

BITSAT Biology Sample Paper-21

Duration: 60 Minutes

Maximum Marks: 120

Instructions

- This paper contains **40** Multiple Choice Questions (Single Correct).
- Each correct answer carries **+3** marks. Each incorrect answer carries 1 mark. 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 cell biologist treats a mammalian cell line with an experimental drug that selectively blocks the active transport of protons out of the matrix of lysosomes. This structural intervention will directly cause:

- (A) Exponential increase in the rate of intracellular autophagic degradation.
- (B) Immediate inactivation of acid hydrolases due to a progressive rise in luminal pH.
- (C) Accelerated leakage of active catalase molecules into the surrounding cytosol.
- (D) Spontaneous conversion of raw heterophagosomes into functional rough endoplasmic reticulum.

Q2. An analytical sample of purified RNA is isolated from a viral core. If chemical quantification determines that Uracil constitutes exactly 28% of the total base composition, which conclusion regarding its structural arrangement is universally sound?

- (A) Adenine must account for exactly 28% of the remaining bases because of Chargaff's rules.
- (B) The organism possesses a double-stranded RNA genome configuration.
- (C) No definitive percentage can be deduced for Adenine or Cytosine without knowing if the strand is single- or double-stranded.



(D) Guanine and Cytosine residues automatically split the remaining 72% into equal halves.

Q3. During a centrifugation assay, cells are mechanically disrupted and sorted. A specific isolated fraction is found to actively catalyze the β -oxidation of very-long-chain fatty acids ($> C_{22}$) and generate hydrogen peroxide as a primary byproduct. This fraction is rich in:

- (A) Outer Mitochondrial Membrane matrices
- (B) Peroxisomes
- (C) Rough Endoplasmic Reticulum cisternae
- (D) Smooth Lysosomal vesicles

Q4. Calculate the absolute net yield of high-energy electron carriers (NADH and $FADH_2$) generated exclusively within the mitochondrial matrix when exactly two molecules of acetyl-CoA enter and are completely oxidized via the citric acid cycle:

- (A) 3 NADH, 1 $FADH_2$
- (B) 6 NADH, 2 $FADH_2$
- (C) 4 NADH, 2 $FADH_2$
- (D) 8 NADH, 4 $FADH_2$

Q5. An enzyme following standard Michaelis-Menten kinetics is treated with an inhibitor. Lineweaver-Burk plot analysis reveals that the vertical y-intercept ($1/V_{max}$) remains completely unchanged, while the horizontal x-intercept ($-1/K_m$) shifts closer to the origin. This kinetic behavior confirms:

- (A) Non-competitive inhibition where the inhibitor locks into an allosteric domain.
- (B) Uncompetitive inhibition where binding occurs only after the substrate occupies the pocket.
- (C) Competitive inhibition where the molecule physically competes for the active site.



(D) Irreversible inactivation via destruction of the core tertiary fold matrix.

Q6. During the pachytene stage of meiotic prophase I, a structural recombination nodule facilitates crossing over between non-sister chromatids. Which enzymatic assembly is directly responsible for resolving these physical DNA Holliday junctions?

(A) DNA Polymerase I proofreading subunits

(B) Recombinases and endonucleases

(C) Ribulose-1,5-bisphosphate carboxylase

(D) Reverse transcriptase complexes

Q7. If a somatic cell entering the G_1 phase of the cell cycle possesses exactly $2c$ content of nuclear DNA mass, evaluate the absolute DNA content present within a single cell during the subsequent mitotic anaphase stage:

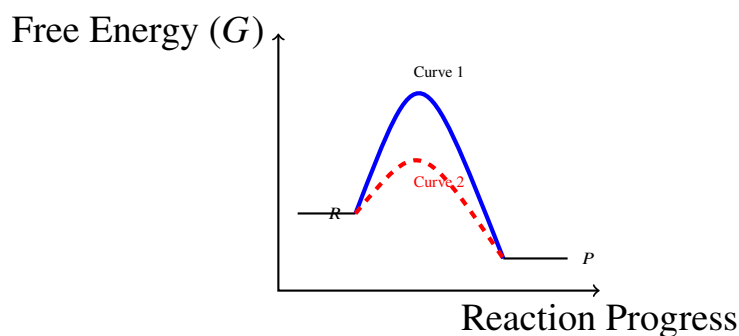
(A) $1c$

(B) $2c$

(C) $4c$

(D) $8c$

Q8. The structural schematic below monitors the change in free energy (ΔG) of a metabolic reaction across two pathways. Select the statement that perfectly characterizes the effect of structural framework change from Curve 1 to Curve 2.



(A) Curve 2 demonstrates an endergonic transition forced by thermal denaturation.



- (B) Curve 2 reflects the catalytic path established by an enzyme lowering the activation energy barrier.
- (C) The change from Curve 1 to Curve 2 significantly alters the net equilibrium constant (K_{eq}) of the reaction.
- (D) Curve 1 maps the structural mechanics of an allosterically accelerated loop.

Q9. An isolated cardiac preparation is exposed to a selective antagonist that blocks voltage-gated L-type calcium channels ($I_{Ca,L}$). This pharmacological intervention will directly result in:

- (A) Drastic shortening or complete abolition of the action potential plateau phase (Phase 2).
- (B) Accelerated rapid depolarization upstroke speed during Phase 0.
- (C) Permanent activation of the sarcoplasmic reticulum ryanodine receptors.
- (D) Exaggerated prolongation of the absolute refractory period.
- (E) Unchecked elevation of intracellular calcium levels.

Q10. A patient presents with a rare condition where the specialized epithelial cells of the thick ascending limb of the loop of Henle completely lose their functional expression of the $\text{Na}^+ - \text{K}^+ - 2\text{Cl}^-$ cotransporter (NKCC2). This pathobiological defect will directly cause:

- (A) A profound loss of the medullary osmotic gradient, rendering the kidney unable to concentrate urine.
- (B) Massive hypercalcemia due to elevated passive paracellular reabsorption rates.
- (C) Drastic reduction in the volume of fluid reaching the distal convoluted tubules.
- (D) Spontaneous hyperpolarization of the outer medullary interstitial matrices.

Q11. During normal cross-bridge cycling in human skeletal muscle, the physical dissociation of the myosin head from the active binding site on the actin thin filament requires:



- (A) Direct hydrolysis of bound ADP into adenosine monophosphate.
- (B) The binding of a fresh molecule of ATP to the catalytic core of the myosin head.
- (C) Complete removal of calcium ions away from the troponin-C subunit.
- (D) Phosphorylation of the structural nebulin support rods.

Q12. A volunteer shifts from breathing sea-level room air to a chamber filled with an hypoxic gas mixture. Within minutes, their respiratory rate expands dramatically. This immediate homeostatic response is triggered by:

- (A) Central chemoreceptors in the medulla detecting an accumulation of lactic acid.
- (B) Peripheral chemoreceptors in the carotid and aortic bodies sensing a significant drop in arterial pO_2 .
- (C) Direct mechanical stretch tracking by pulmonic baroreceptor fibers.
- (D) Sudden down-regulation of the carbonic anhydrase enzyme inside red blood cells.

Q13. A mutation that alters the structural composition of the chief cells located within the gastric mucosal pits of the human stomach will directly impair the secretion of:

- (A) Hydrochloric acid
- (B) Pepsinogen
- (C) Gastrin
- (D) Intrinsic factor

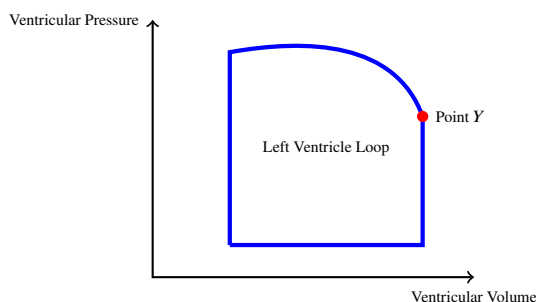
Q14. During photosynthetic electron transport in C_3 plants, the steady-state accumulation of protons (H^+) driven by the photolysis of water occurs strictly within which localized sub-compartment?

- (A) Chloroplast stroma matrix
- (B) Thylakoid lumen space



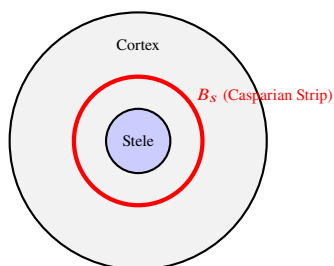
- (C) Intermembrane space of the chloroplast envelope
- (D) Cytoplasmic stroma of the mesophyll cell

Q15. The physiological schematic below details a volume-pressure tracking loop across a normal cardiac cycle in a mammalian left ventricle. If systemic arterial hypertension chronically elevates the afterload parameter, what is the initial structural transformation forced upon point *Y*?



