IISER Biology Sample Paper-8

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 diploid annual plant species is in Hardy-Weinberg equilibrium for a specific locus with two alleles, A and a. Due to a sudden environmental shift, a selective pressure is introduced such that homozygous recessive individuals (aa) fail to reach reproductive maturity, while the fitness of AA and Aa genotypes remains equal to 1.0. If the initial frequency of the a allele was 0.4, what will be the frequency of the A allele in the next generation of mature, reproducing individuals?

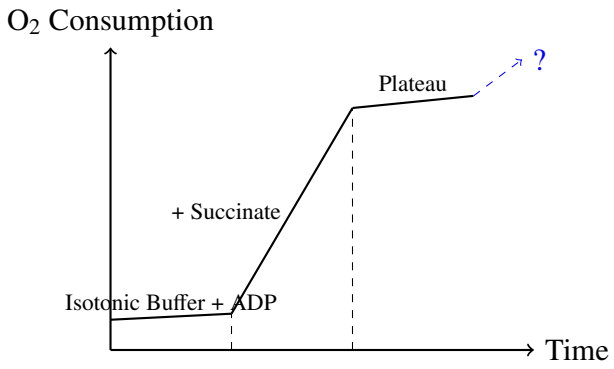
(A) 0.60

(B) 0.71

(C) 0.75

(D) 0.84

Q2. An investigator isolates intact mitochondria from fresh rat liver tissue and suspends them in an isotonic buffer containing inorganic phosphate and ADP. She monitors oxygen consumption over time. Initially, oxygen consumption is negligible. She then adds succinate, which triggers a rapid increase in oxygen consumption. After a short period, oxygen consumption abruptly slows down. Which of the following manipulations would most effectively resume the rapid rate of oxygen consumption?



(A) Addition of an inhibitor of Complex IV

(B) Addition of more succinate

(C) Addition of more ADP

(D) Addition of an uncoupler like 2,4-dinitrophenol (DNP) without adding more ADP

Q3. A molecular biologist constructs a genomic library from a rare marine archaebacterium to identify a novel thermostable DNA polymerase. The screening strategy relies on functional complementation of an *E. coli* mutant that lacks DNA polymerase I activity and is temperature-sensitive for growth. However, despite multiple attempts, no functional clones are recovered. Further analysis reveals that the archaebacterial gene was successfully transcribed into full-length mRNA within *E. coli*. Which of the following provides the most plausible explanation for the lack of functional complementation?

(A) The archaebacterial gene contains multiple introns that *E. coli* lacks the machinery to splice out.

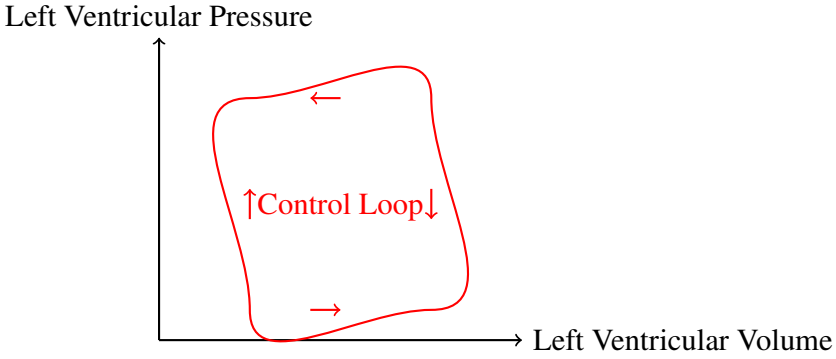
(B) The codon usage bias of the archaebacterium prevents the translation of a stable, functional protein in *E. coli*.

(C) The *E. coli* RNA polymerase fails to recognize the archaebacterial promoter region.

(D) The archaebacterial DNA polymerase requires post-translational glycosylation in the endoplasmic reticulum to become active.

Q4. In an experiment assessing the parameters of the cardiac cycle, an animal's left ventricular pressure and volume are monitored simultaneously under different

conditions. If a drug that selectively blocks the slow L-type Ca^{2+} channels in myocardial contractile cells is administered, how will the ventricular pressure-volume loop be altered compared to the control state?



(A) The end-systolic volume will increase, and the stroke volume will decrease.

(B) The end-diastolic volume will decrease, and the stroke volume will increase.

(C) The peak systolic pressure will increase due to compensatory sympathetic reflex.

(D) The isovolumetric relaxation phase will occur at a significantly lower ventricular volume.

Q5. A mutant strain of *Chlamydomonas reinhardtii* possesses a defective light-harvesting complex II (LHCII) that cannot undergo state transitions (the reversible migration of LHCII between Photosystem II and Photosystem I). When these mutant cells are shifted from low-intensity white light to monochromatic light that exclusively excites Photosystem II (680 nm), which of the following immediate physiological responses is expected?

