PRACTICE EXAM 39: LIFE SCIENCE: BIOLOGY SIMULATION (50 QUESTIONS — SIX-CASE RESEARCH VIGNETTE FORMAT)

Instructions: Practice Exam 39 is organized into six extended research vignettes (Cases 1–6). Each case presents a short scientific scenario followed by a cluster of questions that probe experimental design, data interpretation, biological mechanisms, and applied reasoning. Read each case carefully before attempting its questions. Select the one best answer for each question.

CASE 1: EFFECT OF TEMPERATURE ON ENZYME ACTIVITY (Questions 1–9)

A high school biology student designs an experiment to test how temperature affects the activity of the enzyme catalase, found in fresh chicken liver. She places equal-sized pieces of liver (1 g each) into separate test tubes containing 5 mL of 3% hydrogen peroxide (H_2O_2). The same pH (7.0) is maintained in all tubes. Five tubes are tested at different temperatures, and the rate of oxygen bubble production is measured for each tube. The student's results are shown in the data table below.

Effect of Temperature on Catalase Activity

Temperature (°C)	Rate of Oxygen Production (mL/min)
5	2
20	6
37	14
60	4
90	0

1. The independent variable in this experiment is best identified as:

A. The rate of oxygen production measured from each tube of the experiment in mL/min over the course of one minute of measurement under each tested experimental condition each time
B. The size of the pieces of chicken liver used in each test tube during the entire experimental procedure throughout the course of the experiment in the laboratory setting on that day
C. The temperature of the hydrogen peroxide solution in each test tube, which is the factor deliberately changed by the experimenter in order to test its effect on enzyme activity
D. The pH of the hydrogen peroxide solution in each test tube, which was kept at a constant value of 7.0 throughout the experiment in the laboratory environment during testing

2. The dependent variable in this experiment is best identified as:

A. The rate of oxygen bubble production in mL/min, since this is the variable that responds to and is measured under each different experimental condition that the student tested in the lab
B. The size of the pieces of liver used in each test tube of the experiment, since this is the variable that determines how much enzyme is available in each test tube during the experiment
C. The temperature of the hydrogen peroxide solution in the tubes, since this is the factor that was deliberately changed by the experimenter during the course of the experiment in the laboratory
D. The pH of the hydrogen peroxide solution in each test tube, since this is the factor that must be kept constant in order to make valid comparisons among the different test tubes in the experiment

3. Which variable should be kept constant in this experiment in order to produce a valid test of the student's hypothesis?

A. The temperature of the hydrogen peroxide solution in each test tube, since this is the variable being changed deliberately in order to test the experimental hypothesis on the enzyme during the test
B. The rate of oxygen bubble production in each test tube of the experiment, since this is the measurement being made in order to determine the effect of temperature on enzyme activity each time
C. The independent variable of the experiment as a whole, which must be deliberately changed throughout the experiment in order to test the relationship between the two variables of the experiment
D. The concentration of hydrogen peroxide (the substrate) in each test tube, since variation in substrate concentration could otherwise affect the rate of the reaction independently of the temperature

4. A weakness in this experimental design is that:

A. There is no measurable difference between the test tubes at any of the five temperatures tested in the experiment, so no scientific conclusion can be drawn from the data set collected by the student
B. The experiment lacks a negative control (such as a boiled liver sample) to confirm that the oxygen production is due to enzyme activity rather than to some other unrelated cause in the experiment
C. The experiment uses too many different temperature values, making it impossible to determine which specific temperature produces the highest rate of oxygen production based on the data collected
D. The substrate hydrogen peroxide cannot be broken down by catalase in living tissue, so the experiment fundamentally cannot test the hypothesis that the student wants to test in the laboratory

5. Based on the data shown in the table, the optimum temperature for catalase activity is approximately:

A. 5°C, because at this lower temperature the enzyme is most stable and least likely to denature during the course of the experiment in the laboratory environment under normal conditions during testing
B. 20°C, because this is approximately room temperature, which is generally the optimum temperature for most enzyme-catalyzed reactions that are tested in a typical biology classroom laboratory environment
C. 60°C, because at this temperature the molecules have the most kinetic energy and the enzyme can catalyze the reaction at the highest possible rate during any laboratory experiment carried out in school
D. 37°C, because this is the temperature at which the data table shows the highest rate of oxygen production by the enzyme catalase during this experimental trial in the laboratory environment

6. At 90°C, the data show a rate of 0 mL/min. The most likely biological explanation for this result is:

A. The high temperature has denatured the enzyme catalase, changing the three-dimensional shape of its active site so that it can no longer bind to the substrate hydrogen peroxide and catalyze the reaction
B. The high temperature has destroyed all of the hydrogen peroxide substrate molecules in the test tube, leaving no substrate available for the enzyme to act upon during the experiment in the laboratory
C. The high temperature has caused the liver cells in the tube to grow more rapidly, using up the oxygen produced by the enzyme reaction within the test tube during the course of the laboratory experiment
D. The high temperature has caused the test tube itself to crack and break open, allowing the oxygen produced by the reaction to escape from the test tube into the air of the laboratory surroundings

7. The catalase enzyme catalyzes the reaction $2H_2O_2 \rightarrow 2H_2O + O_2$. In this reaction, catalase functions to:

A. Provide the energy needed for the chemical reaction to occur, since the enzyme acts as a direct source of chemical energy that drives the formation of the reaction products from the substrate molecules
B. Permanently combine with the hydrogen peroxide molecules during the reaction, becoming a structural part of the products that are formed along with the water and the oxygen produced by the reaction
C. Lower the activation energy needed for the reaction, allowing the breakdown of hydrogen peroxide into water and oxygen to occur much more rapidly at normal body temperature than it would otherwise
D. Increase the total amount of oxygen contained in the products of the reaction compared with the amount of oxygen that was present in the original hydrogen peroxide substrate molecules at the start of the reaction

8. To improve the experimental design and confirm that the oxygen production observed is in fact due to catalase activity, the student should:

A. Use a much larger piece of liver in each test tube, since this would produce more total oxygen gas and make the differences between the tubes easier to detect by the student during the experiment in the laboratory
B. Add a control tube containing boiled (denatured) liver tissue to demonstrate that no oxygen is produced when the enzyme catalase has been destroyed by heat before the start of the experimental trial in the laboratory
C. Increase the concentration of hydrogen peroxide used in each tube of the experiment, since this would produce a more dramatic reaction and provide more visible results for the student to record during the

trial
D. Repeat the experiment using only a single temperature value, since multiple different temperatures introduce too much complexity into the interpretation of the data collected by the student during the experiment

9. Suppose the student decided to change both the temperature AND the pH of each test tube at the same time during the experiment. This would create:

