PRACTICE EXAM 23: LIFE SCIENCE: BIOLOGY SIMULATION (50 QUESTIONS)

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.

Students investigated how cell size affects the ability of substances to diffuse throughout a cell. They constructed model "cells" using cubes of agar gel that contained the indicator phenolphthalein, which turns pink in the presence of a base. The students prepared three cubes of different sizes (1 cm, 2 cm, and 3 cm on each side) and placed each cube into a beaker of 0.1 M sodium hydroxide (NaOH) solution. After 10 minutes, the students removed the cubes, cut them open, and measured how far the pink color had penetrated from the surface toward the center. The data are summarized below.

Cube Side Length (cm)	Surface Area (cm^2)	Volume (cm^3)	Surface Area : Volume Ratio	Percentage of Cube Turned Pink
1	6	1	6.0 : 1	100%
2	24	8	3.0 : 1	65%
3	54	27	2.0 : 1	35%

1. What is the main scientific question this experiment is designed to investigate?

A. Whether sodium hydroxide can chemically react with phenolphthalein when no agar is present at all B. Whether agar cubes float or sink when placed into a solution of sodium hydroxide of any concentration C. How the size of a cell-like cube affects the diffusion of substances into the interior D. Whether all cubes will eventually turn pink regardless of their size and surface area to volume ratio

2. As the side length of the cube increased, the surface-area-to-volume ratio:

A. Decreased, meaning each unit of volume had less surface area available for diffusion B. Increased, meaning each unit of volume had more surface area available for diffusion C. Remained the same, because surface area and volume increased at identical rates D. Increased and then decreased again as the cube became too large for diffusion to occur

3. The smallest cube (1 cm) turned 100% pink while the largest cube (3 cm) turned only 35% pink. This pattern best demonstrates that:

A. Larger cubes contain more phenolphthalein than smaller cubes from the very start B. Sodium hydroxide cannot diffuse into any cube larger than 1 cm on each side C. Smaller cubes contain more sodium hydroxide than larger cubes after testing D. Smaller cubes can diffuse substances throughout their entire volume more efficiently

4. The agar cubes are most useful as a model for cells because they demonstrate why:

A. Cells must maintain a constant temperature throughout their entire interior at all times B. Cells must remain small to allow efficient diffusion of substances across the membrane C. Cells need to contain DNA in order to control their internal chemical activities D. Cells with thicker walls can absorb substances more easily than thin-walled cells

5. Based on these results, very large single-celled organisms would likely have difficulty:

A. Reproducing rapidly enough to maintain a constant population size in their environment B. Producing all of the digestive enzymes required to survive in their natural habitat C. Transporting oxygen and nutrients quickly enough to all parts of the cell interior D. Forming a true nucleus that contains the genetic material of the entire organism

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

An enzyme called succinate dehydrogenase normally catalyzes the conversion of succinate (its natural substrate) into fumarate during cellular respiration. Researchers added a chemical called malonate to a test tube containing this enzyme and succinate. Malonate has a chemical structure very similar to that of succinate, but the enzyme cannot convert malonate into a product. The researchers measured the rate of fumarate production at different concentrations of succinate, both with and without malonate present. The results are summarized below.

Succinate Concentration (mM)	Rate Without Malonate (μmol/min)	Rate With Malonate (μmol/min)
1	8	3
5	25	12
10	35	22
50	48	45
100	50	50

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6. The data show that adding malonate to the reaction has what overall effect?

A. Decreases the reaction rate at low succinate concentrations but not at very high concentrations B. Increases the reaction rate at every succinate concentration tested in the experiment C. Has absolutely no effect on the reaction rate at any succinate concentration tested D. Completely stops the reaction so that no fumarate is produced at any concentration

7. Malonate is best classified as a:

A. Substrate for the enzyme, which is converted into fumarate during the reaction B. Competitive inhibitor of the enzyme that competes with succinate for the active site C. Coenzyme that helps the enzyme function more efficiently at all substrate levels D. Product of the reaction that builds up in the test tube over time and stops it

8. At very high succinate concentrations (50 and 100 mM), the rate with malonate was nearly identical to the rate without malonate. The best explanation is that:

A. Malonate is destroyed by high concentrations of succinate before the reaction begins B. The enzyme stops being affected by inhibitors once the temperature exceeds 37°C C. High succinate concentrations convert malonate molecules into more succinate molecules D. Excess succinate outcompetes malonate for the enzyme's active sites at high concentrations

9. The fact that malonate inhibits succinate dehydrogenase because of its similar structure illustrates that:

A. Enzymes can change the shape of their active sites to accept any molecule presented B. Inhibitors must always be larger than the substrate to fit into the enzyme's active site C. Enzyme active sites have specific shapes that bind only certain molecules D. Inhibitors and substrates always produce identical products in any enzyme reaction

