

# UPCATET Biology Sample Paper-7

Duration: 80 Minutes

Maximum Marks: 320

## Instructions

- This paper contains **80** Multiple Choice Questions.
- Each correct answer carries **+4** mark. Incorrect answer: **-1** marks. Only **one** correct option.
- Unattempted questions carry **0** marks.
- Use of mobile phones, smartwatches, or any electronic gadgets is strictly prohibited.

**Q1.** During high light intensity and low CO<sub>2</sub> concentration conditions in C<sub>3</sub> plants, Rubisco initiates photorespiration. Identify the exact metabolite that must be transported from the chloroplast into the peroxisome to maintain the continuity of the glycolate pathway.

- (A) Phosphoglycolate
- (B) Glycolate
- (C) Glycine
- (D) Serine

**Q2.** A researcher applies an uncoupler of oxidative phosphorylation, 2,4-dinitrophenol (DNP), to actively respiring plant root cells. Which of the following continuous physiological responses will be observed first regarding ATP synthesis and oxygen consumption?

- (A) Both ATP synthesis and oxygen consumption stop instantly.
- (B) ATP synthesis drops to zero while oxygen consumption rises significantly.
- (C) ATP synthesis increases exponentially while oxygen consumption drops.
- (D) Both ATP synthesis and oxygen consumption double their net rates.

**Q3.** The Münch pressure flow hypothesis explains translocation in phloem. If a metabolic inhibitor like sodium azide is injected directly into a sieve tube member



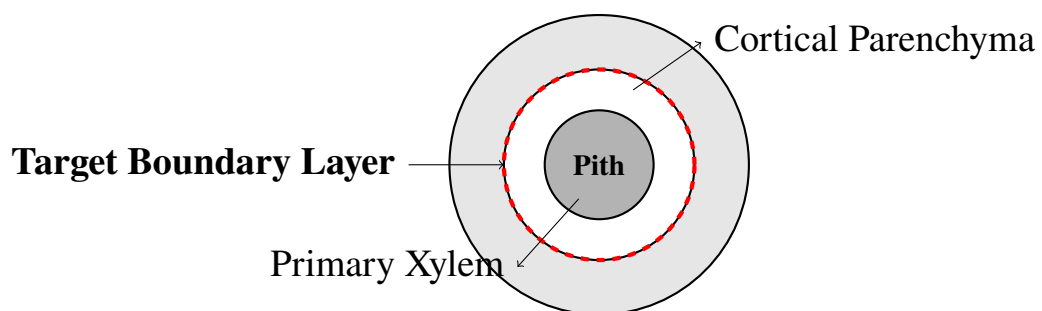
midway down a stem, what is the immediate kinetic effect on sucrose transport?

- (A) Translocation stops completely throughout the entire plant system instantly.
- (B) Local transport continues temporarily driven by the hydrostatic pressure gradient generated at the source.
- (C) Active loading at the source is completely reversed into passive unloading.
- (D) Mass flow accelerates due to decreased viscosity within the phloem sap.

**Q4.** In a mutant *Arabidopsis* plant, the PIN1 polarity-directed auxin efflux carriers are completely immobilized on the basal membranes of vascular parenchyma cells. What specific developmental anomaly will this plant display during organogenesis?

- (A) Complete loss of negative gravitropism in shoots.
- (B) Failure to establish apical-basal polarity and defective venation patterns.
- (C) Hyper-elongation of lateral roots due to accumulation of cytokinin.
- (D) Premature abscission of leaves caused by absolute ethylene dominance.

**Q5.** Examine the technical cross-sectional layout schematic of a specialized plant vascular organization segment depicted below. Identify the structural anatomical marker zone that contains Casparian strips filled with suberin deposits:



- (A) Outer Piliferous Epidermal Layer
- (B) Endodermis Ring Interface
- (C) Multiseriate Pericycle Sheath
- (D) Interfascicular Cambium Zone

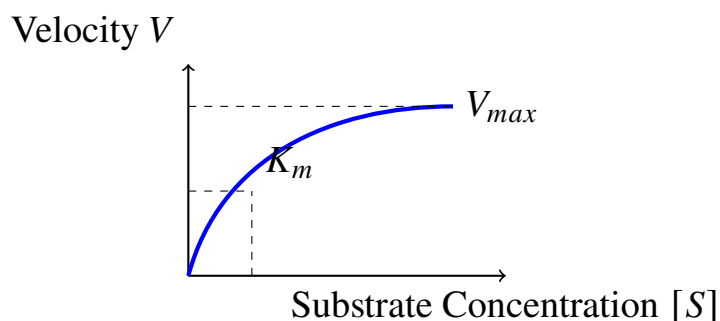


- Q6.** The Kranz anatomy is a defining structural adaptation of C4 plants. Which metabolic enzyme is uniquely localized exclusively inside the bundle sheath chloroplasts, being absent from mesophyll cells?
- (A) Phosphoenolpyruvate carboxylase
  - (B) NADP-Malic Enzyme
  - (C) Pyruvate phosphate dikinase
  - (D) Carbonic anhydrase
- Q7.** During secondary growth in dicotyledonous stems, the vascular cambium exhibits two distinct types of cell divisions. Fusiform initials divide primarily by which specific plane to increase the girth of the secondary xylem and phloem?
- (A) Periclinal divisions
  - (B) Anticlinal divisions
  - (C) Transverse segment divisions
  - (D) Apical oblique divisions
- Q8.** A plant physiologist measures the water potential ( $\Psi_w$ ), solute potential ( $\Psi_s$ ), and pressure potential ( $\Psi_p$ ) of a fully turgid leaf mesophyll cell. Which mathematical relationship correctly represents this physiological state if the cell is in dynamic equilibrium with pure water?
- (A)  $\Psi_w = \Psi_s$  because  $\Psi_p = 0$
  - (B)  $\Psi_w = 0$  because  $\Psi_s = -\Psi_p$
  - (C)  $\Psi_s = \Psi_p$  because  $\Psi_w$  is highly positive
  - (D)  $\Psi_w = \Psi_s + \Psi_p$  where  $\Psi_s$  must be positive
- Q9.** The asymmetric perception of unilateral blue light induces phototropism in coleoptiles. What is the correct molecular sequence of events involving phototropin receptors?
- (A) Dephosphorylation of phototropin  $\rightarrow$  Lateral migration of cytokinin to the illuminated side.



