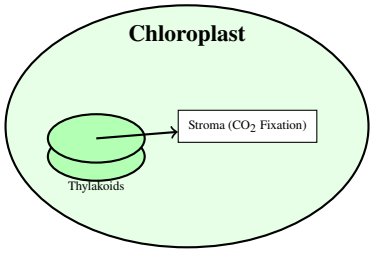
IISER Biology Sample Paper-3

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. An investigator exposes a healthy, actively photosynthesizing green leaf to a continuous stream of carbon dioxide containing the stable isotope ^{13}C (CO_2 enriched with ^{13}C). If the plant utilizes the C_3 pathway, which of the following choices properly identifies the very first stable organic molecule to incorporate the ^{13}C label, and the specific intracellular compartment where this molecule is synthesized?



(A) 3-phosphoglycerate, Chloroplast stroma

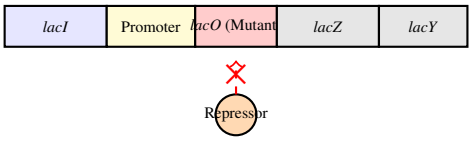
(B) Oxaloacetate, Mesophyll cytoplasm

(C) Ribulose-1,5-bisphosphate, Chloroplast stroma

(D) Phosphoenolpyruvate, Mesophyll cell wall

Q2. A researcher is studying a mutation in *Escherichia coli* where the operator region of the lac operon (*lacO*) has undergone a base substitution that completely

prevents the lac repressor protein from binding to it. If this mutant bacterial strain is cultured in a growth medium that contains high concentrations of both glucose and lactose, what will be the state of transcriptional activity at the lac operon?



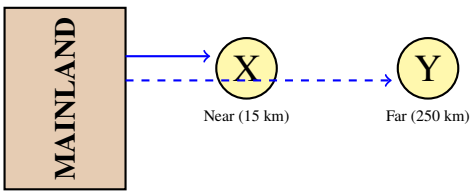
(A) Transcription will be fully active at maximum levels because the repressor cannot bind.

(B) Transcription will be at a low, basal level because cyclic AMP (cAMP) levels are low.

(C) Transcription will be completely shut down due to the presence of glucose.

(D) Transcription will fluctuate cyclically because lactose is present to act as an inducer.

Q3. In an experiment exploring ecological succession and island biogeography, two newly formed volcanic islands of identical surface area are monitored. Island X is located 15 kilometers away from the nearest continental mainland, while Island Y is located 250 kilometers away from the same mainland. According to the equilibrium theory of island biogeography established by MacArthur and Wilson, which island is expected to exhibit a higher rate of species immigration, and what will be its relative species richness at equilibrium compared to the other island?



(A) Island X will have a higher immigration rate and a lower species richness at equilibrium than Island Y.

(B) Island Y will have a higher immigration rate and a higher species richness at equilibrium than Island X.

(C) Island X will have a higher immigration rate and a higher species richness at equilibrium than Island Y.

(D) Both islands will exhibit identical immigration rates, but Island Y will have a higher species richness due to isolation.

Q4. Consider a mammalian cell type that is actively secreting a polypeptide hormone into the extracellular space. A laboratory group uses a radioactive amino acid pulse-chase experiment to map the intracellular trafficking pathway of this hormone. Which of the following sequences represents the correct chronological order of compartments visited by the radioactively labeled hormone from its synthesis to its release?

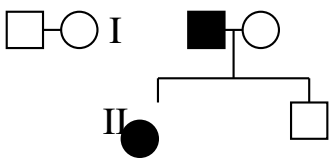
(A) Rough Endoplasmic Reticulum → Cis-Golgi → Trans-Golgi → Secretory Vesicles → Plasma Membrane

(B) Free Ribosomes → Lysosome → Trans-Golgi → Smooth Endoplasmic Reticulum → Plasma Membrane

(C) Cis-Golgi → Rough Endoplasmic Reticulum → Secretory Vesicles → Trans-Golgi → Plasma Membrane

(D) Smooth Endoplasmic Reticulum → Nucleolus → Cis-Golgi → Peroxisome → Plasma Membrane

Q5. During an analysis of a human pedigree tracing a rare physiological condition, an undergraduate notes the following characteristics: (1) The condition appears in every single generation. (2) Affected fathers always pass the condition to all of their daughters, but none of their sons. (3) Affected mothers who are heterozygous pass the condition to approximately 50% of their offspring, regardless of biological sex. Which mode of inheritance is fully consistent with these observation patterns?



(A) Autosomal Recessive

(B) X-linked Recessive

(C) Autosomal Dominant

(D) X-linked Dominant

Q6. During an in vitro translation experiment using eukaryotic cytoplasmic components, a scientist introduces a compound that selectively blocks the formation of peptide bonds by inhibiting the peptidyl transferase activity of the ribosome. If translation has already initiated and is in the elongation phase when the compound is added, what specific intermediate structure will accumulate inside the reaction tube?

