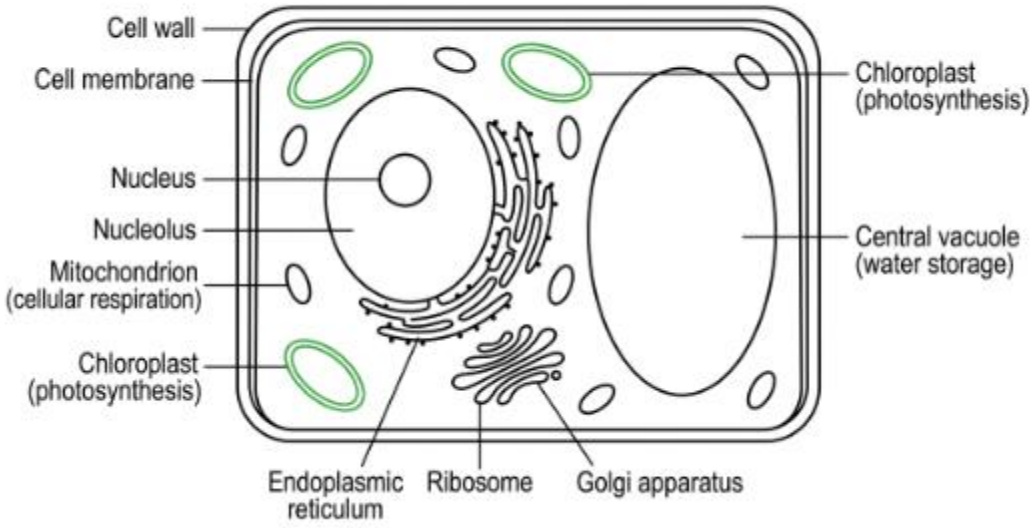
PRACTICE EXAM 13: LIFE SCIENCE: BIOLOGY SIMULATION (50 QUESTIONS)

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.

Eukaryotic cells contain a variety of membrane-bound and non-membrane organelles, each specialized for a particular function. The nucleus stores the genetic material and directs the activities of the cell. Mitochondria release energy from glucose through cellular respiration. Ribosomes assemble proteins from amino acids using mRNA. The endoplasmic reticulum and Golgi apparatus modify, sort, and package proteins and lipids. Plant cells contain additional structures such as a rigid cell wall, large central vacuole, and chloroplasts. The diagram below shows a typical plant cell with several organelles labeled.

Figure PQ-1



1. Which organelle is the primary site of cellular respiration in the cell?

A. The nucleus, where DNA stores the genetic information used by all the cell's processes
B. The ribosome, where individual amino acids are joined together into protein chains
C. The mitochondrion, where glucose is broken down to produce ATP for the cell's needs
D. The endoplasmic reticulum, where many proteins and lipids are synthesized inside the cell

2. Which organelle is responsible for assembling proteins from individual amino acids?

A. The lysosome, which contains digestive enzymes for the breakdown of cellular wastes
B. The ribosome, which reads the mRNA and links amino acids into a polypeptide chain
C. The vacuole, which stores water and other substances in the cytoplasm of plant cells
D. The centriole, which organizes the microtubules of the spindle during cell division

3. A plant cell differs from a typical animal cell by containing which specific structure?

A. A chloroplast, the organelle where photosynthesis converts sunlight into stored sugar
B. A nucleus, which contains the genetic material that directs all the activities of the cell
C. A ribosome, the organelle that produces all of the cellular proteins for daily activities
D. A mitochondrion, which produces most of the ATP that powers the activities of the cell

4. Which organelle is most directly responsible for packaging proteins for secretion outside the cell?

A. The nucleolus, where ribosomal RNA is produced inside the nucleus of the cell
B. The mitochondrion, where most of the cell's ATP is generated through respiration
C. The smooth endoplasmic reticulum, where lipids are synthesized for the cell membrane
D. The Golgi apparatus, where proteins are modified, sorted, and packaged into vesicles

5. A cell that produces and secretes large amounts of digestive enzyme would be expected to contain especially large numbers of:

A. Chloroplasts, since the production of digestive enzymes requires the energy of sunlight
B. Cell walls, since enzymes require additional structural support during their synthesis
C. Ribosomes and rough ER, since digestive enzymes are proteins that must be exported
D. Vacuoles, since the cell must store all of the digestive enzymes before releasing them

Base your answers to questions 6 through 9 on the information below and on your knowledge of biology.

The human digestive system breaks food down into nutrient molecules small enough to be absorbed into the bloodstream and used by body cells. Mechanical digestion physically reduces food into smaller pieces, while chemical digestion uses enzymes to break the chemical bonds in large food molecules. Different enzymes act on different food types at different locations along the digestive tract. The pancreas, liver, and salivary glands secrete digestive juices into the tract. The small intestine is the main

site of nutrient absorption, with its lining covered by tiny finger-like projections called villi that greatly increase its surface area.