- (A) Point *Y* shifts rightward, indicating a massive drop in ventricular end-diastolic pressure.
- (B) Point *Y* shifts vertically upward, reflecting the higher ventricular pressure required to force the aortic valve open.
- (C) The absolute vertical line from the baseline drops down to zero instantly.
- (D) Point *Y* moves leftward to merge directly with the isometric relaxation phase.

Q16. The anatomical cross-section below diagrams a specialized vascular configuration within a higher plant root architecture. Identify the physiological role of the structural band highlighted at locus B_s .



- (A) Facilitating unrestricted, rapid apoplastic flow directly into the central xylem vessels.



- (B) Forcing water and dissolved mineral ions to cross the selectively permeable plasma membrane of endodermal cells via a symplastic route.
- (C) Synthesizing heavy deposits of volatile oils to block all lateral root emergences.
- (D) Actively pumping structural starch grains out into the cortical parenchyma tissue field.

Q17. A double-heterozygous sweet pea plant ($PpLl$) displaying purple flowers (P) and long pollen grains (L) is testcrossed with a double homozygous recessive plant ($ppll$) showing red flowers and round pollen. The resulting progeny display 44% purple long, 44% red round, 6% purple round, and 6% red long phenotypes. These empirical metrics prove that:

- (A) The genes for flower color and pollen shape assort completely independently.
- (B) The two gene loci are linked on the same chromosome with a recombination frequency of 12%.
- (C) Epistatic interaction completely suppresses the recessive phenotype variations.
- (D) Spontaneous maternal lethal mutations selectively eliminate the recombinant combinations.

Q18. During DNA replication in an *E. coli* mutant strain, a biochemical error results in the total loss of the 5' → 3' exonuclease activity of DNA Polymerase I. This processing defect will manifest directly as:

- (A) Absolute failure to initiate replication at the chromosomal origin ($oriC$).
- (B) Inability to remove RNA primers and join adjacent Okazaki fragments along the lagging strand.
- (C) Complete cessation of leading strand synthesis due to topological strain.
- (D) Random accumulation of double-stranded breaks across transcription zones.

Q19. An mRNA transcript carries a functional codon sequence reading 5'-AUG-GUC-UUC-UAA. If a point mutation alters the seventh base from Guanine to Adenine ($G \rightarrow A$), what classification perfectly maps this genetic transformation?



- (A) A silent mutation that does not change the primary structure of the protein.
- (B) A missense mutation that substitutes an alternate amino acid into the chain.
- (C) A nonsense mutation causing premature termination of translation.
- (D) A frameshift mutation that scramble every subsequent downstream codon block.

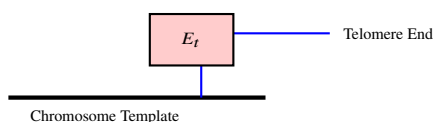
Q20. In an isolated population of 2,000 mountain sheep, a specific genetic locus possesses two operating alleles, B and b . If quantitative counting determines that exactly 320 sheep exhibit the homozygous recessive phenotype (bb), calculate the total number of individuals expected to be heterozygous (Bb) assuming strict Hardy-Weinberg equilibrium conditions:

- (A) 480
- (B) 960
- (C) 640
- (D) 1,200

Q21. According to modern evolutionary synthesis frameworks, when an extreme environmental catastrophe radically shrinks a vast population down to a tiny handful of surviving individuals, the subsequent shift in allele frequencies within the recovering population is driven primarily by:

- (A) Intensive directional natural selection matching high-stress demands.
- (B) Genetic drift operating through a population bottleneck mechanism.
- (C) Increased rate of spontaneous, targeted beneficial mutations.
- (D) Sympatric speciation mediated by hybrid zones.

Q22. The biochemical layout below maps a sequential multi-step replication process inside a eukaryotic cell nucleus. Identify the functional impact on overall structural replication if enzyme factor E_t is completely inhibited.



- (A) Spontaneous assembly of circular plasmid formations from chromosomal fragments.
- (B) Progressive shortening of chromosome ends with each successive round of cell division.
- (C) Hyper-elongation of the internal centromeric core domain lines.
- (D) Permanent inactivation of all leading strand transcription hubs.

Q23. During the mid-luteal phase of a normal human menstrual cycle, which physiological signal acts as the primary negative feedback brake to down-regulate the pulsatile secretion of GnRH from the hypothalamus?

- (A) High, sustained concentrations of progesterone co-secreted with estrogen by the corpus luteum.
- (B) A sharp, sudden drop in circulating luteinizing hormone levels.
- (C) Exponential accumulation of human chorionic gonadotropin from the endometrium.
- (D) Rapid mechanical involution of the primary Graafian matrix lines.

Q24. At the precise moment of fertilization inside the human fallopian tube, the invading sperm cell must penetrate several protective barriers. The exact signal that triggers the oocyte to complete its arrested Meiosis II is mediated by:

- (A) A massive intracellular wave of free calcium (Ca^{2+}) ions within the oocyte cytoplasm initiated by sperm entry.
- (B) Mechanical breakdown of the corona radiata by flagellar motion.
- (C) Direct binding of progesterone to receptors on the outer blastocyst shell.
- (D) Sudden down-regulation of maternal cortical granule production.

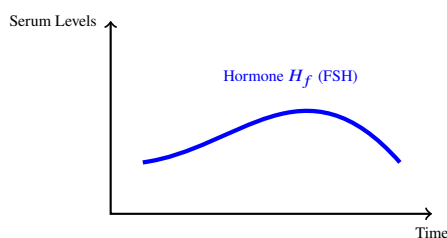
Q25. A pharmaceutical company designs a contraceptive molecule that selectively blocks human chorionic gonadotropin (*hCG*) from binding to its target receptors. If administered immediately post-fertilization, this intervention will prevent pregnancy by causing:

- (A) Direct chemical destruction of the migrating haploid spermatids.



- (B) Premature degeneration of the corpus luteum, causing a drop in progesterone that triggers menstruation and sheds the endometrium.
- (C) Hyper-activation of the acrosomal vesicle enzymatic cleavage array.
- (D) Permanent blocking of zygotic cleavage at the two-cell structural stage.

Q26. The endocrine monitoring tracking chart below profiles systemic human hormone parameters. Identify the specific target cell location where the molecule tracked as curve H_f binds to initiate normal spermatogenesis.



- (A) Interstitial cells of Leydig, stimulating testosterone release.
 - (B) Sertoli cells within the seminiferous tubules, promoting spermatid maturation.
 - (C) Mature prostate epithelial cells.
 - (D) Ependymal cells lining the third ventricle of the brain.
- Q27.** A plant physiology researcher exposes a long-day plant to a short-day photoperiod that would normally inhibit flowering. Which modification to the dark period will successfully trigger flowering in this plant?
- (A) Introducing a brief flash of red light (660 nm) in the middle of the dark period to break the critical night length.
 - (B) Exposing the roots to a heavy dose of exogenous abscisic acid solution.
 - (C) Extending the continuous dark phase by an additional six hours.
 - (D) Shifting the tracking temperature down to freezing levels for forty minutes.
- Q28.** During the double fertilization event characteristic of angiosperms, the two individual male gametes delivered by a single pollen tube perform which unique combination of fusion events?

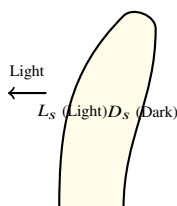


- (A) One sperm fuses with the egg ($2n$ zygote); the other fuses with the antipodal cells to form the testa coat.
- (B) One sperm fuses with the egg ($2n$ zygote); the second sperm fuses with the two polar nuclei to form the triploid ($3n$) primary endosperm.
- (C) Both sperm gametes simultaneously enter the egg cell matrix to build a tetraploid lineage.
- (D) One sperm builds the pollen tube wall while the second generates the primary cotyledon.

Q29. A mutant strain of rice displays an elongated, spindly stem phenotype known as the "foolish seedling" disease (*bakanae*). This hyper-elongation is caused by an overproduction of which phytohormone family?

- (A) Cytokinins
- (B) Gibberellins
- (C) Ethylene gases
- (D) Brassinosteroids

Q30. The structural schematic below tracks the cellular elongation pattern of an asymmetric phototropic coleoptile curve response. Choose the option that correctly describes the distribution pattern and action of phytohormone A_x across regions L_s and D_s .