(A) A ribosome complexed with a completely uncharged tRNA residing permanently in the P-site.

(B) A ribosome carrying a peptidyl-tRNA in the P-site and an aminoacyl-tRNA in the A-site.

(C) Free individual ribosomal small (40S) and large (60S) subunits dissociated from the mRNA template.

(D) A ribosome with an empty P-site and two distinct aminoacyl-tRNAs bound simultaneously to the E-site.

Q7. An agriculture student is monitoring the water potential (ψ_w) components along the soil-plant-atmosphere continuum of a tall woody angiosperm on a warm, sunny afternoon. To maintain a continuous, uninterrupted upward flow of water via the cohesion-tension mechanism, which of the following statements regarding the relative water potentials must be true?

(A) $\psi_{w(\text{soil})} < \psi_{w(\text{root})} < \psi_{w(\text{stem})} < \psi_{w(\text{leaf})} < \psi_{w(\text{atmosphere})}$

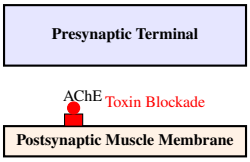
(B) $\psi_{w(\text{soil})} > \psi_{w(\text{root})} > \psi_{w(\text{stem})} > \psi_{w(\text{leaf})} > \psi_{w(\text{atmosphere})}$

(C) $\psi_{w(\text{root})} = \psi_{w(\text{soil})}$ and $\psi_{w(\text{atmosphere})} > \psi_{w(\text{leaf})}$

(D) $\psi_{w(\text{stem})}$ must remain exactly zero to prevent cavitation events.

Q8. A pharmaceutical company isolates a novel toxin that functions as a highly specific, competitive inhibitor of the enzyme acetylcholinesterase at the neuromuscular junctions of mammals. If an animal is exposed to a lethal dose of this

toxin, what will be the primary physiological consequence at the postsynaptic muscle membrane?



(A) Continuous, sustained depolarization of the postsynaptic membrane leading to rigid muscle paralysis.

(B) Instantaneous hyperpolarization of the muscle membrane preventing any future action potential generation.

(C) Immediate clearance of acetylcholine from the synaptic cleft via rapid presynaptic reuptake channels.

(D) Complete failure of voltage-gated calcium channels to open in the presynaptic axon terminal.

Q9. While evaluating an ecosystem, a conservation biologist records a highly specialized plant species that relies exclusively on a single endemic species of long-tongued moth for its pollination. Over the course of evolutionary time, as the moth's proboscis grew longer, the floral corolla tube of the plant became proportionately deeper. This scenario provides a clear, documented example of which evolutionary mechanism?

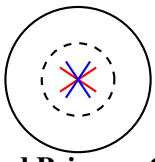
(A) Convergent evolution

(B) Coevolution

(C) Adaptive radiation

(D) Directional genetic drift

Q10. In human female reproductive physiology, a crucial transition occurs during embryonic development where oogenesis initiates, but is subsequently arrested for a prolonged period. At which specific stage of cell division do the primary oocytes remain arrested from before birth until the individual reaches puberty?



Arrested Primary Oocyte

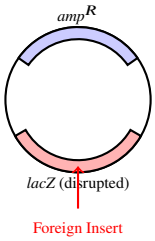
(A) Metaphase of Mitosis

(B) Prophase I of Meiotic Division I

(C) Metaphase II of Meiotic Division II

(D) Anaphase I of Meiotic Division I

Q11. A cloning vector contains a gene encoding resistance to the antibiotic ampicillin (amp^R) and an intact *lacZ* gene containing a unique restriction endonuclease recognition site. A researcher performs a restriction digestion, ligates a foreign genomic DNA fragment into this vector, and transforms competent *E. coli* cells. If the recombinant plasmid has successfully integrated the foreign gene insert into the *lacZ* cloning site, what phenotypic properties will the transformed colonies exhibit when plated on a selection medium containing both ampicillin and X-gal?



(A) They will survive and form bright blue-colored colonies.

(B) They will be sensitive to ampicillin and fail to grow entirely.

(C) They will survive and form white (colorless) colonies.

(D) They will synthesize a fluorescent green pigment under ultraviolet light exposure.

Q12. Suppose a healthy human adult volunteers for a metabolic study where their glomerular filtration rate (GFR) and renal clearance parameters are measured. The clearance of an exogenous carbohydrate polymer, inulin, is determined to be 125 mL/min. Concurrently, the clearance of a newly developed therapeutic

drug is calculated to be 310 mL/min. Based strictly on these clearance values, what can be accurately inferred about the processing of this new drug by the nephrons?

(A) The drug undergoes glomerular filtration followed by massive net tubular reabsorption.

(B) The drug is solely filtered at the glomerulus and experiences no tubular modification whatsoever.