6. Where does the chemical digestion of starch begin in the human digestive system?

A. In the stomach, where strong hydrochloric acid breaks down all starch into glucose units
B. In the mouth, where the enzyme salivary amylase begins breaking down starch into sugars
C. In the small intestine, where bile salts emulsify the starch into much smaller pieces
D. In the large intestine, where resident bacteria ferment any remaining starch into sugars

7. Most absorption of digested nutrients into the bloodstream takes place in the:

A. Stomach, where strong acid kills bacteria before any nutrients enter the blood
B. Esophagus, where smooth muscle contractions move swallowed food downward to the stomach
C. Large intestine, where most of the water and electrolytes are first absorbed into the body
D. Small intestine, where villi greatly increase the surface area available for absorption

8. The villi and microvilli of the small intestine are best described as:

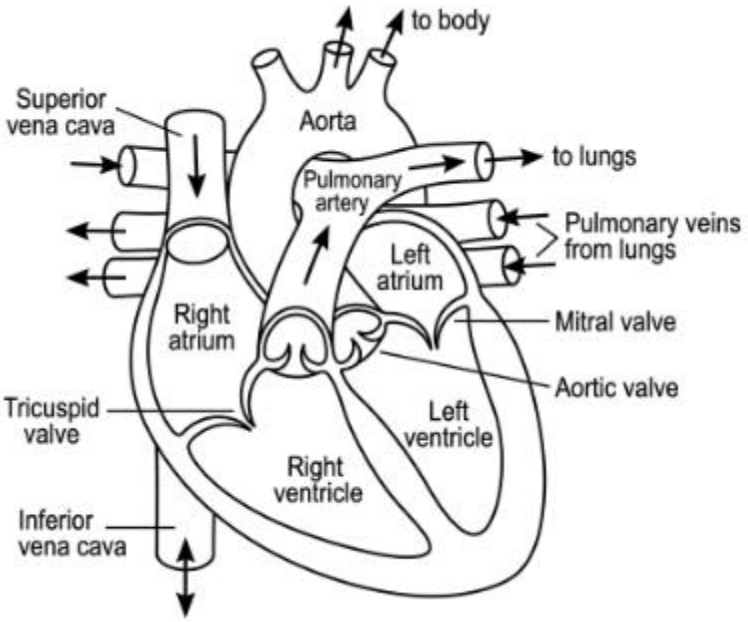
A. Tiny finger-like projections that greatly increase the surface area available for absorption
B. Muscular bands that contract rhythmically to push food along the entire digestive tract
C. Glandular structures that produce hydrochloric acid for the chemical digestion of food
D. Long, thin tubes that drain digested food directly into the kidney for filtering by the body

9. The pancreas contributes to chemical digestion in the small intestine by secreting:

A. Bile, which emulsifies fats so they can be broken down by the lipase enzymes in the gut
B. Hydrochloric acid, which denatures proteins and activates pepsin inside the stomach
C. Digestive enzymes that break down carbohydrates, proteins, and fats in the small intestine
D. Mucus, which lubricates the digestive tract and protects its lining from damaging acid

Base your answers to questions 10 through 14 on the information below and on your knowledge of biology.

The human heart is a four-chambered muscular pump that drives blood through two separate circuits: the pulmonary circuit, which carries blood between the heart and the lungs, and the systemic circuit, which carries blood between the heart and the rest of the body. Oxygen-poor blood returning from the body enters the right atrium, passes into the right ventricle, and is pumped to the lungs. Oxygen-rich blood returning from the lungs enters the left atrium, passes into the left ventricle, and is pumped to the body. Heart valves between chambers and at the entrances to the major arteries prevent blood from flowing backward. The diagram below shows the human heart with its main chambers, valves, and major blood vessels labeled.



10. Which chamber of the heart pumps oxygen-rich blood out to the body?

A. The right atrium, which receives oxygen-poor blood returning from the body via vena cavae
B. The left ventricle, which pumps oxygen-rich blood out through the aorta to the body's tissues
C. The right ventricle, which pumps oxygen-poor blood through the pulmonary artery to lungs
D. The left atrium, which receives oxygen-rich blood returning from the lungs via the pulmonary veins

11. Which type of blood vessel carries blood away from the heart?

A. Veins, which return blood toward the heart from organs throughout the body's tissues
B. Capillaries, where the exchange of gases and nutrients between blood and tissues occurs
C. Venules, the small vessels that connect capillary beds back to the larger veins of the body
D. Arteries, which carry blood away from the heart under relatively high pressure to the body

12. Gas exchange between the blood and the body tissues occurs in the:

A. Capillaries, whose extremely thin walls allow gases to diffuse between blood and the cells
B. Aorta, the largest artery, which carries oxygen-rich blood away from the heart to the body
C. Venae cavae, the large veins that return blood from the body to the right atrium of the heart
D. Pulmonary veins, which carry oxygen-rich blood from the lungs back to the left atrium

13. Blood travels from the right ventricle of the heart to the lungs through the:

A. Aorta, the main artery that carries oxygen-rich blood from the left ventricle to the body
B. Pulmonary veins, which return oxygen-rich blood from the lungs to the left side of the heart
C. Pulmonary arteries, which carry oxygen-poor blood from the right ventricle to the lungs
D. Coronary arteries, which supply oxygen-rich blood directly to the muscle of the heart itself

14. What is the main function of the valves located between the chambers of the heart?

A. To generate the heartbeat by initiating the electrical impulses that spread across the heart
B. To filter waste products out of the blood as it passes through each chamber of the heart
C. To produce red blood cells that transport oxygen throughout the body's tissues
D. To prevent the backflow of blood and ensure one-way flow through the heart chambers

Base your answers to questions 15 through 19 on the information below and on your knowledge of biology.

Photosynthesis is the process by which plants, algae, and some bacteria use light energy to convert carbon dioxide and water into glucose and oxygen. The process takes place inside chloroplasts and is usually divided into two sets of reactions. The light-dependent reactions occur in the thylakoid membranes, where chlorophyll captures light energy and uses it to split water, releasing oxygen as a byproduct. These reactions also produce ATP and NADPH. The light-independent reactions (the Calvin cycle) occur in the stroma of the chloroplast and use the ATP, NADPH, and atmospheric carbon dioxide to build glucose.