- (B) Autophosphorylation of phototropin → Lateral gradient formation of auxin towards the shaded side.
- (C) Activation of gibberellin synthesis → Acid-induced wall loosening on the illuminated side.
- (D) Inactivation of phytochrome B → Sudden systemic drop in cell turgor pressure.

**Q10.** Consider the graphical kinetic profile shown below detailing the velocity of an enzymatic reaction within the plant respiratory matrix under varying substrate availability values:



If a competitive inhibitor is added to this plant enzyme assay system, what precise modifications occur to the apparent  $K_m$  and  $V_{max}$  parameters?

- (A)  $K_m$  increases;  $V_{max}$  remains unchanged.
  - (B)  $K_m$  decreases;  $V_{max}$  decreases.
  - (C)  $K_m$  remains unchanged;  $V_{max}$  decreases.
  - (D) Both  $K_m$  and  $V_{max}$  increase simultaneously.
- Q11.** Abscisic acid (ABA) mediates rapid stomatal closure during drought stress. Which second messenger cascade directly causes the efflux of potassium ions ( $K^+$ ) and anions from the guard cell vacuoles into the cytoplasm?
- (A) Activation of  $H^+$ -ATPase pumps causing hyperpolarization.
  - (B) Elevation of cytosolic free Calcium ( $Ca^{2+}$ ) levels opening anion channels.
  - (C) Absolute depletion of cyclic AMP (cAMP) levels closing all aquaporins.
  - (D) Sudden influx of protons ( $H^+$ ) causing alkaline vacuolar shifts.



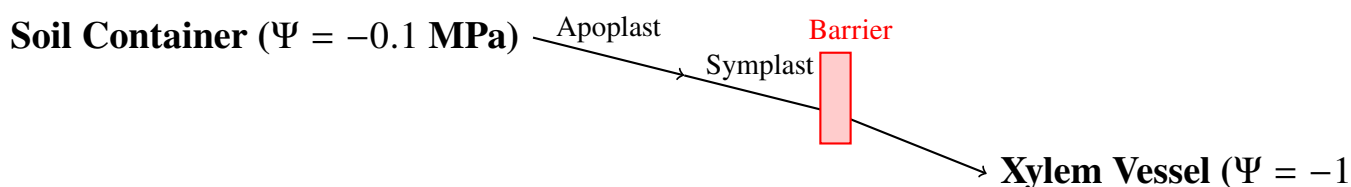
**Q12.** When a short-day plant is grown under non-inductive long-day conditions, flowering can be artificially induced by exposing a single leaf to brief pulses of which light spectrum, thereby activating the FT gene via phytochrome switching?

- (A) Far-red light pulses given continuously during the daytime.
- (B) Red light flash delivered precisely at the midpoint of an extended dark period.
- (C) Far-red light flash delivered precisely during a critical night period break.
- (D) Continuous green light irradiation to suppress cryptochrome activity.

**Q13.** The primary anatomical distinction between the primary root structures of monocotyledonous and dicotyledonous plants lies in the layout of their vascular bundles. Which configuration characterizes the monocotyledonous root?

- (A) Diarch to tetrarch xylem condition with absolute absence of pith.
- (B) Polyarch xylem condition with a large, highly developed central pith.
- (C) Conjoint, collateral, closed vascular bundles scattered throughout the ground tissue.
- (D) Bicollateral open vascular bundles forming a continuous concentric cylinder.

**Q14.** The anatomical vector diagram below maps water potential kinetics across a typical root cortex cross-section during active transpiration:



Identify the physiological force that drives water movement when transpiration is zero at night under highly humid atmospheric conditions:

- (A) Transpiration pull pull-back tension
- (B) Positive root hydrostatic pressure development

- (C) Sub-epidermal cavitation expansion
- (D) Atmospheric pressure suction forces

**Q15.** The conversion of toxic ammonia ( $\text{NH}_4^+$ ) into non-toxic organic compounds within legume root nodules proceeds primarily through which coordinated pathway?

- (A) Glutamate Dehydrogenase and Leucine transaminase system.
- (B) Glutamine Synthetase (GS) and Glutamate Synthase (GOGAT) cycle.
- (C) Reverse Krebs cycle coupled with Nitrate Reductase.
- (D) Direct transamination of oxaloacetate by Nitrogenase.

**Q16.** A patient presents with a defect in the parietal (oxyntic) cells of the gastric mucosa. Quantitative biochemical assays reveal zero secretion from these cells. Which physiological parameter will remain completely unaffected?

- (A) Activation of pepsinogen into active pepsin.
- (B) Absorption of Vitamin  $\text{B}_{12}$  in the terminal ileum.
- (C) Emulsification of dietary lipids by pancreatic lipases.
- (D) Destruction of ingested pathogens entering the gastric chamber.

**Q17.** During a high-altitude expedition at 5000 meters above sea level, a climber undergoes respiratory compensation. What physiological modification shifts the oxygen-hemoglobin dissociation curve to ensure adequate tissue oxygenation?

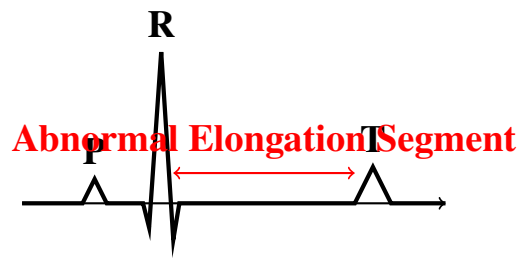
- (A) Decreased 2,3-BPG levels causing a leftward curve shift.
- (B) Increased 2,3-BPG levels causing a rightward curve shift.
- (C) Decreased blood pH causing increased affinity of hemoglobin for oxygen.
- (D) Hypocapnia causing a profound rightward curve shift.

