PRACTICE EXAM 17 — QUESTIONS 1-50

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

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

A high school biology class compared cheek cells (animal) and onion epidermal cells (plant) under the microscope. Students prepared wet mounts of both cell types and added methylene blue stain to the cheek-cell slides and iodine stain to the onion-cell slides. They then recorded which structures could be observed in each cell type. The class data are summarized below.

Structure	Cheek Cells	Onion Epidermal Cells
Cell membrane	Visible	Visible
Cell wall	Absent	Visible
Nucleus	Visible (stained dark)	Visible (stained dark)
Chloroplasts	Absent	Absent (epidermal cells lack them)
Large central vacuole	Absent	Visible

1. Which structural difference between cheek and onion cells is best supported by the data?

A. Only animal cells contain a true nucleus surrounded by a nuclear envelope inside the cell
B. Only plant cells have a rigid cell wall surrounding the cell membrane on the outside
C. Only plant cells have a cell membrane separating cytoplasm from the external environment
D. Only animal cells contain organelles capable of converting glucose into chemical energy

2. The cell wall of an onion cell is composed primarily of:

A. Phospholipid bilayers identical to those found in animal cell membranes
B. Layers of dense protein fibers anchored to the inner cytoplasm of the cell
C. Cellulose, a complex carbohydrate that provides structural support to the cell
D. Calcium phosphate crystals that strengthen the cell against pressure changes

3. Why are chloroplasts absent in onion epidermal cells, even though onion plants are photosynthetic?

A. Onion epidermal cells develop underground where no sunlight reaches them to trigger chloroplast development
B. Onion cells cannot synthesize chlorophyll because they lack the necessary enzymes for it
C. Chloroplasts are only present in cells of animal species that consume green plants
D. Chloroplasts dissolve when onion cells are stained with iodine in laboratory experiments

4. The large central vacuole in onion cells serves primarily to:

A. Synthesize the proteins required for daily cell maintenance and continued growth
B. Carry out the chemical reactions of cellular respiration to produce ATP energy
C. Replicate the DNA of the cell during the early stages of mitotic cell division
D. Store water, ions, and dissolved substances and help maintain turgor pressure

5. The nucleus stained darkly in both cell types because methylene blue and iodine both bind to:

A. The phospholipid bilayer that forms the outer membrane of the cell's nucleus
B. The DNA and other nucleic acids concentrated inside the nucleus of the cell
C. The proteins that make up the ribosomes attached to the rough endoplasmic reticulum
D. The water molecules that fill the central vacuole during normal cell function

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

Students investigated the effect of pH on the digestive enzyme pepsin, which breaks down proteins in the human stomach. They prepared five test tubes containing equal amounts of pepsin and small pieces of cooked egg white (a protein source). Each tube was buffered to a different pH (2, 4, 7, 9, or 11) and kept at 37°C. After 24 hours, students examined each tube and recorded the percentage of egg white remaining undigested.

pH	Egg White Remaining (%)
2	15
4	60
7	95
9	98
11	99

6. Based on the data, pepsin functions best at which pH?

A. pH 2, where the smallest amount of egg white remained after 24 hours of digestion
B. pH 7, where digestion was nearly complete and approximated the body's neutral conditions
C. pH 9, where pepsin reacted most strongly with the egg white protein in solution
D. pH 11, where the alkaline conditions activated the highest level of enzyme activity

7. The optimal pH of pepsin is well-suited to its location in the human body. This location is the:

A. Mouth, where saliva mixes with food during the chewing of solid food into smaller pieces
B. Small intestine, where pancreatic enzymes break down most of the proteins and carbohydrates
C. Stomach, where hydrochloric acid creates a strongly acidic environment for protein digestion
D. Large intestine, where bacterial fermentation acidifies the contents to support digestion

8. At pH 11, almost no digestion of the egg white occurred. The best explanation is that:

A. Egg white protein cannot dissolve in alkaline solutions during enzyme-catalyzed reactions
B. Pepsin requires the presence of bile salts that are only released at acidic pH values
C. The egg white denatured at high pH and could no longer interact with active enzymes
D. The pepsin enzyme denatured at high pH, losing the active site shape it needed

9. Pepsin acts on egg white because the egg white is composed primarily of:

A. Proteins, which pepsin breaks down into shorter chains of amino acids
B. Lipids, which pepsin breaks down into fatty acids and glycerol molecules
C. Starches, which pepsin breaks down into glucose molecules for absorption
D. Nucleic acids, which pepsin breaks down into individual nucleotide subunits

10. Like all enzymes, pepsin speeds up reactions by:

A. Providing the chemical energy needed to drive the digestion reaction forward
B. Lowering the activation energy required for the digestion reaction to occur
C. Becoming incorporated into the protein products of the digestion reaction
D. Raising the temperature of the surrounding solution to accelerate reactions

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

A student investigated the relationship between photosynthesis and cellular respiration by placing snails (which respire) and aquatic plants (*Elodea*, which both photosynthesize and respire) into sealed flasks containing water and bromothymol blue indicator. Bromothymol blue is blue at high pH (low CO2) and yellow at low pH (high CO2). The student set up four flasks and exposed them to bright light for 24 hours, then recorded the final color of the indicator in each flask.