15. Which of the following best represents the overall chemical equation for photosynthesis?

A. glucose + oxygen → carbon dioxide + water + ATP for cellular work and respiration
B. carbon dioxide + water → glucose + oxygen, in the presence of sunlight and chlorophyll
C. glucose + carbon dioxide → water + oxygen + ATP inside the chloroplast of the leaf cell
D. water + oxygen → glucose + carbon dioxide + chemical energy used by the cell

16. The oxygen gas released into the air by photosynthesizing plants originates from which source?

A. The water molecules that are split during the light-dependent reactions of photosynthesis
B. The carbon dioxide molecules absorbed from the air during photosynthesis in the leaf
C. The glucose molecules synthesized during the Calvin cycle in the chloroplast stroma
D. The ATP molecules generated by the mitochondria within the photosynthesizing leaf cell

17. Where in the chloroplast do the light-dependent reactions of photosynthesis take place?

A. In the inner matrix, where the Calvin cycle uses ATP to fix CO_2 into glucose molecules
B. In the cell wall outside the chloroplast, where sunlight first strikes the surface of the leaf
C. In the thylakoid membranes, where chlorophyll captures light energy from the sun's rays
D. In the nucleus, where the genes that encode the photosynthetic proteins are transcribed

18. The light-independent reactions (the Calvin cycle) use which set of inputs to build glucose?

A. Light energy and water, which combine directly to form glucose molecules in the chloroplast
B. Carbon dioxide, ATP, and NADPH, which together are used to build glucose molecules
C. Oxygen gas and glucose, which are broken down to release the energy stored in the cell
D. Hydrogen gas alone, which combines with carbon to form sugar molecules within the cell

19. What is the main role of the pigment chlorophyll in photosynthesis?

A. Chlorophyll combines directly with carbon dioxide to form the first glucose molecule
B. Chlorophyll provides the carbon atoms that become incorporated into the sugar molecule
C. Chlorophyll catalyzes the chemical breakdown of glucose during the photosynthesis process
D. Chlorophyll absorbs light energy and transfers it to drive the light-dependent reactions

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

In Mendel's pea plant experiments, the allele for round seeds (R) is dominant over the allele for wrinkled seeds (r), and the allele for yellow seeds (Y) is dominant over the allele for green seeds (y). These two genes are located on different chromosomes and therefore assort independently of one another. A cross between two pea plants that are heterozygous for both traits (RrYy × RrYy) is known as a dihybrid cross.

20. What is the expected phenotypic ratio of the offspring of a dihybrid cross between two heterozygous parents (RrYy × RrYy)?

A. 9 round yellow : 3 round green : 3 wrinkled yellow : 1 wrinkled green offspring
B. 1 round yellow : 1 round green : 1 wrinkled yellow : 1 wrinkled green offspring
C. 3 round yellow : 1 wrinkled green, with no other phenotypes appearing in this cross
D. All round yellow offspring, since both dominant alleles are present in the cross

21. The 9:3:3:1 ratio observed in this dihybrid cross supports Mendel's principle of:

A. Codominance, in which both alleles for a single gene are fully expressed in the heterozygote
B. Incomplete dominance, in which a blended phenotype appears in heterozygous individuals
C. Independent assortment, in which alleles of different genes separate independently in meiosis
D. Linkage, in which two genes always travel together because they sit on the same chromosome

22. Which cross is a "test cross" used to determine the genotype of a round, yellow pea plant of unknown genotype?

A. Cross the unknown plant with another round, yellow plant of identical outward appearance
B. Cross the unknown plant with a wrinkled, green plant (homozygous recessive for both genes)

C. Cross the unknown plant with a homozygous dominant round, yellow plant (RRYY) of known type
D. Measure the height and seed color of the unknown plant against known average values for peas

23. A cross between a homozygous dominant round, yellow plant (RRYY) and a homozygous recessive wrinkled, green plant (rryy) produces F_1 offspring that are all:

A. Wrinkled and green, since both recessive alleles will be expressed first in this cross
B. Round and green, with a one-to-one ratio of round to wrinkled offspring in this cross
C. Wrinkled and yellow, since the recessive allele masks the dominant allele in this cross
D. Round and yellow, all heterozygous (RrYy) for both genes in this dihybrid cross

24. If two genes are located very close together on the same chromosome, they may fail to assort independently. This pattern is best described as:

A. Linkage, in which alleles of nearby genes tend to be inherited together as one unit
B. Codominance, in which both alleles are fully expressed in the heterozygous condition
C. Nondisjunction, in which chromosomes fail to separate properly during cell division
D. Mutation, in which the actual genetic sequence is altered between generations

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

A karyotype is a picture of all the chromosomes in a single cell, paired together and arranged in order of size. Healthy human body cells normally contain 46 chromosomes — 22 pairs of autosomes plus one pair of sex chromosomes. The sex chromosomes determine biological sex: XX for females and XY for males. During meiosis, homologous chromosomes normally separate so that each gamete carries exactly one of each chromosome. When a pair of homologous chromosomes fails to separate properly during meiosis — a process called nondisjunction — the resulting gamete may carry too many or too few chromosomes. If such a gamete is involved in fertilization, the offspring may have a chromosomal disorder. Down syndrome, for example, is caused by an extra copy of chromosome 21.

