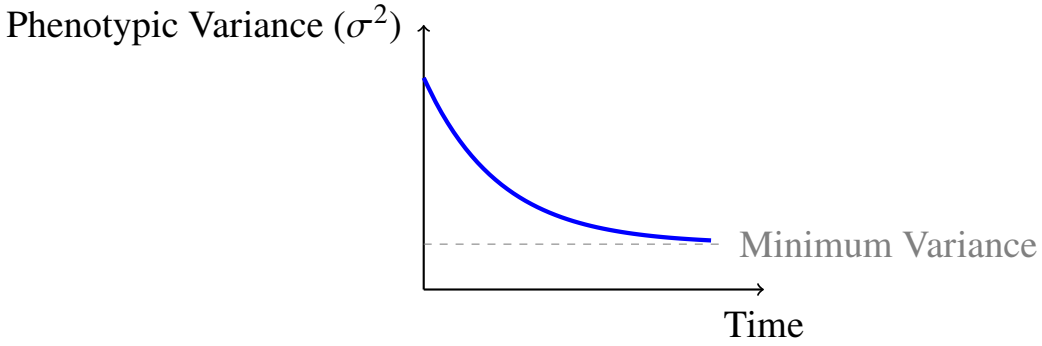
IISER Biology Sample Paper-4

Duration: 45 Minutes **Maximum Marks: 60**

Instructions

- This paper contains **15** Multiple Choice Questions (Single Correct).
- Each correct answer carries **+4 marks**.
- Each incorrect answer carries: **−1** marks.
- Unattempted questions carry **0** marks.
- Only one option is correct for each question.
- Use of mobile phones, smartwatches, calculators, or any electronic gadgets is strictly prohibited.

Q1. A population of a sexually reproducing annual plant species exists in a stable environment. A researcher measures the selection coefficient (s) acting against individuals with extremely small seeds and extremely large seeds over several generations. If the environmental conditions remain unchanged, which of the following graphs best represents the change in phenotypic variance (σ^2) of seed size over time?



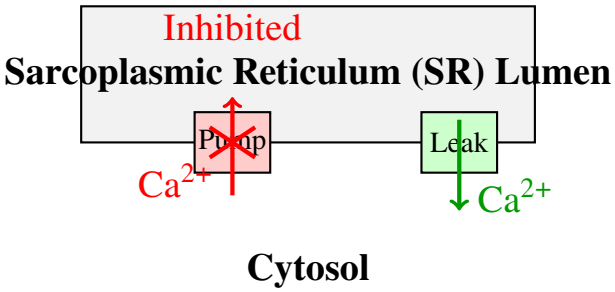
(A) σ^2 increases linearly over time.

(B) σ^2 decreases asymptotically towards a non-zero minimum.

(C) σ^2 remains completely constant from the first generation.

(D) σ^2 undergoes a periodic, sinusoidal fluctuation.

Q2. During a routine laboratory experiment, an isolated sample of healthy human skeletal muscle cells is incubated in a physiological buffer. The buffer is suddenly treated with a metabolic inhibitor that selectively blocks the active transport of Ca^{2+} ions back into the sarcoplasmic reticulum without affecting ATP synthesis or action potential propagation. What is the immediate physiological consequence of this inhibition on the muscle tissue?



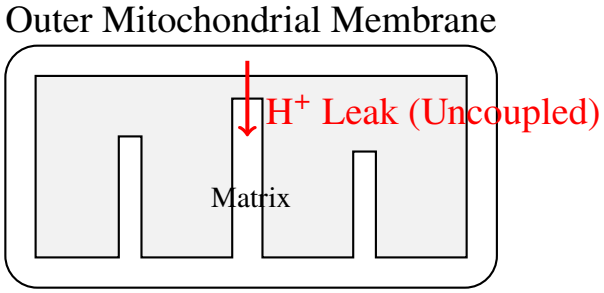
(A) Failure of the muscle to depolarize upon subsequent stimulation.

(B) Immediate and complete relaxation of the muscle fiber due to lack of cross-bridge cycling.

(C) Prolonged activation of the myosin light chain kinase leading to continuous flaccid paralysis.

(D) Persistent cross-bridge formation and sustained contraction due to unmasked myosin-binding sites.

Q3. A molecular biologist isolates a mutant strain of *Saccharomyces cerevisiae* that displays a temperature-sensitive defect in mitochondrial function. At the restrictive temperature (37°C), the inner mitochondrial membrane becomes highly permeable to protons (H^+), while the electron transport chain complex functions and oxygen consumption rates remain fully intact. Which of the following sets of cellular alterations will be observed in this mutant strain at 37°C compared to the wild-type strain?



(A) Decreased rate of citric acid cycle, increased ATP yield per glucose molecule, increased heat generation.

(B) Increased rate of glycolysis, decreased ATP yield per glucose molecule, increased heat generation.

(C) Decreased oxygen consumption rate, increased lactate accumulation, decreased cytosolic pH.

(D) Increased ATP yield per glucose molecule, decreased oxygen consumption rate, cold-sensitive phenotype.