(A) The plastoquinone pool will become highly oxidized, stopping cyclic electron flow.

(B) The rate of non-photochemical quenching (NPQ) will decrease drastically.

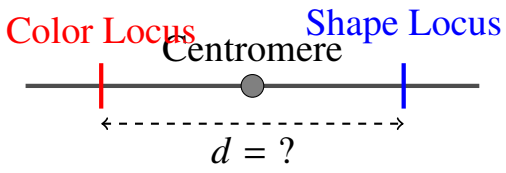
(C) Photosystem II will undergo photoinhibition due to over-reduction of the electron transport chain.

(D) ATP synthesis will accelerate due to enhanced non-cyclic photophosphorylation.

Q6. In a standard diploid angiosperm, a geneticist crosses a true-breeding plant with red, star-shaped flowers to another true-breeding plant with white, round flowers. All F_1 plants exhibit pink, star-shaped flowers. An F_1 plant is test-crossed with a plant having white, round flowers, yielding the following phenotypic distribution in the offspring:

- Pink, star-shaped: 42
- White, round: 44
- Pink, round: 7
- White, star-shaped: 7

What is the map distance between the locus governing flower color and the locus governing flower shape?



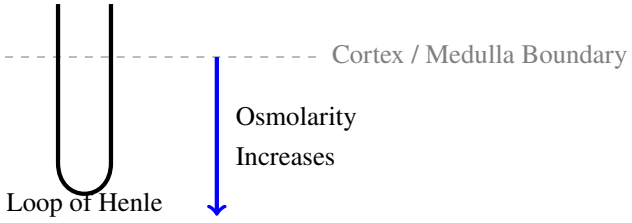
(A) 7 cM

(B) 14 cM

(C) 28 cM

(D) The loci are completely unlinked and assorting independently.

Q7. The loop of Henle acts as a countercurrent multiplier to establish an osmotic gradient in the renal medulla. Suppose a mammalian species is evolved to survive in an extremely hyperosmotic desert environment. If we examine its nephron physiology compared to a freshwater mammal, which of the following characteristics would be prominently observed?



(A) A higher proportion of cortical nephrons relative to juxtamedullary nephrons.

(B) Increased expression of active $NaCl$ transporters in the descending limb of the loop of Henle.

(C) A significantly longer loop of Henle extending deep into the inner medulla, paired with high vasa recta efficiency.

(D) Reduced permeability to urea in the medullary collecting duct to prevent systemic toxicity.

Q8. A pristine temperate forest ecosystem experiences a severe wildfire that clears all vegetation and exposes the bare soil, but leaves the seed bank in the deeper soil layers intact. Over the next several decades, ecological succession is monitored. Which of the following graphs correctly conceptually models the changes in total net primary productivity (NPP) and total ecosystem biomass during this secondary succession process?

(A) NPP peaks in the climax stage, while biomass peaks during the mid-successional shrub stage.

(B) Both NPP and biomass increase monotonically and reach their maximum values simultaneously at the stable climax community stage.

(C) NPP peaks during the mid-successional stages dominated by fast-growing herbaceous and shrub species, then declines slightly and stabilizes, while total biomass plateaus at the climax stage.

(D) NPP remains completely constant throughout succession, while biomass increases exponentially.

Q9. Human chorionic gonadotropin (hCG) is a glycoprotein hormone produced during pregnancy. A group of researchers develops a monoclonal antibody that selectively blocks the binding of hCG to its receptors on the cells of the corpus luteum. If this antibody is administered to a female mammal immediately following successful blastocyst implantation (around day 7–9 post-fertilization), what will be the most direct consequence?

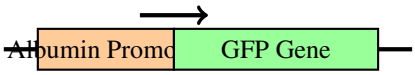
(A) The maternal levels of progesterone will drop sharply, leading to menstruation and termination of the pregnancy.

(B) The anterior pituitary will be triggered to secrete massive amounts of LH to rescue the corpus luteum.

(C) The placenta will accelerate its own production of progesterone prematurely to compensate.

(D) The endometrium will undergo hyper-proliferation and form a benign deciduoma.

Q10. A molecular biologist constructs a chimeric eukaryotic gene by fusing the promoter and enhancer elements of a liver-specific gene (Albumin) to the open reading frame of a green fluorescent protein (GFP). This construct is introduced into the pronucleus of a fertilized mouse oocyte to generate a transgenic mouse line. In which of the following cell types will GFP fluorescence be detectable?



(A) In every cell type of the transgenic mouse because the transgene is integrated into the germline genome.

(B) Only in hepatocytes, because the transcription factors required to activate the Albumin promoter are uniquely functional in liver cells.

(C) Only in the germ cells and early embryonic cells, as somatic differentiation silences foreign transgenes.