25. A karyotype is best described as:

A. A pedigree chart that shows the inheritance pattern of one trait across several generations
B. A drawing of all chromosomes in a population, showing the alleles present at one gene locus
C. A picture of all of an individual's chromosomes, paired together and arranged in size order
D. A record of all the proteins produced by an individual during one stage of life cycle

26. Down syndrome is caused by which type of chromosomal change?

A. A single base substitution in the gene that codes for the amino acid valine in hemoglobin
B. A complete deletion of an entire chromosome from one parent's gamete during meiosis

C. A change in the gene that codes for the protein hemoglobin in the red blood cells
D. An extra copy of chromosome 21, giving an affected individual three copies instead of two

27. The extra chromosome found in a person with Down syndrome most likely arose through:

A. A mutation that occurred in the body cells of the affected individual sometime after birth
B. Nondisjunction, in which chromosomes failed to separate properly during meiosis in a parent
C. Crossing over between the X and Y chromosomes during sperm production in the father
D. The deliberate transfer of an extra chromosome from one parent to the other at fertilization

28. A normal karyotype of a human male shows which set of chromosomes?

A. 22 pairs of autosomes plus an X chromosome and a Y chromosome, totaling 46 chromosomes
B. 22 pairs of autosomes plus two X chromosomes and no Y chromosome, totaling 46 chromosomes
C. 23 pairs of autosomes plus an X chromosome and a Y chromosome, totaling 48 chromosomes
D. 24 pairs of autosomes plus a single X chromosome and no Y chromosome, totaling 49 chromosomes

29. A gamete that contains either too many or too few chromosomes is most directly the result of:

A. A point mutation in a single nucleotide of a chromosome before the start of meiosis
B. The failure of DNA replication to occur before the start of cell division in the gamete
C. Nondisjunction, the failure of homologous chromosomes to separate properly during meiosis
D. The deletion of large segments of DNA from a single chromosome during DNA replication

Base your answers to questions 30 through 35 on the information below and on your knowledge of biology.

Populations grow when birth rates exceed death rates. Two general patterns of population growth are commonly observed. Exponential growth — drawn as a J-shaped curve — occurs when resources are abundant and no factors limit reproduction; the population size increases at an accelerating rate. Logistic growth — drawn as an S-shaped curve — occurs in real environments; the population grows rapidly at first but then slows as it approaches the environment's carrying capacity (K). Carrying capacity is determined by limiting factors, which may be density-dependent (such as disease, predation, and competition for food) or density-independent (such as drought, fire, and severe storms). The graphs below show both growth patterns.

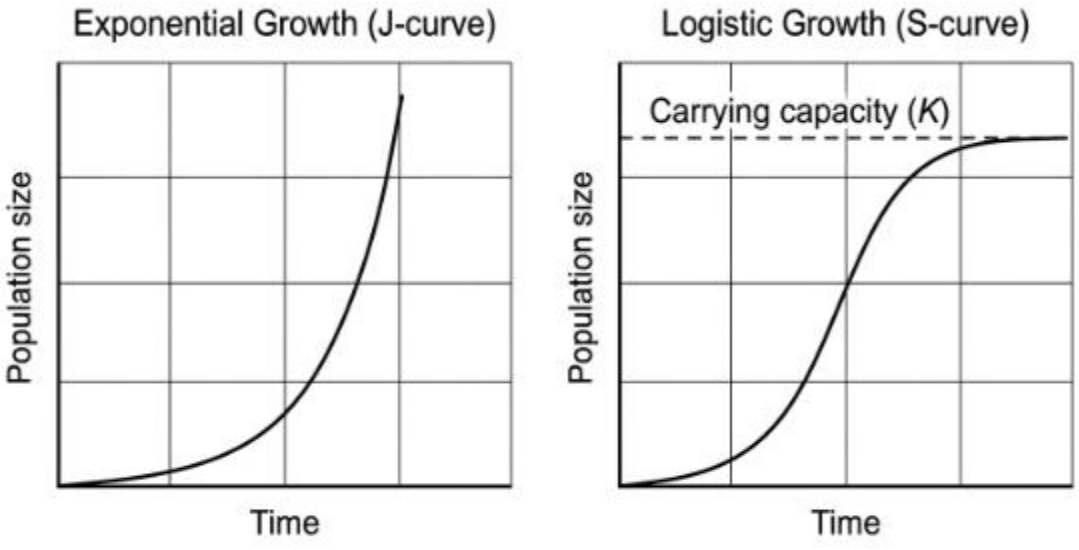


Figure PQ-3

30. Which type of growth curve describes a population that is growing without any limiting factors?

A. Logistic growth (the S-curve), in which population growth slows as it approaches the carrying capacity
B. Exponential growth (the J-curve), in which population size increases at an accelerating rate
C. Linear growth, in which the population increases by exactly the same number each year
D. Negative growth, in which the population steadily decreases over many generations

31. Which type of growth curve describes a population that grows rapidly at first and then levels off at the carrying capacity?

A. Exponential growth (the J-curve), with population size increasing at an accelerating rate
B. Linear growth, in which the population increases by exactly the same number each year
C. Negative growth, in which the population steadily decreases over many generations
D. Logistic growth (the S-curve), in which population growth slows as it approaches K

32. A density-dependent limiting factor is one that:

A. Affects a population in the same way regardless of how many individuals are present
B. Is caused only by physical conditions in the environment such as weather and climate
C. Has a greater effect when the population is large and crowded than when it is small
D. Always increases the carrying capacity of the environment over a short time period

33. Which of the following is the best example of a density-independent limiting factor?

A. A severe drought that affects every individual in a population regardless of population density
B. Predation, in which predators catch more prey as the prey population becomes increasingly large

C. Disease, which spreads more rapidly when many individuals are crowded together in close space
D. Competition for food, which becomes more intense as the population size in an area increases

34. The maximum population size that an environment can sustainably support over time is called the:

A. Limiting factor, any condition that restricts the growth of a population over time
B. Carrying capacity, often abbreviated K in population biology equations and graphs
C. Biotic potential, the maximum reproductive rate possible under ideal conditions
D. Population density, the number of individuals per unit area in a given habitat

35. When a population reaches its carrying capacity, which of the following typically occurs?

A. The population continues to grow exponentially without slowing in any noticeable way
B. The birth rate doubles while the death rate falls to nearly zero per year in the population
C. The population suddenly crashes to extinction within a few short generations of reaching K
D. The birth rate and death rate are approximately equal, causing the population size to be stable

Base your answers to questions 36 through 40 on the information below and on your knowledge of biology.