10. Drugs that act as competitive enzyme inhibitors typically work by:

A. Permanently destroying the enzyme so that it can never function again in any cell B. Binding to the active site of an enzyme and blocking the natural substrate from binding C. Increasing the rate at which the enzyme catalyzes its own normal reactions D. Adding new chemical groups to the substrate before it reaches the active site

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

Students examined the lower surface of a leaf under a microscope and observed many small pores called stomata. Each stoma is bordered by two specialized guard cells that can change shape to open or close the pore. Stomata allow gases (CO2, O2, and water vapor) to move into and out of the leaf. Students recorded the percentage of stomata that were open at different times on a sunny summer day. The data are shown below.

Time of Day	Percentage of Stomata Open
6:00 AM	15%

9:00 AM	75%
12:00 PM (noon)	85%
3:00 PM	70%
6:00 PM	30%
9:00 PM	5%

11. Stomata are open most widely during the middle of the day. This timing is well-suited to photosynthesis because:

A. CO2 must enter the leaf for photosynthesis, which can only occur during daylight hours B. O2 must enter the leaf for photosynthesis to take place inside the leaf during the day C. The leaves must release glucose to the environment during the middle of the day D. Open stomata at noon prevent any water from leaving the leaves during the day

12. Which gas enters the leaf through open stomata to be used in photosynthesis?

A. Nitrogen gas, which is used to build amino acids inside the leaf's photosynthetic cells B. Oxygen gas, which is used to build glucose molecules during the light-independent reactions C. Water vapor, which is split inside the leaf to provide hydrogen for the sugar molecules D. Carbon dioxide, which is incorporated into glucose during photosynthesis

13. Stomata also allow water vapor to escape from the leaf. The loss of water vapor through the stomata is called:

A. Photosynthesis, the process by which leaves create sugar from carbon dioxide and water B. Respiration, the process by which leaves break down sugar to release usable energy C. Transpiration, the loss of water vapor through the stomata of a leaf D. Condensation, the process by which water vapor turns back into liquid water again

14. During a hot, dry afternoon, plants often partially close their stomata. This response helps the plant by:

A. Reducing water loss from the leaf, preventing the plant from drying out B. Increasing photosynthesis by allowing more CO2 to enter the leaf interior C. Releasing oxygen at higher rates than would normally occur during the day D. Increasing the absorption of nitrogen from the air through the leaf surface

15. A plant kept in continuous darkness for several days would most likely show:

A. Open stomata at all times to maximize the absorption of carbon dioxide quickly B. Closed stomata because photosynthesis cannot occur without any sunlight C. Increased rates of photosynthesis to compensate for the absence of light energy D. Increased rates of transpiration because the plant has no light energy to use

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

Cellular respiration is the process by which cells extract energy from food. Aerobic respiration uses oxygen and produces a large amount of ATP, along with carbon dioxide and water as waste products. When oxygen is unavailable, some cells can carry out anaerobic respiration (fermentation), which produces a much smaller amount of ATP. Yeast cells undergo alcoholic fermentation, producing ethanol and CO2 as waste products. Human muscle cells undergo lactic acid fermentation, producing lactic acid (and no CO2). All forms of respiration begin with glycolysis, which takes place in the cytoplasm and does not require oxygen.

16. The first stage of all forms of cellular respiration is:

A. The citric acid cycle, which produces most of the cell's ATP from each glucose molecule B. The electron transport chain, which uses oxygen as the final electron acceptor C. Glycolysis, which breaks down glucose into smaller molecules in the cytoplasm D. Fermentation, which produces ethanol or lactic acid from each glucose molecule

17. Which of the following is a product of yeast alcoholic fermentation but NOT human lactic acid fermentation?

A. ATP, which is the energy molecule produced by all forms of cellular respiration B. Glucose, which serves as the starting molecule for the fermentation pathway C. Pyruvate, which is the molecule that enters fermentation from glycolysis D. Carbon dioxide, which is produced by yeast but not by human muscle cells

18. The reason fermentation produces much less ATP than aerobic respiration is that:

A. Fermentation does not include the citric acid cycle or the electron transport chain B. Fermentation produces more heat than ATP, wasting most of the available energy C. Fermentation reactions occur much more slowly than aerobic respiration reactions D. Fermentation requires more glucose molecules per ATP produced than aerobic respiration

19. One major industrial use of yeast fermentation is the:

A. Production of antibiotics that are used to fight bacterial infections in patients B. Production of bread, beer, and wine, all of which depend on yeast fermentation C. Production of nuclear energy through controlled fermentation in power plants D. Production of pure oxygen for use in hospitals to treat patients with lung disease

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

The structure of DNA was first described by James Watson and Francis Crick in 1953, based on data collected by Rosalind Franklin and others. DNA consists of two long strands of nucleotides wound together into a double helix. Each nucleotide contains a sugar (deoxyribose), a phosphate group, and one of four nitrogenous bases: adenine (A), thymine (T), guanine (G), or cytosine (C). The two strands are held together by hydrogen bonds between complementary base pairs: adenine always pairs with thymine, and guanine always pairs with cytosine. The sequence of bases along a DNA strand carries the genetic information used to build proteins.