(D) In all endoderm-derived tissues, including the liver, pancreas, and intestinal epithelium, due to leaky promoter specificity.

Q11. The cell walls of higher plants are dynamic structures that undergo controlled relaxation to allow for cell elongation, a process known as acid-growth. When the hormone auxin binds to its receptor, it stimulates plasma membrane H^+-ATPases, lowering the cell wall pH to approximately 4.5. This acidic environment directly activates which of the following cell wall proteins to induce wall loosening?

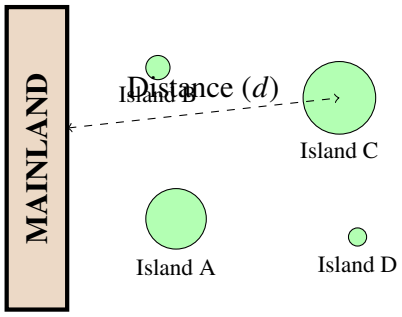
(A) Pectin methylesterases, which cross-link acidic polysaccharides.

(B) Expansins, which disrupt the non-covalent hydrogen bonding between cellulose microfibrils and matrix glycans.

(C) Cellulases, which irreversibly hydrolyze the β-(1,4)-glucosidic bonds of cellulose microfibrils.

(D) Peroxidases, which catalyze the oxidative cross-linking of structural proteins like extensin.

Q12. An island archipelago consists of five islands of varying sizes and distances from a large continental mainland. According to the Equilibrium Theory of Island Biogeography proposed by MacArthur and Wilson, which of the following islands is expected to maintain the highest species richness at equilibrium?



(A) A large island located close to the mainland mainland.

(B) A small island located close to the mainland mainland.

(C) A large island located far away from the mainland mainland.

(D) A small island located far away from the mainland mainland.

Q13. In human oogenesis, primary oocytes are formed during embryonic development and remain arrested in a specific stage of cell division for years until puberty. Upon ovulation, the oocyte resumes meiosis but arrests a second time. At which exact cytological stages do the first and second meiotic arrests occur, respectively?

(A) Prophase I (Diplotene) and Metaphase II

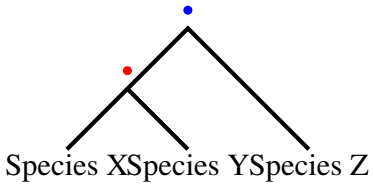
(B) Prophase I (Pachytene) and Anaphase II

(C) Metaphase I and Telophase II

(D) Prophase I (Diakinesis) and Prophase II

Q14. The evolutionary relationship between three closely related avian species (Species X, Y, and Z) is investigated using comparative genomics. Alignment of a highly

conserved nuclear intron reveals that Species X and Y share a unique 12-base pair deletion that is absent in Species Z and all distant outgroups. However, a mitochondrial gene tree indicates that Species Y and Z are sister taxa with a very high bootstrap support value. Which of the following evolutionary phenomena provides the most robust, parsimonious explanation for this phylogenetic discordance?



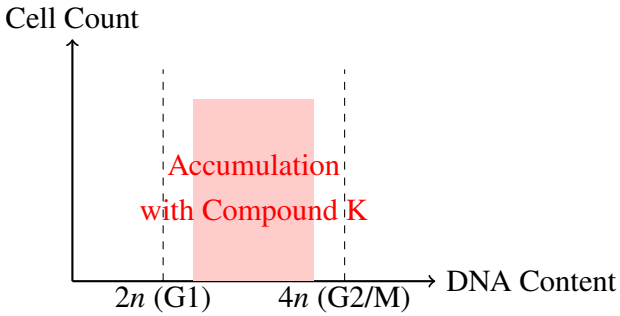
(A) Convergent evolution of the nuclear deletion in both Species X and Y due to identical environmental pressures.

(B) Incomplete lineage sorting or ancient introgressive hybridization between Species Y and Z.

(C) A high rate of silent backward mutations in the mitochondrial genome of Species X.

(D) Horizontal gene transfer of the entire mitochondrial genome from an unrelated reptilian vector.

Q15. A culture of human fibroblasts is treated with a novel synthetic compound, Compound K. Flow cytometric analysis of the DNA content per cell in the treated population reveals a sharp accumulation of cells possessing an intermediate amount of DNA, strictly between the $2n$ (G1 phase) and $4n$ (G2/M phase) values, compared to the control culture. Which of the following cellular processes is Compound K most likely inhibiting?



(A) The assembly of the mitotic spindle apparatus.

(B) The activation of cyclin-dependent kinase 2 (CDK2) at the G1/S transition point.

(C) The process of semi-conservative DNA replication during the S phase.

(D) The degradation of securin by the anaphase-promoting complex/cyclosome (APC/C).

Detailed Solutions

Q1.