Q4. In a primary cell culture of mammalian hepatocytes, a unique synthetic small molecule is introduced that specifically binds to the signal recognition particle (SRP) and completely blocks its interaction with the SRP receptor on the rough endoplasmic reticulum. The synthesis and localization of which of the following proteins will be most severely misdirected by this molecule?

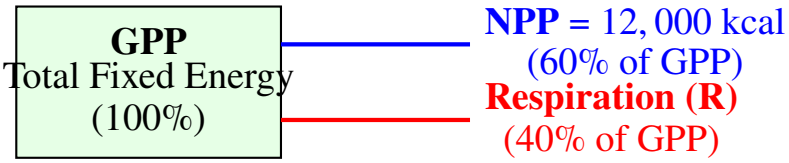
(A) Hexokinase, an enzyme involved in initial steps of cytosolic glycolysis.

(B) Histone H1, a protein responsible for stabilizing linker DNA structure within chromatin.

(C) Insulin-like growth factor 1 (IGF-1), a peptide hormone destined for exocytosis.

(D) Catalase, an antioxidant enzyme localized within the peroxisomal matrix.

Q5. An ecologist studies the trophic efficiency and energy flow within a isolated, pristine post-fire temperate forest ecosystem. She estimates the Net Primary Productivity (NPP) to be $12,000\ \text{kcal} \cdot \text{m}^{-2} \cdot \text{yr}^{-1}$. If the respiration loss (R) by the autotrophs in this ecosystem is exactly 40% of the Gross Primary Productivity (GPP), what is the total energy fixed by the primary producers via photosynthesis before any metabolic utilization?



(A) $7,200\ \text{kcal} \cdot \text{m}^{-2} \cdot \text{yr}^{-1}$

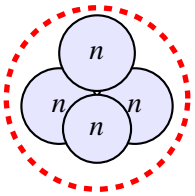
(B) $16,800 \text{ kcal} \cdot \text{m}^{-2} \cdot \text{yr}^{-1}$

(C) $20,000 \text{ kcal} \cdot \text{m}^{-2} \cdot \text{yr}^{-1}$

(D) $30,000 \text{ kcal} \cdot \text{m}^{-2} \cdot \text{yr}^{-1}$

Q6. During microsporogenesis in an angiosperm taxa exhibiting monosporic development, a single microspore mother cell undergoes normal meiotic division followed by standard mitotic divisions to form mature male gametophytes. If a mutation prevents callase enzyme secretion by the tapetal layer during the tetrad stage, what is the most direct developmental bottleneck encountered?

Intact Callose Encapsulation



(A) The microspores fail to separate from one another and remain trapped within a common wall.

(B) The generative cell fails to undergo mitosis to form the two functional male gametes.

(C) The exine layer fails to deposit sporopollenin, making the pollen susceptible to desiccation.

(D) The vegetative cell loses its capability to guide pollen tube growth through the style.

Q7. A plant physiologist places a well-watered, intact C3 plant into a sealed, transparent environmental chamber with controlled illumination. The initial carbon dioxide concentration inside the chamber is adjusted to 400 ppm. Over a period of several days under a continuous 12-hour light and 12-hour dark cycle, the CO_2 concentration inside the chamber stabilizes at a specific baseline level during the light periods. This stable baseline concentration directly represents the:

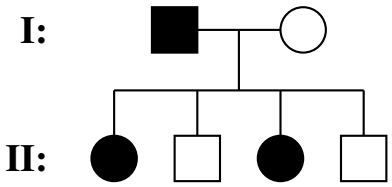
(A) Light saturation point where photosynthetic rate reaches its maximum velocity.

(B) CO_2 compensation point where photosynthetic carbon fixation matches respiratory CO_2 release.

(C) Maximum carboxylation efficiency of the enzyme Ribulose-1,5-bisphosphate carboxylase-oxygenase.

(D) Stomatal closure threshold induced by high accumulation of abscisic acid in guard cells.

Q8. A pedigree analysis of a rare metabolic disorder within a large multi-generational human family reveals the following characteristics: the trait appears in every generation, affected fathers pass the trait to all of their daughters but none of their sons, and affected heterozygous mothers pass the trait to approximately half of their sons and half of their daughters. Which mode of inheritance is most consistent with these observations?



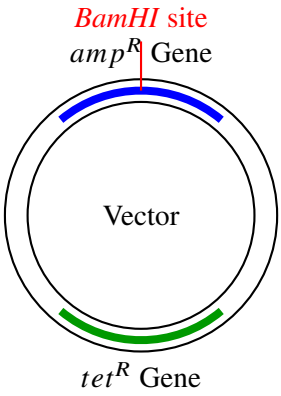
(A) Autosomal Recessive

(B) X-linked Recessive

(C) X-linked Dominant

(D) Y-linked (Holandric)

Q9. In a genetic engineering workflow, a plasmid vector contains a single unique restriction site for the enzyme *BamHI* located squarely within the coding sequence of the ampicillin resistance gene (amp^R). The plasmid also carries an intact tetracycline resistance gene (tet^R). A researcher digests this plasmid with *BamHI*, ligates it with a genomic DNA fragment containing matching cohesive ends, and transforms the recombinant mixture into competent *E. coli* cells lacking any innate antibiotic resistance. To select for the transformants containing the recombinant plasmid, the colonies should be screened for which of the following phenotypes?