(C) The drug is too large to pass through the filtration slits and is excreted via metabolic degradation.

(D) The drug undergoes glomerular filtration along with active net tubular secretion into the filtrate.

Q13. Double fertilization is a defining evolutionary feature unique to angiosperms. If a researcher blocks the mitotic division of the functional megaspore during embryo sac development such that it only completes two rounds of mitosis instead of three, what will be the altered cellular composition of the mature female gametophyte, and how will it affect endosperm formation?

(A) It will lack polar nuclei completely, preventing the formation of a triploid endosperm upon fertilization.

(B) It will form a standard 8-nucleate structure but will fail to differentiate an egg cell.

(C) It will generate a diploid endosperm through the fusion of three identical synergids.

(D) It will fail to develop any cell walls, converting the entire ovule into a unicellular zygote.

Q14. In taxonomic classification, matching structural and developmental features correctly is vital for understanding evolutionary relationships. Consider the following structural pairs and choose the option that correctly categorizes them as homologous or analogous structures: (1) The flipper of a whale and the wing of a bat. (2) The wing of a butterfly and the wing of a bird.

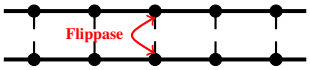
(A) 1 is Analogous; 2 is Homologous

(B) 1 is Homologous; 2 is Homologous

(C) 1 is Homologous; 2 is Analogous

(D) 1 is Analogous; 2 is Analogous

Q15. A cell biologist isolates a mutant line of yeast cells that completely lacks functional flippase enzymes within its endoplasmic reticulum and plasma membranes. Which of the following structural defects will be most prominent in these mutant cells?



(A) The mitochondrial inner membrane will completely lose its characteristic folded cristae structure.

(B) The lipid bilayer of the membranes will lose its characteristic asymmetric distribution of specific phospholipids between the inner and outer leaflets.

(C) Integral transmembrane proteins will be unable to adopt an alpha-helical conformation.

(D) Peripheral carbohydrates will be erroneously attached to the cytosolic face of the plasma membrane.

Detailed Solutions

Q1.

Solution

Concept:

The question explores the biochemical pathway of C_3 photosynthesis (Calvin-Benson cycle) and its precise intracellular localization. In C_3 plants, the primary carbon fixation reaction involves the fixation of gaseous carbon dioxide to a five-carbon sugar acceptor, ribulose-1,5-bisphosphate (RuBP). This initial reaction is catalyzed by the key enzyme ribulose-1,5-bisphosphate carboxylase-oxygenase (RuBisCO). The resulting highly unstable six-carbon intermediate immediately undergoes hydrolytic cleavage to yield two molecules of a three-carbon compound. Understanding the location of this enzyme and its substrates within the sub-cellular structural components of the mesophyll cell is critical for identifying where the stable product is synthesized.

Solution:

Step 1: Analyze the path of the isotope ^{13}C introduced as $^{13}CO_2$. The plant is stated to utilize the C_3 photosynthetic pathway. In C_3 plants, carbon dioxide diffuses through stomatal openings into the mesophyll cells and directly enters the chloroplasts.

Step 2: Inside the chloroplast, the liquid matrix surrounding the thylakoid membranes is known as the stroma. The stroma contains all the necessary soluble enzymes, cofactors, and substrates required for the light-independent reactions (dark reactions) of photosynthesis.

Step 3: The primary acceptor molecule present in the stroma is Ribulose-1,5-bisphosphate (RuBP). When $^{13}CO_2$ is fixed onto RuBP by the stromal enzyme RuBisCO, it forms an unstable transient 6-carbon compound.

Step 4: This unstable intermediate is instantaneously split into two identical three-carbon molecules known as 3-phosphoglycerate (3-PGA). Because 3-PGA is the first stable organic molecule isolated containing the ^{13}C label, this pathway is designated as the C_3 pathway.

Step 5: Since RuBisCO is located exclusively within the chloroplast stroma, the synthesis of this first stable product takes place entirely in the stromal compartment rather than the cytoplasm or the cell wall. Therefore, the stable molecule is 3-phosphoglycerate and the compartment is the chloroplast stroma.

Final Answer: 3-phosphoglycerate, Chloroplast stroma

Answer: (A)

Go Back to Question 1

Q2.

Solution

Concept:

The regulation of the operon system in prokaryotes is governed by dual control: negative regulation by a repressor and positive regulation by an activator. The lac operon in *Escherichia coli* controls the expression of genes involved in lactose metabolism. The operator (*lacO*) is a specific nucleotide sequence where the repressor protein binds to physically obstruct RNA polymerase. However, full expression also requires the catabolite activator protein (CAP) bound to cyclic AMP (cAMP). Glucose concentrations directly dictate cAMP levels through adenylate cyclase regulation, setting up catabolite repression.