- (A) Hormone A_x breaks down on side D_s , causing localized cell shrinkage.
- (B) Hormone A_x (auxin) laterally translocates to accumulate on the shaded side (D_s), where it promotes cell elongation, causing the coleoptile to curve toward the light.
- (C) Hormone A_x accumulates on side L_s to universally block expansin protein assembly.



(D) The concentration of hormone A_x remains perfectly symmetrical across both fields.

Q31. A taxonomic expert discovers a new marine organism. Structural analysis shows a true coelom, metameric segmentation, a closed circulatory system, and lateral appendages known as parapodia bearing chitinous setae. This organism belongs to:

- (A) Platyhelminthes
- (B) Annelida (Polychaeta)
- (C) Arthropoda (Crustacea)
- (D) Echinodermata

Q32. Consider the following statements regarding the Kingdom Fungi: (1) Ascomycetes produce endogenous ascospores within specialized basidia clubs. (2) Phycomycetes feature coenocytic, aseptate hyphal networks. (3) Deuteromycetes completely lack a known, observable sexual reproductive stage. Choose the correct statement evaluation combination:

- (A) 1 and 2 only
- (B) 2 and 3 only
- (C) 1 and 3 only
- (D) 1, 2, and 3

Q33. A marine biological expedition collects a benthic organism displaying radial symmetry as an adult, a water vascular system featuring localized tube feet, a non-centralized nervous system lacking a true brain, and a calcareous endoskeleton composed of distinct ossicles. During its early embryonic development, this organism exhibits blastopore transformation into the anus. Identify the taxonomic phylum to which this animal is classified:

- (A) Coelenterata (Cnidaria)
- (B) Arthropoda
- (C) Echinodermata



(D) Mollusca

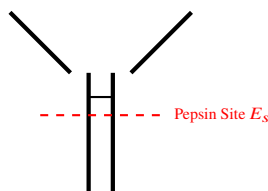
Q34. A patient is diagnosed with an aggressive auto-immune disorder. Laboratory assays confirm that their helper T-cells (T_H) are failing to recognize antigens presented by host macrophages. This defect is rooted in a structural mutation affecting which immunogenetic platform?

- (A) MHC Class I molecules
- (B) MHC Class II molecules
- (C) Interleukin-2 soluble receptors
- (D) Variable domains of light chains

Q35. A child presenting with systemic analytical indicators of a severe helminthic parasite infection shows a significant elevation in a specific antibody class. Which immunoglobulin isotype is specifically specialized to mediate defense against multicellular parasites via eosinophil activation?

- (A) IgG
- (B) IgM
- (C) IgE
- (D) IgA

Q36. The structural schematic below maps the proteolytic cleavage site profile of a monomeric antibody molecule. If the enzyme pepsin cuts the heavy chains on the carboxy-terminal side of the interchain disulfide bonds at site E_s , determine the fractional products generated.



- (A) Two separate univalent Fab fragments and one crystallizable Fc stem.
- (B) One bivalent $F(ab')_2$ fragment and a completely degraded, fragmented Fc stem section.



- (C) Four completely isolated single polypeptide chains without links.
- (D) A macro-complex that precipitates out of serum automatically.

Q37. An ecosystem ecologist measures the energetic metrics of a temperate deciduous forest. If the gross primary productivity (GPP) of the system is evaluated at $45,000 \text{ kcal/m}^2/\text{year}$, and the autotrophic respiratory loss (R_a) consumes exactly $22,000 \text{ kcal/m}^2/\text{year}$, calculate the absolute net primary productivity (NPP) available to the primary consumers:

- (A) $67,000 \text{ kcal/m}^2/\text{year}$
- (B) $23,000 \text{ kcal/m}^2/\text{year}$
- (C) $11,500 \text{ kcal/m}^2/\text{year}$
- (D) $45,000 \text{ kcal/m}^2/\text{year}$

Q38. Two closely related species of paramecia, *Paramecium aurelia* and *Paramecium caudatum*, are grown together in a fixed-volume culture tube containing a limited supply of bacterial food. Over time, *P. aurelia* completely drives *P. caudatum* to extinction. This empirical outcome illustrates:

- (A) The principle of character displacement.
- (B) Gause's competitive exclusion principle operating under niche overlap.
- (C) Commensalistic metabolic transformation tracking.
- (D) Mutualistic co-evolutionary drift networks.

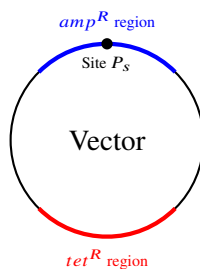
Q39. During a transgenic plant engineering workflow, a team wants to produce a strain of cotton resistant to lepidopteran pests (Bt Cotton). They isolate the *cry1Ac* gene from *Bacillus thuringiensis*. This toxin kills the insect by which mechanism?

- (A) Completely inhibiting the respiratory electron transport chain within the insect muscle cells.
- (B) Binding to epithelial cells of the insect midgut, creating alkaline-induced pores that trigger osmotic lysis.
- (C) Digesting the structural chitin component of the exoskeleton.



(D) Permanently cleaving the nuclear genomic DNA inside nervous system hubs.

Q40. The structural plasmid map below details a cloning vector platform. If a researcher inserts a therapeutic cDNA fragment directly into the unique restriction site labeled at locus P_s located within the Ampicillin resistance gene (amp^R), choose the expected phenotypic selection profile for transformed E. coli host cells.



- (A) Growth and survival on agar media supplemented with both ampicillin and tetracycline.
- (B) Failure to survive on tetracycline agar plates but robust growth on ampicillin plates.
- (C) Selective survival on tetracycline-supplemented medium accompanied by death on ampicillin plates due to insertional inactivation.
- (D) Immediate lysis upon exposure to any standard carbohydrate nutrient bath.



Detailed Solutions

Q1.

Solution

Concept: Lysosomes maintain an internal acidic environment ($\text{pH} \approx 4.5\text{--}5.0$) relative to the neutral cytosol ($\text{pH} \approx 7.2$) to optimize the catalytic function of their degradative enzymes. This electrochemical gradient is actively generated and sustained by a vacuolar-type H^+ -ATPase (V-ATPase) proton pump situated within the lysosomal membrane.

Solution: Lysosomal enzymes, collectively classified as acid hydrolases (including proteases, nucleases, glycosidases, and lipases), possess an absolute structural requirement for an acidic medium to maintain their active tertiary conformations. The experimental drug selectively blocks the V-ATPase proton pump, terminating the active transport of H^+ ions out of the cytosol and into the lysosomal matrix. In the absence of proton pumping, the existing luminal proton concentration is rapidly depleted by passive leakage and metabolic neutralization, causing a progressive rise in luminal pH toward neutrality. This neutralization directly alters the ionization state of amino acid residues within the catalytic triads of the acid hydrolases, causing their immediate denaturation and inactivation, which brings intracellular macromolecular degradation to a halt.

Final Answer: Immediate inactivation of acid hydrolases due to a progressive rise in luminal pH.

Answer: (B)

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Q2.

Solution

Concept: Erwin Chargaff's rules dictate that in any double-stranded nucleic acid molecule, strict base-pairing requirements impose quantitative equivalencies between complementary bases ($\% \text{Adenine} = \% \text{Thymine/Uracil}$ and $\% \text{Guanine} = \% \text{Cytosine}$). However, single-stranded nucleic acid conformations are entirely unconstrained by these pairing rules, meaning the individual base percentages vary independently.

Solution: The sample under analysis is an uncharacterized configuration of viral RNA. While double-stranded RNA (dsRNA) must satisfy the condition that $\% \text{Uracil} = \% \text{Adenine} = 28\%$, many viral genomes exist as single-stranded RNA (ssRNA). In a single-stranded RNA genome, there is no complementary strand to enforce a 1:1 stoichiometry between bases. Therefore, knowing that Uracil accounts for exactly 28

Final Answer: Adenine and cytosine cannot be determined without strand type.

Answer: (C)

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Q3.

Solution

Concept: Eukaryotic cells segregate distinct metabolic pathways into specialized organelles. While typical short- and medium-chain fatty acids are oxidized in the mitochondria, very-long-chain fatty acids (VLCFAs > C22) undergo initial chain-shortening cycles inside peroxisomes via an enzyme pathway that couples electron transfer directly to molecular oxygen, producing hydrogen peroxide as a byproduct.