Flask	Contents	Initial Color	Final Color (24 h bright light)
1	Snail alone	Blue	Yellow
2	*Elodea* alone	Blue	Blue (deeper shade)
3	Snail + *Elodea* together	Blue	Blue
4	Empty (control)	Blue	Blue

11. The yellow color in Flask 1 (snail alone) is best explained by the fact that:

A. The snail consumed all of the oxygen in the water and produced solid waste
B. The snail digested the bromothymol blue and changed its molecular structure
C. The snail performed cellular respiration, releasing CO2 that lowered the water pH
D. The light caused the bromothymol blue to break down into a yellow compound

12. Why did the *Elodea*-only flask (Flask 2) remain blue or become a deeper shade of blue?

A. The *Elodea* performed more photosynthesis than respiration, removing CO2 from the water
B. The *Elodea* actively absorbed bromothymol blue molecules into its leaf tissues
C. The light caused the bromothymol blue to become more concentrated through reflection
D. The *Elodea* released oxygen, which combined with bromothymol blue to form a darker color

13. In Flask 3, the snail and *Elodea* together maintained a blue color. This result demonstrates that:

A. The snail and *Elodea* cannot survive in the same flask without competing for resources
B. The Elodea consumed the snail's oxygen waste and converted it into food molecules
C. Both organisms stopped all metabolic activity when placed together in a sealed flask
D. The *Elodea* consumed the CO2 produced by the snail, recycling it through photosynthesis

14. The relationship between the snail and the *Elodea* in Flask 3 best illustrates which type of cycling at the cellular level?

A. The carbon cycle, in which carbon moves between organisms and the geological rocks
B. The exchange of gases between photosynthesis and cellular respiration in a small ecosystem
C. The nitrogen cycle, in which nitrogen moves between organisms and the soil bacteria
D. The water cycle, in which water moves between the atmosphere, oceans, and living things

15. If Flask 3 were placed in complete darkness instead of bright light, the most likely outcome would be:

A. The indicator would remain blue because no metabolism would occur in either organism without light
B. The indicator would become deeper blue as the snail removed CO2 through its respiration
C. The indicator would turn yellow because both organisms would respire without any photosynthesis
D. The indicator would become colorless as both organisms would stop all biological activity

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

ATP (adenosine triphosphate) is the primary energy currency of all living cells. An ATP molecule consists of an adenosine unit attached to three phosphate groups in a chain. When a cell needs energy, an enzyme breaks the bond between the second and third phosphate groups, releasing energy and producing ADP (adenosine diphosphate) plus an inorganic phosphate. The energy released drives nearly all of the energy-requiring activities of the cell, including muscle contraction, active transport across membranes, and the synthesis of large molecules.

16. The breakdown of food molecules that produces most cellular ATP takes place inside which organelle?

A. The mitochondrion, often called the "powerhouse" of the cell
B. The nucleus, which stores and protects the DNA of each cell
C. The ribosome, which synthesizes proteins from amino acid chains
D. The lysosome, which contains digestive enzymes that break down waste

17. Active transport differs from diffusion in that active transport:

A. Moves molecules from a higher concentration toward a lower concentration of solute
B. Always involves the movement of water molecules across a selectively permeable membrane
C. Requires that the molecules being transported be very small and uncharged in nature
D. Requires the cell to use ATP energy to move molecules against a concentration gradient

18. If an organism stopped producing ATP, which of the following processes would be most immediately affected?

A. The cooling of the body through evaporation of water on the skin's surface
B. The reflection of light from the surface of the organism back into the environment
C. Muscle contraction and active transport, which both directly require ATP energy
D. The folding of new proteins into their three-dimensional functional shapes

19. When ATP is converted to ADP plus phosphate during a cellular activity, the energy released:

A. Is created from nothing each time the bond between two phosphate groups is broken
B. Is transferred from the chemical bond to drive a process that requires energy
C. Is destroyed permanently and cannot be reused for any further cell activities
D. Becomes part of the structure of new proteins synthesized at the cell's ribosomes

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

Before a cell divides, it must duplicate its DNA so that each daughter cell receives a complete copy of the genetic material. This process, DNA replication, occurs in the nucleus of eukaryotic cells. The two strands of the DNA double helix separate, and each strand serves as a template for the synthesis of a new complementary strand. Specific base pairing rules are followed: adenine (A) pairs with thymine (T), and guanine (G) pairs with cytosine (C). Occasionally, an error is made when copying a base. If uncorrected, this error becomes a mutation that is passed on to subsequent cells produced by division.