A. A confounding variable problem, in which it would be impossible to determine whether observed changes in oxygen production were caused by temperature, by pH, or by both factors at the same time during the trial
B. A more thorough and complete experimental design, since changing multiple variables at the same time always provides more useful information than changing only one variable at a time during a single experiment
C. A negative control condition, since varying both factors simultaneously allows the student to rule out the effects of either single factor on the rate of the enzyme activity in the test tubes during the experiment
D. A standardized experimental procedure, since the simultaneous variation of multiple factors is the standard protocol used by professional scientists in research laboratories around the world during normal experiments

CASE 2: SALT MARSH ECOSYSTEM STUDY (Questions 10–17)

A team of researchers studied a coastal salt marsh ecosystem in New York. They identified the following organisms: cordgrass and salt marsh algae (which carry out photosynthesis), fiddler crabs, marsh snails, and grasshoppers (which feed on the cordgrass and algae), killifish and marsh frogs (which feed on the small herbivores), great blue herons and raccoons (which feed on the fish and frogs), and many species of bacteria and fungi (which break down dead organic matter in the marsh sediment). The team also noted that fertilizer runoff from nearby farms was flowing into the marsh waters during heavy rains.

10. In this salt marsh ecosystem, the cordgrass and salt marsh algae are best classified as:

A. Primary consumers, since they are eaten by herbivorous animals such as fiddler crabs and marsh snails throughout the salt marsh ecosystem during the various seasons of the year each year on the coast
B. Decomposers, since they are responsible for breaking down dead organic matter and recycling nutrients back into the soil of the marsh for use by other organisms in the surrounding ecosystem each day
C. Tertiary consumers, since they occupy the highest position in the food chain of the salt marsh ecosystem and feed on the next lower trophic level throughout all of the seasons of the year on the coast
D. Producers, since they capture energy from sunlight through photosynthesis and convert it into the chemical energy stored in organic molecules that supports all of the other organisms in the ecosystem

11. The most accurate description of how energy moves through the salt marsh ecosystem is that:

A. Energy flows in a continuous cycle from producers to consumers and back to producers again, with the same energy being recycled through the ecosystem in a closed and continuous loop throughout time
B. Energy flows in one direction from the sun through producers to consumers, with a large fraction of energy lost as heat at each trophic level and never returning to its original chemical form in the food web
C. Energy flows from the consumers to the producers, with the consumers passing chemical energy along to the producers, which the producers then use to perform the process of photosynthesis each day
D. Energy flows from the decomposers to the producers and only then to the consumers, with the decomposers serving as the primary energy source for the rest of the salt marsh ecosystem each year

12. If the producers in the marsh capture 50,000 kcal of energy through photosynthesis, the energy approximately available to the secondary consumers (such as killifish and marsh frogs) in the marsh is:

A. 25,000 kcal, since approximately half of the energy at each trophic level is passed on to the next higher trophic level during the transfer of energy in any natural ecosystem on Earth at any time of the year
B. 50,000 kcal, since all of the energy captured by the producers of the marsh eventually becomes available to the consumers higher in the food chain through the process of consumption and digestion each day
C. 500 kcal, since approximately 10% of producer energy is passed to primary consumers (5,000 kcal) and approximately 10% of that energy is then passed on to the secondary consumers (500 kcal) in turn
D. 5,000 kcal, since approximately 10% of the energy at any trophic level reaches the next trophic level in the food chain regardless of the actual position of that trophic level within the ecosystem at any time

13. The decomposers (bacteria and fungi) in this salt marsh ecosystem play the essential role of:

A. Recycling nutrients by breaking down dead organisms and waste products into simpler compounds that can be reabsorbed by the producers, sustaining the nutrient cycles within the salt marsh ecosystem over time
B. Producing the original organic molecules that form the basis of the food chain in the marsh through the process of photosynthesis, using the energy of sunlight as the source of energy for these reactions
C. Consuming live primary consumers such as fiddler crabs and marsh snails as the primary source of food for the bacteria and fungi that are present in the marsh during the various seasons of the year on the coast
D. Generating electrical energy from chemical reactions occurring within the marsh soil, which can then be harvested by other organisms within the salt marsh ecosystem during their normal daily activities each day

14. The fertilizer runoff from the nearby farms most directly affects the salt marsh ecosystem by:

A. Decreasing the amount of sunlight reaching the marsh waters, leading to a decline in the rate of photosynthesis among the producers in the surrounding marsh ecosystem during the rainy season each year
B. Adding excess nitrogen and phosphorus to the marsh water, leading to rapid overgrowth of algae and a process called eutrophication that disrupts the natural balance of the marsh ecosystem over time

C. Lowering the temperature of the marsh water during the summer months of each year, leading to a decrease in the metabolic rates of the organisms that live within the salt marsh ecosystem at that time
D. Removing essential nutrients from the marsh water that the producers need for normal growth, leading to a decline in the total plant biomass throughout the entire salt marsh ecosystem during the year

15. Large algal blooms caused by eutrophication often lead to large fish kills in the affected water body. The most direct biological reason for these fish kills is:

A. The algae directly produce a toxin that is lethal to all fish species, killing the affected fish within just a few hours of the algae's release of the toxin into the water of the marsh ecosystem each year of the bloom
B. The algae outcompete the fish for sunlight in the water column, leaving the fish unable to perform their own photosynthesis and produce the food they need to survive in the marsh ecosystem during the bloom
C. The algae physically attach to the gills of the fish in the marsh and prevent them from being able to take in oxygen from the water of the marsh during their normal breathing during the daily life of each fish
D. When the algae die, decomposer bacteria consume the dead algae and use up the dissolved oxygen in the water, leaving the fish and other aquatic animals to suffocate from low oxygen levels (hypoxia)

16. A salt marsh community with a high biodiversity of species is generally more valuable to the overall ecosystem than a low-diversity community primarily because:

A. High-diversity communities use less total energy and require fewer total resources from the surrounding ecosystem than low-diversity communities do during each year and during each season of the year
B. High-diversity communities prevent any species from ever going extinct, regardless of the environmental conditions that are experienced by the marsh ecosystem during the year or during the seasons of the year
C. High-diversity communities are more resilient to environmental change and disturbance because the loss of any one species is less likely to cause the overall collapse of the entire ecosystem during a disturbance
D. High-diversity communities contain only species that are economically beneficial to humans, while low-diversity communities contain only species that have no significant economic value to humans at any time

17. The most effective long-term conservation strategy for protecting this salt marsh ecosystem would be:

A. Preserving and protecting the salt marsh habitat itself, combined with reducing the amount of fertilizer runoff from the surrounding farms into the marsh waters during heavy rains over the long term in the region
B. Removing all of the decomposer organisms from the marsh ecosystem in order to prevent the breakdown of plant materials and animal waste products within the marsh during each year of the marsh's existence
C. Adding more nitrogen-rich fertilizer to the marsh water in order to increase the growth of the

producers, since this would provide more food and energy for the rest of the marsh ecosystem during each year
D. Introducing several large invasive predator species into the marsh in order to reduce the populations of fiddler crabs and snails and other small marsh organisms that live in the marsh during the year

CASE 3: TYPE 1 DIABETES MEDICAL CASE (Questions 18–25)

A 14-year-old patient presents to the doctor's office with frequent urination, excessive thirst, sudden weight loss, and fatigue. Blood tests reveal extremely elevated blood glucose levels (350 mg/dL; normal fasting level is 70–110 mg/dL). Further testing reveals the presence of antibodies in the patient's blood that attack the beta cells of the pancreas. Based on the test results and clinical symptoms, the patient is diagnosed with Type 1 diabetes mellitus.