Solution

Concept: This question applies the principles of natural selection to a population initially in Hardy-Weinberg equilibrium. When a recessive lethal or completely deleterious allele is selected against (aa individuals do not reproduce), the allele frequencies shift in a predictable manner described by selection models.

Solution: Step 1: Identify the initial allele frequencies from the problem. The frequency of the recessive allele a is given as $q_0 = 0.4$. Since it is a two-allele system, the initial frequency of the dominant allele A is $p_0 = 1 - q_0 = 1 - 0.4 = 0.6$.

Step 2: Calculate the genotype frequencies in the zygote stage before selection using the Hardy-Weinberg formula. The frequency of AA is $p_0^2 = (0.6)^2 = 0.36$. The frequency of Aa is $2p_0q_0 = 2(0.6)(0.4) = 0.48$. The frequency of aa is $q_0^2 = (0.4)^2 = 0.16$.

Step 3: Apply the fitness values (w) to each genotype. The problem states that aa individuals fail to reach reproductive maturity, meaning $w_{aa} = 0$. The fitness of AA and Aa genotypes remains equal to 1.0, so $w_{AA} = 1.0$ and $w_{Aa} = 1.0$.

Step 4: Compute the total mean fitness ($\bar{w}$) of the population after selection by summing the products of the initial frequencies and their respective fitness values:

$$\bar{w} = p_0^2(1.0) + 2p_0q_0(1.0) + q_0^2(0) = 0.36 + 0.48 + 0 = 0.84$$

Step 5: Determine the new frequency of the A allele (p_1) among the reproducing adults. The A alleles come from all surviving AA individuals and half of the surviving heterozygous Aa individuals, divided by the total surviving population relative fitness:

$$p_1 = \frac{p_0^2 + p_0q_0}{\bar{w}} = \frac{0.36 + 0.24}{0.84} = \frac{0.60}{0.84} \approx 0.714$$

Rounding to two decimal places, the new frequency of the A allele is 0.71.

Final Answer: 0.71

Answer: (B)

Go Back to Question 1

Q2.

Solution

Concept: Oxidative phosphorylation in mitochondria links the electron transport chain (ETC) to ATP synthesis. Substrate oxidation drives proton pumping across the inner membrane, creating a proton motive force. ATP synthase uses this gradient to make ATP from ADP and Pi. When ADP is depleted, the proton gradient builds up, building backpressure that halts electron transport and oxygen consumption.

Solution: Step 1: Analyze the initial experimental conditions. Intact mitochondria are given substrate (succinate), ADP, and Pi. Succinate donates electrons to Complex II ($FADH_2$ pathway), initiating proton pumping and oxygen consumption.

Step 2: Explain the reason for the abrupt slowdown. The prompt states that after a short period, oxygen consumption slows down. This occurs because the finite amount of added ADP is completely phosphorylated into ATP. In the absence of ADP, ATP synthase stalls, preventing protons from returning to the matrix.

Step 3: Evaluate how to relieve this respiratory control. The high accumulation of protons in the intermembrane space creates an electrochemical gradient that makes further proton pumping thermodynamically unfavorable, slowing down the ETC and oxygen utilization.

Step 4: Consider option mechanisms. To resume oxygen consumption without adding more ADP, the proton gradient must be dissipated by another route. An uncoupler like 2,4-dinitrophenol (DNP) acts as a protonophore, carrying protons directly across the inner mitochondrial membrane into the matrix.

Step 5: Conclude the final physiological outcome. This uncoupling bypasses ATP synthase, destroying the respiratory control mechanism. The ETC can now run at maximum speed to oxidize the remaining succinate, causing a rapid resumption and increase in oxygen consumption.

Final Answer: Addition of an uncoupler like 2,4-dinitrophenol (DNP) without adding more ADP

Answer: (D)

Go Back to Question 2

Q3.

Solution

Concept: Heterologous gene expression involves transcribing and translating a gene from one organism inside a host organism. While core genetic transcription can sometimes occur if a promoter behaves compatibly, successful translation requires that the host tRNA pool matches the codon composition of the foreign mRNA.

Solution: Step 1: Review the experimental observations. The archaebacterial gene is successfully transcribed into a full-length mRNA molecule inside the $E.\ coli$ cells. This eliminates any issues related to promoter recognition or transcriptional termination.

Step 2: Rule out the presence of eukaryotic introns. Archaebacteria are prokaryotic organisms. Although they possess some eukaryotic-like replication and transcription machinery, their structural genes generally lack spliceosomal introns, meaning splicing issues do not explain the failure.

Step 3: Investigate translational limitations. Archaebacteria often live in extreme environments and possess genomic GC or AT biases that result in highly specialized codon usage. $E.\ coli$ has a specific abundance profile for different tRNAs matching its own preferred codons.