20. If one strand of DNA has the sequence A–T–G–C–A–T, the complementary strand produced during DNA replication will have the sequence:

A. T–A–C–G–T–A, in which each base pairs with its specific complement on the template strand
B. T–A–G–C–T–A, in which adenine pairs with cytosine and thymine pairs with guanine on the strand
C. U–A–C–G–U–A, in which uracil pairs with adenine, as it does in messenger RNA molecules
D. A–T–G–C–A–T, in which the new strand is identical to the original template strand exactly

21. DNA replication is necessary because:

A. The DNA in a cell must be broken down to release the energy stored within its bonds
B. Each cell loses some of its DNA every day and must replace it through ongoing replication
C. Each new daughter cell produced during cell division must receive a complete copy of the DNA
D. Different cells in the body require different DNA sequences to perform their many functions

22. A mutation in a body (somatic) cell would most likely affect:

A. Every cell in the next generation, because mutations are always inherited from parents
B. Only the sperm and egg cells of the organism in which the mutation has occurred
C. The DNA of the organism's offspring without affecting the parent organism in any way
D. Only the cells derived from the original mutated cell during ongoing cell division

23. A point mutation that changes a single DNA base from G to A could result in:

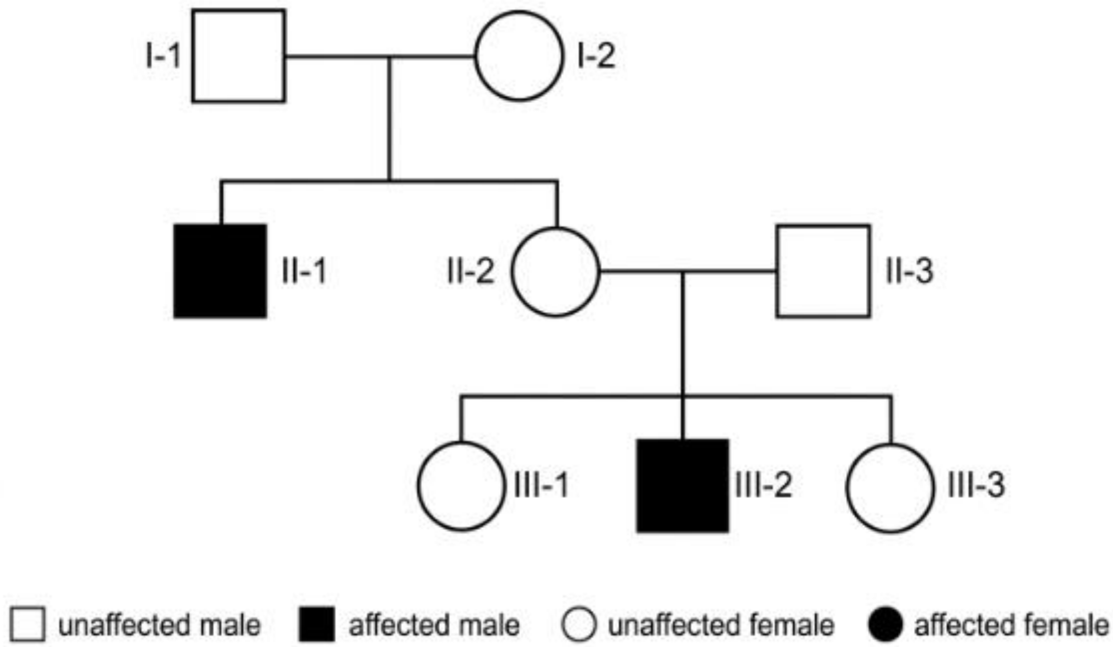
A. A different amino acid being inserted into the protein at the location of the mutation
B. A complete loss of all proteins produced from the affected gene in every body cell
C. A duplication of an entire chromosome inside the cell containing the mutated gene
D. An immediate increase in the rate of DNA replication in the affected cell lineage

24. Not all mutations are harmful. A mutation might be classified as beneficial if it:

A. Causes the affected cells to divide as rapidly as possible to outcompete other cells
B. Produces a protein variant that improves the organism's survival or reproduction
C. Prevents the organism from passing any of its genetic material on to its offspring
D. Increases the rate at which other mutations occur in the organism's DNA molecules

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

The pedigree below shows the inheritance of an autosomal recessive disorder in a family across three generations. In the diagram, squares represent males, circles represent females, shaded symbols represent affected individuals, and unshaded symbols represent unaffected individuals. The disease is autosomal recessive: affected individuals must inherit one recessive allele from each parent.



25. Based on the pedigree, what must be true about the genotypes of I-1 and I-2?

A. Both individuals are homozygous dominant for the normal allele of the gene
B. One parent is homozygous dominant and the other parent is homozygous recessive
C. Both individuals are affected by the disorder but show very mild physical symptoms
D. Both individuals are heterozygous carriers, each carrying one recessive disease allele

26. II-2 is unaffected but has both an affected brother (II-1) and an affected son (III-2). What is the probability that II-2 is a carrier of the recessive allele?