18. In the patient's body, the cells that have been destroyed by the immune system normally produce:

A. Glucagon, a hormone that raises blood glucose levels by signaling the liver to convert stored glycogen back into glucose for release into the bloodstream during fasting periods between meals each day
B. Adrenaline, a hormone that prepares the body for emergency situations by increasing the heart rate and blood pressure in response to stress during a fight-or-flight response of the autonomic nervous system
C. Cortisol, a hormone that helps the body to respond to long-term stress and that has many effects on metabolism throughout the body of the affected patient during the course of each day of life
D. Insulin, a hormone that lowers blood glucose levels by signaling body cells to take up glucose from the bloodstream and by signaling the liver to store excess glucose as glycogen for later use

19. The specific cells of the pancreas that are destroyed in Type 1 diabetes mellitus are the:

A. Acinar cells, which secrete digestive enzymes into the small intestine through the pancreatic duct during the normal process of digestion of food after eating each meal during the day of the patient
B. Alpha cells, which produce the hormone glucagon, which then acts to raise blood glucose levels during periods of fasting or low blood sugar throughout the patient's daily life and activities each day
C. Beta cells of the islets of Langerhans, which produce and secrete the hormone insulin into the bloodstream in response to rising blood glucose levels following meals consumed by the patient
D. Delta cells, which produce the hormone somatostatin and help to regulate the activity of the other endocrine cells of the pancreas during the normal hormonal function of the gland in the body

20. The phrase "autoimmune disease" is best defined as a condition in which:

A. The body becomes unable to mount an immune response of any kind against pathogens, leaving the patient extremely vulnerable to infections of all types they might encounter in their daily life and activities

B. The body's immune system mistakenly attacks and destroys the body's own healthy cells and tissues, instead of attacking foreign pathogens such as bacteria and viruses that have invaded the body
C. The body produces large quantities of antibodies that attack only foreign pathogens, providing the patient with a stronger than normal immune response against all infections during life and daily activities
D. The body's immune system is completely absent at birth, resulting in a complete inability of the patient to fight off any pathogens that the patient encounters during their daily life and activities each day

21. The patient's symptom of frequent urination is most directly explained by:

A. High blood glucose levels exceeding the kidney's capacity for reabsorption of glucose, so excess glucose passes into the urine and draws additional water along with it through osmosis as it is excreted
B. Damage to the patient's bladder muscle that has occurred as a direct complication of the patient's high blood glucose levels during the past few weeks of the patient's illness with this disease over time
C. An increase in the patient's blood pressure that has been caused by the rising blood glucose levels in the body of the patient during the past several weeks of their illness with this disease overall
D. A complete loss of antidiuretic hormone (ADH) production by the pituitary gland of the patient, leading to a separate disease condition that is properly called diabetes insipidus instead of diabetes mellitus

22. The most appropriate long-term treatment for this patient is:

A. Increasing the patient's physical exercise routine to extreme levels each and every day, in order to burn off all of the excess glucose in the patient's bloodstream throughout the day of the patient each day of life
B. Strict carbohydrate avoidance through a diet that contains no carbohydrate-rich foods of any type at all, since this is sufficient by itself to prevent the elevation of blood glucose in Type 1 diabetes mellitus
C. Oral medications that increase the body's sensitivity to its own insulin production, since these medications are the primary first-line treatment used for Type 1 diabetes mellitus in patients of all ages each year
D. Lifelong injections of insulin (or insulin pump therapy) to replace the hormone that the patient's body no longer produces, combined with careful management of the patient's diet and exercise routine

23. Normally, when blood glucose rises after a meal, insulin is released into the bloodstream and causes:

A. The liver to break down stored glycogen back into glucose and release that glucose into the bloodstream, raising the blood glucose levels even further than they were after the meal was eaten in the body
B. Body cells to release stored glucose from their cytoplasm into the bloodstream, raising blood glucose levels even further than they were after the meal had been eaten and digested by the patient
C. Body cells to take up glucose from the bloodstream and the liver to convert excess glucose into glycogen for storage, lowering blood glucose levels back toward the normal homeostatic set point
D. The pancreas to release additional glucagon into the bloodstream, which then helps to lower blood glucose levels back toward the normal range after the meal has been digested by the body each time

24. The relationship between the hormone insulin and blood glucose levels is best classified as an example of:

A. Positive feedback, in which the rise in blood glucose causes increased insulin release, which then causes a further rise in blood glucose to continue indefinitely throughout the body of the patient each day
B. Negative feedback, in which the rise in blood glucose triggers insulin release, which then lowers blood glucose back toward the normal set point and reduces the original stimulus that caused the response
C. Active transport, in which insulin uses ATP energy to move glucose molecules across the cell membranes of body cells against the concentration gradient that exists within the body of the patient each day
D. Genetic regulation, in which insulin acts on the DNA inside the nucleus of body cells to turn specific genes on or off in direct response to the changing levels of blood glucose in the body of the patient

25. The main difference between Type 1 and Type 2 diabetes mellitus is that:

A. Type 1 diabetes involves little or no insulin production due to autoimmune destruction of pancreatic beta cells, while Type 2 diabetes typically involves normal or elevated insulin production with cellular insulin resistance
B. Type 1 diabetes involves insulin resistance with normal insulin production by the pancreas, while Type 2 diabetes involves an absolute deficiency of insulin production by the pancreas due to autoimmune destruction
C. Type 1 diabetes is caused by a poor diet and lifestyle factors over many years of life, while Type 2 diabetes is caused entirely by genetic factors inherited from the parents of the affected patient at birth
D. Type 1 diabetes always develops in adulthood after many years of poor general health, while Type 2 diabetes always develops in early childhood without any warning to the affected patient before symptoms begin

CASE 4: HEMOPHILIA IN A FAMILY PEDIGREE (Questions 26–33)

Mary's father has hemophilia, a blood-clotting disorder caused by a recessive allele on the X chromosome (X^h). Mary's mother does not carry the hemophilia allele. Mary married John, who does not have hemophilia. Mary and John have three children: two sons and one daughter, and none of them currently shows any symptoms of hemophilia. The family wants to understand the genetic risks to themselves and to their future children and grandchildren.