Solution: The cellular fraction isolated during the centrifugation assay demonstrates a highly specific biochemical profile. The β -oxidation of very-long-chain fatty acids (VLCFAs) cannot be initiated by mitochondrial matrices due to a lack of compatible transport proteins and initial synthases. Instead, peroxisomes take up these long carbon chains and utilize a specialized flavoenzyme, acyl-CoA oxidase, to catalyze the first step of the pathway. Unlike the mitochondrial pathway, which captures high-energy electrons in FADH_2 to generate ATP via the electron transport chain, the peroxisomal oxidase transfers electrons directly from the substrate to molecular oxygen (O_2). This reaction forms hydrogen peroxide (H_2O_2), a toxic reactive oxygen species that is subsequently broken down into water and oxygen by the peroxisomal marker enzyme catalase.

Final Answer: Peroxisomes

Answer: (B)

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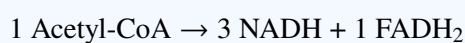


Q4.

Solution

Concept: The citric acid cycle (Krebs cycle) is a central metabolic pathway operating within the mitochondrial matrix. Each turn of the cycle completely oxidizes one molecule of acetyl-CoA, conserving metabolic energy by reducing coenzymes into high-energy electron carriers at specific enzymatic steps.

Solution: When a single molecule of acetyl-CoA (2-carbon) enters the citric acid cycle, it condenses with oxaloacetate (4-carbon) to form citrate (6-carbon). Throughout one complete turn of the cycle, three specific oxidation steps reduce NAD^+ to NADH (catalyzed by isocitrate dehydrogenase, α -ketoglutarate dehydrogenase, and malate dehydrogenase), and one oxidation step reduces FAD to FADH_2 (catalyzed by the membrane-bound succinate dehydrogenase complex). Therefore, the stoichiometry for the processing of a single acetyl-CoA molecule is:



Because exactly two molecules of acetyl-CoA enter the matrix and undergo complete oxidation, we double these values:



Final Answer: 6 NADH, 2 FADH₂

Answer: (B)

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Q5.

Solution

Concept: Enzyme inhibition mechanisms can be distinguished graphically using double-reciprocal Lineweaver-Burk plots, where the y-intercept matches $\frac{1}{V_{max}}$ and the x-intercept matches $-\frac{1}{K_m}$. Competitive inhibitors bind exclusively to the free enzyme's active site, a dynamic that can be overcome by high substrate concentrations.

Solution: In a Lineweaver-Burk double-reciprocal plot, the algebraic representation of Michaelis-Menten kinetics is converted into a linear equation:

$$\frac{1}{V_0} = \left(\frac{K_m}{V_{max}} \right) \frac{1}{[S]} + \frac{1}{V_{max}}$$

The problem states that when the enzyme is treated with the inhibitor, the vertical y-intercept ($\frac{1}{V_{max}}$) remains entirely unchanged. This signifies that the maximum catalytic velocity (V_{max}) is unaltered because at saturating substrate concentrations ($[S] \rightarrow \infty$, meaning $\frac{1}{[S]} \rightarrow 0$), the substrate outcompetes the inhibitor for the binding sites. Conversely, the horizontal x-intercept ($-\frac{1}{K_m}$) shifts closer to the origin (becoming a less negative value), which mathematically means that the apparent Michaelis constant (K_m) has increased. An increased apparent K_m combined with an unperturbed V_{max} is the classic kinetic signature of a competitive inhibitor that physically competes with the substrate for the active binding pocket.

Final Answer: Competitive inhibition where the molecule physically competes for the active site.

Answer: (C)

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Q6.

Solution

Concept: Homologous recombination during meiotic prophase I drives genetic diversity by physically swapping segments of DNA between non-sister chromatids. This crossover event creates a branched DNA structure known as a Holliday junction, which links the participating strands and must be enzymatically resolved to separate the chromosomes.

Solution: During the pachytene stage of prophase I, homologous chromosomes pair up tightly to form bivalents. Recombination nodules track along this synaptonemal complex, organizing the physical breaking and swapping of non-sister chromatid DNA strands. This strand invasion produces a four-way DNA crossover architecture called a Holliday junction. To complete the crossing-over process and allow the chromosomes to separate later, these junctions must undergo resolution. Specialized genetic machinery—composed of endonucleases (resolvases) and recombinase enzymes—recognizes the core structure, introduces precise symmetrical cuts across opposing strands, and ligates the ends. This separates the non-sister chromatids while leaving them with newly reassorted, combined genetic segments.

Final Answer: Recombinases and endonucleases

Answer: (B)

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Q7.

Solution

Concept: The cell cycle coordinates changes in nuclear DNA mass (c) and chromosome number (n). DNA replication during S phase duplicates the genomic content, but the cell does not divide its cytoplasm until cytokinesis, meaning the total DNA mass remains doubled throughout the intermediate mitotic stages.

Solution: At the start of the cell cycle in the G_1 phase, a standard diploid somatic cell possesses a baseline nuclear DNA mass designated as $2c$ (with a chromosome number of $2n$). When the cell progresses through the S (synthesis) phase, semi-conservative replication duplicates every genomic strand, doubling the total nuclear DNA mass to $4c$. This $4c$ value persists through the G_2 phase and the early stages of mitosis (prophase, prometaphase, and metaphase). During mitotic anaphase, sister chromatids are pulled apart toward opposite poles of the cell by the mitotic spindle. Although the individual chromosomes separate, they are still contained within the plasma membrane of a single cell that has not yet undergone cytokinesis. Therefore, the absolute DNA mass within that single cell during anaphase remains at the duplicated level of $4c$.

Final Answer:

Answer: (C)

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Q8.

Solution

Concept: Enzymes function as biocatalysts that accelerate chemical reactions by lowering the thermodynamic activation energy (E_a) barrier. Crucially, catalysts lower this kinetic hurdle equally for both the forward and reverse directions, which leaves the free energies of the initial reactants and final products completely unchanged.

Solution: The graphical plot maps the thermodynamic progress of an exergonic reaction ($G_{\text{Products}} < G_{\text{Reactants}}$). Curve 1 represents the un-catalyzed pathway, which requires a substantial input of kinetic energy to reach the high-energy transition state configuration. Curve 2 shows a modified pathway where the peak of the energy barrier is significantly lowered. This transition from Curve 1 to Curve 2 represents the effect of introducing an enzyme catalyst. The enzyme stabilizes the transition state through weak, non-covalent interactions, lowering the activation energy barrier (E_a). It is critical to note that the net free energy change (ΔG) and the equilibrium constant (K_{eq}) depend solely on the fundamental energy difference between states R and P , meaning they remain unchanged by the catalyst.

Final Answer:

Answer: (B)

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Q9.

Solution

Concept: The ventricular action potential profile is characterized by a prolonged plateau phase (Phase 2). This sustained depolarization is driven by a precise balance between outward repolarizing potassium currents (I_K) and inward depolarizing calcium currents ($I_{Ca,L}$) flowing through voltage-gated L-type calcium channels.

Solution: In mammalian cardiomyocytes, Phase 0 represents a rapid depolarization upstroke driven by inward sodium currents, followed by a brief initial repolarization notch (Phase 1). The cell then enters the plateau phase (Phase 2), which prolongs the action potential to ensure adequate time for mechanical contraction and prevent tetany. This plateau is maintained by calcium ions entering the cell through voltage-gated L-type calcium channels ($I_{Ca,L}$). If a selective antagonist blocks these L-type channels, the inward depolarizing calcium current is abolished. As a result, the outward repolarizing potassium currents act unopposed, causing a rapid drop in membrane potential that shortens or completely eliminates the plateau phase (Phase 2).

Final Answer: Loss or shortening of action potential plateau phase.

Answer: (A)

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Q10.

Solution

Concept: The kidney concentrates urine using a countercurrent multiplier system that establishes a hyperosmotic concentration gradient in the medullary interstitium. This process relies on the thick ascending limb of the loop of Henle, where the NKCC2 cotransporter actively pumps ions into the interstitium without allowing water to follow.

Solution: The thick ascending limb of the loop of Henle is impermeable to water but highly active in solute reabsorption. This segment expresses the $\text{Na}^+ - \text{K}^+ - 2\text{Cl}^-$ cotransporter (NKCC2) on its apical membrane, which actively moves sodium, potassium, and chloride ions out of the tubular fluid and into the surrounding medullary interstitial tissue. This continuous transport of solutes builds a concentrated, hyperosmotic medullary gradient. If a pathobiological defect causes a total loss of functional NKCC2 expressions (similar to the phenotype observed in Bartter syndrome type I), ion reabsorption in this segment fails. Without this solute transport, the countercurrent multiplier system is disrupted, destroying the medullary osmotic gradient. As a result, the collecting ducts lose the osmotic driving force needed to reabsorb water, rendering the kidney unable to concentrate urine and leading to profound polyuria.