Solution:

Step 1: Examine the nature of the mutation provided. The mutation is located within the operator region (*lacO*) and completely prevents the binding of the active lac repressor protein. Under normal conditions, a lack of repressor binding allows transcription, provided RNA polymerase can initiate efficiently.

Step 2: Evaluate the composition of the growth medium. The medium contains high concentrations of both glucose and lactose simultaneously. The presence of glucose triggers a physiological phenomenon known as glucose repression or catabolite repression.

Step 3: When intracellular glucose levels are high, the transport of glucose into the cell inhibits the enzyme adenylate cyclase. This inhibition prevents the conversion of ATP into cyclic AMP (cAMP), causing the internal concentration of cAMP to drop significantly.

Step 4: Low levels of cAMP mean that it cannot bind to the Catabolite Activator Protein (CAP). Unbound CAP remains inactive and cannot bind to the promoter region to recruit or assist RNA polymerase. Without active CAP binding, RNA polymerase has a very low affinity for the lac promoter.

Step 5: Consequently, even though the repressor cannot bind to block transcription due to the operator mutation, the operon cannot achieve high operational efficiency. Transcription proceeds only at a low, basal level because of the absence of positive activation by the cAMP-CAP complex.

Final Answer: Transcription will be at a low, basal level because cyclic AMP (cAMP) levels are low.

Answer: (B)

Go Back to Question 2

Q3.

Solution

Concept:

The equilibrium theory of island biogeography developed by Robert MacArthur and Edward O. Wilson explains how species richness on an island is determined by a dynamic balance between two processes: immigration of new species from a mainland source and extinction of established species. The rate of immigration is primarily driven by the isolation of the island (distance from the mainland reservoir), whereas the rate of extinction is dictated by the size of the island (surface area), which determines resource availability and population sizes.

Solution:

Step 1: Identify the constant variables and independent variables given. Both Island X and Island Y have identical surface areas, meaning their potential extinction rates are equivalent. The changing factor is distance: Island X is near (15 km), and Island Y is distant (250 km) from the mainland.

Step 2: Evaluate the immigration rate based on distance. Organisms, seeds, spores, or individuals traveling from the mainland are much more likely to encounter an island that is closer to the source. Therefore, closer islands experience higher colonization frequencies. Island X will have a significantly higher rate of species immigration than Island Y.

Step 3: Analyze the equilibrium species richness (S). The equilibrium point occurs where the immigration curve intersects the extinction curve. Because the immigration curve for a near island is shifted upwards relative to a far island, its intersection point with the extinction curve occurs at a higher number of species.

Step 4: Synthesize the outcomes for both islands. Island X, being closer, receives more dispersing individuals per unit time, supporting higher immigration. Over ecological time, this increased influx maintains a larger pool of coexisting species before extinction balances the system.

Step 5: Thus, Island X will maintain a higher immigration rate and achieve a greater total species richness at equilibrium compared to the isolated Island Y.

Final Answer: Island X will have a higher immigration rate and a higher species richness at equilibrium than Island Y.

Answer: (C)

Go Back to Question 3

Q4.

Solution

Concept:

The endomembrane system of eukaryotic cells functions as a coordinated secretory pathway responsible for synthesizing, processing, modifying, sorting, and transporting proteins destined for secretion outside the cell. This pathway can be traced experimentally using pulse-chase radiolabeling techniques. Polypeptide hormones that are targeted for export contain a specific amino-terminal signal peptide that directs the nascent translating ribosome complex to dock on the membrane of the endoplasmic reticulum.

Solution:

Step 1: Trace the site of translation. Secretory proteins are co-translationally translocated across the membrane of the Rough Endoplasmic Reticulum (RER). Thus, the newly synthesized, radioactively labeled polypeptide chain first accumulates inside the lumen of the RER.

Step 2: Monitor transport out of the RER. After initial folding and core glycosylation within the RER lumen, the proteins are packed into membrane-bound transport vesicles that bud off and travel along microtubules toward the Golgi apparatus.

Step 3: Track entry into the Golgi complex. The transport vesicles fuse with the receiving face of the Golgi complex, which is known as the cis-Golgi. Here, the protein undergoes subsequent carbohydrate modifications as it moves through the medial cisternae.

Step 4: Track exit from the Golgi complex. The fully processed and sorted hormone exits the Golgi network from its shipping face, designated as the trans-Golgi, where it is packaged into specialized, concentrated secretory vesicles.

Step 5: Identify the final release mechanism. These secretory vesicles migrate toward the periphery of the cell. Upon receiving an extracellular signal, they fuse with the plasma membrane, releasing their contents into the extracellular space via exocytosis. This matches the chronological sequence: RER → Cis-Golgi → Trans-Golgi → Secretory Vesicles → Plasma Membrane.

Final Answer: Rough Endoplasmic Reticulum → Cis-Golgi → Trans-Golgi → Secretory Vesicles → Plasma Membrane

Answer: (A)

Go Back to Question 4

Q5.