An adaptation is an inherited trait that improves an organism's ability to survive and reproduce in its environment. Structural adaptations involve physical features (such as the thick fur of a polar bear), behavioral adaptations involve patterns of action (such as bird migration), and physiological adaptations involve internal processes (such as the production of a particular hormone in response to stress). Adaptations arise through natural selection, in which heritable traits that improve fitness become more common in a population over many generations. Specific examples of adaptations include camouflage, in which organisms blend in with their surroundings, and mimicry, in which one species resembles another.

36. A walking stick insect closely resembles a small twig on a tree branch. This is the best example of:

A. Mimicry, in which a harmless species resembles a harmful species for added protection
B. Warning coloration, in which a brightly colored species advertises that it is poisonous
C. Camouflage, in which an organism blends into its surrounding environment for protection
D. Migration, in which an organism moves to a different habitat seasonally during each year

37. A nonpoisonous king snake has bright red, yellow, and black bands that closely resemble those of the dangerous coral snake. This is best described as:

A. Mimicry, in which a harmless species resembles a harmful species for added protection
B. Camouflage, in which an organism blends into its environment to avoid being seen by predators

C. Hibernation, in which an animal becomes inactive during the cold winter months of the year
D. Coevolution, in which two species evolve in response to one another over many generations

38. Polar bears have thick layers of insulating fat and dense white fur. These traits are best classified as:

A. Behavioral adaptations, which are learned during the individual lifetime of each bear
B. Acquired traits, which the parents physically pass on to their offspring after birth
C. Migratory behavior, in which individuals move long distances seasonally each year
D. Structural adaptations, which are inherited physical features that aid survival in the Arctic

39. Many bird species fly long distances south for the winter, a behavior known as migration. This behavior is best classified as:

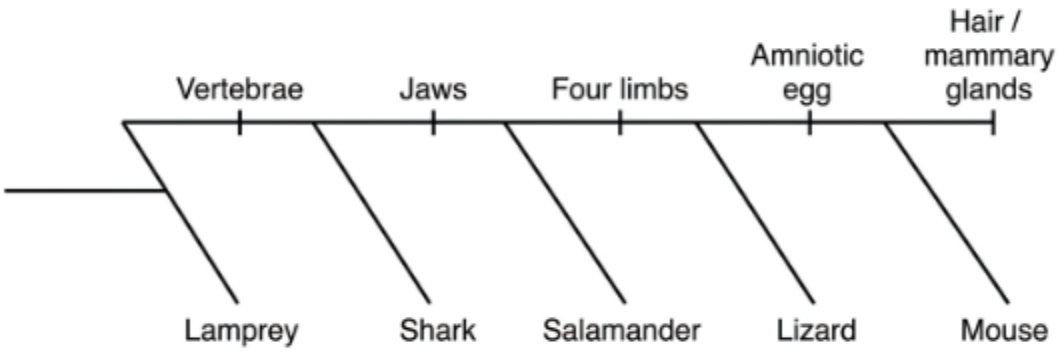
A. A structural adaptation, since it involves the bones and feathers of the bird in flight
B. A behavioral adaptation, since it is an inherited pattern of behavior that aids survival
C. An acquired characteristic, since the bird learns the route from its parent each year
D. A mutation, since each new generation must develop the route again from scratch in life

40. Adaptations of an organism to its environment ultimately result from:

A. Conscious effort by individual organisms to improve their physical traits during their lifetime
B. A single dominant gene that controls all of the organism's physical characteristics for life
C. Natural selection acting on heritable variation over many successive generations of organisms
D. Direct environmental signals that physically alter the DNA of each organism during its lifetime

Base your answers to questions 41 through 45 on the information below and on your knowledge of biology.

A cladogram is a branching diagram that shows the evolutionary relationships among groups of organisms. Each branch point (node) represents a common ancestor from which two or more lineages diverged. Cladograms are constructed using shared derived characteristics — traits that are present in a group of related species because they were inherited from a recent common ancestor. The more recently two species share a common ancestor, the more shared derived characteristics (and the more similar DNA sequences) they tend to have. The cladogram below shows the inferred evolutionary relationships among five animal groups based on shared traits.