Final Answer: Loss of medullary osmotic gradient prevents urine concentration.

Answer: (A)

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Q11.

Solution

Concept: The cross-bridge cycle describes the cyclic interaction between actin and myosin that drives muscle contraction. The physical detachment of the myosin head from the actin filament at the end of a stroke is an active process that requires a structural change induced by nucleotide binding.

Solution: During the cross-bridge cycle, the myosin head binds tightly to the active site on an actin thin filament in a state called the "rigor complex." In this state, the myosin head has already released its bound inorganic phosphate (P_i) and ADP to execute the power stroke. To break this strong bond and allow the cycle to continue, a fresh molecule of adenosine triphosphate (ATP) must bind to the catalytic nucleotide-binding pocket on the myosin head. The binding of ATP induces an immediate conformational shift in the myosin head that lowers its binding affinity for actin, causing it to detach from the thin filament track. If ATP is absent, the myosin heads remain locked to the actin filaments, a state seen post-mortem as rigor mortis.

Final Answer: The binding of a fresh molecule of ATP to the catalytic core of the myosin head.

Answer: (B)

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Q12.

Solution

Concept: Mammalian ventilation is homeostatically regulated by two distinct chemical sensing systems. While central chemoreceptors in the brain monitor metabolic shifts by tracking pH changes in the cerebrospinal fluid, peripheral chemoreceptors track gas pressures in the blood, specializing in detecting falls in arterial oxygen levels.

Solution: When a volunteer breathes a hypoxic gas mixture, the partial pressure of oxygen dissolved in their arterial blood (pO_2) drops significantly. This fall in oxygen tension is detected by peripheral chemoreceptors located in the carotid bodies (at the bifurcation of the common carotid arteries) and the aortic bodies (along the aortic arch). Unlike the central chemoreceptors in the medulla oblongata, which are primarily sensitive to changes in CO_2 and hydrogen ion concentrations, these peripheral chemoreceptors contain specialized glomus cells that are highly sensitive to hypoxia. When arterial pO_2 drops below a critical threshold (typically around 60 mmHg), these glomus cells depolarize and send rapid sensory signals via the glossopharyngeal and vagus nerves to the respiratory centers in the brainstem, triggering an immediate increase in respiratory rate to counteract the hypoxia.

Final Answer: Carotid and aortic body chemoreceptors detect low arterial pO_2 .

Answer: (B)

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Q13.

Solution

Concept: The gastric mucosa contains specialized secretory pits lined with distinct cell populations. While parietal cells secrete hydrochloric acid and intrinsic factor, chief cells specialize in protein digestion by synthesizing and releasing the inactive enzyme precursor pepsinogen.

Solution: The human stomach lining contains deep gastric glands composed of several highly specialized cell types, each producing distinct components of gastric juice:

- **Parietal cells** secrete hydrochloric acid (HCl) to lower luminal pH and intrinsic factor for vitamin B₁₂ absorption.
- **G-cells** act as endocrine units that release the regulatory hormone gastrin into the bloodstream.
- **Chief cells** (or peptic cells) are located near the base of the gastric pits and specialize in protein digestion. They synthesize and secrete **pepsinogen**, an inactive zymogen.

When pepsinogen is released into the acidic environment created by the parietal cells, it undergoes conformational cleavage to become the active protease pepsin, which cleaves dietary proteins. Therefore, a structural mutation affecting the chief cells will directly impair pepsinogen secretion.

Final Answer: Pepsinogen

Answer: (B)

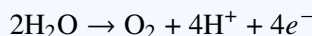
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Q14.

Solution

Concept: Photosynthetic light-dependent reactions convert solar energy into chemical energy across the thylakoid membrane. As electrons move through the transport chain, protons are actively pumped and deposited into an enclosed inner compartment, building an electrochemical gradient that drives ATP synthesis.

Solution: During the light-dependent reactions of photosynthesis in C₃ plants, photon absorption by Photosystem II (PSII) activates its reaction center, driving the primary photolysis (splitting) of water molecules:



This reaction takes place exclusively on the inner, luminal face of the thylakoid membrane. The resulting molecular oxygen (O₂) diffuses out, while the extracted electrons enter the photosynthetic electron transport chain. The protons (H⁺) released by this photolysis step are deposited directly into the **thylakoid lumen space**. Combined with protons pumped across the membrane by the cytochrome *b₆f* complex, this accumulation builds a steep proton gradient across the thylakoid membrane, storing the electrochemical energy used by ATP synthase to produce ATP.

Final Answer: Thylakoid lumen space

Answer: (B)

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Q15.

Solution

Concept: A left ventricular pressure-volume (PV) loop charts the mechanical events of the cardiac cycle. The loop is defined by specific corners that mark valve movements, where the rightward vertical transition represents the period of pressure development needed to open the aortic valve against systemic resistance.

Solution: The diagram illustrates a standard ventricular pressure-volume loop, where the width shows stroke volume and the height reflects chamber pressures. Point Y marks the end of isovolumetric contraction, the exact moment when ventricular pressure equals systemic arterial pressure, forcing the aortic valve open to initiate ejection. Systemic arterial hypertension increases afterload, meaning the heart faces higher resistance in the aorta. To open the aortic valve under these conditions, the left ventricle must contract harder and generate higher pressure during the isovolumetric phase. Consequently, to reach this higher opening threshold, **Point Y must shift vertically upward** along the volume axis, reflecting the increased pressure demand placed on the cardiomyocyte walls.

Final Answer: Higher ventricular pressure needed to open aortic valve.

Answer: (B)

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Q16.

Solution

Concept: Plant roots regulate nutrient absorption by filtering incoming water and minerals. In the root cortex, water can move freely through cell walls via the apoplastic pathway until it reaches the endodermis, where a waxy, impermeable barrier blocks this path and forces fluid into the living cytoplasm for selective filtering.

Solution: The diagram shows a transverse cross-section of a plant root, highlighting the endodermal ring marked B_s . This ring represents the Casparian strip, a specialized band of hydrophobic suberin and lignin embedded within the primary cell walls of endodermal cells. Water and dissolved minerals moving through the root cortex can travel via two pathways: the symplastic route (through the living cytoplasm via plasmodesmata) or the apoplastic route (through the non-living cell walls and intercellular spaces). When apoplastic water reaches the endodermis, the waxy Casparian strip blocks its path. This barrier prevents further unregulated movement through the cell walls, **forcing water and solutes to cross the selectively permeable plasma membrane** of the endodermal cells. This symplastic transition allows the plant to selectively filter and regulate the specific ions entering the vascular cylinder (stele) for transport to the shoots.

Final Answer: Symplastic transport of water and minerals through endodermis.

Answer: (B)

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Q17.

Solution

Concept: Linkage describes the tendency of genes located close together on the same chromosome to be inherited together during meiosis. While unlinked genes assort independently to produce equal ratios of all phenotypes, linked genes show a higher proportion of parental combinations and a lower proportion of recombinant phenotypes, with the total percentage of recombinants reflecting the distance between the loci.

Solution: The testcross involves a double-heterozygous parent ($PpLl$) and a double-homozygous recessive tester ($ppll$). If the two gene loci for flower color and pollen shape were unlinked and located on separate chromosomes, they would undergo independent assortment, yielding a classic Mendelian 1:1:1:1 phenotypic ratio (25

- **Parental Phenotypes:** Purple long (44)
- **Recombinant Phenotypes:** Purple round (6)

The high proportion of parental combinations demonstrates that the two gene loci are physically linked on the same chromosome. The map distance between the two linked genes is calculated directly from the recombination frequency, which is the total percentage of recombinant offspring in the population:

$$\text{Recombination Frequency} = 6\% + 6\% = 12\%$$

This confirms that the loci are linked on the same chromosome with a map distance of 12 centimorgans (cM).

Final Answer: Linked genes with 12% recombination frequency.

Answer: (B)

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Q18.

Solution

Concept: Lagging strand DNA replication is discontinuous, producing short segments called Okazaki fragments that require enzymatic processing to form a continuous strand. This processing relies on DNA Polymerase I, which uses its specialized exonuclease activity to degrade RNA primers ahead of it while filling the gaps with DNA nucleotides.

