT from all the prey they eat over a lifetime, so concentrations are highest at the top of the food chain. This is the defining pattern of biomagnification.

38. A — DDT's persistence and fat solubility mean that organisms cannot easily eliminate it, and predators consume many prey over time. The DDT load from each prey item is added to the predator's body, so concentrations rise dramatically with each trophic level. This makes top predators uniquely vulnerable to persistent pollutants.

39. D — DDT interfered with calcium metabolism in birds, producing eggshells too thin to bear the weight of incubating parents. The cracked eggs prevented chicks from developing, leading to widespread reproductive failure and population collapse. Several iconic species, including the bald eagle and peregrine falcon, were brought to the brink of extinction by this effect.

40. B — Once DDT entered the environment, it took decades to degrade and clear from food webs. As DDT levels gradually dropped, eggshells thickened and reproductive success returned, allowing predator populations to recover. The bald eagle's recovery — culminating in its removal from the endangered species list in 2007 — is a major conservation success story.

41. C — The DDT case demonstrates that synthetic chemicals released into the environment can persist, spread through food webs, and harm species far removed from the original target. Effects can be slow to appear and difficult to reverse. This principle now guides the regulation of pesticides, plastics, and other persistent organic pollutants worldwide.

42. A — Evaporation is the change of liquid water into water vapor, driven by heat energy from the Sun. Most of Earth's atmospheric water vapor originates from evaporation at the ocean surface. This is the primary mechanism by which water enters the atmosphere.

43. B — Transpiration is the release of water vapor from the leaves of plants through small pores called stomata. It accompanies the upward flow of water from roots to leaves and contributes significantly to atmospheric moisture, especially over forests. Together, evaporation and transpiration are sometimes referred to as "evapotranspiration."

44. D — When water vapor rises into cooler regions of the atmosphere, it condenses into tiny liquid droplets that collect to form clouds. Once droplets grow large enough, they fall as precipitation. Condensation is the necessary intermediate step between evaporation and precipitation.

45. C — The water cycle continuously redistributes fresh water across Earth's surface through precipitation and runoff. This delivers the water that plants, animals, and entire ecosystems depend on for survival. Without the cycle, most terrestrial life would be impossible.

46. A — Antigens are molecules (often proteins or carbohydrates) on a pathogen's surface that the immune system identifies as foreign. Recognition of antigens by specialized white blood cells triggers an immune response tailored to that particular pathogen. Each pathogen carries a unique set of antigens, allowing specific identification.

47. D — Antibodies are large Y-shaped proteins produced by B cells. Their precise three-dimensional shape allows each antibody to bind a specific antigen with very high specificity, much like an enzyme binds its substrate. This specificity is what makes antibody-based defenses so effective and so adaptable.

48. B — Vaccines contain weakened, inactivated, or fragmented forms of a pathogen — enough to trigger an immune response without causing disease. The immune system makes antibodies and memory cells in response, so it can mount a rapid defense if the real pathogen invades later. This is the foundation of immunization programs worldwide.

49. C — During a chickenpox infection, the immune system produces memory B and T cells specific to the virus. These memory cells persist for decades and can mount a rapid, strong response if the virus is encountered again, usually preventing illness. This long-term protection is what we mean by acquired immunity.

50. A — HIV specifically targets and destroys helper T cells (CD4 cells), which coordinate the activity of the rest of the immune system. As helper T cells decline, the body loses its ability to respond effectively to other pathogens, leaving the patient vulnerable to opportunistic infections. This progressive immune failure defines the transition from HIV infection to AIDS.