41. A cladogram is a diagram that shows:

A. The evolutionary relationships among different species based on shared inherited traits
B. The complete fossil record of every species that has ever existed on Earth over time
C. The geographic distribution of one single species across the various continents of the world
D. The pedigree of a single family showing the inheritance pattern of one specific trait

42. On a cladogram, a branch point (node) represents:

A. A specific year in the past when scientists believe each species first appeared on Earth
B. A change in the geographic location of a species during its evolutionary history on Earth
C. The total number of fossils ever found of the species represented in the diagram
D. A common ancestor from which two or more later lineages diverged over evolutionary time

43. Two species that share a more recent common ancestor on a cladogram are most likely to:

A. Share fewer derived characteristics than two species that diverged from each other long ago
B. Share more derived characteristics than two species that diverged from each other long ago
C. Have completely identical genomes with no differences between them at the molecular level
D. Be incapable of interbreeding because of their very close evolutionary relationship to each other

44. A shared derived characteristic — such as feathers among birds, or hair among mammals — is best described as:

A. A vestigial structure that no longer functions but is still present in modern members of the group
B. A homologous structure that is shared with every other group of vertebrate animals on Earth
C. A trait inherited from a recent common ancestor that is unique to that particular group of species
D. A trait that evolved independently in each species through the process of convergent evolution

45. Comparisons of DNA sequences are now commonly used to construct cladograms because:

A. Similarities and differences in DNA reflect the time since species shared a common ancestor
B. DNA sequences are completely identical in all species, allowing reliable comparison among groups
C. DNA evidence completely replaces the need for fossil evidence in all modern biology research
D. DNA from extinct species is always readily available for sequencing using modern techniques

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

When coal and oil are burned in power plants, factories, and vehicles, they release sulfur dioxide (SO_2) and nitrogen oxides (NO_x) into the atmosphere. These gases combine with water vapor in the atmosphere to form sulfuric acid and nitric acid, which then fall to the ground as acid rain (precipitation with a pH below about 5.6). Acid rain lowers the pH of lakes, streams, and forest soils, harming sensitive plants and animals. Lichens, which are sensitive to airborne pollutants, often disappear from heavily polluted areas and are commonly used as biological indicators of air quality. Engineering solutions such as smokestack scrubbers can reduce the emission of acid-rain precursors at the source.

46. Acid rain is caused primarily by atmospheric emissions of:

A. Carbon dioxide and methane, which trap heat in the lower atmosphere of Earth
B. Chlorofluorocarbons (CFCs), which depleted the ozone layer over the polar regions
C. Particulate matter such as soot and ash released from forest fires across the continent
D. Sulfur dioxide and nitrogen oxides, which combine with water vapor to form acids

47. Acid rain harms many forest ecosystems by:

A. Increasing the rate of photosynthesis in trees so they outgrow their available soil resources
B. Adding extra nitrogen to forest soils, which kills many of the resident plant species directly
C. Lowering the pH of soil and surface water, harming sensitive plants and aquatic organisms
D. Producing greenhouse gases that warm the forest and dry out the soil over many years

48. Lichens are often called "bioindicators" of air quality because:

A. Lichens grow only in heavily polluted areas, so their abundance signals high air pollution levels
B. Lichens are very sensitive to air pollutants and decline in areas with poor surrounding air quality
C. Lichens absorb and store all atmospheric pollutants, completely removing them from the air
D. Lichens produce strong acids that neutralize industrial pollutants throughout the lower atmosphere

49. Which engineering solution most directly reduces the formation of acid rain?

A. Installing scrubbers on factory smokestacks that remove sulfur dioxide before it is released
B. Planting trees in cities to absorb the rain after it has already become acidic in the atmosphere
C. Building taller smokestacks that release pollutants into the upper atmosphere away from cities
D. Increasing the burning of coal so that warmer atmospheric air dilutes the resulting pollutants

50. A freshwater lake affected by long-term acid rain is most likely to show:

A. A sudden increase in the diversity of fish species not previously found in the lake before
B. A complete absence of all decomposer organisms within the affected aquatic ecosystem
C. A higher carrying capacity for top predators living in the affected aquatic ecosystem
D. A decline in the diversity and abundance of fish, amphibians, and aquatic insects

Practice Exam 13 — Full Explained Answer Key

1. C — Mitochondria are the site of aerobic cellular respiration, where glucose is oxidized through the citric acid cycle and electron transport chain to produce large amounts of ATP. Their double membrane and internal cristae provide the surface area for the enzymes involved. The mitochondrion is therefore correctly called the "powerhouse of the cell."

2. B — Ribosomes are the molecular machines that read mRNA codons and link amino acids into polypeptide chains during translation. They occur free in the cytoplasm and bound to the rough endoplasmic reticulum. Without ribosomes, no protein synthesis could occur.

3. A — Chloroplasts are found in plant cells and other photosynthetic eukaryotes but are absent from animal cells. They contain chlorophyll and carry out photosynthesis, capturing light energy to make glucose. Their presence is one of the defining structural differences between plant and animal cells.

4. D — The Golgi apparatus receives proteins from the rough ER and modifies, sorts, and packages them into vesicles for secretion or for delivery to other organelles. It functions as the cell's post office. Without the Golgi, proteins could not be properly processed for export.

5. C — Digestive enzymes are proteins that must be exported from the cell to act extracellularly, so they are synthesized by ribosomes attached to the rough ER and then processed for secretion. Cells specialized for high-volume protein export — like pancreatic acinar cells — are packed with rough ER and ribosomes. The organelle composition reflects the cell's function.

6. B — Salivary amylase secreted by the salivary glands begins hydrolyzing starch into shorter chains and maltose as food is chewed and mixed with saliva in the mouth. This is the first step of chemical carbohydrate digestion. Starch digestion is paused in the acidic stomach and resumed by pancreatic amylase in the small intestine.

7. D — The small intestine is the principal site of nutrient absorption because its inner lining is folded into villi and microvilli that produce an enormous surface area for uptake. Most amino acids, sugars, fatty

acids, vitamins, and minerals enter the bloodstream here. Disorders that damage the villi (such as celiac disease) sharply reduce absorption.

8. A — Villi are finger-like projections of the intestinal lining, and the cells covering them have even smaller microvilli on their apical surface. Together these structures amplify the absorptive surface area by hundreds of times. Greater surface area means faster and more complete nutrient uptake into the bloodstream.