Solution: During DNA replication in *E. coli*, the lagging strand is synthesized discontinuously as Okazaki fragments, each initiated by a short RNA primer. To complete replication, these RNA primers must be removed and replaced with DNA. DNA Polymerase I is uniquely specialized for this task because it possesses a 5' → 3' exonuclease activity alongside its standard polymerase activity. As it tracks along the lagging strand, its 5' → 3' exonuclease domain degrades the RNA primer directly ahead of it, while its polymerase domain simultaneously fills the resulting gap with DNA nucleotides (a process called nick translation). If a mutation causes a total loss of this 5' → 3' exonuclease activity, the RNA primers cannot be removed. This blocks DNA ligase from sealing the nicks between adjacent Okazaki fragments, resulting in an unjoined, fragmented lagging strand.

Final Answer: Failure to remove RNA primers and join Okazaki fragments.

Answer: (B)

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Q19.

Solution

Concept: Point mutations alter single nucleotide bases within a genetic sequence, leading to different structural outcomes depending on how they affect the triplet codon reading frame. A mutation that converts a codon specifying an amino acid into a termination signal causes translation to stop prematurely, producing a truncated protein.

Solution: The baseline mRNA transcript sequence is organized into triplet codons as follows:

Codon 1: 5'-AUG-3' Codon 2: 5'-GUC-3' Codon 3: 5'-UUC-3' Codon 4: 5'-UAA-3'

The problem states that a point mutation alters the seventh base from Guanine to Adenine ($G \rightarrow A$). Let us look at the structure of the third codon, which spans bases 7, 8, and 9:

Original Codon 3: 5'-GUC-3' \rightarrow Base 7 is G

Mutated Codon 3: 5'-AUC-3' \rightarrow Base 7 becomes A

Using the genetic code, the original codon 5'-GUC-3' codes for the amino acid Valine, while the mutated codon 5'-AUC-3' codes for Isoleucine. Because this nucleotide substitution changes the codon to specify a different amino acid without altering the reading frame or creating a stop codon, it is classified as a missense mutation.

Final Answer: A missense mutation that substitutes an alternate amino acid into the chain.

Answer: (B)

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Q20.

Solution

Concept: The Hardy-Weinberg principle provides a mathematical model to calculate allele and genotype frequencies in an ideal, non-evolving population. For a gene locus with two alleles (B and b), the frequencies are represented as p and q , where the distribution of genotypes follows the binomial expansion $p^2 + 2pq + q^2 = 1$.

Solution: The total population size of the mountain sheep is $N = 2,000$. Exactly 320 sheep exhibit the homozygous recessive phenotype (bb). Under Hardy-Weinberg equilibrium, the frequency of the homozygous recessive genotype (bb) is represented as q^2 :

$$q^2 = \frac{320}{2,000} = \frac{16}{100} = 0.16$$

To find the frequency of the recessive allele (b), we take the square root of q^2 :

$$q = \sqrt{0.16} = 0.4$$

Since the sum of the allele frequencies must equal 1 ($p + q = 1$), we can calculate the frequency of the dominant allele (B):

$$p = 1 - q = 1 - 0.4 = 0.6$$

The frequency of the heterozygous genotype (Bb) is represented by the $2pq$ term in the Hardy-Weinberg equation:

$$\text{Frequency of } Bb = 2pq = 2 \times (0.6) \times (0.4) = 0.48$$

To find the total number of individual heterozygous sheep in the population, we multiply this frequency by the total population size:

$$\text{Number of Heterozygotes} = 0.48 \times 2,000 = 960 \text{ sheep}$$

Final Answer:

Answer: (B)

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Q21.

Solution

Concept: Evolutionary change can be driven by adaptive or non-adaptive mechanisms. When an environmental catastrophe drastically reduces population size, the survival of individuals is largely random rather than a result of fitness, allowing genetic drift to rapidly alter allele frequencies through a bottleneck effect.

Solution: When an extreme environmental catastrophe (such as a volcanic eruption, drought, or overhunting) radically shrinks a large population down to a small number of survivors, the event is non-selective. The survival of a handful of individuals is determined primarily by chance rather than adaptive genetic advantages. The gene pool of these few survivors forms the sole genetic foundation for the recovering population. This random reduction creates a population bottleneck, a key mechanism of genetic drift. Because the sample size is small, the allele frequencies in the surviving group can differ drastically from those of the original population. This can lead to the fixation or loss of alleles by chance, reducing overall genetic variation.

Final Answer: Genetic drift operating through a population bottleneck mechanism.

Answer: (B)

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Q22.

Solution

Concept: Linear eukaryotic chromosomes face the "end-replication problem" because standard DNA polymerases require an upstream primer and can only synthesize DNA in the 5' → 3' direction, leaving the extreme 3' lagging template strand incomplete after primer removal.

Solution: The diagram models a specialized reverse transcriptase enzyme system (E_t) known as telomerase. Telomerase carries an internal RNA template that matches the repetitive sequences of chromosome ends, allowing it to extend the 3' parental strand and ensure that the lagging strand can be fully completed by standard replication machinery. If enzyme factor E_t is completely inhibited, the cell loses its ability to counteract the end-replication problem. As a result, the RNA primers at the extreme ends of the lagging strand are removed but cannot be replaced with DNA. This leads to a progressive, mandatory shortening of the chromosome telomeres with each successive round of cell division, eventually triggering cellular senescence or apoptosis once critical coding segments are threatened.

Final Answer: Progressive telomere shortening with each cell division.

Answer: (B)

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Q23.

Solution

Concept: The human menstrual cycle is regulated by a complex feedback network between the ovaries and the hypothalamic-pituitary axis. Following ovulation, the corpus luteum acts as a temporary endocrine gland that secretes steroid hormones to inhibit upstream trophic signals and prevent the initiation of a new follicular phase.

Solution: During the mid-luteal phase (days 20–24 of a standard cycle), the corpus luteum reaches its peak secretory capacity. It releases high, sustained concentrations of progesterone alongside moderate amounts of estrogen into the bloodstream. These circulating steroid hormones act via negative feedback loops on the central nervous system. Specifically, progesterone binds to receptors in the hypothalamus, increasing the activity of inhibitory opioid neurons that down-regulate the pulse frequency of Gonadotropin-Releasing Hormone (GnRH) secretion. This reduction in GnRH pulses suppresses the release of LH and FSH from the anterior pituitary, preventing the recruitment of new ovarian follicles while the uterus prepares for potential implantation.

Final Answer: High progesterone and estrogen from corpus luteum.

Answer: (A)

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Q24.

Solution

Concept: Oocyte maturation is arrested at specific checkpoints during gametogenesis. In humans, ovulation releases a secondary oocyte locked in metaphase of Meiosis II; completion of this final division requires a trigger provided by fertilization.

Solution: The human secondary oocyte is ovulated and enters the fallopian tube arrested in metaphase of Meiosis II, held there by cytostatic factor complexes that inhibit the anaphase-promoting complex. When an invading sperm successfully penetrates the plasma membrane of the oocyte, it introduces a specialized phospholipase enzyme (PLC-zeta). This enzyme hydrolyzes membrane lipids to trigger a massive intracellular wave of free calcium (Ca^{2+}) ions from the endoplasmic reticulum into the oocyte cytoplasm. This calcium wave activates calmodulin-dependent protein kinase II, which breaks down the cytostatic factors holding the cell in arrest. This signaling cascade allows the oocyte to exit metaphase II, complete its final meiotic division, and extrude the second polar body, preparing the egg for pronuclear fusion.

Final Answer: Sperm entry triggers a Ca^{2+} wave in the oocyte.

Answer: (A)

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Q25.

Solution

Concept: Early pregnancy requires the maintenance of the uterine endometrium to support a developing blastocyst. This maintenance relies on human chorionic gonadotropin (*hCG*), a hormone secreted by the trophoblast that signals the ovary to continue producing progesterone.

Solution: Following successful fertilization, the migrating blastocyst implants into the maternal endometrial wall and begins secreting human chorionic gonadotropin (*hCG*). This hormone enters the maternal circulation and binds to LH/hCG receptors on the cells of the corpus luteum within the ovary. This signaling rescues the corpus luteum from its default degeneration (luteolysis), stimulating it to continue producing high levels of progesterone. Progesterone maintains the structural integrity and secretory capacity of the endometrium. If a contraceptive molecule blocks *hCG* from binding to its receptors immediately post-fertilization, the corpus luteum will fail to receive the survival signal and undergo premature degeneration. This causes a sharp drop in progesterone levels, triggering menstruation and shedding the endometrium along with the un-implanted blastocyst.