A. 0%, because she is unaffected and cannot possibly carry the disease allele
B. 25%, because one in four children of two heterozygotes inherits two recessive alleles
C. 100%, because she must carry at least one recessive allele to have an affected son
D. 50%, because she has only a one in two chance of carrying the recessive allele

27. For III-2 to be affected, II-3 (his father, who married into the family) must:

A. Be a heterozygous carrier of the recessive disease allele on his autosomal chromosomes
B. Be affected by the disease despite showing no outward symptoms of any kind
C. Have donated his Y chromosome carrying the recessive disease allele to his son
D. Have inherited two recessive alleles from his own affected parents earlier in his life

28. Two parents who are both heterozygous carriers (Cc × Cc) have a child. What is the probability that the child will be affected by this recessive disorder?

A. 0%, because at least one parent must be affected for the child to inherit the disease
B. 25%, because one of every four offspring genotype combinations produces an affected child

C. 50%, because half of all children of carriers will be affected by the disorder
D. 75%, because three of every four offspring will inherit at least one recessive allele

29. Two parents who are both heterozygous carriers (Cc × Cc) have a child who is unaffected. Given that the child is unaffected, what is the probability that this child is a carrier of the recessive allele?

A. 0%, because the child is unaffected and therefore cannot carry the recessive allele
B. 25%, because only one of every four combinations produces a carrier genotype
C. 2/3, because among unaffected offspring, two-thirds are heterozygous carriers
D. 100%, because every unaffected child of two carriers must also be a carrier

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

Whales are mammals that live exclusively in water, but fossil evidence and DNA analysis show that whales evolved from land-dwelling, four-legged mammals over approximately 50 million years. Early ancestors of whales, such as *Pakicetus*, were land mammals with four limbs that walked on land. Intermediate fossils show gradual changes over time: the hind limbs shrank and disappeared, the front limbs became flippers, the body became streamlined, the nostrils migrated to the top of the head (becoming the blowhole), and the tail developed flukes for swimming. Modern whales still retain vestigial pelvic bones — small bones in the body that are remnants of the hip structure of their land-dwelling ancestors.

30. The vestigial pelvic bones in modern whales provide evidence that:

A. Whales currently use these bones to support hind limbs that have not yet developed
B. Modern whales are slowly evolving the ability to walk on land in addition to swimming
C. The pelvic bones serve a critical role in modern whale reproduction and locomotion
D. Whales evolved from ancestors that had functional hind limbs and walked on land

31. The fossil record of whale evolution shows gradual changes over millions of years. This pattern is best classified as evidence for:

A. Evolution by natural selection acting on heritable variation over long time periods
B. The sudden appearance of completely new species without intermediate forms in the fossils
C. The spontaneous generation of fully formed whales from non-living material in the oceans
D. Acquired traits being passed from individual whales to their offspring during a single lifetime

32. The streamlining of the whale body over evolutionary time was most likely driven by:

A. Random changes in whale anatomy that had no effect on swimming performance whatsoever
B. Natural selection favoring whales that could swim efficiently and capture prey more easily

C. Whales actively choosing to change their body shape during their individual lifetimes
D. Genetic engineering carried out by humans over the past few centuries of whale observation

33. Comparing the front limb of a whale to the front limb of a horse, a dog, and a human reveals that all four share a similar internal bone structure (one upper bone, two lower bones, wrist, and digits). This similarity is best explained by:

A. The four species needing similar limbs to perform the same daily activities in their habitats
B. Random coincidence, since the bones of these unrelated species have no shared genetic history
C. Convergent evolution, in which all four species independently evolved the same exact structure
D. Common ancestry, in which the four species inherited the same basic limb structure from a shared ancestor

34. Genes responsible for hind-limb development are still present in modern whale DNA, even though whales do not develop hind limbs. This finding is best explained by:

A. The genes will produce hind limbs again as soon as whales return to live on the land
B. The genes were inserted into whale DNA recently by scientists studying whale evolution
C. The genes are inherited from land-dwelling ancestors but are no longer fully expressed during development
D. The genes have completely lost their original function and now code for blowhole development only

35. The transition from a four-limbed land mammal to a fully aquatic, streamlined whale occurred over approximately:

A. 50 million years, a length of time consistent with major evolutionary transitions in the fossil record
B. 5,000 years, a length of time short enough to have occurred during human recorded history
C. 500 years, a length of time short enough to have been directly observed by early naturalists
D. 50 years, a length of time within the lifetime of a single human researcher's career

36. Which type of evidence has provided the strongest support for whale evolution from land mammals?

A. Direct observation of modern whales evolving into new species in the wild during recent years
B. Multiple lines of converging evidence from fossils, comparative anatomy, and DNA comparisons
C. Computer simulations alone, without any independent evidence from biology or geology
D. Religious and cultural beliefs about the relationship between land and sea creatures

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

Symbiosis is a close, long-term interaction between two species. Three major types of symbiotic relationships are recognized by ecologists: mutualism (both species benefit), commensalism (one species benefits, the other is unaffected), and parasitism (one species benefits, the other is harmed). Examples include lichens (a fungus and a photosynthetic alga or cyanobacterium living together), barnacles attached to whale skin, and tapeworms living in the intestines of host animals.