Solution

Concept:

Pedigree analysis allows geneticists to deduce the mode of inheritance of phenotypic traits across human generations. Modes of inheritance include autosomal dominant, autosomal recessive, X-linked dominant, X-linked recessive, and Y-linked patterns. To differentiate between these mechanisms, specific phenotypic transmission patterns between parents and offspring are evaluated, tracking how alleles on sex chromosomes (X and Y) or autosomes are segregated during meiosis.

Solution:

Step 1: Evaluate the first clue: the condition appears in every single generation without skipping. This indicates a dominant trait rather than a recessive one, as recessive alleles often skip generations by hiding in asymptomatic heterozygous carriers.

Step 2: Evaluate the second clue: affected fathers always pass the condition to 100% of their biological daughters, but never to their biological sons. A father contributes his single X chromosome to all his daughters and his Y chromosome to all his sons.

Step 3: If the trait were autosomal dominant, an affected father would have a 50% chance of passing the autosome to any offspring regardless of sex. The observation that all daughters and zero sons are affected strongly excludes autosomal inheritance and points specifically to an X-linked location.

Step 4: Evaluate the third clue: affected heterozygous mothers (X^DX^d) pass the trait to 50% of their children, irrespective of sex. This matches meiotic segregation perfectly because a heterozygous mother has a 50% chance of passing the affected X chromosome to a son (X^DY) or a daughter (X^DX^d).

Step 5: Combining these observations rules out recessive options and autosomal dominant inheritance, confirming that the condition follows an X-linked dominant pattern of inheritance.

Final Answer: X-linked Dominant

Answer: (D)

Go Back to Question 5

Q6.

Solution

Concept:

Translation elongation is a cyclical process where amino acids are sequentially joined by peptide bonds to form a polypeptide chain. The ribosome contains three distinct binding sites for transfer RNA (tRNA): the Aminoacyl (A) site, the Peptidyl (P) site, and the Exit (E) site. Peptidyl transferase is a ribozyme activity located within the large ribosomal subunit that catalyzes the formation of a peptide bond between the amino acid attached to the tRNA in the A-site and the growing peptide chain attached to the tRNA in the P-site.

Solution:

Step 1: Visualize the ribosome status during active elongation just before a new peptide bond is formed. A tRNA carrying the growing polypeptide chain sits in the central P-site (peptidyl-tRNA).

Step 2: Concurrently, a newly arrived elongation factor-bound charged tRNA matching the next mRNA codon enters and occupies the vacant A-site (aminoacyl-tRNA).

Step 3: Under uninhibited conditions, peptidyl transferase breaks the ester bond linking the polypeptide to the P-site tRNA and forms a new peptide bond with the amino acid on the A-site tRNA, shifting the peptide to the A-site.

Step 4: The introduction of the experimental compound selectively blocks this specific peptidyl transferase activity. Consequently, the chemical reaction linking the two adjacent amino acids cannot take place.

Step 5: Because the reaction is arrested at this exact point, translation stalls completely. The ribosome cannot undergo translocation, resulting in the structural accumulation of an intermediate complex where the ribosome remains bound to a peptidyl-tRNA in its P-site and an aminoacyl-tRNA stuck within its A-site.

Final Answer: A ribosome carrying a peptidyl-tRNA in the P-site and an aminoacyl-tRNA in the A-site.

Answer: (B)

Go Back to Question 6

Q7.

Solution

Concept:

Water movement through a vascular plant is driven passively by changes in water potential (ψ_w) along a pathway extending from the soil, through the plant tissues, and out into the surrounding atmosphere. This framework is described by the cohesion-tension theory. Water always flows spontaneously from an area of higher water potential (less negative, closer to zero) to an area of lower water potential (more negative). To maintain a continuous, uninhibited upward transpirational stream, a steady descending thermodynamic gradient must exist.

Solution:

Step 1: Identify the source and the sink of water in the continuum. The original source of water is the moisture present within the soil pores, and the ultimate sink is the dry ambient atmosphere outside the leaves.

Step 2: Apply the direction of spontaneous water movement. For water to enter the root hairs from the surrounding soil, the water potential of the root cells must be lower (more negative) than that of the soil: $\psi_{w\,(\text{soil})} > \psi_{w\,(\text{root})}$.

Step 3: For water to move upward from the root cortex into the conducting xylem elements of the stem, the stem xylem must have a lower water potential than the root: $\psi_{w\,(\text{root})} > \psi_{w\,(\text{stem})}$.

Step 4: Following the same logic, to pull water out of the stem xylem into the mesophyll cell walls of the photosynthesizing leaf, the leaf must exhibit a lower water potential than the stem: $\psi_{w\,(\text{stem})} > \psi_{w\,(\text{leaf})}$.