(A) Growth on media containing both ampicillin and tetracycline.

(B) Growth on media containing ampicillin, but failure to grow on media containing tetracycline.

(C) Growth on media containing tetracycline, but failure to grow on media containing ampicillin.

(D) Inability to grow on media containing either ampicillin or tetracycline.

Q10. A clinical investigator monitors the changes in plasma hormone levels during a normal human menstrual cycle. She notes a specific point in the mid-luteal phase where both progesterone and estradiol levels reach their peak concentrations. If fertilization does not occur, what is the primary structural trigger that initiates the subsequent decline of these hormones and the eventual onset of menstruation?

(A) Regressive luteolysis of the corpus luteum due to the lack of human chorionic gonadotropin (hCG).

(B) A massive surge of luteinizing hormone (LH) from the anterior pituitary gland causing follicle rupture.

(C) Rapid hypertrophy of the endometrial functionalis layer blocking local blood supply.

(D) Positive feedback of inhibin B on the hypothalamus suppressing gonadotropin-releasing hormone (GnRH).

Q11. A standard eukaryotic gene contains three exons separated by two introns in the order: Exon 1 – Intron 1 – Exon 2 – Intron 2 – Exon 3. A mutation occurs at the 5′ splice site sequence of Intron 1, changing the highly conserved 5'-GU-3'

dinucleotide to 5'-AU-3', completely rendering it non-functional. Assuming the splicing machinery skips to the next available functional splice site, what will be the structural composition of the mature mRNA transcript translated by the ribosome?

(A) Exon 1 – Intron 1 – Exon 2 – Exon 3

(B) Exon 1 – Exon 2 – Exon 3

(C) Exon 1 – Exon 3

(D) Exon 1 – Intron 1 – Exon 2 – Intron 2 – Exon 3

Q12. An experimental setup involves exposing a green alga (*Chlorella*) to brief flashes of light while measuring oxygen evolution. When the alga is simultaneously illuminated with a combination of monochromatic far-red light ($\lambda = 700$ nm) and red light ($\lambda = 680$ nm), the rate of oxygen evolution is significantly greater than the sum of the rates obtained when each wavelength is provided individually. This classic physiological phenomenon provides direct experimental evidence for:

(A) The existence of two distinct, cooperating photosystems working in series.

(B) The cyclic flow of electrons around photosystem I to maximize ATP generation.

(C) The localized destruction of chlorophyll molecules by high-energy blue-light photons.

(D) The operational independence of the light-independent Calvin cycle from light reactions.

Q13. In a deep-sea hydrothermal vent ecosystem, primary production is driven completely in the absence of sunlight. Bacteria utilizing specialized biochemical pathways oxidize inorganic hydrogen sulfide (H_2S) released from the vents to fix dissolved inorganic carbon into organic macromolecules. These bacteria form the nutritional foundation for complex communities of giant tube worms and crabs. Based on their source of energy and carbon, these primary producers are classified as:

(A) Photoheterotrophs

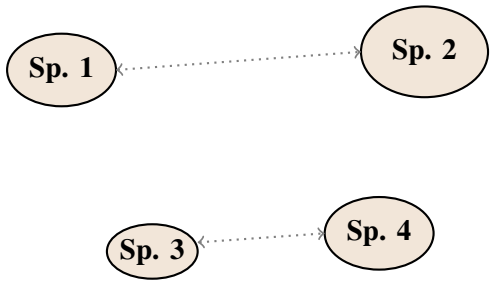
(B) Chemoautotrophs

(C) Photoautotrophs

(D) Chemoheterotrophs

Q14. An evolutionary biologist studies a pristine archipelago and discovers four distinct species of flightless beetles restricted to separate islands. Geological data shows that these islands were connected as a single landmass several million years ago before rising sea levels fragmented the terrain. Genetic analysis indicates the four species share a highly conserved common ancestor. Which evolutionary mechanism and speciation pattern are most clearly illustrated by this scenario?

Geographical Isolation by Sea Level Rise



(A) Sympatric speciation via polyploidy events.

(B) Allopatric speciation via vicariance.

(C) Parapatric speciation across a continuous environmental gradient.

(D) Speciation driven exclusively by directional sexual selection.

Q15. While investigating human renal handling of a newly synthesized therapeutic drug, a nephrologist determines that the clearance rate of the drug from the plasma is significantly higher than the clearance rate of inulin measured in the same subject. Assuming the drug is fully filterable at the glomerulus and is not metabolized or synthesized by the kidney, which of the following transport processes must be occurring along the nephron?

(A) Net tubular reabsorption via passive non-ionic diffusion.

(B) Complete active reabsorption mediated by sodium-coupled cotransporters.