37. Lichens consist of a fungus and a photosynthetic partner (alga or cyanobacterium) living together as one body. The fungus contributes:

A. Sugars produced from sunlight to feed the photosynthetic algae living within its body tissues
B. Movement of the entire lichen across different rock surfaces in search of better sunlight
C. A protective structure that holds water and minerals for the use of the photosynthetic partner
D. Oxygen needed by the photosynthetic algae to perform their daily metabolic activities

38. The photosynthetic partner in a lichen contributes:

A. Sugars from photosynthesis that supply energy to the fungal portion of the lichen
B. Mineral nutrients absorbed directly from the rock surface beneath the lichen colony
C. Mechanical support that holds the lichen tightly against rock or tree bark surfaces
D. Reproduction by means of spore-like structures dispersed by passing wind currents

39. A barnacle attached to a whale's skin gains free transportation to areas with more abundant food without significantly harming the whale. This relationship is best classified as:

A. Mutualism, since both the barnacle and the whale benefit equally from the close interaction
B. Parasitism, since the barnacle clearly harms the whale by clinging tightly to its skin surface
C. Predation, since the barnacle slowly consumes the whale's outer skin layers over time
D. Commensalism, since the barnacle benefits while the whale is essentially unaffected by it

40. A tapeworm in the intestine of a host animal absorbs nutrients from food the host has eaten, gradually weakening the host over time. This relationship is best classified as:

A. Mutualism, because both the tapeworm and the host benefit from the close interaction
B. Parasitism, because the tapeworm benefits while harming the host that it infects
C. Commensalism, because the tapeworm benefits while the host is essentially unaffected
D. Competition, because the tapeworm and the host fight for the same available food resources

41. If a parasite is too harmful to its host (killing the host very quickly), the parasite is also harmed because:

A. The host's body chemistry becomes too acidic for the parasite to survive in its tissues
B. The host's immune system increases in strength after death and continues to attack the parasite
C. The parasite loses its source of food and habitat when the host dies, ending its own life
D. The host releases a chemical signal as it dies that kills all other parasites in the body

Base your answers to questions 42 through 46 on the information below and on your knowledge of biology.

All living organisms need nitrogen to build proteins and nucleic acids. Although nitrogen gas (N2) makes up about 78% of Earth's atmosphere, most organisms cannot use it directly. Certain bacteria living in the soil and in the roots of legume plants (such as beans, peas, and clover) can convert atmospheric N2 into ammonia (NH3) in a process called nitrogen fixation. Other soil bacteria convert ammonia into nitrates ($NO3^-$), which plants can absorb through their roots and use to build amino acids. Animals obtain nitrogen by eating plants or other animals. When organisms die, decomposer bacteria and fungi return nitrogen compounds to the soil, and other bacteria convert these compounds back into N2 gas, completing the cycle.

42. Most living organisms cannot use atmospheric N2 directly because:

A. Nitrogen gas is too rare in the atmosphere to provide a significant nitrogen source
B. Atmospheric nitrogen molecules are too large to enter the cells of most organisms
C. Plants reject nitrogen gas when their leaves come into contact with the surrounding air
D. The strong triple bond in N2 molecules makes it difficult to break apart and use chemically

43. Nitrogen-fixing bacteria living in the roots of legume plants benefit the plant by:

A. Converting atmospheric N2 into a usable form (ammonia/ammonium) that the plant can absorb
B. Producing the oxygen the plant requires to carry out cellular respiration in its roots
C. Breaking down the plant's old roots to provide nitrogen recycled from the plant itself
D. Eating the herbivorous insects that would otherwise eat the plant during its growing season

44. Farmers often grow legume crops in rotation with other crops because:

A. Legumes physically displace pests that would otherwise infest the soil where they grow
B. Legumes, through their bacterial symbionts, add nitrogen-rich compounds to the soil
C. Legumes attract pollinator insects that improve the yields of all surrounding crops
D. Legumes cool the soil temperature, allowing other crops to germinate more quickly

45. Plants absorb nitrogen from the soil primarily in which form?

A. As nitrogen gas (N2) that has dissolved into the water surrounding the plant's roots
B. As nitrogen-containing proteins released by other plants growing in the surrounding soil
C. As nitrate ions ($NO3^-$) and ammonium ions ($NH4^+$) dissolved in the soil water
D. As nitrogen atoms transported into the roots by direct contact with the atmosphere

46. When an organism dies, the nitrogen in its body returns to the soil through the action of:

A. Decomposers such as bacteria and fungi that break down the nitrogen-containing molecules
B. Producers such as plants that absorb whole nitrogen compounds from dead organisms directly

C. Primary consumers such as herbivores that release nitrogen into the soil as they walk on it
D. Sunlight, which breaks down the dead body and releases its nitrogen content as gases

Base your answers to questions 47 through 50 on the information below and on your knowledge of biology.