**Q18.** An experimental drug blocks the active transport of sodium out of the thick ascending limb of the loop of Henle. What is the immediate impact on the hyperosmotic medullary interstitial gradient and urine concentration abilities?



- (A) Interstitial gradient is maintained; urine becomes highly concentrated.
- (B) Interstitial gradient is abolished; urine becomes highly dilute.
- (C) Interstitial gradient doubles; urine volume drops to near zero.
- (D) Urea recycling compensates perfectly; no net alteration occurs.

**Q19.** The electrocardiogram (ECG) trace of an individual shows a distinct abnormality as illustrated in the vector profile diagram below:



This pathologically elongated ST segment directly implies a profound disturbance in which underlying myocardial event?

- (A) Atrial depolarization speed increase.
  - (B) Ventricular depolarization initiation phase delay.
  - (C) Duration of the ventricular plateau phase of repolarization.
  - (D) Absolute failure of the sinoatrial node pacemaker cells.
- Q20.** During the transmission of a nerve impulse, what specific ion channel event is exclusively responsible for the rapid repolarization phase of the action potential across the axolemma?
- (A) Opening of voltage-gated  $\text{Na}^+$  channels with parallel  $\text{K}^+$  efflux.
  - (B) Closure of voltage-gated  $\text{Na}^+$  channels and opening of voltage-gated  $\text{K}^+$  channels.
  - (C) Activation of the active  $\text{Na}^+/\text{K}^+$  ATPase exchange pump exclusively.
  - (D) Rapid influx of  $\text{Cl}^-$  ions through ligand-gated ion channels.
- Q21.** A patient is diagnosed with an aldosterone-secreting tumor of the adrenal cortex (Conn's syndrome). Analysis of their blood plasma will reveal which combination of electrolyte and blood pressure abnormalities?

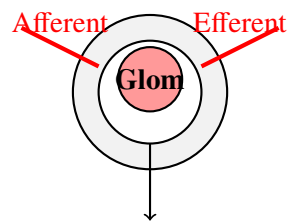


- (A) Hyponatremia, Hyperkalemia, and Severe Hypotension.
- (B) Hypernatremia, Hypokalemia, and Severe Hypertension.
- (C) Normal Sodium, Normal Potassium, and Idiopathic Hypotension.
- (D) Hypernatremia, Hyperkalemia, and Normal Blood Pressure.

**Q22.** The sliding filament model of muscle contraction requires cyclic molecular interactions. What event triggers the detachment of the myosin cross-bridge head from the actin filament active site?

- (A) Hydrolysis of bound ATP into ADP and Pi by myosin ATPase.
- (B) Binding of a fresh molecule of ATP to the myosin head structure.
- (C) Influx of calcium ions back into the sarcoplasmic reticulum lumen.
- (D) Binding of acetylcholine molecules to nicotinic endplate receptors.

**Q23.** The diagram below displays the cross-sectional physiological arrangement of a functional structural unit within the human kidney cortex:



**Proximal Convoluted Tubule Exit Zone**

If the hydrostatic pressure inside the glomerulus drops significantly, which physiological response is initiated by the juxtaglomerular apparatus?

- (A) Direct secretion of Atrial Natriuretic Peptide (ANP) to cause diuresis.
- (B) Release of Renin to convert angiotensinogen into angiotensin I.
- (C) Inhibition of Antidiuretic Hormone (ADH) release from the neurohypophysis.
- (D) Local vasoconstriction of the afferent arteriole to drop pressure further.

**Q24.** A structural neurobiologist blocks the function of the arachnoid villi within the human central nervous system. What dangerous secondary clinical presentation will manifest due to this intervention?



- (A) Absolute cessation of cerebrospinal fluid (CSF) production in the choroid plexus.
- (B) Accumulation of CSF in the subarachnoid space causing elevated intracranial pressure.
- (C) Rapid degeneration of the myelin sheath surrounding peripheral motor nerves.
- (D) Complete block of saltatory conduction across the nodes of Ranvier.

**Q25.** The physiological phenomenon known as the Haldane effect states that oxygenation of blood in the lungs displaces carbon dioxide from hemoglobin. What is the fundamental chemical explanation for this effect?

- (A) Oxyhemoglobin is a stronger acid than deoxyhemoglobin, releasing protons that drive bicarbonate toward  $\text{CO}_2$  formation.
- (B) Oxygen directly competes for the exact same carbamino binding sites located on the heme iron atoms.
- (C) Carbonic anhydrase activity is allosterically inhibited by high partial pressures of oxygen.
- (D) Carbon monoxide outcompetes both gases, fixing hemoglobin in the R-state configuration.

**Q26.** During the physiological mechanism of vision, what exact molecular change takes place inside the human rod cells when they transition from total darkness into bright light conditions?

- (A) Activation of guanylyl cyclase  $\rightarrow$  Elevation of cGMP  $\rightarrow$  Opening of  $\text{Na}^+$  channels  $\rightarrow$  Depolarization.
- (B) Activation of transducin  $\rightarrow$  Activation of phosphodiesterase  $\rightarrow$  Breakdown of cGMP  $\rightarrow$  Hyperpolarization.
- (C) Inactivation of rhodopsin  $\rightarrow$  Sudden massive opening of calcium channels  $\rightarrow$  Neurotransmitter surge.
- (D) Conversion of trans-retinal into 11-cis-retinal inside the opsin binding pockets.