26. Hemophilia is best classified as:

A. An autosomal dominant trait, in which a single copy of the dominant allele on a non-sex chromosome is sufficient to cause the disorder in any individual carrying the allele in their cells throughout life
B. An autosomal recessive trait, in which two copies of the recessive allele on a non-sex chromosome

are required to cause the disorder in any individual carrying the alleles in their cells throughout life
C. An X-linked recessive trait, in which the recessive allele is carried on the X chromosome and males need only one copy of the recessive allele to be affected while females need two copies to be affected
D. A Y-linked trait, in which the recessive allele is carried on the Y chromosome and is passed only from affected fathers to all of their sons but never to any of their daughters during the course of reproduction

27. Based on the family history given, Mary's genotype with respect to the hemophilia gene must be:

A. X^HX^H (homozygous dominant), since her mother does not carry the hemophilia allele and she did not inherit the recessive allele from her father through the process of normal sex-linked inheritance
B. X^hX^h (homozygous recessive), since both of her parents must have carried the recessive allele in order for her to have inherited two copies of the recessive allele from her parents at the time of her conception
C. X^HY (unaffected male), since this is the genotype of an unaffected male, which would be consistent with the fact that Mary does not show symptoms of hemophilia herself in the family history given above
D. X^HX^h (heterozygous carrier), since she received the X^h allele from her affected father and the X^H allele from her non-carrier mother, making her heterozygous and phenotypically unaffected for the trait

28. John, who does not have hemophilia, has the genotype:

A. X^HX^H, the homozygous dominant female genotype for the hemophilia gene, which would result in a completely unaffected and non-carrier female phenotype in any individual carrying that combination of alleles
B. X^HY, the unaffected male genotype with one dominant allele on the single X chromosome and a Y chromosome from his father, resulting in the normal blood clotting phenotype that is seen in John
C. X^hY, the affected male genotype with one recessive allele on the single X chromosome and a Y chromosome from his father, which would result in the affected hemophilia phenotype rather than the normal one
D. X^HX^h, the carrier female genotype with one dominant and one recessive allele on the two X chromosomes, which would result in a phenotypically unaffected carrier individual rather than an affected one

29. The probability that any son of Mary and John will have hemophilia is approximately:

A. 50%, because Mary is a carrier (X^HX^h) and each of her sons has a 1 in 2 chance of inheriting either her X^H or her X^h chromosome along with the Y chromosome from John during conception
B. 25%, because both parents must contribute affected alleles in order for the son to be affected by the disorder, and the chance of each parent contributing an affected allele is only one quarter of the total
C. 0%, because John does not have hemophilia, so none of his sons can possibly inherit the hemophilia allele from John during the process of fertilization at the time of each conception in the family
D. 100%, because Mary is a carrier of the hemophilia allele and therefore always passes her X^h chromosome to every one of her sons during the process of fertilization at the time of each conception

30. The probability that any daughter of Mary and John will be affected by hemophilia (express the trait phenotypically) is approximately:

A. 50%, because Mary is a carrier and each of her daughters has a 1 in 2 chance of inheriting the X^h chromosome from her in the same general way that each of her sons would inherit it from her during conception
B. 0%, because the daughters of Mary and John will always receive a normal X^H chromosome from their unaffected father John, so they cannot be homozygous recessive (X^hX^h) for the hemophilia allele
C. 25%, because both parents must contribute affected alleles in order for the daughter to be affected by hemophilia, and the chance of each parent contributing an affected allele is one quarter of the total
D. 100%, because Mary is a carrier of the hemophilia allele and therefore always passes her recessive X^h chromosome to every one of her daughters during the process of fertilization at the time of conception

31. The probability that any daughter of Mary and John will be a heterozygous carrier of the hemophilia allele is approximately:

A. 100%, since Mary is a carrier and always passes her X^h allele to every one of her daughters during conception, making every single one of her daughters a carrier of the recessive allele for the trait
B. 0%, since John does not have hemophilia and therefore cannot pass the recessive X^h allele to any of his daughters during conception, leaving them unable to be carriers of the recessive allele for the disorder
C. 25%, since both parents would have to contribute affected alleles in order for a daughter to be heterozygous for the trait, and the chance of each parent contributing one such allele is only one quarter overall
D. 50%, because Mary is heterozygous and each daughter has a 1 in 2 chance of receiving Mary's X^h allele while always receiving the X^H from John, making her phenotypically unaffected but a carrier of the allele

32. X-linked recessive disorders such as hemophilia affect males much more frequently than they affect females primarily because:

A. The recessive allele for X-linked traits is actually carried on the Y chromosome that only males inherit, which makes males the only sex that can possibly be affected by these traits in any population
B. Female embryos with X-linked recessive traits are spontaneously aborted before birth, while male embryos with the same recessive traits develop normally and are eventually born expressing the trait
C. Males have only one X chromosome, so a single recessive allele on that single X chromosome is expressed in the male phenotype, while females need two copies of the recessive allele to express the trait
D. The X-linked recessive alleles in females are converted into dominant alleles during embryonic development, while the same alleles remain recessive in males throughout their embryonic development each time

33. Mary and John's daughter eventually has a son with her unaffected husband. Suppose Mary and John's daughter has been determined through genetic testing to be a carrier (X^HX^h). The probability that her son will be affected by hemophilia is approximately:

A. 50%, because the carrier mother has a 1 in 2 chance of passing the X^h allele to any of her sons during the process of fertilization at the time of conception of each of her sons during her reproductive life
B. 25%, because both parents would have to contribute affected alleles in order for the son to be affected

by the trait, and the chance of this happening is approximately one out of four times during reproduction
C. 100%, because all sons of any carrier mother will always inherit the X^h allele and develop hemophilia regardless of any other genetic factors in the family situation during each pregnancy of each carrier mother
D. 0%, because the carrier mother only passes her normal X^H allele to her sons during reproduction at conception, leaving the recessive X^h allele unable to be inherited by any of her sons during her reproductive life

CASE 5: ISLAND LIZARD EVOLUTION (Questions 34–41)

A research team has been studying small lizard populations on two neighboring islands in the Caribbean. Island A is densely forested with many tree branches at various heights and few open spaces. Island B is rocky and dry, with few trees and mostly open ground between scattered boulders. After many years of measurement, the team found that Island A lizards have longer toes for gripping branches and somewhat shorter legs, while Island B lizards have shorter toes and longer, more muscular legs better suited for running across open rocky ground. DNA analysis showed that both island populations descended from a single ancestral mainland population that colonized both islands many thousands of years ago.