Step 4: Connect codon usage to expression failure. If the archaebacterial mRNA relies heavily on codons that are extremely rare in $E.\ coli$, the translation machinery will stall due to the scarcity of corresponding charged tRNAs. This stalling leads to premature translation termination or protein degradation.

Step 5: Synthesize the conclusion. Because translation stalls or fails entirely, no stable, functional thermostable DNA polymerase protein is produced. This explains why the temperature-sensitive $E.\ coli$ mutant failed to be complemented despite full-length transcription.

Final Answer: The codon usage bias of the archaebacterium prevents the translation of a stable, functional protein in $E.\ coli$.

Answer: (B)

Go Back to Question 3

Q4.

Solution

Concept: The cardiac ventricular pressure-volume (PV) loop illustrates the phases of the cardiac cycle: filling, isovolumetric contraction, ejection, and isovolumetric relaxation. Altering myocardial contractility changes the slope of the end-systolic pressure-volume relationship (ESPVR), which shifts the boundaries of the loop.

Solution: Step 1: Understand the physiological role of slow L-type Ca^{2+} channels. During the plateau phase of the myocardial action potential, calcium entry through these channels triggers calcium-induced calcium release from the sarcoplasmic reticulum, which dictates the force of contraction.

Step 2: Determine the pharmacological effect of the blocker. Blocking these channels decreases the intracellular calcium concentration available for actin-myosin cross-bridge formation. This produces a negative inotropic effect, significantly reducing myocardial contractility.

Step 3: Analyze the effect on the end-systolic state. A reduction in contractility shifts the ESPVR line downwards and to the right. Consequently, for a given afterload, the ventricle cannot pump blood as effectively, meaning it will empty less completely during the ejection phase.

Step 4: Relate this to specific loop parameters. Because the ventricle empties less efficiently, the volume of blood remaining in the heart at the end of ejection increases, which corresponds to an increased end-systolic volume (ESV).

Step 5: Deduce the impact on stroke volume. Stroke volume is defined as the difference between end-diastolic volume and end-systolic volume (SV = EDV − ESV). With an increased ESV and assuming a constant or slightly restricted venous return, the total stroke volume must decrease.

Final Answer: The end-systolic volume will increase, and the stroke volume will decrease.

Answer: (A)

Go Back to Question 4

Q5.

Solution

Concept: Photosynthetic electron transport requires a balance of excitation energy between Photosystem II (PSII) and Photosystem I (PSI). State transitions regulate this distribution. When PSII is over-excited, the plastoquinone pool becomes over-reduced, prompting the phosphorylation and migration of LHCII to PSI to restore balance.

Solution: Step 1: Examine the nature of the mutant strain. The *Chlamydomonas reinhardtii* mutant cannot perform state transitions because its LHCII is defective and cannot dissociate from PSII to migrate to PSI.

Step 2: Analyze the experimental shift. The cells are placed under monochromatic 680 nm light. This specific wavelength of light is primarily absorbed by the reaction center and antenna complexes of Photosystem II, leaving Photosystem I under-excited.

Step 3: Trace the flow of electrons. PSII continuously extracts electrons from water and transfers them down the chain to the plastoquinone (PQ) pool. Because PSI is not receiving enough light energy to oxidize plastocyanin and the cytochrome b_6f complex, electron flow bogs down.

Step 4: Identify the state of the electron transport chain components. The plastoquinone pool rapidly becomes completely reduced (PQH_2). Without the ability to shift LHCII away via state transitions to lower the absorption cross-section of PSII, PSII continues to absorb energy.

Step 5: Conclude the ultimate damage mechanism. This state of persistent over-reduction leads to the accumulation of reactive oxygen species and singlet oxygen within the thylakoid membrane, causing severe oxidative damage to the D1 protein of PSII, a process known as photoinhibition.

Final Answer: Photosystem II will undergo photoinhibition due to over-reduction of the electron transport chain.

Answer: (C)

Go Back to Question 5

Q6.

Solution

Concept: Genetic linkage and gene mapping utilize the frequency of recombinant offspring from a testcross to determine the relative distance between two loci on a chromosome. One map unit, or centimorgan (cM), is defined as equal to a 1% recombination frequency.

Solution: Step 1: Determine the parental genotypes and phenotypes. The cross is between a true-breeding red, star-shaped plant (RRSS) and a white, round plant (rrss). The F_1 generation shows incomplete dominance for color (pink, Rr) and complete dominance for shape (Ss).

Step 2: Analyze the testcross. The F_1 heterozygote (RrSs) is crossed with a homozygous recessive tester plant (rrss). The parental combinations of alleles entering the F_1 were Red-Star (RS) and White-Round (rs).