Final Answer: Corpus luteum degeneration lowers progesterone, triggering menstruation.

Answer: (B)

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Q26.

Solution

Concept: Spermatogenesis is regulated by gonadotropic hormones released from the anterior pituitary gland. Follicle-Stimulating Hormone (FSH) targets the structural cells of the seminiferous tubules to establish an environment that supports germ cell development.

Solution: The hormone tracked as curve H_f is Follicle-Stimulating Hormone (FSH). In the male reproductive system, FSH is released from the anterior pituitary and enters the testicular microcirculation, where it binds to specific G-protein-coupled receptors located exclusively on the membranes of **Sertoli cells** (nurse cells) within the seminiferous tubules. Once activated, Sertoli cells produce essential regulatory molecules, including androgen-binding protein (ABP) and inhibin, and form tight junctions that maintain the blood-testis barrier. This response creates the biochemical and physical environment required to support spermatid maturation and normal spermatogenesis.

Final Answer: Sertoli cells within the seminiferous tubules, promoting spermatid maturation.

Answer: (B)

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Q27.

Solution

Concept: Photoperiodism in plants is regulated by tracking the continuous length of the dark period (night) using the phytochrome system, rather than measuring daylight. Long-day plants require a dark period that falls below a critical night length to induce flowering.

Solution: Long-day plants flower when the day length exceeds a specific threshold, meaning they require a short night that falls below a critical night length. If a long-day plant is exposed to an unfavorable short-day photoperiod, the continuous dark period will exceed this critical length, maintaining the phytochrome system in its inactive state and preventing flowering. To trigger flowering under these conditions, the continuous dark phase must be disrupted. Introducing a brief flash of red light (660 nm) in the middle of the dark period cleaves the night into two short intervals. This light flash converts inactive P_r phytochromes into the active P_{fr} form, tricking the plant's internal clock into recording a short night and successfully activating the downstream florigen genes required for flowering.

Final Answer: Red light interrupting the dark period breaks night length.

Answer: (A)

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Q28.

Solution

Concept: Angiosperms are characterized by a reproductive mechanism called double fertilization. Each pollen tube delivers two haploid male gametes into the embryo sac, where they undergo independent fusion events to form both the next-generation embryo and its surrounding nutritive tissue.

Solution: During pollination in flowering plants, a pollen tube grows down the style and enters the ovule through the micropyle, delivering two individual haploid ($1n$) sperm cells into the female gametophyte (embryo sac). These two male gametes perform distinct fusion events:

- The first sperm cell fuses directly with the haploid ($1n$) egg cell to form a diploid ($2n$) zygote, which develops into the plant embryo.
- The second sperm cell travels to the center of the embryo sac and fuses with the two haploid central polar nuclei. This triple fusion event forms a triploid ($3n$) cell, which divides mitotically to develop into the primary endosperm tissue that provides nutrients to the growing embryo.

Final Answer: Double fertilization forms a diploid zygote and triploid endosperm.

Answer: (B)

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Q29.

Solution

Concept: Phytohormones regulate diverse growth and developmental processes in plants. Certain plant diseases can cause extreme, abnormal stem elongation by introducing fungal pathogens that overproduce growth-promoting hormones.

Solution: The "foolish seedling" disease (**bakanae**) in rice plants is characterized by an abnormal, spindly hyper-elongation of the stems that leaves the plants weak and unable to support their own weight. This condition is caused by an infection with the fungal pathogen **Gibberella fujikuroi**. The fungus secretes large quantities of ****gibberellins**** into the host plant's tissues. Gibberellins are a class of phytohormones that promote stem elongation by stimulating both cell division and cell wall elongation through the activation of expansin proteins. This discovery led to the isolation and identification of gibberellic acid (GA_3) as a major endogenous plant hormone.

Final Answer:

Answer: (B)

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Q30.

Solution

Concept: Phototropism is the growth of a plant organ toward a light source, driven by an asymmetric distribution of the hormone auxin. Light exposure induces the lateral translocation of auxin away from the illuminated side and toward the shaded side of the stem.

Solution: The diagram models a phototropic curvature response in a plant coleoptile. When directional light strikes side L_s , photoreceptors called phototropins are activated on the illuminated side. This activation triggers the lateral translocation of the phytohormone auxin (A_x) across the tip, causing it to accumulate on the shaded side (D_s). Auxin stimulates proton pumps in the plasma membrane of these cells, lowering the cell wall pH and activating expansin proteins that loosen the cellulose matrix (the acid growth hypothesis). Driven by turgor pressure, the cells on the shaded side (D_s) elongate rapidly, while the cells on the illuminated side (L_s) undergo minimal elongation. This unequal growth rate causes the coleoptile to curve toward the light source.

Final Answer:

Answer: (B)

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Q31.

Solution

Concept: Invertebrate phyla are classified based on distinct body plans, cavity configurations, and structural appendages. Annelids are characterized by a true coelom, metameric segmentation, and a closed circulatory system, with many marine species possessing specialized lateral appendages for locomotion.

Solution: The organism's suite of anatomical characteristics aligns with the phylum **Annelida**, specifically within the class **Polychaeta** (marine bristle worms). Key defining features include:

- A true coelom (a fluid-filled body cavity lined entirely by mesoderm).
- Metameric segmentation (linear repetition of homologous body segments).
- A closed circulatory system where blood remains confined within vascular vessels.
- Unjointed lateral fleshy appendages called **parapodia** that project from each segment, bearing bristles composed of chitinous setae used for swimming, crawling, and respiration.

This combination of traits excludes Platyhelminthes (acoelomate, unsegmented), Arthropoda (open circulatory system, jointed appendages), and Echinodermata (water vascular system, pentaradial symmetry).

Final Answer: Annelida (Polychaeta)

Answer: (B)

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Q32.

Solution

Concept: The Kingdom Fungi is divided into distinct phyla based on the structural characteristics of their hyphae and their specific mechanisms of spore production during reproductive stages.

Solution: Let us evaluate each of the provided statements individually:

- (a) *Statement 1:* "Ascomycetes produce endogenous ascospores within specialized basidia clubs." This statement is **incorrect**. Ascomycetes (sac fungi) produce ascospores endogenously inside sac-like structures called asci, whereas basidia are club-shaped structures characteristic of the phylum Basidiomycetes.
- (b) *Statement 2:* "Phycomycetes feature coenocytic, aseptate hyphal networks." This statement is **correct**. Lower fungi, traditionally grouped as phycomycetes (such as Zygomycetes), have hyphae that lack cross-walls (septa), resulting in a continuous, multinucleate cytoplasmic network.
- (c) *Statement 3:* "Deuteromycetes completely lack a known, observable sexual reproductive stage." This statement is **correct**. Deuteromycetes are collectively classified as "fungi imperfecti" because they reproduce exclusively via asexual spores (conidia), with no identified sexual phase.

Since statements 2 and 3 are correct, option B is the matching combination.

Final Answer: 2 and 3 only

Answer: (B)

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Q33.

Solution

Concept: Animal phyla are characterized by distinct structural blueprints, embryonic cleavage patterns, and specialized physiological systems. Organisms belonging to the deuterostome lineage exhibit an embryonic development pattern where the blastopore matures into the definitive anus rather than the mouth, a characteristic configuration shared exclusively by chordates and echinoderms.

Solution: The benthic specimen collected by the expedition exhibits a highly specific, diagnostics suite of anatomical and developmental features:

- **Deuterostome Development:** The transformation of the embryonic blastopore into the anus confirms that this animal belongs to the Deuterostomia clade. This immediately eliminates protostome phyla such as Arthropoda and Mollusca, where the blastopore develops into the mouth.
- **Water Vascular System and Tube Feet:** This is a unique hydro-vascular network derived from the coelom that runs through the body cavity to operate localized tube feet via hydrostatic pressure. This system functions in locomotion, gas exchange, and prey capture, and is found exclusively in one animal phylum.
- **Symmetry and Skeleton:** Although the larval forms exhibit bilateral symmetry, they undergo a complex structural metamorphosis into adults characterized by secondary radial (typically pentaradial) symmetry. They are supported internally by a calcareous endoskeleton composed of distinct, individual crystalline ossicles.
- **Nervous System:** The animal features a completely decentralized nervous configuration consisting of a circumoral nerve ring and radial nerves, entirely lacking cephalization or a centralized brain matrix.