Biotechnology refers to the use of living organisms, cells, or biological processes to develop products and technologies that benefit humans. Modern biotechnology techniques include genetic engineering, in which DNA from one organism is inserted into another organism to give it a new trait. One well-known example is the production of human insulin by bacteria: the human gene that codes for insulin is inserted into bacterial DNA, and the modified bacteria are then grown in large quantities to produce human insulin used to treat diabetes. Other applications include genetically modified crops, DNA fingerprinting for criminal investigations, and gene therapy to treat inherited disorders.

47. A bacterium that has been given the human insulin gene produces functional human insulin. This shows that:

A. Bacterial cells contain natural insulin that can be activated by inserting a human gene
B. Human cells and bacterial cells use entirely different codes to translate DNA into proteins
C. Insulin is the only protein that bacteria are capable of producing using human DNA
D. The genetic code is essentially universal — different organisms read DNA in the same way

48. Producing human insulin in bacteria offers an important medical advantage because:

A. Bacterial insulin is chemically different from human insulin and provides longer-lasting effects
B. The insulin produced this way is given directly to bacteria, not to human patients with diabetes
C. Large quantities of pure human insulin can be produced relatively quickly and at low cost
D. Bacterial insulin can be absorbed through the skin without needing any injections at all

49. DNA fingerprinting can be used to identify individuals because:

A. Every person has exactly the same DNA sequence except for the genes affecting eye color
B. DNA fragments produced from any sample always result in identical patterns of bands
C. Identical twins have different DNA sequences and produce different DNA fingerprints
D. The unique pattern of DNA sequence variation differs from one individual to another

50. When evaluating a proposed biotechnology application, which factor is most important to consider?

A. The aesthetic appeal of the laboratory equipment used to perform the genetic engineering
B. The balance among potential benefits, safety concerns, ethical issues, and broader social impacts
C. The number of patents the biotechnology company has filed during the previous calendar year
D. The amount of attention the biotechnology project receives from popular news media reporting

PRACTICE EXAM 17 — EXPLAINED ANSWER KEY (Q1–Q50)

1. B — Cell walls are a defining structural feature of plant cells and are absent from animal cells. The data show the cell wall present only in onion cells, not in cheek cells, while both cell types have a nucleus and a cell membrane. The wall is therefore the key distinguishing feature.

2. C — Plant cell walls are built primarily of cellulose, a structural polysaccharide composed of long chains of glucose units. Cellulose fibers form a rigid network that gives plants their shape and protects against osmotic bursting. This contrasts with the lipid-based animal cell membrane, which lacks structural rigidity.

3. A — Chloroplast development requires light to convert proplastids into mature, chlorophyll-containing chloroplasts. Onion bulbs develop underground in darkness, so their epidermal cells never receive the light signal and remain without chloroplasts. The leaf cells of the same onion plant, which do receive light, contain abundant chloroplasts.

4. D — The central vacuole stores water, dissolved salts, sugars, and waste products, and the resulting internal pressure (turgor) pushes the cell membrane against the rigid cell wall. This turgor pressure is what keeps non-woody plant tissues firm and upright. When water is lost from the vacuole, turgor falls and the plant wilts.

5. B — Both methylene blue and iodine bind strongly to nucleic acids (DNA and RNA), which are densely concentrated within the nucleus. This is why the nucleus appears as a darkly stained region in both cell types. Nuclear staining is a fundamental technique in cell identification and microscopy.

6. A — At pH 2, only 15% of the egg white remained, meaning digestion was greatest in this most acidic tube. The smallest amount of remaining substrate indicates the highest enzyme activity. This optimum matches the acidic environment in which pepsin normally functions.

7. C — Pepsin works best at pH ~2, which matches the strongly acidic environment created by hydrochloric acid secreted by gastric cells in the stomach. This match between enzyme optimum and location is no accident — pepsin evolved to function in the gastric environment. Drugs that reduce stomach acid can impair protein digestion as a side effect.

8. D — Strongly alkaline conditions disrupt the hydrogen and ionic bonds that hold pepsin in its functional shape, denaturing the active site. Once the active site is distorted, substrate can no longer bind and catalysis stops. This is also why pepsin is inactivated when stomach contents enter the alkaline small intestine.

9. A — Egg white (albumin) is composed almost entirely of protein. Pepsin is a protease — an enzyme that hydrolyzes peptide bonds, breaking proteins into smaller chains of amino acids. Each digestive enzyme is highly specific to a particular type of substrate.

10. B — All enzymes accelerate reactions by lowering the activation energy required for the reaction to occur, by stabilizing the transition state at the active site. They are not consumed in the reaction and do not add energy to the system — they simply make the reaction easier to start. This is a unifying principle across all biological catalysis.

11. C — The snail respired, releasing CO_2 into the water. The dissolved CO_2 reacted with water to form carbonic acid, lowering the pH and turning the indicator yellow. With no photosynthesizer present to remove the CO_2, it accumulated throughout the day.

12. A — In bright light, the *Elodea* photosynthesized rapidly, absorbing CO_2 from the water faster than its own respiration produced it. This net removal of CO_2 raised the pH, keeping the indicator blue and even deepening the color. Net gas exchange in plants always depends on the balance between photosynthesis and respiration.