Step 5: Finally, because the ambient atmosphere on a warm afternoon has a very low relative humidity, its water potential is exceptionally low (highly negative). This drives the evaporation of water vapor out through open stomata: $\psi_{w\,(\text{leaf})} > \psi_{w\,(\text{atmosphere})}$. Combining these steps gives the uninterrupted gradient: $\psi_{w\,(\text{soil})} > \psi_{w\,(\text{root})} > \psi_{w\,(\text{stem})} > \psi_{w\,(\text{leaf})} > \psi_{w\,(\text{atmosphere})}$.

Final Answer: $\psi_{w\,(\text{soil})} > \psi_{w\,(\text{root})} > \psi_{w\,(\text{stem})} > \psi_{w\,(\text{leaf})} > \psi_{w\,(\text{atmosphere})}$

Answer: (B)

Go Back to Question 7

Q8.

Solution

Concept:

Synaptic transmission at the mammalian neuromuscular junction relies on the neurotransmitter acetylcholine (ACh). When an action potential reaches the presynaptic terminal, ACh is released into the synaptic cleft, where it binds to nicotinic ACh receptors on the postsynaptic muscle membrane, opening ion channels and inducing depolarization. To prevent continuous firing and allow relaxation, ACh must be rapidly degraded. This inactivation is carried out by the enzyme acetylcholinesterase (AChE), which cleaves ACh into choline and acetate.

Solution:

Step 1: Determine the direct biochemical action of the toxin. The toxin acts as a competitive inhibitor of acetylcholinesterase (AChE). This means it binds to the active site of AChE, preventing it from interacting with and breaking down acetylcholine molecules.

Step 2: Analyze the consequences within the synaptic cleft. Because AChE is fully inhibited, any ACh released by nerve impulses accumulates within the neuromuscular junction, remaining active for an abnormally prolonged duration.

Step 3: Determine the state of the postsynaptic receptors. The persistent presence of high concentrations of ACh results in the continuous, uninterrupted binding of the neurotransmitter to the postsynaptic chemically-gated ion channels.

Step 4: Determine the electrical status of the muscle membrane. Continuous channel opening allows a sustained, massive influx of sodium ions (Na^+) across the postsynaptic sarcolemma, causing chronic, long-term depolarization of the muscle membrane.

Step 5: Link the depolarization to the physical symptoms. Because the membrane cannot repolarize to reset its voltage-gated channels, the muscle fibers enter a state of continuous contraction and electrical refractory deadlock, culminating in rigid muscle paralysis.

Final Answer: Continuous, sustained depolarization of the postsynaptic membrane leading to rigid muscle paralysis.

Answer: (A)

Go Back to Question 8

Q9.

Solution

Concept:

Evolutionary biology distinguishes between different patterns of structural and behavioral changes driven by natural selection. When two or more species share a close ecological relationship, they can exert selective pressures on each other. This reciprocal evolutionary change, where a genetic modification in one species drives an evolutionary adaptation in another interacting species, is a key mechanism shaping tight ecological specializations.

Solution:

Step 1: Examine the relationship between the organisms described. The plant and the long-tongued moth species share an exclusive, obligate mutualistic relationship centered on pollination and nectar feeding.

Step 2: Trace the evolutionary timeline provided. Natural selection favors moths with slightly longer proboscises because they can access nectar rewards more effectively from deep flowers. This is an evolution in the moth population.

Step 3: Analyze the counter-pressure exerted on the plant. As the moth's tongue length increases, plants with shallower corolla tubes might not force the moth to rub against their reproductive structures, reducing pollination efficiency. Plants with deeper corolla tubes ensure contact, favoring their reproduction.

Step 4: Identify the macroevolutionary pattern. The change in the morphological trait of the consumer (moth proboscis length) directly drives a corresponding, parallel morphological modification in the producer (floral corolla depth) over generations.

Step 5: Classify this reciprocal process. This tight, interlinked, step-by-step mutual adaptation between two interacting species is the classic definition of coevolution, separating it from convergent evolution, adaptive radiation, or genetic drift.

Final Answer: Coevolution

Answer: (B)

Go Back to Question 9

Q10.

Solution

Concept:

Oogenesis is the complex developmental process by which female gametes, or ova, are produced. Unlike spermatogenesis in males, which is a continuous process starting at puberty, human oogenesis is initiated early during embryonic development. Millions of primary oocytes are formed in the fetal ovaries via mitotic multiplication followed by the initiation of meiosis. However, this meiotic process does not proceed to completion continuously; instead, it undergoes two distinct developmental arrests.

Solution:

Step 1: Trace the start of oogenesis. During the fetal period, primordial germ cells differentiate into oogonia, which then undergo mitosis and begin differentiating into primary oocytes.

Step 2: Identify the first meiotic division. Primary oocytes enter Meiosis I and replicate their DNA. They proceed through the initial stages of nuclear division, which include leptotene, zygotene, and pachytene substages.