34. The differences in lizard physical traits between Island A and Island B are best explained by:

A. The conscious choice of each lizard species to develop the particular set of traits they need for their own island environment, since the lizards can choose which physical characteristics to develop over their lifetimes
B. Direct physical effects of the environment on the bodies of individual lizards, such as the act of climbing branches causing the toes to grow longer over the course of any single lizard's lifetime on Island A
C. Natural selection, in which the lizards on each island with traits best suited to their local environment survived and reproduced more successfully than lizards with different traits over many generations of evolution
D. Random changes in gene frequencies caused entirely by genetic drift, with no consistent relationship between the lizard traits and the actual environmental conditions present on each of the two islands at any time

35. If lizards from Island A and Island B were brought together and could no longer produce fertile offspring with each other, this would indicate that:

A. The two lizard populations are genetically identical to each other, since they descended from a single ancestral population that colonized both of the islands many thousands of years ago in the distant past of the islands
B. Two new species have formed through reproductive isolation, since the two populations have diverged enough genetically that they can no longer successfully interbreed and produce viable fertile offspring with each other
C. The lizards on the two islands have evolved into different kingdoms of organisms through the long process of evolution by natural selection over the course of the past several thousand years of

evolutionary history
D. The lizards have not undergone any evolutionary changes at all, since the inability to interbreed is purely a behavioral characteristic and has nothing to do with any genetic differences between the two island populations

36. The hypothesis that both island populations descended from a single ancestral population is most directly supported by which of the following observations?

A. The fact that the two populations live on different islands, since organisms living on different islands always share a common ancestor regardless of any other biological evidence about the populations of the islands
B. The fact that the two populations show different physical traits, since differences in physical traits always indicate common ancestry regardless of any actual genetic data collected from the populations of the islands
C. The fact that lizards exist on both islands, since the presence of the same general type of animal on two islands always proves that they must share a recent common ancestor between them on either island
D. The fact that DNA analysis shows substantial genetic similarity between the two island populations, much more genetic similarity than would be expected if they had independently evolved on the two separate islands

37. The pattern of speciation shown by these two island lizard populations is best classified as:

A. Allopatric speciation, in which a physical barrier (the ocean between the islands) separates two populations and allows them to diverge into separate species over many generations of evolution by natural selection
B. Sympatric speciation, in which new species form within the same shared geographic area as the parent population without any physical barrier separating the two diverging groups during the process of speciation
C. Convergent evolution, in which two unrelated species independently develop similar physical traits in response to similar environmental pressures over many generations of natural selection acting on each population
D. Coevolution, in which two interacting species develop reciprocal adaptations to each other over many generations of natural selection acting on both species during the course of their long shared evolutionary history

38. Additional evidence that the two lizard populations share a common ancestor would include:

A. Records showing that the two islands were once both inhabited only by humans before the lizards arrived on the islands, since this would prove that the lizards arrived from elsewhere together at the same time
B. Observations that the two lizard populations eat exactly the same types of food in the same proportions in their diet, regardless of the differences in the environments of the two islands inhabited by the two populations
C. Similar embryological development patterns and the presence of homologous skeletal structures (such as the bones of the limbs) shared between the two lizard populations on the two different islands they inhabit

D. The fact that the two lizard populations have completely different numbers of chromosomes in their cells, suggesting that they could not possibly have descended from any common ancestor in the past of the islands

39. Suppose researchers were to introduce 50 long-toed lizards from Island A onto Island B. Over many generations, the most likely outcome would be:

A. The introduced Island A lizards would maintain their long-toed phenotype indefinitely on Island B, since their traits are genetically determined and cannot be changed by natural selection on the new island over time
B. The proportion of long-toed lizards on Island B would gradually decrease over time, since natural selection would favor lizards with shorter toes and stronger legs better suited to the open rocky environment of Island B
C. All of the lizards on Island B would quickly evolve to have longer toes, since the introduced long-toed lizards from Island A would always be more reproductively successful in any environment they entered on Island B
D. The lizards on Island B would all die out within just a few generations, since the presence of the introduced long-toed Island A lizards would prevent the original lizards from finding any food in the environment

40. The close match between the physical traits of each lizard population and the environment of its island demonstrates the biological concept of:

A. Adaptation, in which the traits of a population become better suited to the local environment over many generations through the process of natural selection acting on heritable variation in the population each generation
B. Acclimatization, in which an individual organism makes physiological adjustments during its own lifetime in response to changes in environmental conditions experienced by that single individual organism over time
C. Genetic determinism, in which the genes of an organism completely determine its phenotype regardless of any role played by the environment in which the organism happens to live during its own lifespan each year
D. Convergent evolution, in which two unrelated populations independently evolve similar traits in response to the same general environmental pressures over many generations of natural selection acting on each population

41. Which of the following observations would NOT support the modern theory of evolution by natural selection?

A. Fossil evidence showing intermediate forms between modern species and their ancient ancestors throughout the fossil record across many different geographic regions of the world over very long spans of geological time
B. The observation that bacterial populations exposed to an antibiotic develop antibiotic resistance over the course of several generations through the survival and reproduction of the resistant bacterial cells in the population
C. Comparative anatomy showing homologous structures (such as similar bone arrangements) in the

forelimbs of mammals such as whales, bats, and humans, indicating a shared evolutionary history among these species
D. The observation that giraffes today have long necks because giraffes in past generations stretched their necks throughout their lifetimes to reach high leaves on tall trees and then passed the long necks on to their offspring

CASE 6: CRISPR-Cas9 GENETIC ENGINEERING OF A PLANT (Questions 42–50)

A biotechnology company uses CRISPR-Cas9 gene editing technology to insert the luciferase gene from a firefly (Photinus pyralis) into the cells of a tobacco plant. The luciferase enzyme catalyzes a chemical reaction that produces visible light. The company's goal is to produce tobacco plants that glow in the dark, which the company would then use to visually study patterns of gene expression in different tissues of the plant under different environmental conditions.