**Q27.** The microscopic examination table below compiles structural and functional properties across three distinct classifications of epithelial tissues found within human physiological organs:

<b>Structural Parameter</b>	<b>Epithelium Category X</b>	<b>Epithelium Category Y</b>	<b>Epithelium Category Z</b>
Cell Layer Thickness	Single Layer (Simple)	Multi-layered (Stratified)	Single Layer (Appears Stratified)
Apical Surface Markers	Microvilli (Brush Border)	Keratinized / Non-Keratinized	Motile Cilia Extensions
Primary Organ Locations	Proximal Convoluted Tubule	Epidermis / Esophageal Lining	Upper Respiratory Tract

Identify the correct identification sequence matching Category X, Y, and Z respectively:

- (A) Simple Cuboidal Epithelium, Stratified Squamous Epithelium, Pseudostratified Columnar Epithelium
- (B) Simple Columnar Epithelium, Transitional Epithelium, Simple Squamous Epithelium
- (C) Pseudostratified Columnar Epithelium, Stratified Cuboidal Epithelium, Simple Cuboidal Epithelium
- (D) Transitional Epithelium, Stratified Squamous Epithelium, Stratified Columnar Epithelium

**Q28.** Which hormone acts via a membrane-bound receptor and initiates a cascade using cyclic AMP (cAMP) as a second messenger, rather than crossing the plasma membrane to interact with intracellular nuclear receptors?

- (A) Cortisol
- (B) Epinephrine
- (C) Testosterone
- (D) Thyroxine (T<sub>4</sub>)

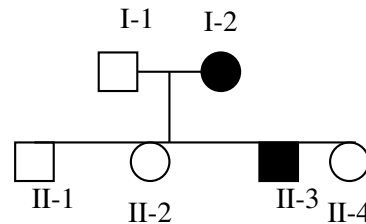


- Q29.** The physiological functional safety mechanism that protects human skeletal muscles from tearing during excessively high tension generation workloads is mediated by which specialized sensory organ structure?
- (A) Intrafusal muscle spindle fibers
  - (B) Golgi tendon organs
  - (C) Pacinian corpuscles
  - (D) Free unmyelinated nerve endings
- Q30.** A genetic cross between two heterozygous individuals for two independently assorting genes ( $AaBb \times AaBb$ ) yields an unusual 9 : 7 phenotypic ratio in the F<sub>2</sub> generation. What specific gene interaction allele dynamic explains this distribution?
- (A) Dominant Epistasis
  - (B) Recessive Epistasis
  - (C) Duplicate Recessive Epistasis (Complementary Gene Action)
  - (D) Duplicate Genes with Cumulative Effects
- Q31.** During DNA replication in *Escherichia coli*, the high fidelity of base matching is maintained by the proofreading activity of DNA Polymerase III. What is the precise catalytic direction of this exonucleolytic proofreading mechanism?
- (A) 5' → 3' exonuclease activity
  - (B) 3' → 5' exonuclease activity
  - (C) 5' → 3' endonuclease cleavage
  - (D) 3' → 5' mismatch repair endonuclease activity
- Q32.** The initiation of transcription in eukaryotic organisms requires the assembly of the pre-initiation complex. Which general transcription factor possesses intrinsic helicase catalytic activity that unwinds the promoter DNA sequence near the start site?
- (A) TFIID



- (B) TFIIB
- (C) TFIIH
- (D) TFIIF

**Q33.** The diagram below shows a classic pedigree chart tracing the inheritance pattern of an extremely rare metabolic condition across three successive generations within a family lineage:



Determine the exact mode of genetic transmission indicated by this pedigree sequence:

- (A) Autosomal Recessive Inheritance
  - (B) X-linked Dominant Inheritance
  - (C) Maternal / Mitochondrial Inheritance
  - (D) Y-linked Holandric Inheritance
- Q34.** A molecular biologist designs an in-vitro translation assay. They introduce a synthetic mRNA molecule containing an insertion of a single nucleotide base directly into the middle of the reading frame sequence. What phenotypic molecular event is triggered at the ribosomal level?
- (A) Missense point mutation replacing a single amino acid.
  - (B) Frame-shift mutation completely altering all downstream codons.
  - (C) Nonsense silent transition conserving the tertiary folding shape.
  - (D) Immediate spliceosome activation to excise the extra nucleotide.
- Q35.** The tryptophan (*trp*) operon of *E. coli* is regulated by attenuation. If the intracellular concentration of charged tRNA-Trp molecules is extremely high within the bacterial cytosol, what structural formation occurs within the leader mRNA sequence?



- (A) Formation of the 2-3 stem-loop structure allowing transcription to proceed.
- (B) Formation of the 3-4 terminator stem-loop structure causing premature transcription termination.
- (C) Binding of the tryptophan corepressor directly to the region 4 loop segment.
- (D) Dissociation of RNA polymerase from the promoter due to ribosome stalling.

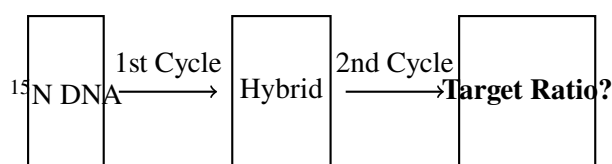
**Q36.** An analysis of a double-stranded DNA sample shows a total Adenine content of 34%. According to Chargaff's rules of base pairing, calculate the exact percentage of Cytosine expected in this genomic isolate.

- (A) 34%
- (B) 68%
- (C) 16%
- (D) 32%

**Q37.** In the context of eukaryotic chromatin structure, which specific post-translational histone modification is universally associated with transcriptional activation and chromatin relaxation into euchromatin?

- (A) Methylation of Histone H3 at Lysine 9 (H3K9me)
- (B) Acetylation of core histone amino-terminal tails by HATs
- (C) Ubiquitination of Histone H2A structures
- (D) Deacetylation of histones by HDAC enzymes

**Q38.** The experimental design schematic below illustrates a classic Meselson-Stahl density gradient centrifugation timeline using heavy isotope marking configurations:



What precise molecular ratio of Light ( $^{14}\text{N}/^{14}\text{N}$ ) to Hybrid ( $^{14}\text{N}/^{15}\text{N}$ ) DNA molecules will be resolved after exactly two generations of replication in light media?