Step 3: Classify the offspring into parental and recombinant classes. Looking at the data:

- Pink, star-shaped (RrSs): 42 (Parental combination)
- White, round (rrss): 44 (Parental combination)
- Pink, round (Rrss): 7 (Recombinant combination)
- White, star-shaped (rrSs): 7 (Recombinant combination)

Step 4: Calculate the total number of progeny produced in the testcross:

$$\text{Total Offspring} = 42 + 44 + 7 + 7 = 100$$

Step 5: Determine the recombination frequency by taking the sum of the recombinant progeny, dividing by the total population, and multiplying by 100:

$$\text{Recombination Frequency} = \frac{7+7}{100} \times 100\% = \frac{14}{100} \times 100\% = 14\%$$

Since 1% recombination frequency corresponds to 1 cM, the map distance is 14 cM.

Final Answer: 14 cM

Answer: (B)

Go Back to Question 6

Q7.

Solution

Concept: The mammalian kidney concentrates urine via the countercurrent multiplier system established by the loops of Henle. The depth of the medullary osmotic gradient is proportional to the length of these loops, allowing for higher water reabsorption in the presence of antidiuretic hormone (ADH).

Solution: Step 1: Evaluate the environmental demands. A desert mammal faces extreme dehydration stresses and must minimize water loss by producing highly concentrated urine, requiring a very high medullary osmotic gradient.

Step 2: Relate anatomy to physiological capacity. To establish a steeper osmotic gradient in the inner medulla, the physical multiplier system must have a longer path length. This requires long loops of Henle belonging to juxtamedullary nephrons.

Step 3: Contrast with freshwater mammals. Freshwater mammals have no need to conserve water and possess short loops of Henle that reside mostly within the cortex. Desert mammals possess specialized kidneys dominated by deep-dipping juxtamedullary loops.

Step 4: Understand the of the vasa recta. The capillaries of the vasa recta must form highly specialized, slow-flowing loops that mirror the loops of Henle. This architecture preserves the gradient by minimizing solute washout, known as countercurrent exchange.

Step 5: Match the physiological options. Long loops of Henle combined with optimized vasa recta systems directly increase the concentration of the medullary interstitial fluid, maximizing the driving force for water extraction from the collecting ducts.

Final Answer: A significantly longer loop of Henle extending deep into the inner medulla, paired with high vasa recta efficiency.

Answer: (C)

Go Back to Question 7

Q8.

Solution

Concept: Ecological succession describes changes in ecosystem structural and functional parameters over time. Net primary productivity (NPP) is the rate of energy storage as organic matter after respiratory losses, while biomass is the total accumulated standing organic mass.

Solution: Step 1: Define the initial successional conditions. Following a wildfire with an intact soil seed bank, secondary succession begins. Initially, both biomass and net primary productivity are low due to the lack of mature vegetative cover.

Step 2: Trace the mid-successional dynamics. Fast-growing, pioneer, and intermediate herbaceous plants and shrubs colonize the area. These species invest heavily in rapid growth and photosynthetic machinery, causing a dramatic surge in total ecosystem NPP.

Step 3: Analyze the transition to the climax stage. As slow-growing woody perennial trees establish and form a closed canopy, the ratio of photosynthetic foliage to non-photosynthetic structural biomass (trunks, large roots) begins to decline.

Step 4: Explain why NPP decreases later. In a mature forest, a large fraction of fixed carbon is consumed by the cellular respiration of the massive structural wood components. Consequently, net primary productivity drops from its mid-successional peak and stabilizes at a lower equilibrium.

Step 5: Characterize total biomass accumulation. Unlike NPP, total ecosystem biomass continuously increases throughout the successional series as carbon accumulates in the woody tissue of trees, eventually plateauing at its maximum value during the stable climax community stage.

Final Answer: NPP peaks during the mid-successional stages dominated by fast-growing herbaceous and shrub species, then declines slightly and stabilizes, while total biomass plateaus at the climax stage.

Answer: (C)

Go Back to Question 8

Q9.

Solution

Concept: Early pregnancy maintenance in primates requires endocrine signaling from the implanting embryo to prevent regression of the corpus luteum. Human chorionic gonadotropin (hCG) acts as an analog of luteinizing hormone (LH) to maintain progesterone secretion until the placenta takes over.

Solution: Step 1: Understand the role of hCG post-implantation. Following blastocyst implantation, cells of the developing trophoblast secrete hCG. This hormone enters maternal circulation and binds specifically to LH/hCG receptors on the granulosa-lutein cells of the corpus luteum.

Step 2: Describe the normal function of the corpus luteum. Under the influence of hCG, the corpus luteum continues to synthesize and secrete high amounts of progesterone and estrogens, which are essential for maintaining the vascular integrity of the endometrium.

Step 3: Deduce the effect of the monoclonal antibody. The administration of a neutralizing monoclonal antibody completely blocks the binding interaction between hCG and its receptors on the luteal cells, leaving the corpus luteum without its essential survival signal.