Step 3: Pinpoint the exact point of developmental arrest. Upon reaching the diplotene stage of Prophase I in Meiosis I, the cell division process is actively suspended by local biochemical inhibitors within the fetal ovary.

Step 4: Assess the duration of this arrest. The primary oocytes remain frozen in this specific Prophase I state throughout the remainder of fetal life, through birth, childhood, and up until individual follicles are recruited during puberty.

Step 5: At puberty, surging luteinizing hormone (LH) levels rescue a subset of oocytes each month, allowing them to complete Meiosis I and advance to Metaphase II, where the second arrest occurs until fertilization. Thus, the pre-birth arrest happens during Prophase I of Meiotic Division I.

Final Answer: Prophase I of Meiotic Division I

Answer: (B)

Go Back to Question 10

Q11.

Solution

Concept:

Recombinant DNA technology utilizes cloning vectors equipped with selectable markers and reporter systems to identify host cells that have taken up a plasmid containing the desired gene insert. The alpha-complementation of the *lacZ* gene forms the basis of blue-white screening. The *lacZ* gene encodes the enzyme β-galactosidase, which cleaves the chromogenic substrate X-gal to produce a blue precipitate. When a foreign DNA fragment is successfully inserted into a restriction site within the coding sequence of *lacZ*, it disrupts the reading frame, a process known as insertional inactivation.

Solution:

Step 1: Evaluate the functionality of the ampicillin resistance gene (amp^R). The foreign gene insert was ligated into the *lacZ* gene site, leaving the separate amp^R gene sequence intact and undisturbed. Therefore, any bacterium transformed with this plasmid will express amp^R and survive on ampicillin media.

Step 2: Analyze the status of the *lacZ* reporter gene. Because the foreign genomic fragment was successfully cloned directly into the restriction site situated inside the *lacZ* locus, the continuity of the *lacZ* gene is physically disrupted.

Step 3: Determine the biochemical outcome of this disruption. Due to insertional inactivation, the recombinant plasmid can no longer produce a functional, full-length β-galactosidase enzyme.

Step 4: Observe the reaction with the substrate X-gal. When the transformed bacteria are grown on plates containing X-gal, the lack of functional β-galactosidase means that X-gal cannot be metabolized.

Step 5: Deduce the colony phenotype. Because no blue dimeric dye product can be formed, the surviving ampicillin-resistant colonies retain their natural, uncolored appearance, developing into white (colorless) colonies. This distinguishes them from non-recombinant blue colonies.

Final Answer: They will survive and form white (colorless) colonies.

Answer: (C)

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Q12.

Solution

Concept:

Renal clearance (C) is defined as the volume of plasma that is completely cleared of a specific substance by the kidneys per unit time. It serves as an indicator of how different compounds are processed by the nephrons. Inulin is an exogenous polysaccharide that is freely filtered at the glomerulus and is neither reabsorbed nor secreted by the renal tubules. Therefore, the clearance of inulin is exactly equal to the Glomerular Filtration Rate (GFR = 125 mL/min). Comparing the clearance of any other substance to that of inulin reveals its net handling within the tubules.

Solution:

Step 1: Note the baseline reference value provided by inulin. The clearance of inulin (C_{inulin}) is given as 125 mL/min, which represents the absolute volume of filtrate formed by the glomeruli each minute.

Step 2: Examine the clearance value calculated for the new therapeutic drug. The clearance of this novel drug (C_{drug}) is determined to be 310 mL/min.

Step 3: Perform a quantitative comparison. Note that $C_{\text{drug}} = 310$ mL/min, which is significantly greater than $C_{\text{inulin}} = 125$ mL/min. This means that more plasma is cleared of the drug per minute than can be accounted for by filtration alone.

Step 4: Deduce the physiological mechanism responsible for this excess clearance. For the cleared volume to exceed the filtered volume, additional drug molecules must be actively extracted from the peritubular capillaries and transported across the tubular epithelial cells directly into the tubular fluid.

Step 5: Conclude the net renal handling. This pathway of moving substances from the blood into the filtrate is termed active tubular secretion. Thus, the drug must undergo standard glomerular filtration supplemented by net active tubular secretion.

Final Answer: The drug undergoes glomerular filtration along with active net tubular secretion into the filtrate.

Answer: (D)

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Q13.

Solution

Concept:

The development of the female gametophyte (embryo sac) in typical angiosperms follows the monosporic Polygonum type. A single functional megaspore undergoes three consecutive rounds of free-nuclear mitotic divisions ($2^3 = 8$ nuclei), which partition into a 7-celled, 8-nucleate structure containing one egg cell, two synergids, three antipodal cells, and one large central cell containing two polar nuclei. Double fertilization involves one sperm fusing with the egg cell to form a diploid zygote ($2n$), while a second sperm fuses with the two polar nuclei to yield a triploid endosperm ($3n$).