- (A) 1:1 ratio
- (B) 3:1 ratio
- (C) 0:1 ratio
- (D) 1:3 ratio

**Q39.** The human genetic disorder Huntington's disease is caused by an expansion of trinucleotide repeats. What is the specific nucleotide triplet sequence that undergoes expansion, and what amino acid tract does it encode within the huntingtin protein?

- (A) CGG tract encoding Poly-Arginine
- (B) CAG tract encoding Poly-Glutamine
- (C) GAA tract encoding Poly-Lysine
- (D) CTG tract encoding Poly-Leucine

**Q40.** During eukaryotic mRNA processing, a specialized linkage is created at the 5' end. Which chemical bond describes the nature of the 5' cap added to the nascent pre-mRNA transcript?

- (A) 3' → 5' phosphodiester linkage
- (B) 5' → 5' triphosphate linkage
- (C) 3' → 3' pyrophosphate bridge
- (D) 1' → 5' glycosidic carbon bond

**Q41.** Which statement correctly differentiates between the mechanisms of retrotransposons and DNA transposons within the eukaryotic genome?

- (A) Retrotransposons use a "cut-and-paste" method via transposase enzymes.
- (B) DNA transposons require an RNA intermediate processed by reverse transcriptase.
- (C) Retrotransposons duplicate via a "copy-and-paste" mechanism using an RNA intermediate.



(D) DNA transposons are completely dependent on spliceosomal machineries to transpose.

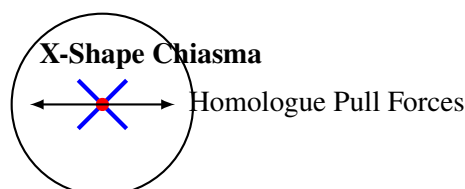
**Q42.** The lysosomal lumen maintains an acidic pH (~ 4.5 to 5.0) compared to the neutral cytosol. This proton concentration gradient is established and driven by which membrane transporter mechanism?

- (A) Na<sup>+</sup>/H<sup>+</sup> antiporter system exchange
- (B) V-type H<sup>+</sup>-ATPase proton pump powered by ATP hydrolysis
- (C) Passive leakage of protons through specialized aquaporins
- (D) F-type ATP synthase working in the reverse direction

**Q43.** During the phase transitions of the eukaryotic cell cycle, the activation of Cyclin-Dependent Kinase 1 (CDK1) requires association with Cyclin B. What specific phosphorylation pattern determines the active state of this complex?

- (A) Phosphorylation at Thr14 and Tyr15 positions.
- (B) Dephosphorylation at Thr14 and Tyr15 paired with phosphorylation at Thr161.
- (C) Hyperphosphorylation across all serine and threonine motifs simultaneously.
- (D) Complete dephosphorylation at all residues by active histones.

**Q44.** The cell division chromosome configuration diagram below depicts an absolute stage configuration during cellular gametogenesis:



Identify the precise sub-stage of Prophase I shown, where homologous chromosome crossover resolution displays chiasmata structures clearly:

- (A) Leptotene stage
- (B) Pachytene stage



- (C) Diplotene stage
- (D) Zygotene stage

**Q45.** The fluid mosaic model stipulates that plasma membrane fluidity is modulated by lipid composition. How does a high concentration of cholesterol affect membrane physical parameters at extremely high ambient temperatures?

- (A) Increases fluidity by disrupting the packing of fatty acid tails.
- (B) Stabilizes the membrane and decreases fluidity by restricting phospholipid lateral movement.
- (C) Triggers immediate phase transition into a completely solid crystalline structure.
- (D) Promotes rapid leakage of large hydrophilic macromolecules across the bilayer.

**Q46.** Which organelle is the primary site for the synthesis of phospholipids, cholesterol, and the detoxification of hydrophobic xenobiotic drugs via the cytochrome P450 enzyme family?

- (A) Rough Endoplasmic Reticulum
- (B) Smooth Endoplasmic Reticulum
- (C) Cis-Golgi Network Matrix
- (D) Peroxisomal Core Matrix

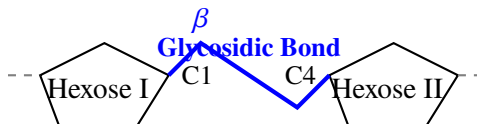
**Q47.** Proteins destined for import into the mitochondrial matrix require a specific targeting sequence. What are the general biochemical features of this mitochondrial signal peptide?

- (A) Continuous stretch of 20 hydrophobic amino acids at the carboxyl terminus.
- (B) Amphipathic alpha-helix containing positively charged residues clustered on one side.
- (C) Negatively charged aspartate-rich loop sequence situated midway down the chain.



(D) Highly branched oligosaccharide chain attached via N-glycosidic linkages.

**Q48.** The structural map below classifies a crucial biomolecule polymer category according to its precise chemical monomer linkage geometry:



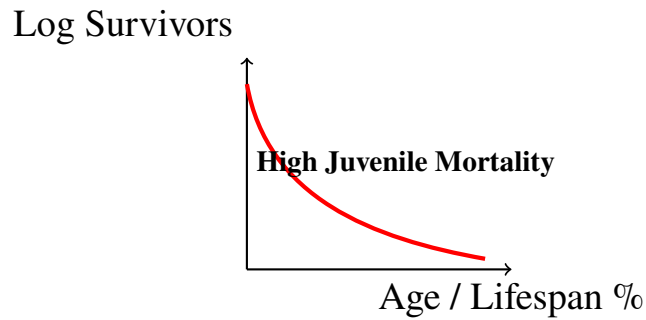
Which structural polysaccharide matches this configuration, rendering it completely indigestible by standard human amylase enzymes?