(C) Net active tubular secretion into the luminal fluid.

(D) Intramembranous binding of the drug to podocyte slit diaphragms.

Detailed Solutions

Q1.

Solution

Concept: This question tests understanding of evolutionary mechanisms and their effects on phenotypic variance within a population. Stabilizing selection occurs when environmental conditions remain constant, penalizing extreme phenotypes (small and large seeds) while favoring intermediate phenotypes. Over time, this selective pressure alters the statistical distribution of the trait within the population without necessarily shifting the mean value.

Solution: Step 1: Identify the type of natural selection acting on the plant population. The prompt states that a selection coefficient (s) acts against individuals possessing extremely small seeds as well as individuals possessing extremely large seeds. This means both phenotypic extremes are being selected against simultaneously, which is the definition of stabilizing selection.

Step 2: Relate the selective pressure to the statistical metrics of the population. Stabilizing selection favors the average or intermediate individuals. While the mean value of the seed size remains unchanged due to symmetric selection on both tails of the distribution, the spread of the data around that mean is altered.

Step 3: Analyze the mathematical behavior of phenotypic variance (σ^2). Phenotypic variance is a quantitative measure of the variability of the trait. As individuals at both extremes are continually removed from the breeding pool in each successive generation, the distribution narrows. This directly causes the phenotypic variance (σ^2) to decrease.

Step 4: Determine the mathematical trend of this decrease over time in a stable environment. The variance decreases sharply initially because extreme variants are highly penalized. As the population becomes more uniform, the rate of loss of variance slows down because fewer extreme individuals are produced, approaching a baseline asymptotically. The variance cannot drop to absolute zero due to regular environmental perturbations, baseline mutation rates, and genetic recombination. Therefore, σ^2 decreases asymptotically towards a non-zero minimum value.

Final Answer: σ^2 decreases asymptotically towards a non-zero minimum.

Answer: (B)

Go Back to Question 1

Q2.

Solution

Concept: The regulation of skeletal muscle contraction depends heavily on intracellular calcium ion (Ca^{2+}) dynamics. Muscle contraction is initiated by an increase in cytosolic calcium and terminated by its active re-sequestration back into the sarcoplasmic reticulum via SERCA (Sarcoplasmic/Endoplasmic Reticulum Calcium ATPase) pumps. Inhibiting this active transport process isolates the calcium ions within the cytosol.

Solution: Step 1: Understand the physiological role of calcium ions in muscle cells. In a resting muscle state, cytosolic Ca^{2+} concentration is kept extremely low. When an action potential depolarizes the sarcolemma, Ca^{2+} is released from the sarcoplasmic reticulum into the cytosol.

Step 2: Trace the structural consequences of calcium release. Cytosolic Ca^{2+} binds directly to troponin C. This binding induces a conformational structural change in the troponin-tropomyosin complex, shifting tropomyosin away from the active sites on the actin filament. This unmasks the myosin-binding sites, allowing cross-bridge cycling to occur.

Step 3: Analyze the mechanism of muscle relaxation. Under normal physiological conditions, relaxation requires the active removal of Ca^{2+} from the cytosol back into the sarcoplasmic reticulum lumen via ATP-dependent pumps against a steep concentration gradient.

Step 4: Evaluate the impact of the metabolic inhibitor described in the prompt. The inhibitor blocks the active transport of Ca^{2+} back into the sarcoplasmic reticulum but does not affect ATP synthesis. Consequently, the Ca^{2+} ions remain bound to troponin C in the cytosol, keeping the myosin-binding sites on actin permanently exposed. Cross-bridge cycling and force generation continue uninterrupted, resulting in sustained contraction (tetanus) rather than flaccid paralysis or relaxation.

Final Answer: Persistent cross-bridge formation and sustained contraction due to unmasked myosin-binding sites.

Answer: (D)

Go Back to Question 2

Q3.

Solution

Concept: This question deals with cellular respiration and the structural uncoupling of the mitochondrial electron transport chain (ETC) from oxidative phosphorylation. The inner mitochondrial membrane is normally impermeable to protons, forcing them to flow through ATP synthase to generate ATP. Increasing the proton permeability of this membrane acts as an uncoupler, dissipating the electrochemical proton gradient.

Solution: Step 1: Analyze the state of the proton gradient in the mutant strain. At 37°C, the inner mitochondrial membrane becomes highly permeable to protons (H^+). Protons that have been pumped into the intermembrane space by the ETC complex will leak back freely into the matrix without passing through the F_0F_1-ATP synthase complex.

Step 2: Determine the effect on ATP production. Because the proton motive force is bypassed by the leak, the synthesis of ATP via oxidative phosphorylation is severely compromised. This leads to a dramatic decrease in the total ATP yield per molecule of glucose oxidized.

Step 3: Determine the effect on metabolic feedback regulation. Since the intracellular concentration of ATP falls and ADP levels rise, regulatory enzymes in the glycolytic pathway (such as phosphofructokinase) are strongly stimulated through allosteric feedback loops. This results in an increased rate of glycolysis to compensate for low ATP.