13. D — The snail's respiration produced CO_2, while the *Elodea*'s photosynthesis consumed CO_2 at roughly the same rate. With production and consumption balanced, CO_2 levels remained stable and the indicator stayed blue. This mini-ecosystem illustrates how photosynthesizers and respirers complement each other.

14. B — Photosynthesis takes in CO_2 and releases O_2; cellular respiration does the reverse. The two processes form a coupled exchange of gases that continuously recycles carbon and oxygen at the cellular level. Flask 3 is a small-scale model of this exchange in any ecosystem.

15. C — In complete darkness, *Elodea* cannot photosynthesize but continues to respire. Both organisms would then become net CO_2 producers, lowering pH and turning the indicator yellow. This shows that the gas balance in Flask 3 depended on light to drive photosynthesis.

16. A — Mitochondria perform the citric acid cycle and oxidative phosphorylation, generating roughly 90% of cellular ATP from food molecules. Their inner membrane houses the electron transport chain, where most ATP is made. Cells with high energy demand — muscle, heart, neurons — contain especially large numbers of mitochondria.

17. D — Active transport moves substances against their concentration gradient — from a region of lower concentration to one of higher concentration — which requires energy input from ATP. Diffusion, in contrast, is passive and follows the gradient downhill. The sodium-potassium pump is a classic example of active transport.

18. C — Muscle contraction requires ATP to drive myosin cycling against actin filaments, and active transport pumps need ATP to move ions against their gradients. Without ATP, these processes stop almost immediately. This is why even brief ATP depletion is rapidly lethal to cells.

19. B — Breaking the bond between the second and third phosphate of ATP releases stored chemical energy that the cell uses to power other reactions, including muscle contraction, transport, and biosynthesis. Energy is not created or destroyed — it is transferred from one form to another. This principle underlies all of cellular metabolism.

20. A — DNA base pairing follows strict rules: A pairs with T, and G pairs with C. Reading the template A-T-G-C-A-T gives the complementary strand T-A-C-G-T-A. Note that uracil (U) replaces thymine only in RNA, not in DNA replication.

21. C — Without replication, only one of the two daughter cells could receive the genome, leaving the other without genetic instructions. Replication doubles the DNA precisely so that mitosis can distribute one complete copy to each daughter cell. Errors in this process produce mutations that may have consequences for the organism.

22. D — Somatic (body cell) mutations are passed only to the descendant cells produced by the original mutated cell. They do not occur in germ-line cells (sperm or egg) and so are not transmitted to offspring. Only germ-line mutations are heritable across generations.

23. A — A single-base substitution can change a codon to one specifying a different amino acid, altering the resulting protein (a missense mutation). Depending on which amino acid is changed, the protein may function normally, abnormally, or not at all. The sickle-cell mutation is a classic example of this kind of point mutation.

24. B — A mutation is considered beneficial when it produces a protein variant that helps the organism survive or reproduce more successfully. Such variants increase in frequency over generations through natural selection. Examples include lactase persistence in humans and antibiotic resistance in bacteria.

25. D — Both parents are unaffected (so neither is homozygous recessive), but they produced an affected son (II-1), who must be homozygous recessive (cc). He must therefore have inherited one recessive allele from each parent. Both parents must be heterozygous carriers (Cc).

26. C — III-2 is affected (cc), so he must have inherited one recessive allele from each parent. II-2 must therefore have contributed a recessive allele, and because she is unaffected she must be heterozygous (Cc). Given that she has an affected son, her probability of being a carrier is 100%.

27. A — III-2 is affected (cc), so he must have inherited one recessive allele from each parent. II-3 is unaffected but had to contribute a recessive allele to III-2, so he must be heterozygous (Cc). This shows how a "married-in" individual can be a hidden carrier of a recessive disorder.

28. B — In a Cc × Cc cross, the Punnett square gives 1 CC : 2 Cc : 1 cc, so 1 of 4 offspring (25%) will be homozygous recessive and affected. This 25% recurrence risk applies to each pregnancy independently. It is the standard prediction for autosomal recessive disorders with two carrier parents.

29. C — Of the four Cc × Cc outcomes, three are unaffected (1 CC and 2 Cc). Given that the child is unaffected, the conditional probability of being a carrier (Cc) is 2/3. This 2/3 result is a key calculation in genetic counseling for unaffected siblings of an affected child.

30. D — Vestigial structures are reduced or nonfunctional remnants of features that were functional in ancestral species. The presence of pelvic bones in modern whales — which have no hind limbs — indicates that whale ancestors did have functional hind limbs. Vestigial structures are an important line of evidence for evolution.

31. A — The gradual transition from land mammal to fully aquatic whale, documented across many intermediate fossils, matches the pattern predicted by natural selection acting on heritable variation over time. Each small change had to confer some advantage in a changing environment. The whale lineage is one of the best-documented evolutionary transitions known.