9. C — The pancreas secretes a mix of digestive enzymes — including pancreatic amylase (carbohydrates), trypsin and chymotrypsin (proteins), and lipase (fats) — into the small intestine via the pancreatic duct. These enzymes complete the chemical digestion of all three major macronutrient classes. Loss of pancreatic enzyme function causes malabsorption.

10. B — The left ventricle has the thickest muscular wall in the heart because it must generate enough pressure to drive oxygen-rich blood out through the aorta to the entire systemic circulation. This is the highest-pressure chamber. The thicker wall is a direct structural adaptation to its function.

11. D — By definition, arteries are blood vessels that carry blood away from the heart, typically under relatively high pressure generated by ventricular contraction. Their walls are thick and elastic to handle this pressure. Veins, in contrast, return blood toward the heart at lower pressure.

12. A — Capillaries are microscopic vessels with walls only one cell thick, which allows oxygen, carbon dioxide, nutrients, and waste products to diffuse rapidly between the blood and surrounding tissue cells. This is the only site in the circulatory system where exchange with tissues actually occurs. Their enormous total surface area maximizes efficiency.

13. C — The right ventricle pumps oxygen-poor blood into the pulmonary arteries, which carry it to the lungs for gas exchange. These are unusual in being arteries that carry oxygen-poor blood, because the defining feature of arteries is direction of flow (away from heart), not oxygen content. Recognizing this is essential for understanding pulmonary circulation.

14. D — The atrioventricular and semilunar valves open and close to maintain one-way flow through the heart: blood enters atria, passes to ventricles, and exits into the major arteries without flowing backward. Damaged valves cause regurgitation, reducing efficiency and increasing cardiac workload. Functional valves are essential for effective circulation.

15. B — Photosynthesis can be summarized as $6\ CO_2 + 6\ H_2O \rightarrow C_6H_{12}O_6 + 6\ O_2$, with light energy and chlorophyll required to drive the reaction. The plant takes in carbon dioxide and water and produces glucose and oxygen. This is the reverse of cellular respiration.

16. A — Isotope-tracing experiments showed that the oxygen released during photosynthesis originates from the splitting (photolysis) of water molecules during the light-dependent reactions, not from CO_2. Hydrogen ions and electrons released by water splitting feed the rest of the light reactions. This finding fundamentally clarified the chemistry of photosynthesis.

17. C — The light-dependent reactions occur in the thylakoid membranes inside chloroplasts, where chlorophyll embedded in the photosystems captures light energy. This drives water splitting and the production of ATP and NADPH. The light-independent reactions (Calvin cycle) occur separately in the stroma.

18. B — The Calvin cycle uses CO_2 from the atmosphere together with ATP and NADPH generated by the light reactions to reduce carbon and assemble glucose precursors. ATP supplies energy and NADPH supplies reducing power. This connects the two stages of photosynthesis into one process.

19. D — Chlorophyll molecules in the thylakoid membranes absorb photons of visible light (most strongly in the red and blue wavelengths) and transfer the resulting excitation energy into the electron transport chain of the light reactions. This is the energy-capture step that drives all of photosynthesis. Chlorophyll's green color reflects the wavelengths it does not absorb.

20. A — A Punnett square for RrYy × RrYy produces a 9:3:3:1 phenotypic ratio: 9 round yellow, 3 round green, 3 wrinkled yellow, 1 wrinkled green. This classic Mendelian outcome appears whenever two genes assort independently. It is the hallmark dihybrid result.

21. C — The 9:3:3:1 ratio arises only when alleles of the two different genes segregate into gametes independently of one another, generating all four possible gamete combinations in equal frequencies. This is Mendel's law of independent assortment. The same logic does not apply to linked genes on the same chromosome.

22. B — A test cross pairs an individual of unknown genotype with a fully homozygous recessive partner; the appearance of any recessive offspring reveals the presence of recessive alleles in the unknown parent. For an unknown round, yellow pea plant, that means crossing with a wrinkled, green (rryy) plant. The phenotypes of the offspring directly reveal the unknown's genotype.

23. D — Crossing homozygous dominant (RRYY) with homozygous recessive (rryy) parents gives F_1 offspring that are uniformly heterozygous (RrYy) and therefore all show the dominant round yellow phenotype. This is the classic F_1 result of Mendel's experiments. It sets up the 9:3:3:1 F_2 ratio in the next generation.

24. A — Linkage occurs when two genes lie close together on the same chromosome and therefore tend to be inherited as a single unit rather than assorting independently. Linked genes violate Mendel's law of independent assortment. The closer the genes, the stronger the linkage.

25. C — A karyotype is produced by photographing the chromosomes of a cell during metaphase, then pairing the homologs and arranging them in order from largest to smallest. It is used to screen for chromosomal abnormalities. Karyotyping is the standard tool for diagnosing conditions such as Down syndrome.

26. D — Down syndrome (trisomy 21) is caused by the presence of an extra copy of chromosome 21, so affected individuals have 47 chromosomes instead of 46. The extra chromosome typically arises from nondisjunction during gamete formation. The condition is the most common autosomal trisomy compatible with live birth.

27. B — Nondisjunction is the failure of homologous chromosomes (or sister chromatids) to separate properly during meiosis, producing gametes with one extra or one missing chromosome. Fertilization with such a gamete yields aneuploid offspring. Most cases of Down syndrome trace to maternal nondisjunction during meiosis I.

28. A — A normal human male karyotype contains 46 chromosomes: 22 pairs of autosomes plus one X and one Y sex chromosome. The Y chromosome determines male development through the SRY gene. Females have the same 22 autosome pairs plus two X chromosomes.