Step 4: Evaluate the energy conservation breakdown. The prompt states that the electron transport chain remains functional and oxygen consumption is fully intact. The potential energy stored in the electrochemical gradient, which is normally converted into chemical energy in ATP, is instead completely dissipated as thermal energy, leading to increased heat generation.

Final Answer: Increased rate of glycolysis, decreased ATP yield per glucose molecule, increased heat generation.

Answer: (B)

Go Back to Question 3

Q4.

Solution

Concept: Protein targeting in eukaryotic cells relies on specific signaling pathways. The Signal Recognition Particle (SRP) is a cytosolic ribonucleoprotein complex that identifies and binds to amino-terminal hydrophobic signal sequences on nascent polypeptide chains during translation. It targets the entire ribosome-mRNA-peptide complex to the rough endoplasmic reticulum (RER) membrane by interacting with the membrane-bound SRP receptor.

Solution: Step 1: Differentiate between the translation pathways of different cellular proteins. Proteins synthesized in eukaryotic cells are translated either on free cytosolic ribosomes or on ribosomes bound to the rough endoplasmic reticulum.

Step 2: Identify the types of proteins that require the co-translational SRP pathway. The SRP-RER pathway is strictly required for proteins destined for the secretory pathway (exocytosis), incorporation into the plasma membrane, or localization within the lumens of endomembrane organelles like lysosomes and the golgi apparatus.

Step 3: Evaluate the destinations of the proteins given in the options. Hexokinase is a cytosolic enzyme and is fully translated on free ribosomes. Histone H1 is a nuclear protein containing a nuclear localization signal, synthesized on free ribosomes. Catalase is localized to peroxisomes via a C-terminal peroxisomal targeting signal (PTS1) and is post-translationally imported from the cytosol.

Step 4: Analyze Insulin-like growth factor 1 (IGF-1). IGF-1 is a peptide hormone synthesized by hepatocytes that must be secreted into the extracellular space to function systemically. It possesses an N-terminal signal peptide that absolutely requires SRP for co-translational translocation into the RER lumen. Blocking the SRP-receptor interaction will selectively halt its transport, causing severe misdirection or degradation.

Final Answer: Insulin-like growth factor 1 (IGF-1), a peptide hormone destined for exocytosis.

Answer: (C)

Go Back to Question 4

Q5.

Solution

Concept: Ecosystem energetics involves the quantification of Gross Primary Productivity (GPP), Net Primary Productivity (NPP), and Autotrophic Respiration (R). GPP is the total amount of organic matter and energy fixed by primary producers via photosynthesis over a given time interval. NPP is the organic matter that remains after meeting the respiratory energy demands of the plants.

Solution: Step 1: Recall the core algebraic relationship between the primary productivity parameters. The fundamental mathematical equation governing energy allocation in primary producers is:

$$\text{NPP} = \text{GPP} - R$$

Step 2: Express the autotrophic respiration (R) in terms of GPP based on the problem criteria. The prompt states that the respiration loss is exactly 40% of the Gross Primary Productivity. Therefore, we can write:

$$R = 0.40 \times \text{GPP}$$

Step 3: Substitute the expression for R back into the primary productivity equation:

$$\text{NPP} = \text{GPP} - 0.40 \times \text{GPP}$$

$$\text{NPP} = 0.60 \times \text{GPP}$$

Step 4: Substitute the known value of Net Primary Productivity into the simplified equation to calculate GPP. The given value of NPP is $12,000\ \text{kcal} \cdot \text{m}^{-2} \cdot \text{yr}^{-1}$:

$$12,000 = 0.60 \times \text{GPP}$$

$$\text{GPP} = \frac{12,000}{0.60}$$

$$\text{GPP} = 20,000\ \text{kcal} \cdot \text{m}^{-2} \cdot \text{yr}^{-1}$$

Thus, the total energy fixed by the primary producers prior to any metabolic respiration is $20,000\ \text{kcal} \cdot \text{m}^{-2} \cdot \text{yr}^{-1}$.

Final Answer: $20,000\ \text{kcal} \cdot \text{m}^{-2} \cdot \text{yr}^{-1}$

Answer: (C)

Go Back to Question 5

Q6.

Solution

Concept: Microsporogenesis involves the formation of microspores inside the anther. The diploid microspore mother cell undergoes meiosis to produce a tetrad consisting of four haploid microspores. Throughout this process, the cells are physically held together and isolated by a thick beta-1,3-glucan polymer wall known as callose. Disassembly of this wall is mandatory for subsequent development.

Solution: Step 1: Understand the structural organization of the microspore tetrad. Immediately following the completion of meiotic divisions, the four newly formed haploid microspores are physically enclosed and held together within a rigid matrix of callose.

Step 2: Identify the source and role of the callase enzyme. The tapetum, which is the innermost nutritive tissue layer of the microsporangial wall, synthesizes and secretes the highly specific hydrolytic enzyme callase into the anther locule at a precise developmental timestamp.