32. B — A streamlined body reduces drag in water, allowing whales to swim faster, use less energy, and catch more prey. Individuals with more streamlined bodies left more offspring, gradually shifting the population toward this form. This is exactly how natural selection produces adaptive change.

33. D — A shared underlying limb plan — one upper bone, two lower bones, wrist/ankle, and digits — inherited from a common ancestor is the textbook definition of a homologous structure. Different species modify this same basic plan for different functions (swimming, running, grasping). Homology is one of the strongest lines of anatomical evidence for evolution.

34. C — Whales inherited the full set of mammalian limb-development genes from their land-dwelling ancestors. These genes remain in the genome, but the developmental program that would activate them for hind-limb formation is suppressed or altered. Such "silent" genes provide molecular evidence of evolutionary history.

35. A — Major morphological transitions — such as fish to amphibian or land mammal to whale — typically take tens of millions of years in the fossil record. The roughly 50-million-year time scale for whale evolution is consistent with these patterns. The shorter options are far too brief for evolutionary changes of this magnitude.

36. B — Three independent lines of evidence — transitional fossils, comparative anatomy (including vestigial structures), and DNA sequence comparisons with other mammals — all point to the same conclusion. Convergence of multiple independent lines is the gold standard for scientific evidence. No single line stands alone in establishing whale evolution.

37. C — In a lichen, the fungus forms the bulk of the body, providing physical structure, protection from desiccation, and absorption of water and minerals. This protective framework allows the photosynthetic partner to survive in harsh environments. Mutualistic exchange is what makes lichens so successful as pioneer organisms.

38. A — The photosynthetic partner (alga or cyanobacterium) produces sugars from sunlight and CO_2 and shares them with the fungus, which cannot photosynthesize. In return, the fungus provides shelter, water, and minerals. Both partners benefit, making lichens a classic example of mutualism.

39. D — Commensalism is a relationship in which one species benefits while the other is essentially unaffected. The barnacle gains transportation and access to food-rich waters, while the whale neither benefits nor suffers measurable harm. Many epibiont relationships in the ocean fit this commensal pattern.

40. B — Parasitism is a relationship in which one organism (the parasite) benefits while harming its host. Tapeworms drain nutrients and weaken the host without immediately killing it. Successful parasites typically harm their hosts slowly enough to maintain a long-term food supply.

41. C — A host is the parasite's source of food and habitat. A parasite that kills its host too quickly destroys its own resource base and may also die before reproducing. This is why most successful parasites have evolved to harm their hosts in measured, sub-lethal ways.

42. D — N2 is held together by a very strong triple bond that requires substantial energy to break. Most organisms lack the specialized enzymes (such as nitrogenase) needed to disrupt this bond. Only certain bacteria, called nitrogen-fixers, can perform this chemistry biologically.

43. A — *Rhizobium* and related bacteria living in legume root nodules convert atmospheric N2 into ammonia/ammonium, which the plant can incorporate into amino acids. The plant provides sugars to the bacteria in return. This mutualism is the foundation of legume-based agriculture and natural soil fertility.

44. B — Because of their nitrogen-fixing bacterial partners, legumes leave behind nitrogen-rich residues that enrich the soil for the following crop. Crop rotation with legumes (clover, alfalfa, beans) is a traditional way to maintain soil fertility without synthetic fertilizers. This practice has been used in agriculture for thousands of years.

45. C — Plants take up nitrogen mainly as nitrate ($NO3^{-}$) and ammonium ($NH4^{+}$) ions dissolved in soil water. These ions are absorbed through the root hairs and incorporated into amino acids and other nitrogen-containing molecules. Most synthetic fertilizers supply these same usable ions directly.

46. A — Decomposers — primarily bacteria and fungi — break down dead organisms and their wastes, releasing nitrogen back into the soil as ammonia and other usable compounds. Without decomposers, nitrogen would remain locked in dead organic matter and the nitrogen cycle would halt. Decomposers are therefore essential to all ecosystems.

47. D — Bacteria can produce a functional human protein from a human gene because the genetic code — which codons specify which amino acids — is essentially the same across all organisms. This universality is strong evidence of common ancestry and is what makes genetic engineering possible. A human gene placed in bacteria yields the same protein it would in a human cell.

48. C — Before recombinant DNA technology, insulin had to be extracted in small amounts from animal pancreases. Engineered bacteria can be grown in large fermentation tanks to produce abundant, pure human insulin quickly and inexpensively. This was one of the first major successes of medical biotechnology.

49. D — Each person (except identical twins) has a unique pattern of variations in DNA sequence, particularly in repetitive non-coding regions. DNA fingerprinting compares these variations to identify individuals or determine biological relationships with very high reliability. This technique is now standard in forensic science and paternity testing.

50. B — Evaluating biotechnology requires weighing intended benefits (medical, agricultural, economic) against safety concerns, ethical issues, and broader social or environmental impacts. No single criterion is sufficient on its own. This kind of multidimensional trade-off analysis is essential to the responsible application of any powerful technology.