20. In the DNA molecule, adenine always pairs with:

A. Guanine, with which it forms three hydrogen bonds across the double helix B. Cytosine, with which it forms two hydrogen bonds across the double helix C. Thymine, with which it forms two hydrogen bonds across the double helix D. Adenine itself, in a structure called an adenine-adenine self-pairing pattern

21. If one strand of a DNA molecule has the sequence A–T–G–C–T–A, the complementary strand will have the sequence:

A. A–T–G–C–T–A, in which the new strand exactly matches the original template strand B. U–A–C–G–A–U, in which uracil replaces thymine in the complementary strand sequence C. G–C–A–T–G–C, in which the bases are reversed but not complementary to the strand D. T–A–C–G–A–T, in which each base is paired with its specific complement

22. The two strands of DNA are described as "antiparallel" because they:

A. Run in opposite directions along the double helix, with one running 5′ to 3′ and the other 3′ to 5′ B. Are made of completely different chemical units that do not bind to each other at all C. Carry opposite genetic information, with one strand encoding life and one encoding death D. Are wound together so tightly that they cannot be separated under any circumstances

23. The sequence of bases along a DNA strand carries the genetic information that:

A. Determines the precise number of cells that an organism will have at birth B. Causes an organism to age at exactly the same rate as all members of its species C. Codes for the amino acid sequences of all proteins produced by the cell D. Provides the ATP energy that all cellular processes require to function properly

24. The shape of the DNA molecule is described as a:

A. Single helix made of a single twisted strand of nucleotides arranged in a row B. Double helix made of two complementary strands twisted around each other C. Branching tree of nucleotides extending outward from one central main strand D. Flat sheet of nucleotides arranged in rows and columns in a flat plane

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

In a particular plant species, the gene for seed color and the gene for seed shape are located on different chromosomes and assort independently during meiosis. The allele for yellow seeds (Y) is dominant over the allele for green seeds (y). The allele for round seeds (R) is dominant over the allele for wrinkled seeds (r). A plant heterozygous for both traits (genotype YyRr) is crossed with another plant that is also heterozygous for both traits (also YyRr). This is called a dihybrid cross.

25. The expected phenotypic ratio of the offspring from this dihybrid cross is:

A. 1 yellow-round : 1 yellow-wrinkled : 1 green-round : 1 green-wrinkled offspring B. 3 yellow-round : 1 green-wrinkled, with no other phenotypes appearing in the cross C. All offspring will be yellow and round, identical to both of the parent plants D. 9 yellow-round : 3 yellow-wrinkled : 3 green-round : 1 green-wrinkled

26. The principle that the gene for seed color and the gene for seed shape are inherited independently is known as Mendel's law of:

A. Independent assortment, which describes the random separation of alleles for different genes during meiosis B. Segregation, which describes the separation of two alleles for the same gene during meiosis C. Dominance, which describes the masking of one allele by another during the expression of a trait D. Codominance, which describes the simultaneous expression of two alleles in the heterozygote

27. What percentage of offspring from this YyRr × YyRr cross is expected to have green, wrinkled seeds (genotype yyrr)?

A. 0%, because at least one parent must contribute a dominant allele for both genes B. 50%, because half of all offspring of two heterozygotes are homozygous recessive C. 25%, because one of every four offspring will be homozygous recessive at one gene D. About 6%, because 1 of every 16 combinations is yyrr in a standard dihybrid cross

28. How many different genotypes are possible among the offspring of a YyRr × YyRr cross?

A. Four, including only the four phenotype classes (YR, Yr, yR, and yr) of the offspring B. Nine, including all possible combinations of YY, Yy, yy and RR, Rr, rr alleles C. Sixteen, with each Punnett square box representing a separate, unique genotype D. Three, including only the homozygous and heterozygous types for one gene at a time

29. What percentage of offspring from a YyRr × YyRr cross would have a phenotype of both yellow seeds and round seeds (the double dominant)?