Step 4: Track the endocrine downstream effects. Denied luteotrophic stimulation, the corpus luteum rapidly undergoes functional and structural regression (luteolysis). Consequently, maternal plasma progesterone levels drop precipitously.

Step 5: Analyze the anatomical outcome. Without progesterone support, the highly vascularized endometrial lining cannot maintain its structure. It sheds in a process identical to menstruation, resulting in early termination of the pregnancy.

Final Answer: The maternal levels of progesterone will drop sharply, leading to menstruation and termination of the pregnancy.

Answer: (A)

Go Back to Question 9

Q10.

Solution

Concept: Transgenic expression profiles are dictated by the promoter and enhancer elements driving the gene of interest. While a transgene integrated at the zygote stage is physically present in the DNA of every single cell, expression occurs only where appropriate transcription factors are present.

Solution: Step 1: Analyze the construction of the transgene. The chimeric gene contains the structural open reading frame for Green Fluorescent Protein (GFP) linked downstream of the regulatory promoter and enhancer regions derived from the liver-specific Albumin gene.

Step 2: Note the genetic status of the organism. Because the construct was injected into a fertilized oocyte, the DNA integrates into the host genome prior to cleavage, ensuring that every cell in the resulting transgenic mouse line carries this exact transgene sequence.

Step 3: Apply the rules of differential gene expression. Although the transgene is physically present in all tissues, transcription requires the binding of specific trans-acting transcription factors (such as HNF-1, HNF-4, and CCAAT/enhancer-binding proteins).

Step 4: Identify tissue distribution of these factors. These regulatory proteins are uniquely active and abundant inside mature, differentiating hepatocytes. In non-hepatic tissues, these specific transcription factors are missing or repressed, meaning the promoter remains silent.

Step 5: Determine where fluorescence will occur. Because the biochemical machinery to initiate transcription from the Albumin promoter is restricted to liver tissue, functional GFP protein will be synthesized and detectable exclusively within hepatocytes.

Final Answer: Only in hepatocytes, because the transcription factors required to activate the Albumin promoter are uniquely functional in liver cells.

Answer: (B)

Go Back to Question 10

Q11.

Solution

Concept: The acid-growth hypothesis explains auxin-induced cell elongation in plants. Auxin stimulates proton pumps, lowering the pH of the apoplast. This acidic environment activates specific cell wall-loosening proteins that break the structural cross-links between wall polysaccharides.

Solution: Step 1: Understand the mechanical structure of the plant cell wall. The primary plant cell wall is a rigid network composed of rigid cellulose microfibrils embedded in a matrix of hemicelluloses (glycans) and pectins, bound together by extensive hydrogen bonding.

Step 2: Trace the action of auxin. Auxin binds to its receptor and triggers the activation and insertion of plasma membrane H^+-ATPases. These pumps actively pump protons from the cytoplasm into the cell wall apoplast, dropping the wall pH to around 4.5.

Step 3: Evaluate how the cell wall loosens. The structural expansion of the wall requires a temporary disruption of the non-covalent cross-links between cellulose and hemicellulose, allowing the microfibrils to slide past one another under turgor pressure.

Step 4: Identify the specific protein class involved. This pH drop directly activates a group of non-enzymatic cell wall proteins called expansins. Expansins have an optimal operational pH profile that peaks under acidic conditions (4.5).

Step 5: Detail the molecular mechanism. Expansins act by weakening the non-covalent hydrogen bonds that glue the matrix glycans to the surfaces of the cellulose microfibrils. This reversible loosening allows turgor pressure to drive wall elongation without breaking covalent bonds.

Final Answer: Expansins, which disrupt the non-covalent hydrogen bonding between cellulose microfibrils and matrix glycans.

Answer: (B)

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Q12.

Solution

Concept: The Equilibrium Theory of Island Biogeography predicts that the species richness of an isolated ecosystem stabilizes at an equilibrium point where the rate of new species immigration equals the rate of resident species extinction.

Solution: Step 1: Analyze how distance from the mainland affects immigration. The mainland serves as the primary pool of potential colonizing species. Islands that are geographically closer to the mainland have a higher probability of receiving dispersing propagules, increasing immigration rates.

Step 2: Analyze how island area affects extinction rates. Larger islands offer a greater diversity of ecological niches, larger sustainable population sizes, and more abundant resources. Consequently, resident populations face a lower risk of accidental extinction.

Step 3: Combine both factors graphically. On a standard MacArthur-Wilson equilibrium graph, the immigration curve is highest for "near" islands, and the extinction curve is lowest for "large" islands. The intersection of these two curves yields the equilibrium species number (S).

Step 4: Identify the optimal parameters for species richness. The maximum equilibrium number of species will occur where high immigration rates meet low extinction rates. This condition is perfectly met by an island that is both large in size and close to the mainland.