- (A) Amylopectin storage cores
  - (B) Cellulose microfibrils
  - (C) Glycogen branching segments
  - (D) Alpha-amylose coils
- Q49.** During apoptosis (programmed cell death), cytochrome c is released from the mitochondrial intermembrane space into the cytosol. Which cytosolic protein does it directly bind to form the functional apoptosome complex?
- (A) Caspase-3
  - (B) Apoptotic Protease Activating Factor-1 (Apaf-1)
  - (C) Bcl-2 survival factor
  - (D) Fas death receptor complex
- Q50.** The macromolecular structure of the nuclear pore complex allows selective transport of cargo. Proteins larger than 40 kDa require the interaction of their Nuclear Localization Signal (NLS) with which specific cytosolic receptor protein?
- (A) Exportin-1
  - (B) Importin alpha/beta heterodimer
  - (C) Ran-GAP activator
  - (D) Clathrin heavy chain adaptors



- Q51.** An analytical biochemist extracts a structural protein that forms a triple-helix conformation rich in glycine, proline, and hydroxyproline. This description matches which extracellular matrix component?
- (A) Elastin fibers
  - (B) Fibronectin dimers
  - (C) Collagen matrix elements
  - (D) Laminin meshworks
- Q52.** In an ecosystem energy flow study, a researcher tracks the Lindeman's efficiency across trophic boundaries. If the primary producers lock down 10,000 Joules of net energy, what approximate quantum of energy is available to the tertiary consumer level?
- (A) 1,000 Joules
  - (B) 100 Joules
  - (C) 10 Joules
  - (D) 1 Joule
- Q53.** The competitive exclusion principle proposed by Gause states that two species competing for the exact same limiting resource cannot coexist indefinitely. What ecological mechanism allows similar species to overcome this and coexist in nature?
- (A) Biomagnification of toxins
  - (B) Resource partitioning and niche differentiation
  - (C) High reproductive rate mutations
  - (D) Environmental stochasticity stabilization
- Q54.** The demographic matrix graph below profiles a specific survivorship curve strategy observed in natural wildlife ecosystem habitats:





Which organism classification represents this Type III survivorship curve strategy accurately?

- (A) Large mammals like elephants
- (B) Marine pelagic fish and oysters
- (C) Passerine songbirds
- (D) Domesticated canine lines

**Q55.** The island biogeography model by MacArthur and Wilson correlates species richness with two main geographic parameters. Which type of island will support the absolute highest equilibrium number of species at steady state?

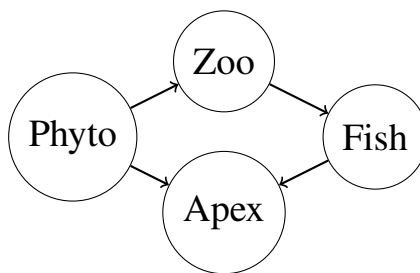
- (A) Small islands located far from the mainland continent.
- (B) Large islands located close to the mainland continent.
- (C) Small islands located close to the mainland continent.
- (D) Large islands located far from the mainland continent.
- (E) Large islands located far from the mainland continent.

**Q56.** During an aquatic pollution monitoring survey, an environmental engineer records a massive discharge of untreated organic sewage into a river system. What immediate kinetic trend will be tracked regarding dissolved oxygen (DO) and biochemical oxygen demand (BOD)?

- (A) DO rises sharply; BOD drops to zero.
- (B) Both DO and BOD values experience parallel exponential spikes.
- (C) DO drops precipitously while BOD values surge upwards.
- (D) Both parameters equilibrate to baseline values instantly.



- Q57.** The concept of ecological succession involves predictable changes in community composition. Which of the following functional traits characterizes a typical pioneer species or r-strategist colonizing a barren volcanic terrain?
- (A) Large seed size, slow growth rate, and high competitive ability.
  - (B) Small seed size, rapid development, early reproduction, and wide dispersal capacity.
  - (C) Deep root networks, low allocation to reproduction, and high shade tolerance.
  - (D) Strict dependency on mycorrhizal symbiotic networks for seed germination.
- Q58.** The visual food web structure matrix below logs the interaction links across a simplified aquatic community configuration:



If a lipophilic persistent organic pollutant (like DDT) enters this habitat at the Phytoplankton base layer, which node will exhibit the absolute highest tissue concentration due to biomagnification processes?

- (A) Phyto node base
  - (B) Zoo middle layer
  - (C) Fish consumer node
  - (D) Apex consumer node
- Q59.** The Shannon-Wiener Index ( $H'$ ) is an index used by ecologists to quantify biodiversity. What two distinct components of community structure are mathematically accounted for within this single value?
- (A) Species richness and genetic heterozygosity variations.
  - (B) Species richness and species evenness (relative abundance).
  - (C) Total biomass productivity and geographical area size.



(D) Trophic level counts and absolute population counts.

**Q60.** Which international environmental treaty explicitly targets the phased reduction and complete elimination of ozone-depleting substances, such as chlorofluorocarbons (CFCs), from the global industrial sector?

- (A) Kyoto Protocol
- (B) Montreal Protocol
- (C) Nagoya Protocol
- (D) Cartagena Protocol

**Q61.** In the five-kingdom classification system proposed by Robert Whittaker, which defining criteria served as the primary basis for separating the Kingdom Fungi from the Kingdom Plantae?

- (A) Absence of a true membrane-bound nucleus structure.
- (B) Cell wall composition (chitin vs. cellulose) and heterotrophic absorptive mode of nutrition.
- (C) Presence of circular extra-chromosomal plasmid segments.
- (D) Ability to survive under extreme thermophilic environmental parameters.

**Q62.** A systematist analyzes a flower specimen belonging to the family Solanaceae. Which specific combination of floral characters confirms its taxonomic placement in this group?

- (A) Zygomorphic symmetry, diadelphous stamens, and marginal placentation.
- (B) Actinomorphic symmetry, epipetalous stamens, and an obliquely placed ovary with swollen placenta.
- (C) Cruciform corolla, tetradynamous stamens, and siliqua type fruit.
- (D) Monadelphous stamens, twisted aestivation, and axile placentation.