A. About 56%, which corresponds to 9 of 16 boxes in the Punnett square having both dominants B. Exactly 25%, which corresponds to 4 of 16 boxes having a combination of both dominants C. Exactly

75%, which corresponds to 12 of 16 boxes having a combination of both dominants D. Exactly 100%, because both parents have at least one dominant allele for each trait

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

Scientists studying evolution look for evidence that different species share common ancestors. One important line of evidence comes from comparing anatomical structures. Homologous structures are body parts that may look different and perform different functions in different species but share a common underlying structure inherited from a common ancestor (for example, the forelimbs of a human, a whale, a bat, and a cat all share the same arrangement of bones, even though they function as arms, flippers, wings, and legs). Analogous structures, in contrast, are body parts that may look similar and perform similar functions but evolved independently in unrelated species (for example, the wings of an insect and the wings of a bird both serve for flight but have completely different internal structures).

30. The forelimbs of a human, a whale, a bat, and a cat all share the same internal bone arrangement. These limbs are best described as:

A. Vestigial structures, which are remnants of features used by an extinct common ancestor B. Analogous structures, which evolved similar functions independently in unrelated species C. Embryonic structures, which appear only during the development of the early embryo D. Homologous structures, which share a common evolutionary origin across species

31. The wings of an insect and the wings of a bird both serve for flight but have completely different internal anatomies. These wings are best described as:

A. Homologous structures, which share a common evolutionary origin in the animal kingdom B. Vestigial structures, which are remnants of structures used by a recent common ancestor C. Analogous structures, which independently evolved similar functions for the same purpose D. Identical structures, which are evidence that the two species share a recent common ancestor

32. Homologous structures provide evidence for evolution because they:

A. Show that all species are perfectly adapted to their current environments B. Suggest that different species inherited the same underlying body plan from a common ancestor C. Show that no two species have evolved to share any common physical traits with each other D. Suggest that species learn to develop new structures during their lifetimes

33. The wings of a bird and the wings of a bat share the same underlying bone arrangement (one upper bone, two lower bones, wrist bones, and digits). These wings are best classified as:

A. Homologous structures, because they share the same underlying bone arrangement B. Analogous structures, because birds and bats are completely unrelated species C. Vestigial structures, because the wings are no longer used for any function D. Embryonic structures, because the wings only appear during embryonic development

34. The fact that bird wings and insect wings are analogous rather than homologous structures supports the conclusion that:

A. Birds and insects share an immediate common ancestor that also had wings for flight B. Birds evolved from flying insects over the course of many generations of insects C. Wings have evolved more than once in different animal groups through convergent evolution D. Birds and insects are members of the same biological class of animals at all

35. Comparing the early embryos of fish, chickens, and humans reveals striking similarities in body structure, such as the presence of gill-like pouches and tails. This observation supports the idea that:

A. Fish, chickens, and humans are identical in their adult body plans and behavior at all stages B. Embryos are completely different from adults of the same species in every way possible C. Embryos can be transformed from one species to another by changing their environment D. All vertebrates share a common ancestry, as revealed by their similar embryonic development

36. In addition to comparative anatomy, modern evidence for evolution also includes:

A. Religious teachings that have been preserved through many generations of historical record B. DNA sequence comparisons, which show how closely different species are genetically related C. The opinions of expert biologists, which can be used in place of physical evidence D. The behaviors that individual organisms display during their own lifetimes only

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

Energy flows through ecosystems in one direction: from the Sun to producers (plants) to consumers and finally to decomposers. At each step (trophic level), most of the energy taken in by an organism is used for life processes such as growth, movement, and maintaining body temperature, and is ultimately lost as heat to the environment. Only about 10% of the energy at one trophic level is incorporated into the next level. This relationship is often represented as an energy pyramid, with producers at the base (containing the most available energy) and top predators at the apex (containing the least). Because of this energy loss, food chains rarely have more than four or five trophic levels.

37. If producers in an ecosystem contain 10,000 kilocalories (kcal) of available energy, approximately how much energy would be available to primary consumers (herbivores)?

A. About 1,000 kcal, because roughly 10% of energy is transferred to the next trophic level B. About 5,000 kcal, because roughly half of energy is transferred to the next trophic level C. About 100 kcal, because most energy passes through the system as heat radiation D. About 10,000 kcal, because energy is conserved without loss between trophic levels

38. Most of the energy taken in by an organism at one trophic level is:

A. Stored permanently in the body of the organism as a chemical compound for future use B. Passed to the decomposers in a single quick transfer at the end of each organism's life C. Transferred efficiently to the next trophic level with very little loss of any kind D. Used for life processes and ultimately lost as heat to the surrounding environment