29. C — Nondisjunction during meiosis produces gametes with too many or too few chromosomes; when such a gamete is fertilized, the resulting zygote is aneuploid (e.g., trisomic or monosomic). Point mutations and small deletions change DNA sequences but not chromosome number. This is why nondisjunction is the central cause of aneuploidy.

30. B — Exponential or J-curve growth occurs when a population reproduces at its maximum rate because resources are abundant and there are no limits on survival or reproduction. Each generation adds more individuals than the last, producing the characteristic accelerating curve. This pattern is unsustainable in real environments.

31. D — Logistic or S-curve growth begins with rapid increase but slows as resources become limited, eventually stabilizing at the environment's carrying capacity (K). The curve has a characteristic S shape because density-dependent factors brake the growth. This is the more realistic model for natural populations.

32. C — Density-dependent factors — such as competition, disease, and predation — exert stronger effects as a population becomes larger and more crowded. They help regulate populations around K. Their density dependence is what makes logistic growth possible.

33. A — Density-independent factors affect populations regardless of size or density; severe weather events such as droughts, floods, fires, and freezes kill a similar proportion of individuals whether the population is large or small. Their effects do not scale with population size. They can crash even thriving populations suddenly.

34. B — Carrying capacity (K) is the largest population size that the resources of a particular environment can sustainably support over time. Populations tend to fluctuate around K under logistic growth. Recognizing K is fundamental to population ecology.

35. D — At carrying capacity, births and deaths roughly balance, so population size stabilizes rather than growing or crashing. Density-dependent factors tighten this balance. Long-term population stability is the defining feature of life at K.

36. C — Camouflage describes adaptations of color, pattern, or shape that allow an organism to blend in with its surroundings and avoid detection. A walking stick's twig-like appearance is a textbook example. Such cryptic appearance reduces predation pressure.

37. A — Mimicry occurs when a harmless species (the mimic) evolves to resemble a dangerous or distasteful species (the model), gaining protection because predators avoid the model. The king snake's resemblance to the venomous coral snake is the classic Batesian-mimicry example. The harmless snake benefits from the predators' learned avoidance.

38. D — Structural adaptations are inherited anatomical features that improve survival in a particular environment, such as the polar bear's insulating fat and dense white fur in the Arctic. These traits are physical, not behavioral or physiological. They evolved through natural selection over many generations.

39. B — Migration is an inherited pattern of seasonal movement that improves survival and reproductive success — a behavioral adaptation. Like other adaptations, it is shaped by natural selection. Many migration routes are guided by inherited responses to environmental cues.

40. C — Adaptations arise through natural selection acting on the heritable variation already present in a population: individuals with traits that improve survival and reproduction leave more offspring, so those alleles become more common. Conscious effort and direct environmental modification of DNA do not produce adaptations. This is the core insight of Darwinian evolution.

41. A — A cladogram is a branching diagram that represents the evolutionary relationships among species based on shared derived characteristics. The branching pattern shows which species share more recent common ancestors. It is a fundamental tool of modern systematics.

42. D — Each branch point or node on a cladogram represents a common ancestor from which two or more daughter lineages diverged. The diagram does not show specific dates; it shows the order of branching. Reading nodes correctly is essential for interpreting evolutionary trees.

43. B — Species that share a more recent common ancestor have had less time to evolve independently, so they tend to share more derived characteristics and more similar DNA sequences. This is the principle behind cladistic classification. Greater shared derivation is direct evidence of closer evolutionary relationship.

44. C — A shared derived characteristic (synapomorphy) is a trait inherited from a recent common ancestor that uniquely identifies a particular clade — feathers in birds, hair and mammary glands in mammals. It distinguishes that clade from outgroups. Such traits are the building blocks of cladistic analysis.

45. A — DNA sequences accumulate mutations over evolutionary time, so the degree of sequence similarity between two species reflects the time since their most recent common ancestor — more similar sequences imply more recent divergence. This molecular-clock idea underpins modern phylogenetic methods. Molecular data often complement and refine fossil-based trees.

46. D — Sulfur dioxide (SO_2) and nitrogen oxides (NO_x), released largely by burning coal and oil, react with atmospheric water vapor to form sulfuric and nitric acids that fall as acid rain. Carbon dioxide and CFCs cause different environmental problems. Recognizing the SO_2/NO_x source is essential for understanding control strategies.

47. C — Acid rain lowers the pH of soils and surface waters, releasing toxic metals (such as aluminum) and stressing organisms that cannot tolerate acidic conditions, including many fish, amphibians, and trees. Forest decline and fish kills are well-documented consequences. The damage occurs even at moderately reduced pH values.

48. B — Lichens are symbiotic associations of fungi and algae that absorb water and nutrients directly from the air through their thin surfaces, making them highly sensitive to airborne pollutants such as sulfur dioxide. Their disappearance from an area is an early warning of poor air quality. Lichen surveys are routinely used to map air-pollution gradients.

49. A — Smokestack scrubbers chemically remove sulfur dioxide (and many nitrogen oxides) from industrial flue gases before they enter the atmosphere, directly reducing the precursors of acid rain. Trapping pollutants at the source is more effective than treating effects later. This approach has substantially reduced acid rain in regions with strong emission controls.

50. D — Long-term acidification reduces survival and reproduction of acid-sensitive species — many fish, amphibians, and aquatic insects disappear first — so overall species diversity and abundance decline. Trophic cascades follow as predators lose prey. These ecological losses motivated international emissions agreements such as the U.S. Clean Air Act amendments.