**Q63.** Archebacteria are able to survive under extreme hydrothermal vent conditions characterized by temperatures exceeding 100 degrees Celsius. What molecular adaptation within their plasma membrane imparts this structural stability?



- (A) Highly unsaturated fatty acid tails linked by ester bonds to glycerol.
- (B) Branched-chain hydrocarbons linked to glycerol by chemically stable ether linkages forming a monolayer.
- (C) High concentrations of cholesterol embedded within standard phospholipid bilayers.
- (D) Outer peptidoglycan matrix containing thick teichoic acid cross-links.

**Q64.** The floral formula summary profile listed below captures structural details of a specific economic food crop family:

$$\oplus \int K_{2+2} C_4 A_{2+4} G_{(2)}$$

Identify the plant family characterized by this structural organization map:

- (A) Family Fabaceae
  - (B) Family Brassicaceae (Cruciferae)
  - (C) Family Liliaceae
  - (D) Family Poaceae
- Q65.** Which evolutionary milestone correctly marks the transition from primitive non-vascular bryophytes to advanced pteridophytes within the plant kingdom lineages?
- (A) Development of heterospory and the seed habit concept.
  - (B) Transition from a dominant gametophyte phase to a dominant sporophyte phase with true vascular tissues.
  - (C) Emergence of double fertilization mechanisms inside closed carpels.
  - (D) Absolute loss of motile flagellated male gametes during syngamy.
- Q66.** An invertebrate zoologist isolates a marine organism exhibiting bilateral symmetry as a larva but radial pentamerous symmetry as an adult, a water vascular system, and a calcareous endoskeleton. To which phylum does this organism belong?



- (A) Phylum Cnidaria
- (B) Phylum Mollusca
- (C) Phylum Echinodermata
- (D) Phylum Arthropoda

**Q67.** The character matrix table below tracks primitive and derived physiological configurations across four chordate taxonomies:

Taxonomic Unit	Heart Chambers	Aortic Arches	Excretory Product
Group Alpha	2 Chambers	Single Systemic Loop	Ammonia
Group Beta	3 Chambers	Double Left/Right Arch	Urea
Group Gamma	4 Chambers	Single Right Arch Core	Uric Acid

Identify the class represented by Group Gamma:

- (A) Class Amphibia
- (B) Class Reptilia
- (C) Class Aves (Birds)
- (D) Class Mammalia

**Q68.** The life cycle of the liver fluke (*Fasciola hepatica*) involves complex developments across multiple hosts. Identify the correct sequential order of larval stages emerging during its lifecycle progression.

- (A) Miracidium → Redia → Sporocyst → Cercaria → Metacercaria
- (B) Miracidium → Sporocyst → Redia → Cercaria → Metacercaria
- (C) Cercaria → Miracidium → Redia → Sporocyst → Metacercaria
- (D) Sporocyst → Redia → Miracidium → Metacercaria → Cercaria

**Q69.** During megasporogenesis and megagametogenesis in angiosperms, a single functional megaspore undergoes successive nuclear divisions to form a mature Polygonum-type embryo sac. What is the precise cellular and nuclear layout of this mature embryo sac?

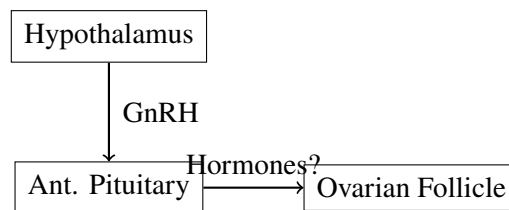


- (A) 8-celled and 8-nucleate structure
- (B) 7-celled and 8-nucleate structure
- (C) 8-celled and 7-nucleate structure
- (D) 3-celled and 3-nucleate structure

**Q70.** The acrosome reaction in human spermatozoa is essential for fertilization. Which oocyte extracellular layer matrix glycoprotein functions as the primary receptor that binds sperm, triggering this exocytotic release of lytic enzymes?

- (A) Zona Pellucida Glycoprotein 3 (ZP3)
- (B) Integrin-beta surface receptors
- (C) Hyaluronic acid capsule matrix
- (D) Cortical granule receptor proteins

**Q71.** The reproductive endocrinology cascade schematic below traces hormone relationships controlling the human female ovarian cycle:



What precise hormonal event triggers ovulation on exactly day 14 of a standard 28-day menstrual cycle?

- (A) A sudden steep drop in progesterone concentration levels.
- (B) A rapid, high-amplitude surge of Luteinizing Hormone (LH) induced by positive feedback of estrogen.
- (C) Chronic elevation of Follicle Stimulating Hormone (FSH) alone.
- (D) Absolute withdrawal of Gonadotropin-Releasing Hormone from the portal tracks.

**Q72.** The physiological phenomenon of "double fertilization" is unique to angiosperms. What are the precise products generated from this dual fusion event?

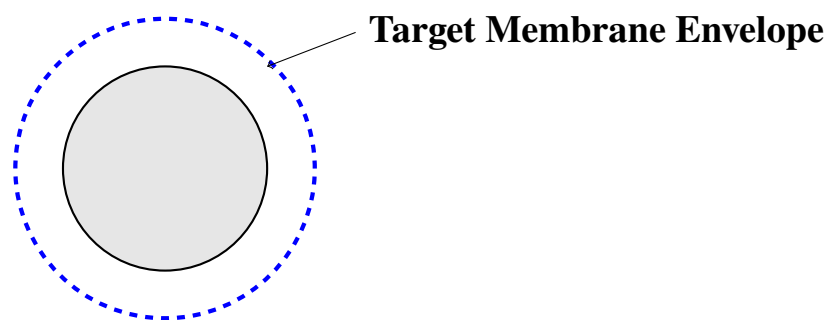


- (A) Diploid Zygote and Diploid Endosperm tissue.
- (B) Triploid Zygote and Haploid Perisperm core.
- (C) Diploid Zygote and Triploid Primary Endosperm Nucleus.
- (D) Two identical Diploid Embryonic initialization tracks.