Step 3: Trace the functional effect of callase action. The callase enzyme degrades the beta-1,3-glucan callose wall surrounding the tetrad. This degradation releases the individual haploid microspores, allowing them to expand, build independent cell walls (exine and intine), and mature into free pollen grains.

Step 4: Predict the biochemical block caused by the mutation. If a mutation blocks callase enzyme secretion from the tapetal layer, the callose wall cannot be dissolved. Consequently, the four haploid microspores fail to separate from one another and remain permanently trapped within the common callose matrix, preventing independent maturation and pollen release.

Final Answer: The microspores fail to separate from one another and remain trapped within a common wall.

Answer: (A)

Go Back to Question 6

Q7.

Solution

Concept: The gas exchange of plants in a closed system depends on the balance between two opposing metabolic pathways: photosynthesis (which consumes CO_2) and cellular respiration/photorespiration (which generate CO_2). The concentration at which these processes reach an exact dynamic equilibrium is a specific physiological parameter.

Solution: Step 1: Trace the gas changes in the sealed environmental chamber during light periods. When the C3 plant is exposed to light, the rate of photosynthetic carbon fixation initially exceeds the rate of respiratory carbon dioxide release. This causes a continuous net reduction in the concentration of CO_2 in the chamber from its starting value of 400 ppm.

Step 2: Understand the constraint of declining CO_2 levels on enzyme kinetics. As the ambient CO_2 level drops inside the sealed chamber, the rate of carboxylation by Rubisco decreases linearly because CO_2 is a substrate. Concurrently, the oxygenase activity of Rubisco increases, driving up photorespiratory CO_2 release.

Step 3: Define the stabilization point. Eventually, the ambient CO_2 drops to a precise baseline concentration where the rate of CO_2 uptake via the Calvin cycle becomes exactly equal to the combined rates of CO_2 output from autotrophic dark respiration and photorespiration.

Step 4: Identify the technical term for this equilibrium point. This specific concentration where net gas exchange is exactly zero is defined as the CO_2 compensation point. For a standard C3 plant, this values stabilizes between 30 ppm and 70 ppm under optimal lighting.

Final Answer: CO_2 compensation point where photosynthetic carbon fixation matches respiratory CO_2 release.

Answer: (B)

Go Back to Question 7

Q8.

Solution

Concept: Pedigree analysis evaluates phenotypic distributions across generations to determine the transmission pattern of an inherited allele. Modes of inheritance include autosomal dominant, autosomal recessive, X-linked dominant, X-linked recessive, and Y-linked traits. Distinct criss-cross or sex-specific distributions help isolate genetic linkage.

Solution: Step 1: Assess the vertical distribution of the trait. The prompt states that the disorder appears in every single generation without skipping. This strong vertical pattern provides primary evidence that the mutant allele acts in a dominant manner rather than a recessive manner.

Step 2: Analyze the transmission pattern from affected fathers. An affected father passes the clinical trait to 100% of his daughters but to 0% of his biological sons. A father passes his single Y chromosome to all of his sons and his single X chromosome to all of his daughters.

Step 3: Correlate paternal transmission with chromosomal inheritance. Because all daughters receive the father's X chromosome and all daughters display the trait, the dominant mutant allele must reside explicitly on the X chromosome. The sons receive only the father's Y chromosome, explaining why they remain unaffected.

Step 4: Verify the maternal transmission pattern. An affected heterozygous female ($X^D X^d$) will pass either the mutant allele (X^D) or the normal allele (X^d) to her offspring with an equal probability of 50%. This matches the prompt observation that heterozygous mothers pass the trait to half of their sons and half of their daughters. All criteria align perfectly with X-linked dominant inheritance.

Final Answer: X-linked Dominant

Answer: (C)

Go Back to Question 8

Q9.

Solution

Concept: This question explores recombinant selection using antibiotic resistance markers and the phenomenon of insertional inactivation. When a foreign piece of DNA is ligated directly inside the coding region of an antibiotic resistance gene, the insertion disrupts the open reading frame, rendering that specific gene non-functional.

Solution: Step 1: Analyze the structure of the non-recombinant vector plasmid. The starting vector contains an intact ampicillin resistance gene (amp^R) and an intact tetracycline resistance gene (tet^R). Cells transformed with this original plasmid survive on both drugs.

Step 2: Trace the location of the restriction enzyme cleavage site. The unique restriction site for *BamHI* is located precisely within the coding sequence of the amp^R gene.

Step 3: Determine the consequence of successful foreign DNA ligation. When the researcher cuts the plasmid with *BamHI* and introduces a genomic DNA fragment, successful insertion disrupts the continuity of the amp^R nucleotide sequence. This insertional inactivation means the recombinant plasmid can no longer produce functional beta-lactamase, causing the host cell to lose its ampicillin resistance phenotype.

Step 4: Check the status of the second selection marker. The tetracycline resistance gene (tet^R) does not contain a *BamHI* site and remains completely unaltered and fully functional. Therefore, successful recombinants will express resistance to tetracycline but will be sensitive to ampicillin. Recombinant colonies are identified by their ability to grow on media with tetracycline, but failure to grow on media containing ampicillin.