Solution:

Step 1: Analyze the experimental intervention described. The researcher blocks the third round of mitosis. The functional megaspore completes only two rounds of free-nuclear divisions instead of the normal three rounds.

Step 2: Calculate the number of nuclei produced. Starting with 1 nucleus, the first mitosis yields 2 nuclei, and the second mitosis yields a total of 4 nuclei. The third round, which would normally produce 8 nuclei, does not happen.

Step 3: Consider the cellular organization of a 4-nucleate embryo sac. These 4 available nuclei must be distributed into essential structures. Typically, they differentiate into an egg apparatus (one egg cell and two flanking synergids) at the micropylar end, leaving only 1 remaining nucleus.

Step 4: Determine the composition of the central cell. Because 3 nuclei are consumed to form the critical egg apparatus and a single nucleus may remain at the chalazal end, there are no remaining nuclei available to migrate into the center to form the typical pair of polar nuclei.

Step 5: Assess the impact on endosperm formation. Because the mature gametophyte completely lacks the two central polar nuclei, the second entering sperm cell has no female genomic target to fuse with inside the central cell. Consequently, the development of the characteristic triploid ($3n$) nutritive endosperm tissue is completely prevented.

Final Answer: It lack polar nuclei completely, preventing the formation of a triploid endosperm upon fertilization.

Answer: (A)

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Q14.

Solution

Concept:

Evolutionary biology classifies structural features across diverse organisms into homologous or analogous structures based on their embryonic origin and evolutionary history. Homologous structures are anatomical features that share a common structural plan and developmental origin derived from a common ancestor, even if they have evolved to serve entirely different functions in response to different environmental pressures (divergent evolution). Analogous structures are features that serve superficially similar functions but have independent embryonic origins and evolved separately due to similar environmental demands (convergent evolution).

Solution:

Step 1: Analyze the first pair: the flipper of a whale and the wing of a bat. Whales and bats are both mammals that share a common mammalian ancestor. Dissection reveals that both the flipper and the wing possess the same basic pentadactyl skeletal framework, including a humerus, radius, ulna, carpals, and phalanges.

Step 2: Determine the classification for pair 1. Despite being modified for swimming in whales and flying in bats, their shared ancestral skeletal architecture classifies the flipper of a whale and the wing of a bat as homologous structures.

Step 3: Analyze the second pair: the wing of a butterfly and the wing of a bird. Butterflies are invertebrates (Arthropods) whose wings are thin sheets of chitin supported by hemolymph sinuses. Birds are vertebrates (Chordates) whose wings are built from a bony endoskeleton covered with feathers.

Step 4: Determine the classification for pair 2. These two structures do not share a common anatomical or ancestral template. They evolved independently to satisfy the same functional requirement of flight. Therefore, the wing of a butterfly and the wing of a bird are analogous structures.

Step 5: Combine the conclusions: Structure pair 1 represents a homologous relationship, whereas structure pair 2 represents an analogous relationship. This matches option C.

Final Answer: 1 is Homologous; 2 is Analogous

Answer: (C)

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Q15.

Solution

Concept:

Biological membranes are composed of an asymmetric lipid bilayer where specific classes of phospholipids are preferentially localized to either the inner (cytosolic) or outer (exoplasmic) leaflet. Phospholipids are synthesized primarily on the cytosolic face of the endoplasmic reticulum membrane. Because spontaneous transverse movement ("flip-flop") of polar lipid headgroups through the hydrophobic core of the bilayer is thermodynamically unfavorable, cells utilize specialized ATP-dependent transporter enzymes called flippases to actively translocate specific lipids from one leaflet to the other.

Solution:

Step 1: Define the physiological role of flippase enzymes. Flippases are transmembrane proteins that catalyze the unidirectional translocation of specific phospholipids, such as phosphatidylserine and phosphatidylethanolamine, from the extracellular/luminal leaflet back to the cytosolic leaflet.

Step 2: Analyze the experimental status of the yeast mutant. The mutant strain completely lacks functional flippase enzymes across its cellular membrane networks, meaning active trans-bilayer lipid movement is abolished.

Step 3: Evaluate the effect on lipid synthesis and distribution. When new lipids are added during membrane biogenesis, or when random lipid scrambling occurs, there is no mechanism to selectively pump specific phospholipids into their proper designated leaflets.

Step 4: Determine the structural consequence. Without the active sorting activity of flippases, the thermodynamic equilibrium takes over or lipids remain where they were synthesized, causing the membrane to lose its highly regulated asymmetric lipid composition between the two leaflets.

Step 5: Conclude the primary defect. This lack of asymmetry means the distinct composition of the inner and outer faces of the plasma and endoplasmic reticulum membranes is lost, resulting in a randomized, symmetric distribution of lipid species across the bilayer.

Final Answer: The lipid bilayer of the membranes will lose its characteristic asymmetric distribution of specific phospholipids between the inner and outer leaflets.

Answer: (B)

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Answer Key

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