42. CRISPR-Cas9 is best described as a molecular biology tool that is used for:

A. Sequencing the entire genome of an organism by reading the order of nucleotide bases in its DNA molecules through a series of carefully controlled chemical reactions in the laboratory environment over time
B. Producing many copies of a specific DNA segment through repeated cycles of heating and cooling using a heat-stable DNA polymerase enzyme and short primer sequences to bracket the target DNA region each cycle
C. Editing the genome of a living organism by making precise cuts in DNA at specific target sequences, which then allows researchers to insert, delete, or modify specific genes inside the cells of the organism
D. Separating DNA fragments of different sizes from each other by their migration through a gel matrix under the influence of an electric field applied across the gel during the course of the laboratory experiment

43. The fact that a gene from a firefly can be inserted into a tobacco plant and still function to produce the luciferase enzyme is best explained by:

A. The genetic code being completely different for every species, so each new gene introduction requires extensive modification to make the gene work in the recipient organism in any meaningful way during the process
B. The genetic code being essentially universal across all living organisms on Earth, allowing genes from one species to be transcribed and translated correctly when inserted into the cells of another species
C. The fact that fireflies and tobacco plants are closely related species on the evolutionary tree of life on Earth, since they share a very recent common ancestor from which both species directly descended over time
D. A special enzyme produced by tobacco plants that automatically translates any foreign DNA into the proteins of the host species during the process, regardless of the original source of the foreign DNA inserted

44. The fact that the same DNA-based genetic code is used by both fireflies and tobacco plants to produce functional proteins provides strong evidence for:

A. A single common evolutionary origin of all life on Earth, since the universality of the genetic code suggests that it arose only once in the deep evolutionary past and was inherited by all subsequent descendants of life
B. Multiple independent origins of life on Earth in the deep past, since different organisms developed similar but not identical genetic codes from different evolutionary starting points in the early history of life on Earth
C. The non-existence of evolution as a real biological process, since the genetic code would be expected to be completely different in different species if evolution had ever occurred on the planet during its history
D. Frequent horizontal gene transfer between fireflies and tobacco plants in nature, with genes regularly moving between these two species during their normal life cycles in their natural environments each year

45. A plant that has been genetically modified to contain a gene from a different species (such as the tobacco plants in this study) is best classified as:

A. A hybrid, which is the offspring produced by mating two different but closely related species during normal sexual reproduction in the wild without the assistance of any human intervention or any modern technology
B. A clone, which is a genetically identical copy of another organism produced through asexual reproduction techniques in the laboratory without the use of any sexual reproduction during the production of the clone
C. A polyploid, which is an organism that has more than two complete sets of chromosomes in each of its cells throughout the body of the organism during the entire life cycle of the organism on the planet
D. A transgenic organism (or genetically modified organism, GMO), which is an organism that has been genetically engineered to contain DNA from a different species, allowing it to express traits not originally present

46. Public concerns about genetically modified organisms (GMOs) include several important issues. Which of the following is NOT generally considered a major concern about GMOs?

A. The potential for unforeseen ecological consequences if a GMO escapes into the wild and interbreeds with wild relatives, possibly disrupting natural ecosystems in unintended ways over the course of time after release
B. The potential for allergens or other health-related issues that might result from unintended changes in the chemistry of the GMO crop plant that could affect human consumers of the plant after they eat the plant
C. The claim that genetic modification using modern biotechnology is technically impossible, so no actual GMOs have ever been successfully produced anywhere in the world to date despite the many claims to the contrary
D. The ethical implications of patenting living organisms and the resulting economic effects on farmers who might be forced to depend on a single biotechnology company for their seed supply each year of their farming careers

47. For the luciferase gene from the firefly to actually produce a functional luciferase enzyme inside the cells of the tobacco plant, the gene must undergo:

A. Mitosis and cytokinesis, which would divide the plant cells containing the luciferase gene into two daughter cells, each carrying its own copy of the gene from the original parent cell during the process of cell division
B. Transcription (DNA → mRNA) followed by translation (mRNA → protein) using the tobacco plant's own RNA polymerase, ribosomes, and tRNAs to produce the firefly luciferase enzyme inside the plant cells
C. DNA replication only, which would copy the luciferase gene many times in the cells of the tobacco plant without ever actually producing any of the luciferase enzyme inside the cells of the plant during the process
D. Direct conversion of the DNA sequence into a functional protein without any intermediate steps, since the universal genetic code allows the DNA molecule itself to act directly as a functional enzyme in the cell

48. If the luciferase gene is successfully inserted into the tobacco plant cells but no light is produced by the plant, the most likely explanation is that:

A. The genetic code in tobacco plants is fundamentally different from that of fireflies, so the inserted gene cannot possibly be translated into a functional protein in the tobacco plant cells under any circumstances at all
B. The luciferase gene has degraded completely between the time it was inserted into the cells and the time of testing for light, since foreign DNA cannot survive in any cell for more than a few hours of time in the cell
C. The tobacco plant has actively destroyed the inserted gene to protect itself from foreign DNA, since plants automatically eliminate all genetic material from other species whenever it enters into their cells at any time
D. The inserted gene is missing the regulatory sequences (such as a plant promoter) needed by the tobacco plant's transcription machinery to recognize the gene and transcribe it into mRNA inside the plant cells

49. To confirm that the luciferase gene has actually been incorporated into the DNA of the tobacco plant cells, the researchers could use:

A. PCR to amplify the luciferase gene sequence from the plant DNA, followed by gel electrophoresis to confirm the presence of a DNA band of the correct expected size for the luciferase gene from the firefly
B. Microscopic examination of the tobacco plant cells under a standard light microscope in the laboratory, which would directly reveal the presence or absence of the inserted firefly gene in each cell of the plant
C. Treatment of the plant with a broad-spectrum antibiotic, since plants containing the firefly luciferase gene are always resistant to all known antibiotic compounds at the molecular level inside their cells
D. Simply observing whether the entire tobacco plant glows in the dark when placed in a dark room, since glowing is the only possible way to determine whether the luciferase gene is present in the plant cells

50. Genetic engineering of organisms using CRISPR-Cas9 differs from traditional selective breeding mainly because CRISPR-Cas9 technology:

A. Always produces organisms with traits that are completely identical to those produced by traditional selective breeding, with no significant difference in the final outcomes of these two distinct breeding processes
B. Cannot introduce traits that are not already present in the species being modified, while traditional selective breeding is the only method that can introduce entirely new traits into an organism's gene pool over time
C. Allows precise insertion of specific genes from any species (including unrelated species) in a single generation, while traditional selective breeding works only with traits already present in a species and requires many generations
D. Always produces sterile organisms that cannot pass on the newly introduced traits to their offspring during reproduction, while traditional selective breeding always produces fertile offspring with the modified traits

Practice Exam 39: Life Science: Biology Simulation — Answer Key with Explanations

1. C — The independent variable is the factor the experimenter deliberately manipulates to test its effect. Here the student changed only the temperature (5°C, 20°C, 37°C, 60°C, 90°C) while holding all other conditions constant. Correctly identifying the IV is the foundation of valid experimental design.

2. A — The dependent variable is the measured outcome whose value depends on the IV. The student measures the rate of oxygen bubble production in mL/min in response to the different temperatures imposed. The DV is what changes as a result of the experimenter's manipulation of the IV.

3. D — Substrate concentration directly affects reaction rate independently of temperature, so it must be held constant to isolate the effect of temperature. The student kept the H_2O_2 amount uniform (5 mL of 3%) across all tubes for exactly this reason. Failing to control such variables introduces confounding effects that invalidate the conclusions.