Final Answer: Growth on media containing tetracycline, but failure to grow on media containing ampicillin.

Answer: (C)

Go Back to Question 9

Q10.

Solution

Concept: The human menstrual cycle is regulated by endocrine feedback loops across the hypothalamic-pituitary-ovarian axis. Following ovulation, the remnants of the ruptured Graafian follicle luteinize under the influence of LH to form the corpus luteum, which acts as a temporary endocrine gland secreting large amounts of progesterone and estrogen.

Solution: Step 1: Identify the endocrine state of the mid-luteal phase. Around day 21-23 of a standard cycle, the corpus luteum reaches its peak secretory capacity, producing high concentrations of progesterone and estradiol to prepare the endometrium for implantation.

Step 2: Understand the regulatory feedback exerted by these ovarian steroids. High circulating levels of progesterone and estrogen exert strong negative feedback on the anterior pituitary gland and hypothalamus. This feedback suppresses the secretion of luteinizing hormone (LH) and follicle-stimulating hormone (FSH).

Step 3: Analyze the biological dependence of the corpus luteum. The structural integrity and functional survival of the corpus luteum depend entirely on continuous, low baseline trophic support from LH. Due to the sustained negative feedback, LH levels fall below the threshold required to maintain the structure.

Step 4: Track the structural fate in the absence of fertilization. If fertilization fails to take place, no blastocyst implants, and no human chorionic gonadotropin (hCG) is produced to rescue the structure. Deprived of trophic support, the corpus luteum undergoes spontaneous programmed degeneration called luteolysis. As it degrades into the corpus albicans, its steroid output collapses, triggering the sloughing of the functional endometrium.

Final Answer: Regressive luteolysis of the corpus luteum due to the lack of human chorionic gonadotropin (hCG).

Answer: (A)

Go Back to Question 10

Q11.

Solution

Concept: Eukaryotic pre-mRNA splicing relies on highly conserved consensus dinucleotide sequences at intron boundaries. The 5′ splice site (donor site) almost universally begins with the dinucleotide sequence 5'-GU-3'. Mutations in these conserved sequences disrupt spliceosome recognition, forcing the splicing machinery to utilize alternative or adjacent functional sites.

Solution: Step 1: Analyze the wild-type splicing pattern. Normally, the spliceosome cuts at the 5′ splice site (GU) of Intron 1 and connects it to the 3′ splice site (AG) at the end of Intron 1, removing Intron 1 and accurately joining Exon 1 to Exon 2.

Step 2: Evaluate the impact of the specific point mutation. The mutation modifies the 5'-GU-3' sequence at the beginning of Intron 1 into a 5'-AU-3' sequence. The U1 small nuclear ribonucleoprotein (snRNP) of the spliceosome can no longer bind or recognize this mutated site, rendering the 5′ donor site of Intron 1 entirely non-functional.

Step 3: Determine the behavior of the spliceosome under the skipping conditions described. The prompt specifies that the splicing machinery skips over the disabled site to the next available functional splice site. The next operational 5′ splice site is located at the junction after Exon 2 (the beginning of Intron 2).

Step 4: Trace the physical excision process. The spliceosome initiates splicing at the 5′ boundary of Exon 1, but cannot cut until it pairs with a functional donor site. It skips the mutated site of Intron 1 and the entirety of Exon 2, finally executing the cut at the functional 5′ splice site of Intron 2. The entire segment from the end of Exon 1 to the end of Intron 2 is excised as a single large lariat loop. Consequently, Exon 1 is joined directly to Exon 3, omitting Exon 2 entirely.

Final Answer: Exon 1 – Exon 3

Answer: (C)

Go Back to Question 11

Q12.

Solution

Concept: The light reactions of photosynthesis drive the synthesis of chemical energy. The Emerson enhancement effect provides the historical and conceptual framework for understanding the composition of the photosynthetic electron transport chain. It demonstrates that coordination between distinct operational units is necessary for maximum photosynthetic efficiency.

Solution: Step 1: Recall the baseline observation made by Robert Emerson. When photosynthetic organisms are illuminated with far-red light alone ($\lambda \geq 700$ nm), the photosynthetic yield decreases sharply (the red drop). When illuminated with shorter-wavelength red light alone ($\lambda = 680$ nm), a modest rate of photosynthesis is recorded.

Step 2: Analyze the synergistic result when both wavelengths are applied simultaneously. When both far-red and red light flashes are delivered together, the rate of oxygen evolution is significantly higher than the simple mathematical sum of the individual rates measured independently.

Step 3: Interpret this synergy on a molecular level. This non-additive enhancement indicates that photosynthesis requires two separate light-driven operations that function in tandem and depend on each other's metabolic throughput.

Step 4: Map the phenomenon to the structural components of the thylakoid membrane. Photosystem I (PS I) contains a reaction center chlorophyll called P700, which absorbs far-red light optimally. Photosystem II (PS II) contains a reaction center called P680, which absorbs shorter-wavelength red light. The enhancement effect proves that these two photosystems do not work in isolation; instead, they operate in series, linked by an intermediate electron transport chain, to drive non-cyclic photophosphorylation and generate oxygen.