39. Food chains rarely have more than four or five trophic levels because:

A. Top predators in nature actively avoid forming more than four levels in a chain B. Decomposers prevent the formation of food chains of more than four trophic levels C. So little energy reaches the highest levels that they cannot support large populations D. Higher trophic levels would require organisms that have never evolved on Earth

40. Producers form the base of the energy pyramid because they:

A. Are the largest organisms in any ecosystem, containing the most total biomass B. Capture energy from the Sun and convert it into the chemical energy stored in food C. Are the only organisms in the ecosystem that need to perform cellular respiration D. Are eaten directly by every organism at every higher level in the energy pyramid

41. An ecosystem with a large number of producers can typically support:

A. More consumers at higher trophic levels than an ecosystem with few producers B. Fewer consumers because the producers compete with consumers for resources C. Only one consumer for every thousand producers in the ecosystem at any time D. No consumers at all, because the producers consume all of the available energy

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

Phosphorus is an essential element for life. It is a key component of DNA, RNA, ATP, and the phospholipids of cell membranes. Unlike carbon and nitrogen, phosphorus does not have a common gaseous form and does not cycle through the atmosphere. Instead, phosphorus is released slowly from rocks and minerals through weathering, taken up by plants from the soil, and passed through food chains to animals. When organisms die, decomposers return phosphorus to the soil. Phosphorus runoff from agricultural fertilizers and sewage can enter lakes and streams, where excess phosphorus can cause rapid algal growth (algal blooms). When the algae die, decomposers consume the oxygen in the water, killing fish and other aquatic organisms. This process is called eutrophication.

42. Phosphorus is essential for life primarily because it is a key component of:

A. Cell walls of plant cells and the cellulose found inside them B. Hemoglobin, the protein that carries oxygen in the bloodstream of all vertebrates C. DNA, RNA, ATP, and the phospholipids of all cell membranes D. Chlorophyll, the green pigment that absorbs light during photosynthesis in plants

43. Unlike the carbon and nitrogen cycles, the phosphorus cycle does not significantly involve:

A. The decomposition of dead organisms by bacteria and fungi in the surface soil B. The uptake of phosphorus by plants from the soil through their root systems C. The movement of phosphorus through food chains from one organism to another D. The cycling of phosphorus through the atmosphere as a gas between organisms

44. Excess phosphorus runoff from fertilizers and sewage entering a lake often causes:

A. An immediate decrease in algal growth and a complete clearing of the lake water B. Rapid algal blooms, followed by oxygen depletion and the death of aquatic organisms C. A permanent increase in fish populations due to the additional plant nutrients D. The complete elimination of all decomposers in the bottom sediments of the lake

45. The death of fish during eutrophication is most directly caused by:

A. Oxygen depletion in the water as decomposers break down the large mass of dead algae B. The presence of additional phosphorus in the water poisoning the fish gills directly C. The fish being eaten more rapidly by the increased numbers of large algal organisms D. Increased water temperature caused by the dense layer of algae on the lake surface

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

The human circulatory system is a closed system that transports blood throughout the body. The heart, the central organ of the circulatory system, is a muscular pump with four chambers: the right atrium, right ventricle, left atrium, and left ventricle. Blood that has returned from the body enters the right atrium, passes to the right ventricle, and is pumped to the lungs to receive oxygen. Oxygen-rich blood returns from the lungs to the left atrium, passes to the left ventricle, and is pumped out to the rest of the body. Arteries carry blood away from the heart, veins return blood to the heart, and capillaries are the tiny vessels where exchange of gases and nutrients occurs between blood and body tissues.

46. Which chamber of the heart receives oxygen-rich blood returning from the lungs?

A. The right atrium, which receives oxygen-poor blood returning from the rest of the body B. The right ventricle, which pumps oxygen-poor blood out to the lungs for oxygenation C. The left atrium, which receives oxygen-rich blood returning from the lungs D. The left ventricle, which pumps oxygen-rich blood out to the rest of the body

47. Oxygen and nutrients are exchanged between the blood and body cells in the:

A. Arteries, which carry blood away from the heart to body tissues under high pressure B. Capillaries, the smallest vessels with very thin walls that allow rapid exchange C. Veins, which carry blood back toward the heart from the tissues of the body D. Aorta, the largest artery in the body that carries blood from the left ventricle

48. Which type of blood vessel carries blood away from the heart to the body's tissues?

A. Veins, which carry blood under relatively low pressure back toward the heart B. Capillaries, where exchange occurs between blood and body cells in the tissues C. Venules, which collect blood from the capillaries and merge into larger veins D. Arteries, which carry blood under high pressure away from the heart

49. The function of red blood cells in the circulatory system is to:

A. Transport oxygen from the lungs to body tissues using the protein hemoglobin B. Defend the body against invading bacteria, viruses, and other harmful pathogens C. Form clots at the site of wounds to prevent excessive loss of blood from the body D. Carry digested food molecules from the small intestine to the cells of the body