4. B — A negative control demonstrates the baseline result when the variable of interest (here, active enzyme) is absent. Without a tube containing boiled liver, the student cannot rule out that oxygen bubbles came from some non-enzymatic source. Negative controls are essential for distinguishing real biological effects from background artifacts.

5. D — The data table shows 14 mL/min at 37°C, the highest rate of any temperature tested. This matches the fact that mammalian enzymes have evolved optimal activity near normal body temperature. Above and below this optimum, enzyme activity falls off sharply, as the table also shows.

6. A — At extreme heat, the weak interactions (hydrogen bonds, hydrophobic contacts) that hold an enzyme's three-dimensional shape are disrupted. The active site loses the precise geometry needed to bind hydrogen peroxide, and the enzyme is permanently denatured. This is why most enzymes function only within a narrow temperature window.

7. C — Enzymes are biological catalysts that work by lowering the activation energy required for a reaction. They do not provide energy themselves and are not consumed as part of the products. By lowering activation energy, catalase allows H_2O_2 to be broken down rapidly at body temperature instead of slowly accumulating to toxic levels.

8. B — A control tube with boiled (denatured) liver provides a side-by-side comparison in which the enzyme is inactivated but everything else is identical. If no bubbles form in that tube, the bubbles in the experimental tubes can confidently be attributed to functional catalase. This is the textbook way to verify that an observed effect is enzymatic in origin.

9. A — Changing two variables at once is a textbook example of a confounding variable problem because any observed change in the DV cannot be attributed to either factor alone. Valid experimental design requires varying only one factor at a time while controlling all others. This is why "one-variable-at-a-time" testing is a fundamental rule of the scientific method.

10. D — Producers (autotrophs) capture energy from sunlight through photosynthesis and convert it into chemical energy stored in glucose and other organic molecules. Cordgrass and salt marsh algae perform photosynthesis, occupying the base of every food chain in the marsh. All higher trophic levels ultimately depend on producer energy.

11. B — Energy in an ecosystem flows unidirectionally from sunlight → producers → consumers → decomposers, with substantial energy lost as heat at each transfer. Energy cannot be recycled the way matter is, because the second law of thermodynamics requires that some energy be dissipated as heat during each conversion. This is why ecosystems require a constant input of solar energy.

12. C — Roughly 10% of the energy at each trophic level passes to the next. Producers (50,000 kcal) → primary consumers (5,000 kcal) → secondary consumers (500 kcal). This rapid loss explains why food chains rarely exceed four or five trophic levels in natural ecosystems.

13. A — Decomposers break down dead organic matter and waste products into inorganic forms (such as ammonium, phosphate, and CO_2) that producers can then reabsorb. Without this recycling activity, essential nutrients would remain locked up in dead biomass and ecosystem productivity would collapse. Decomposers are the unsung connectors of every biogeochemical cycle.

14. B — Fertilizer is rich in nitrogen and phosphorus, the nutrients that most often limit aquatic plant and algal growth. When runoff delivers excess of these nutrients, algae bloom rapidly and the resulting cascade is called eutrophication. This well-documented effect of agricultural runoff drives "dead zones" worldwide, including the Gulf of Mexico hypoxic zone.

15. D — Fish kills in eutrophic waters are driven by oxygen depletion, not direct toxicity from the algae. After a bloom dies off, decomposer bacteria respire so much oxygen breaking down the algal mass that the water becomes hypoxic. Fish and other aquatic animals then suffocate, sometimes in large numbers within a single night.

16. C — High biodiversity increases ecosystem resilience because functional redundancy means that the loss of one species can be partly compensated by others. Low-diversity systems often collapse entirely when a key species declines. This is one of the strongest scientific arguments for biodiversity conservation.

17. A — Effective conservation requires both protecting the habitat itself and addressing the upstream pollution source, in this case agricultural runoff. Habitat protection alone fails if pollution continues, and pollution control alone fails if habitat is destroyed. Integrated watershed-level management is now the standard approach in salt marsh conservation.

18. D — Beta cells of the pancreatic islets produce insulin, the only hormone that lowers blood glucose. Autoimmune destruction of beta cells eliminates insulin production, leading to the chronic hyperglycemia that defines Type 1 diabetes. Without insulin replacement, the disease was uniformly fatal before its discovery in the 1920s.

19. C — The islets of Langerhans are clusters of endocrine cells scattered throughout the pancreas, with beta cells producing insulin and alpha cells producing glucagon. In Type 1 diabetes, autoantibodies specifically target beta cells while sparing the alpha cells. Acinar cells (exocrine) and other islet cell types are not affected.

20. B — Autoimmunity occurs when the immune system fails to distinguish self from non-self and attacks the body's own healthy cells and tissues. The presence of antibodies against beta cells in this patient is direct evidence of autoimmune attack. Other autoimmune diseases include multiple sclerosis, rheumatoid arthritis, and lupus.

21. A — Once blood glucose exceeds about 180 mg/dL, the kidney's glucose reabsorption transporters become saturated and excess glucose spills into the urine. Glucose in the renal tubule pulls water along osmotically, producing the polyuria (frequent urination) classic for diabetes. The resulting water loss triggers the intense thirst (polydipsia) also seen in this patient.

22. D — Because Type 1 diabetics produce essentially no insulin, exogenous insulin must be supplied for life through injections or insulin pumps. No oral medication can replace absent insulin production, since insulin itself is a peptide that would be digested if taken by mouth. Diet management and exercise are important adjuncts but cannot replace insulin.

23. C — Insulin's two main actions are to stimulate glucose uptake by skeletal muscle and adipose cells (via translocation of GLUT4 transporters to the membrane) and to drive the liver to store glucose as glycogen. Together, these actions lower blood glucose back toward the normal set point of about 90 mg/dL. Glucagon, secreted by alpha cells, has the opposite effect during fasting.

24. B — Negative feedback regulation occurs when a change in a variable triggers a response that returns the variable toward its set point. Rising glucose triggers insulin release, which lowers glucose, which in turn shuts off further insulin secretion. Almost all homeostatic systems in the body rely on negative feedback loops of this kind.

25. A — Type 1 diabetes results from autoimmune destruction of pancreatic beta cells and an absolute deficiency of insulin, typically beginning in childhood or adolescence. Type 2 diabetes typically develops in adulthood and is characterized by insulin resistance with normal or elevated insulin production, often associated with obesity. The treatments and prognoses for the two types differ accordingly.

26. C — Hemophilia is caused by a recessive allele on the X chromosome. Males with one X^h are affected because they have no second X to mask the recessive allele, while females need two X^h alleles to be affected. This pattern explains why hemophilia, like red-green colorblindness, is overwhelmingly seen in males.