This morpho-developmental blueprint maps perfectly to the phylum **Echinodermata** (such as sea stars, sea urchins, and sand dollars). While Coelenterata (Cnidaria) also shows radial symmetry and lacks a true brain, they are diploblastic acoelomates that lack an anus, a calcareous ossicle endoskeleton, or a water vascular system.

Final Answer: Echinodermata

Answer: (C)

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Q34.

Solution

Concept: T-lymphocytes require antigens to be processed and presented on specialized surface platforms to recognize them. Helper T-cells (T_H , expressing CD4) respond specifically to exogenous antigens presented on Major Histocompatibility Complex (MHC) Class II molecules, which are expressed primarily by professional antigen-presenting cells like macrophages.

Solution: Professional antigen-presenting cells (APCs), such as macrophages and dendritic cells, engulf foreign pathogens via phagocytosis, degrade their proteins into short peptide fragments within phagolysosomes, and load these peptides onto specialized surface receptors. For helper T-lymphocytes (T_H cells) to recognize these antigens, the peptide fragments must be displayed on **MHC Class II molecules**. The T-cell receptor (TCR) on the T_H cell binds simultaneously to the foreign peptide and the self-MHC Class II platform, a docking interaction stabilized by the CD4 co-receptor. A structural mutation that alters these MHC Class II molecules prevents helper T-cells from recognizing presented antigens, disrupting the signaling cascades required to activate adaptive immune responses.

Final Answer: MHC Class II molecules

Answer: (B)

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Q35.

Solution

Concept: Immunoglobulins exist as distinct isotypes that specialize in targeting different classes of pathogens. While IgG and IgM handle bacterial and viral infections, a specific isotype targets large, multicellular parasites by cross-linking with granulocytic white blood cells.

Solution: Helminthic parasites (such as parasitic worms) are too large to be engulfed by standard phagocytic cells like macrophages. To combat these multicellular pathogens, the adaptive immune system utilizes **Immunoglobulin E (IgE)**. When a helminth infection occurs, plasma cells produce IgE antibodies that bind to the parasite's surface antigens. The constant (Fc) regions of these bound IgE molecules are then recognized by high-affinity $Fc\epsilon R1$ receptors expressed on the surfaces of eosinophils, mast cells, and basophils. This binding triggers eosinophil activation, causing them to degranulate and release cytotoxic proteins (such as major basic protein and eosinophil cationic protein) directly onto the parasite's cuticle to destroy it.

Final Answer: IgE

Answer: (C)

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Q36.

Solution

Concept: The structural domains of antibodies can be analyzed using targeted proteolytic cleavage. Different proteolytic enzymes cleave the heavy chain backbone at specific positions relative to the hinge disulfide bonds, generating characteristic fragments that alter the antibody's antigen-binding capacity.

Solution: A monomeric IgG antibody is a Y-shaped molecule composed of two identical light chains and two identical heavy chains linked by interchain disulfide bonds at a flexible hinge region. The proteolytic enzyme pepsin targets and cleaves the heavy chain backbones at a specific site on the carboxy-terminal side of these interchain disulfide bonds. This cleavage leaves the hinge region intact, keeping the two antigen-binding arms physically linked together. This generates **one bivalent $F(ab')_2$ fragment** that retains both antigen-binding sites and can still cross-link antigens. The remaining constant portion of the heavy chains (the F_c stem) is cut downstream of the hinge, exposing it to extensive proteolytic degradation that breaks it down into small, inactive peptide fragments.

Final Answer: One $F(ab')_2$ fragment and degraded F_c fragment.

Answer: (B)

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Q37.

Solution

Concept: Ecosystem energy flow begins with primary productivity. Gross Primary Productivity (*GPP*) represents the total amount of solar energy captured and converted into chemical energy by autotrophic producers, a portion of which is consumed by the producers themselves during cellular respiration (R_a) to sustain metabolic functions.

Solution: The Net Primary Productivity (*NPP*) represents the actual amount of chemical energy that remains stored as biomass in plant tissues after accounting for the energy lost to autotrophic respiration. This remaining energy forms the foundational biomass available for harvest and consumption by heterotrophic primary consumers (herbivores). The thermodynamic relationship is calculated using the following equation:

$$NPP = GPP - R_a$$

Given the energetic metrics for the temperate deciduous forest:

$$GPP = 45,000 \text{ kcal/m}^2/\text{year}$$

$$R_a = 22,000 \text{ kcal/m}^2/\text{year}$$

Substituting these values into the equation yields:

$$NPP = 45,000 - 22,000 = 23,000 \text{ kcal/m}^2/\text{year}$$

Final Answer:

Answer: (B)

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Q38.

Solution

Concept: Interspecific competition occurs when different species compete for the same limiting resources within an ecosystem. Gause's competitive exclusion principle dictates that two species with identical ecological niches cannot stably co-exist if their resource requirements overlap completely; the competitor with even a slight advantage will outcompete the other, driving it to local extinction.

Solution: The classical laboratory experiments conducted by ecologist Georgy Gause involved growing two closely related ciliate species, *Paramecium aurelia* and *Paramecium caudatum*, under controlled conditions. When grown in isolation, each population exhibits normal logistic growth, stabilizing at a steady carrying capacity. However, when introduced together into a single culture tube with a fixed, limited supply of bacterial food, their ecological niches overlap completely. Because both species compete intensely for the same food source, they cannot co-exist indefinitely. *Paramecium aurelia* possesses a slightly faster growth rate and higher efficiency in gathering bacteria under low-resource conditions. This competitive advantage allows *P. aurelia* to capture a larger share of the resource pool, driving *P. caudatum* to complete competitive exclusion and local extinction.

Final Answer: Gause's competitive exclusion principle operating under niche overlap.

Answer: (B)

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Q39.

Solution

Concept: Transgenic pest resistance uses microbial genes to express insecticidal proteins in plants. *Bacillus thuringiensis* synthesizes crystalline delta-endotoxins that target specific insect orders, acting selectively within the specialized environment of the larval digestive tract.

Solution: The *cry1Ac* gene isolated from the soil bacterium *Bacillus thuringiensis* encodes an inactive crystalline delta-endotoxin protoxin. When a lepidopteran pest feeds on Bt cotton and ingests this protein, the protoxin enters the highly alkaline environment of the insect's midgut. This alkaline pH, combined with midgut proteases, cleaves the protoxin into its active, toxic conformation. The activated toxin binds specifically to cadherin-like receptors on the microvillar membranes of the midgut epithelial cells. This binding causes the toxin molecules to oligomerize and insert into the lipid bilayer, creating open, unregulated cation-permeable pores. These pores disrupt osmotic balance, leading to a massive influx of water that triggers osmotic lysis of the epithelial cells. This destroys the midgut lining, causing the insect to die from starvation or septicemia.

Final Answer: Midgut epithelial binding forms pores causing osmotic lysis.

Answer: (B)

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Q40.

Solution

Concept: Recombinant DNA selection often utilizes antibiotic resistance genes as selectable markers on cloning vectors. Inserting a foreign DNA fragment into a restriction site located within a resistance gene disrupts its sequence, removing the host cell's resistance to that specific antibiotic while leaving other marker genes intact.

Solution: The cloning vector features two separate selectable marker genes: an ampicillin resistance gene (amp^R) and a tetracycline resistance gene (tet^R). The unique restriction site P_s is located directly within the coding sequence of the amp^R gene region. When a researcher restricts the plasmid and inserts a therapeutic cDNA fragment into this site, the foreign DNA disrupts the gene's open reading frame. This process, known as **insertional inactivation**, renders the resulting ampicillin resistance protein non-functional. Because the cDNA was inserted exclusively at site P_s , the downstream tetracycline resistance gene (tet^R) remains completely intact and functional. Consequently, transformed *E. coli* cells carrying this recombinant plasmid will display a selective screening profile: they will survive and grow on agar plates supplemented with tetracycline, but will die on plates containing ampicillin due to the loss of their resistance mechanism.

Final Answer: Survival on tetracycline but death on ampicillin due to insertional inactivation.

Answer: (C)

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Answer Key

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	B	2	C	3	B	4	B	5	C
6	B	7	C	8	B	9	A	10	A
11	B	12	B	13	B	14	B	15	B
16	B	17	B	18	B	19	B	20	B
21	B	22	B	23	A	24	A	25	B
26	B	27	A	28	B	29	B	30	B
31	B	32	B	33	C	34	B	35	C
36	B	37	B	38	B	39	B	40	C