50. A person whose heart cannot effectively pump blood would most likely experience:

A. Increased oxygen delivery to all body tissues, leading to improved energy levels B. A lowered demand for oxygen by cells throughout the body during this condition C. Fatigue, weakness, and shortness of breath due to inadequate oxygen delivery to cells D. Improved health because the body would adapt to require less circulating blood

PRACTICE EXAM 23 — EXPLAINED ANSWER KEY (Q1–Q50)

1. C — The experiment varies cube size (the model "cell" size) and measures how far NaOH diffuses into each cube. This setup is designed to reveal the relationship between cell size and diffusion efficiency. The data link surface-area-to-volume ratio to how completely substances penetrate the interior.

2. A — Surface area increases with the square of side length while volume increases with the cube of side length, so volume grows faster than surface area. The SA:V ratio therefore falls from 6:1 to 3:1 to 2:1 as the cube enlarges. Less surface per unit of volume means less area available for diffusion to supply each part of the interior.

3. D — Because the small cube had a much higher SA:V ratio, NaOH could reach all of its interior within the 10-minute window, turning it 100% pink. The large cube had far less surface per unit volume, so its center was never reached. This is a direct demonstration that diffusion is more efficient in smaller volumes.

4. B — Real cells are limited by the same SA:V relationship: a cell too large cannot exchange oxygen, nutrients, and wastes through its membrane fast enough to supply its interior. This constraint is the main reason cells are microscopic and divide rather than continuing to grow indefinitely. Tissues use many small cells rather than a few large ones.

5. C — A very large single cell would have a low SA:V ratio, so its membrane could not supply oxygen and nutrients to deeper regions or remove wastes quickly enough. Diffusion is too slow over long distances inside the cell. This is one reason multicellular organisms exist instead of giant single cells.

6. A — Comparing the two columns shows that at low succinate (1 mM and 5 mM) the rate falls sharply with malonate, while at high succinate (50 mM and 100 mM) the rates are nearly identical. Inhibition is therefore concentration-dependent and disappears when substrate is plentiful. This pattern is the signature of competitive inhibition.

7. B — Malonate resembles succinate closely enough to fit the active site but cannot be converted, so it blocks the enzyme without being used up. Because it competes with succinate for the same site, it is a competitive inhibitor. Many drugs in medicine — including statins and some anti-cancer agents — work by this mechanism.

8. D — At high succinate concentrations, succinate molecules vastly outnumber malonate molecules and win the competition for the active site almost every time. The enzyme therefore approaches its normal maximum rate. This "outcompeting" behavior is the hallmark of competitive inhibition.

9. C — Malonate inhibits the enzyme only because its shape closely mimics the natural substrate, allowing it to fit into the active site. Molecules with very different shapes would not bind at all. This shape specificity is what allows enzymes — and the drugs that target them — to be so selective.

10. B — A competitive inhibitor blocks the enzyme by occupying the active site, preventing the natural substrate from binding. Catalysis stops as long as the inhibitor is in place. This is the basis of many pharmaceutical drugs, including some antibiotics and antihypertensives.

11. A — Photosynthesis requires both light and CO2. Opening the stomata during the brightest part of the day lets CO2 diffuse in just when light is most available to drive the reactions. This matching of stomatal opening to sunlight maximizes the leaf's photosynthetic output.

12. D — Carbon dioxide enters the leaf through open stomata and is fixed into glucose during the light-independent reactions of photosynthesis. The other gases listed are either products (oxygen) or not involved in this process. CO2 supply often becomes a limiting factor for photosynthesis when stomata are closed.

13. C — Transpiration is the loss of water vapor from leaves, mostly through open stomata. Although it costs the plant water, transpiration also generates the "pull" that draws water and dissolved minerals up the xylem from the roots. The plant constantly balances the trade-off between CO2 uptake and water loss.

14. A — Closing the stomata during hot, dry conditions blocks the path by which water vapor would otherwise escape, conserving the plant's water supply. The trade-off is reduced CO2 uptake and slower photosynthesis. Plants adapted to dry climates have evolved many variations on this strategy.

15. B — Light is the trigger that signals guard cells to open the stomata; without light, photosynthesis stops and there is no benefit to opening. Closed stomata also reduce unnecessary water loss in the dark. This light-dependent regulation is part of how plants coordinate stomatal function with photosynthetic activity.

16. C — Glycolysis is the first stage of every form of cellular respiration, splitting glucose into two pyruvate molecules in the cytoplasm. Because it does not require oxygen, it can proceed under both aerobic and anaerobic conditions. Whatever happens next — citric acid cycle or fermentation — depends on oxygen availability.