27. D — Mary's father had hemophilia (X^hY) and must have passed his single X^h to every daughter; her mother was non-carrier (X^HX^H) and passed X^H. Mary therefore inherited one X^H and one X^h and is an obligate carrier (X^HX^h). She is phenotypically unaffected but can pass the recessive allele to her own children.

28. B — An unaffected male carries one normal allele on his single X chromosome and a Y from his father, denoted X^HY. Because John has only one X and only one allele at this locus, his phenotype is uniquely determined by that single allele. There is no possibility for him to be a "carrier" in the way a heterozygous female can be.

29. A — Mary (X^HX^h) × John (X^HY) → sons receive Y from John and either X^H or X^h from Mary with equal probability. Half of sons will be X^HY (unaffected) and half X^hY (affected). The 50% risk for each son is the classic finding in X-linked recessive inheritance from a carrier mother.

30. B — Daughters of John receive his X^H chromosome and therefore cannot be homozygous recessive (X^hX^h). They will be either X^HX^H (homozygous unaffected) or X^HX^h (heterozygous carrier), but never affected. This is why X-linked recessive disorders are so rare in females.

31. D — Each daughter receives X^H from John (always) and either X^H or X^h from Mary with equal probability. Half of daughters will therefore be X^HX^H and half will be X^HX^h carriers. A 50% carrier risk for daughters of a carrier mother is the standard expectation in X-linked recessive inheritance.

32. C — Because males have a single X chromosome (XY) instead of two (XX), any recessive allele on that single X is expressed in the phenotype with no chance of being masked by a dominant counterpart. Females with one recessive allele are typically carriers rather than affected. This hemizygous condition in males explains the dramatic male bias in X-linked recessive disorders.

33. A — A carrier daughter (X^HX^h) crossed with an unaffected man (X^HY) produces sons that receive Y from dad and either X^H or X^h from mom with equal probability. Half of the sons will be X^HY (unaffected) and half X^hY (affected). This 50% recurrence risk for sons of carrier mothers is identical to the original cross in Mary's family.

34. C — Natural selection requires heritable variation, differential survival or reproduction based on that variation, and a resulting shift in population trait frequencies — all three are present in this scenario. Lizards with traits better matched to their island environment leave more offspring, gradually shifting the population mean toward those traits. This is the standard Darwinian mechanism for adaptive evolution.

35. B — Under the biological species concept, two populations are considered distinct species if they cannot interbreed and produce fertile offspring. Reproductive isolation is therefore the defining criterion of speciation in animals. The inability to produce fertile hybrids confirms that speciation has been completed between the two island groups.

36. D — Genetic similarity at the molecular level provides the strongest direct evidence of common ancestry because closely related populations share more recently inherited sequences than independently evolved populations would. The DNA data effectively rule out independent colonization by genetically distinct mainland sources. Modern phylogenetics relies heavily on this kind of comparative DNA evidence.

37. A — Allopatric speciation occurs when a physical barrier — here, the ocean between the islands — prevents gene flow between populations, allowing them to diverge through natural selection and genetic drift. This is the most common mode of speciation in animals. Sympatric speciation, by contrast, occurs without geographic isolation and is less common.

38. C — Homologous structures (such as the same bone arrangement in the forelimbs) and similar embryological development patterns reflect inherited developmental programs from a shared ancestor. These features are independent lines of evidence that supplement molecular data. Together, anatomical, developmental, and molecular evidence converge to support common descent.

39. B — On Island B's rocky terrain, long toes provide no advantage and short toes with strong legs are favored. Over many generations, natural selection would reduce the frequency of long-toed alleles in the introduced population. This is essentially the reverse of the original selective process that produced the difference between the two islands.

40. A — Adaptation refers to traits that have become better suited to an environment through natural selection acting on heritable variation. The match between lizard morphology and island habitat is a textbook case. Adaptation is one of the central concepts of evolutionary biology and is observable in the field within human lifetimes.

41. D — The idea that giraffes lengthened their necks by stretching and passed that length to offspring is Lamarck's discredited "inheritance of acquired characteristics." Modern evolutionary theory rejects this because somatic (lifetime) changes do not alter germline DNA. The other options — fossils, antibiotic resistance, and homologous structures — are all classic lines of evidence for evolution by natural selection.

42. C — CRISPR-Cas9 is a programmable gene-editing system that uses a guide RNA to direct the Cas9 nuclease to a specific DNA target, where it makes a double-strand cut. Researchers can then insert, delete, or alter sequences at the cut site. Its precision, low cost, and ease of use have transformed molecular biology research over the past decade.

43. B — Because the genetic code (the relationship between codons and amino acids) is nearly identical in all living organisms, an mRNA produced from a firefly gene can be correctly translated by tobacco plant ribosomes. This universality is what makes recombinant DNA technology possible across species. It is also one of the strongest pieces of evidence for the common origin of all life.

44. A — The near-universality of the genetic code across bacteria, plants, animals, and fungi is most parsimoniously explained by descent from a single common ancestor that already used this code. Independent origins would almost certainly have produced different codes. The genetic code is one of the deepest pieces of evidence for the unity of life on Earth.

45. D — A transgenic organism (or GMO) contains DNA from another species that has been introduced through genetic engineering. The luciferase-bearing tobacco plant fits this definition exactly. Common transgenic organisms in agriculture include Bt corn, Roundup Ready soybeans, and golden rice.

46. C — The claim that GMO production is "technically impossible" is factually false; GMOs have been produced and commercialized for decades. The other three options reflect legitimate scientific, health, and ethical concerns that are actively debated. Recognizing the difference between real concerns and factually incorrect claims is essential to informed discussion of biotechnology.

47. B — Gene expression requires transcription of DNA into mRNA followed by translation of mRNA into protein. The tobacco plant uses its own RNA polymerase, ribosomes, and tRNAs to carry out these processes on the inserted firefly gene. The protein produced is the same luciferase enzyme that fireflies make.

48. D — Even a perfect coding sequence cannot be transcribed without appropriate regulatory elements, especially a promoter recognized by the host's RNA polymerase. Researchers therefore typically attach a plant-compatible promoter (such as the CaMV 35S promoter) when introducing animal genes into plants. Without this, the gene remains transcriptionally silent in the host genome.

49. A — PCR can specifically amplify the luciferase gene sequence from the plant's genomic DNA using firefly-specific primers, and gel electrophoresis confirms that the amplified product is the correct size. The presence of an appropriately sized band is strong molecular evidence that the gene has been integrated. This combined PCR-plus-gel approach is the standard in transgenic verification.

50. C — CRISPR-Cas9 can introduce DNA from any species, overcoming the species barrier that limits selective breeding, and can do so with high precision in a single generation. Selective breeding, by contrast, only recombines alleles already present within a sexually compatible group and requires many generations to achieve a desired trait. These differences explain both the power and the controversy of modern genetic engineering.