Final Answer: The existence of two distinct, cooperating photosystems working in series.

Answer: (A)

Go Back to Question 12

Q13.

Solution

Concept: Organisms are classified into nutritional categories based on how they satisfy two primary metabolic requirements: their source of energy (light vs. chemical compounds) and their source of carbon for biosynthesis (organic molecules vs. inorganic carbon dioxide). Hydrothermal vent ecosystems illustrate non-solar primary production.

Solution: Step 1: Determine the energy source of the vent bacteria. The prompt states that these bacteria operate in complete darkness at the deep-sea floor, meaning light energy is entirely unavailable. Instead, they extract energy by breaking down and oxidizing inorganic chemical compounds, specifically hydrogen sulfide (H_2S). Organisms that derive energy from chemical oxidations are termed chemotrophs.

Step 2: Determine the carbon source utilized by these organisms. The text states that the bacteria fix dissolved inorganic carbon (CO_2 or carbonate ions) to build their cellular organic macromolecules. Organisms capable of using inorganic CO_2 as their sole or primary carbon source are termed autotrophs.

Step 3: Combine both metabolic classifications. Merging a chemical energy source with an inorganic carbon-fixing capability classifies these organisms as chemoautotrophs (or chemolithoautotrophs).

Step 4: Contrast with other modes of nutrition. Photoautotrophs require sunlight and CO_2. Chemoheterotrophs require organic molecules for both energy and carbon. Because these specialized deep-sea bacteria fix inorganic carbon using energy harvested strictly from chemical bonds without any solar input, they are classic chemoautotrophs.

Final Answer: Chemoautotrophs

Answer: (B)

Go Back to Question 13

Q14.

Solution

Concept: Speciation refers to the evolutionary lineage-splitting process that gives rise to distinct biological species. Speciation is categorized based on the spatial relationship between deteriorating populations, primarily into allopatric, sympatric, parapatric, and peripatric mechanisms. Allopatric speciation involves physical geographic barriers.

Solution: Step 1: Evaluate the physical distribution of the organisms described. The four flightless beetle species are found isolated on separate islands within an archipelago, indicating complete spatial isolation.

Step 2: Analyze the geological history provided. The islands were originally unified as a single continuous landmass before rising sea levels fragmented the terrain. This geological division of a continuous habitat into isolated segments is termed a vicariance event.

Step 3: Determine the evolutionary consequences of this fragmentation. Once the sea levels rose, the flightless beetles were unable to cross the water barriers, completely halting gene flow between the newly isolated island populations. Over millions of years, each isolated population accumulated independent mutations, underwent localized natural selection, and experienced genetic drift.

Step 4: Identify the corresponding speciation pattern. Speciation that occurs when populations become geographically isolated due to a physical barrier or environmental fragmentation is defined as allopatric speciation. Because the barrier arose from environmental division rather than migration/dispersal, it represents allopatric speciation via vicariance.

Final Answer: Allopatric speciation via vicariance.

Answer: (B)

Go Back to Question 14

Q15.

Solution

Concept: Renal clearance (C) measures the volume of plasma completely cleared of a substance by the kidneys per unit time. Inulin is a unique exogenous polysaccharide that is freely filtered at the glomerulus and undergoes absolutely no reabsorption or secretion along the nephron. Therefore, the clearance of inulin is exactly equal to the Glomerular Filtration Rate (GFR).

Solution: Step 1: Establish the baseline equation for renal handling. The net clearance of any fully filterable substance is a mathematical function of filtration, reabsorption, and secretion:

$$\text{Clearance} = \frac{\text{Mass Filtered} - \text{Mass Reabsorbed} + \text{Mass Secreted}}{\text{Plasma Concentration}}$$

Step 2: Use inulin as the reference benchmark for net transport. Because inulin is neither reabsorbed nor secreted, its clearance rate serves as a direct marker for filtration alone ($C_{\text{inulin}} = \text{GFR}$).

Step 3: Compare the clearance rate of the therapeutic drug to inulin. The prompt states that the clearance rate of the newly synthesized drug is significantly higher than the clearance rate of inulin ($C_{\text{drug}} > C_{\text{inulin}}$). This means $C_{\text{drug}} > \text{GFR}$.

Step 4: Deduce the underlying transport mechanism along the nephron. For a substance to exit the plasma at a rate faster than filtration alone can account for, additional molecules of the drug must be actively extracted from the peritubular capillaries by the renal tubular epithelial cells and transported into the tubular lumen. This direction of net movement represents net active tubular secretion, which elevates the total excretion mass beyond the filtered load.

Final Answer: Net active tubular secretion into the luminal fluid.

Answer: (C)

Go Back to Question 15

Answer Key

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	B	2	D	3	B	4	C	5	C
6	A	7	B	8	C	9	C	10	A
11	C	12	A	13	B	14	B	15	C