17. D — Yeast convert pyruvate to ethanol and release CO2 as a byproduct. Human muscle cells convert pyruvate to lactic acid without producing CO2. CO2 is therefore the distinguishing byproduct of alcoholic (yeast) fermentation versus lactic acid (muscle) fermentation.

18. A — Fermentation stops after glycolysis and an extra step to regenerate NAD+, so it never goes through the high-yield citric acid cycle or electron transport chain. The result is only about 2 ATP per glucose, compared with about 36 from aerobic respiration. Most of glucose's energy remains locked in the fermentation byproducts.

19. B — Yeast fermentation is the basis of much of the food and beverage industry: the CO2 makes bread rise, and the ethanol is what makes beer and wine alcoholic. Industrial-scale fermentation has supported these products for thousands of years. The other options describe processes that have nothing to do with yeast metabolism.

20. C — Adenine and thymine pair through two hydrogen bonds, while guanine and cytosine pair through three. This A–T, G–C pairing rule explains why the two DNA strands always have complementary sequences. Errors in base pairing during replication are the source of point mutations.

21. D — Applying the A–T and G–C pairing rules to the sequence A-T-G-C-T-A gives T-A-C-G-A-T as the complementary strand. Uracil appears only in RNA, never in DNA, so options containing U are ruled out. This kind of base-pairing exercise is a foundational skill for understanding DNA replication and transcription.

22. A — Each DNA strand has a directional 5′ end and a 3′ end, and the two strands in a duplex run in opposite directions (one 5′→3′, the other 3′→5′). This antiparallel arrangement is necessary for correct base pairing and for the enzymes that copy DNA to work properly. It is one of the defining features of the double helix.

23. C — A gene's nucleotide sequence specifies the amino acid sequence of the protein it codes for, with each codon (three nucleotides) corresponding to one amino acid. The protein's sequence in turn determines its three-dimensional shape and biological function. This is the heart of the "central dogma" of molecular biology.

24. B — DNA's distinctive shape consists of two complementary nucleotide strands twisted together into a right-handed double helix. The sugars and phosphates form the outer "backbones," with paired bases stacked on the inside. Recognizing this structure won Watson and Crick the Nobel Prize in 1962.

25. D — A YyRr × YyRr cross is the classic dihybrid cross that produces the 9:3:3:1 phenotypic ratio in the F2 generation when both genes show complete dominance. This pattern emerges directly from the 16 boxes of the dihybrid Punnett square. It is the most famous numerical prediction in Mendelian genetics.

26. A — Mendel's law of independent assortment states that alleles of different genes are sorted into gametes independently of each other when the genes are on different chromosomes. This is why a parent's "yellow" allele does not have to travel with the "round" allele into the same gamete. The law explains the appearance of the 9:3:3:1 ratio in dihybrid crosses.

27. D — Only 1 of the 16 boxes in a dihybrid Punnett square contains the double-recessive yyrr genotype, giving 1/16 = 6.25%, which rounds to about 6%. This is the same logic that gives 1/4 (25%) for a single recessive in a monohybrid cross, applied to two independent traits. Recognizing this 1/16 ratio is a standard Regents-level skill.

28. B — Each gene contributes three possible genotypes (YY, Yy, yy and RR, Rr, rr), so combining the two genes gives 3 × 3 = 9 distinct genotypes overall. Several of these share phenotypes, which is why only four phenotype classes appear in the 9:3:3:1 ratio. The genotype-vs-phenotype distinction is important to keep straight.

29. A — In a 9:3:3:1 dihybrid ratio, 9 of the 16 boxes show both dominant phenotypes (yellow and round here). 9 ÷ 16 = 0.5625, or about 56%. This is the largest single phenotype class produced by a dihybrid cross of two heterozygotes.

30. D — The forelimbs of human, whale, bat, and cat share the same underlying bone arrangement because all four species inherited it from a common vertebrate ancestor. Different selective pressures then modified the limb for different purposes — grasping, swimming, flying, walking. This is the textbook definition of homologous structures.

31. C — Insect wings and bird wings serve the same function (flight) but evolved independently in lineages that did not share a winged ancestor. Their internal anatomy is completely different — one based on an insect exoskeleton, the other on vertebrate bones. This makes them analogous, not homologous.

32. B — When different species share an underlying body plan, the most parsimonious explanation is that they inherited it from a common ancestor and then modified it. Without common ancestry, the same complex pattern arising in many species would be extremely unlikely. This is one of the strongest lines of comparative anatomical evidence for evolution.