Step 5: Conclude based on the choices. Island A (large and near) will maintain the highest species richness, whereas small, distant islands will exhibit the lowest species diversity due to low colonization rates and frequent extinction events.

Final Answer: A large island located close to the mainland mainland.

Answer: (A)

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Q13.

Solution

Concept: Human oogenesis is a discontinuous process characterized by prolonged developmental arrests. Meiosis begins during embryonic life, stops for years, resumes around ovulation, stops a second time, and finishes only upon successful fertilization.

Solution: Step 1: Trace fetal oocyte development. During the fetal period, primordial germ cells differentiate into oogonia and undergo mitosis. These cells enter Meiosis I and differentiate into primary oocytes before birth.

Step 2: Identify the first meiotic arrest point. Progress through Meiosis I is halted during the diplotene stage of Prophase I. Oocytes remain dormant inside primordial follicles for years, arrested in this prolonged state known as the dictyate stage, until puberty.

Step 3: Trace the changes at puberty. Each month, a surge of Luteinizing Hormone (LH) induces a cohort of follicles to mature, prompting the primary oocyte to complete Meiosis I, divide unequally into a secondary oocyte and the first polar body, and enter Meiosis II.

Step 4: Identify the second meiotic arrest point. The secondary oocyte progresses through Meiosis II until it reaches Metaphase II. It is ovulated in this state and remains arrested at Metaphase II in the fallopian tube.

Step 5: Determine the requirement for completion. Meiosis II is completed only if a sperm penetrates the oocyte membrane, triggering calcium waves that activate the anaphase-promoting complex. Thus, the correct arrest stages are Prophase I (Diplotene) and Metaphase II.

Final Answer: Prophase I (Diplotene) and Metaphase II

Answer: (A)

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Q14.

Solution

Concept: Phylogenetic discordance occurs when gene trees built from different genetic loci yield conflicting topologies. Paraphyly or conflicting signals between nuclear and mitochondrial genomes are often caused by incomplete lineage sorting or hybridization events.

Solution: Step 1: Analyze the nuclear gene data. Species X and Y share an identical, rare 12-base pair deletion within a highly conserved intron. Such structural mutations are rare and stable, serving as strong evidence that Species X and Y share a close common ancestor.

Step 2: Analyze the mitochondrial gene data. The mitochondrial gene tree places Species Y and Z as sister taxa with high bootstrap confidence. This configuration directly conflicts with the nuclear gene tree topology (((X,Y),Z) vs (X,(Y,Z))).

Step 3: Evaluate biological explanations for this discordance. Mitochondrial DNA is maternally inherited and does not undergo recombination, making it highly susceptible to rapid fixation across species boundaries via introgressive hybridization or incomplete lineage sorting.

Step 4: Assess the alternatives. If an ancestral species Y hybridized with species Z after separating from species X, subsequent backcrossing could cause the mitochondrial genome of species Z to completely replace that of species Y, while nuclear markers preserve the true species history.

Step 5: Select the most parsimonious evolutionary mechanism. Incomplete lineage sorting of ancestral polymorphisms or ancient introgressive hybridization can explain the conflicting topologies without relying on unlikely parallel deletions or massive rates of back-mutation.

Final Answer: Incomplete lineage sorting or ancient introgressive hybridization between Species Y and Z.

Answer: (B)

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Q15.

Solution

Concept: Flow cytometry measures cellular DNA content to determine the distribution of a cell population across the phases of the cell cycle: G1 phase cells have a $2n$ amount of DNA, G2 and M phase cells have a $4n$ amount, and cells actively undergoing S phase possess an intermediate amount.

Solution: Step 1: Interpret the cytometric profiling data. The control culture shows clear peaks at $2n$ and $4n$. Upon adding Compound K, cells accumulate exclusively between the $2n$ and $4n$ boundaries.

Step 2: Map this intermediate state to the cell cycle. Cells with a DNA value strictly greater than $2n$ but less than $4n$ are actively processing through the S (Synthesis) phase, where genomic replication takes place.

Step 3: Deduce the effect of the block. If cells are accumulating inside this intermediate range rather than passing through it to reach the $4n$ state, it indicates that cells can enter the S phase but cannot complete it.

Step 4: Identify the biochemical target. This arrest profile occurs when a drug directly interferes with active DNA polymerization or replication fork progression, stalling cells mid-replication.

Step 5: Eliminate the other choices. Inhibiting mitotic spindle assembly or APC/C would arrest cells at the M phase with a full $4n$ DNA content. Inhibiting CDK2 at the G1/S boundary would freeze cells at the $2n$ stage. Thus, Compound K must block semi-conservative DNA replication.

Final Answer: The process of semi-conservative DNA replication during the S phase.

Answer: (C)

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Answer Key

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