33. A — Even though bat wings and bird wings serve the same function, their underlying skeletons follow the same vertebrate limb plan inherited from a shared ancestor. They are therefore homologous structures despite their similar function. Their use as wings is a separate phenomenon — a case of convergent evolution on top of a homologous foundation.

34. C — Insect and bird wings arose independently in lineages whose last common ancestor was wingless. The fact that very different structural solutions for flight evolved in unrelated groups shows that natural selection can produce similar adaptations more than once. This pattern is the definition of convergent evolution.

35. D — All vertebrates pass through early embryonic stages that look remarkably similar, with pharyngeal pouches, post-anal tails, and segmented body plans. These shared features point to a shared evolutionary ancestor whose developmental program has been inherited by all descendants. The pattern is one of the classic lines of evidence for common descent.

36. B — Comparing DNA sequences between species directly measures the genetic similarity that comparative anatomy can only suggest. Species sharing a more recent common ancestor have more similar DNA, providing quantitative evolutionary evidence. Modern molecular biology has confirmed and extended virtually all the family trees originally drawn from anatomical comparisons.

37. A — The "10% rule" predicts that only about 10% of the energy at one trophic level is incorporated into the next. From 10,000 kcal in producers, primary consumers would therefore receive roughly 1,000 kcal. The remaining 90% is lost as heat, used for metabolism, or excreted as waste.

38. D — An animal uses most of the energy it consumes to power its own life processes — movement, growth, maintenance, body temperature — and most of that energy is ultimately lost as heat to the surroundings. Only a small fraction ends up stored in tissues that can be eaten by a predator. This inefficiency is what creates the energy pyramid.

39. C — Because each trophic level captures only about 10% of the previous level's energy, energy declines exponentially up the chain. After four or five transfers, so little energy remains that it cannot support a viable top-predator population. This is a fundamental constraint on food-chain length.

40. B — Producers (mainly plants, algae, and cyanobacteria) capture solar energy through photosynthesis and convert it into the chemical energy of organic molecules. All higher trophic levels are ultimately powered by this initial conversion. Without producers, the entire energy pyramid would collapse.

41. A — A larger producer base means more total energy is captured from the Sun and made available to higher levels. Even though only about 10% transfers at each step, a larger starting amount supports larger populations of consumers all the way up. This is why high-productivity ecosystems generally have richer animal communities.

42. C — Phosphate groups are part of the backbone of DNA and RNA, the energy-carrying bonds of ATP, and the phospholipids that make up cell membranes. Without phosphorus, none of these essential molecules could be built. This is why phosphorus is required by all known forms of life.

43. D — Carbon and nitrogen cycle through the atmosphere as CO2 and N2 gas, but phosphorus has no significant gaseous form under normal Earth conditions. It moves instead between rocks, soil, water, and organisms. This makes the phosphorus cycle much slower and more locally bound than the carbon or nitrogen cycle.

44. B — Excess phosphorus acts as a fertilizer for algae, triggering rapid population growth (blooms). When the algae die, decomposer bacteria consume oxygen as they break the algae down, leading to hypoxia and the death of aerobic aquatic life. This cascade is the defining sequence of eutrophication.

45. A — Fish need dissolved oxygen to breathe through their gills. When decomposers strip the lake of oxygen following an algal bloom, the fish suffocate. Phosphorus itself is not directly toxic — it is the resulting low oxygen levels that kill aquatic animals.

46. C — Oxygenated blood returning from the lungs through the pulmonary veins enters the left atrium. From there it moves to the left ventricle and is pumped out to the body through the aorta. Knowing this pulmonary-to-systemic flow is fundamental to understanding cardiovascular physiology.

47. B — Capillaries are only one cell thick, with walls thin enough that oxygen, CO2, and dissolved nutrients can diffuse rapidly between blood and surrounding tissue. Arteries and veins are too thick-walled for this exchange. The huge total surface area of the body's capillaries is what makes efficient gas and nutrient exchange possible.

48. D — By definition, arteries carry blood away from the heart to the body's tissues, while veins return blood toward the heart. The high pressure generated by the ventricles drives blood through the arteries. Arteries therefore have thick muscular walls to withstand and maintain this pressure.

49. A — Red blood cells contain hemoglobin, an iron-containing protein that binds oxygen in the lungs and releases it in body tissues. This delivery is essential because most cells depend on a steady oxygen supply for aerobic respiration. Conditions that reduce red blood cell number or hemoglobin function (such as anemia) impair oxygen delivery throughout the body.

50. C — When the heart pumps inadequately, cells throughout the body do not receive enough oxygen and nutrients for normal function. This produces the classic symptoms of heart failure: fatigue, weakness, and shortness of breath, often worsened on exertion. Effective cardiac output is essential for sustaining all aerobic body activities.