**Q73.** In human embryology, the blastocyst implants into the maternal endometrium. Which embryonic cellular layer directly differentiates into the syncytiotrophoblast layer, invading the uterine wall to establish the primitive maternal-fetal circulatory interface?

- (A) Inner Cell Mass (Epiblast)
- (B) Trophoblast outer shell layer
- (C) Extra-embryonic parietal mesoderm
- (D) Hypoblast secondary layer

**Q74.** The technical architectural drawing below shows the layout of a developing human embryo inside its protective gestational extraembryonic membrane enclosures:



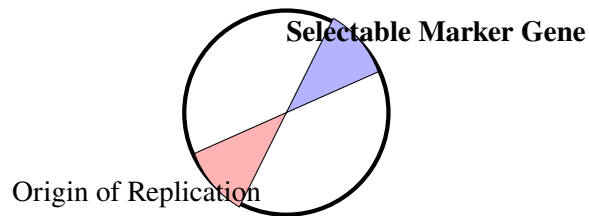
Identify the membrane layer that directly participates in forming the structural fetal component of the placenta:

- (A) Amnion membrane
- (B) Yolk sac envelope
- (C) Chorion membrane
- (D) Allantois residual sac



- Q75.** Which oral contraceptive pill formulation mechanism correctly describes the function of emergency morning-after pills containing high doses of Levonorgestrel?
- (A) Direct chemical destruction of sperm cells residing within the vaginal vault.
  - (B) Delays or inhibits ovulation by disrupting the LH surge pattern, or alters cervical mucus density.
  - (C) Initiates immediate immunological rejection of the implanted blastocyst structure.
  - (D) Permanently deactivates the maternal progesterone receptors within the ovaries.
- Q76.** A genetic engineer clones a target gene into the BamHI restriction site located within the tetracycline resistance gene of plasmid pBR322. What selection phenotype will recombinant bacterial colonies display when screened?
- (A) Resistance to both Ampicillin and Tetracycline drugs.
  - (B) Sensitivity to both Ampicillin and Tetracycline drugs.
  - (C) Resistance to Ampicillin but sensitivity to Tetracycline.
  - (D) Sensitivity to Ampicillin but resistance to Tetracycline.
- Q77.** The Polymerase Chain Reaction (PCR) requires a specialized DNA polymerase enzyme. Why is standard human DNA Polymerase I entirely unsuitable for this automated amplification technology?
- (A) It lacks the required  $5' \rightarrow 3'$  synthesis rate parameters.
  - (B) It undergoes immediate thermal denaturation at the high temperatures ( $94^{\circ}\text{C}$ ) required for DNA strand denaturation.
  - (C) It cannot bind to synthetic oligonucleotide DNA primers.
  - (D) It possesses high exonuclease activity that destroys the template DNA.
- Q78.** The schematic vector map below models the operational molecular architecture of a modern cloning plasmid vehicle:





What is the absolute physiological function of the selectable marker gene component embedded within this vector?

- (A) To initiate high-speed autonomous replication of the plasmid circle.
- (B) To allow host cell expression of the foreign cloned protein product.
- (C) To permit identification and selective survival of host cells that have successfully taken up the plasmid vector.
- (D) To facilitate target gene integration into the host bacterial chromosome.

**Q79.** Bt corn varieties are engineered to express crystal (Cry) endotoxins derived from the bacterium *Bacillus thuringiensis*. What is the physiological mechanism of action of this toxin inside the targeted insect pests?

- (A) Complete inhibition of acetylcholinesterase enzymes in the nervous system.
- (B) Binding to specific receptors in the alkaline midgut epithelial cells, creating pores that cause osmotic lysis.
- (C) Shutting down the cellular mitochondrial electron transport chain completely.
- (D) Preventing the synthesis of chitin during larval molting phases.

**Q80.** The methodology of RNA interference (RNAi), used extensively to develop pest-resistant transgenic crops, achieves specific gene silencing by exploiting which cellular molecular mechanism?

- (A) Direct enzymatic cleavage of target genomic DNA loci by Cas9 complexes.
- (B) Degradation of specific target single-stranded mRNA molecules by the RISC complex using complementary double-stranded RNA guides.
- (C) Transcriptional blocking at the promoter level by regulatory repressors.
- (D) Post-translational tagging of target proteins with ubiquitin for proteasomal destruction.



**Detailed Solutions****Q1.****Solution**

**Concept:** Photorespiration (the  $C_2$  cycle) occurs in  $C_3$  plants under conditions of high light intensity and low  $CO_2 : O_2$  ratios, where Rubisco acts as an oxygenase. This metabolic pathway is compartmentalized across three distinct organelles: the chloroplast, the peroxisome, and the mitochondrion.

**Solution:**

Let's trace the initial biochemical steps of the photorespiratory pathway:

- (a) Inside the chloroplast, the oxygenation of ribulose-1,5-bisphosphate (RuBP) yields one molecule of 3-phosphoglycerate (3-PGA) and one molecule of toxic 2-phosphoglycolate.
- (b) The 2-phosphoglycolate is rapidly dephosphorylated within the chloroplast by a specific phosphatase enzyme to form glycolate.
- (c) To maintain the continuity of the pathway, this glycolate metabolite must be exported across the chloroplast envelope via a specialized transporter and imported directly into the peroxisome, where it is subsequently oxidized to glyoxylate.

**Final Answer:** Glycolate

**Answer: (B)**

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Q2.

**Solution**

**Concept:** Oxidative phosphorylation depends on a tight coupling between the electron transport chain (ETC) and the ATP synthase complex, mediated by the establishment of an electrochemical proton gradient across the inner mitochondrial membrane.

**Solution:**

Let's analyze the physiological effects of adding an uncoupling agent like 2,4-dinitrophenol (DNP):

- (a) DNP is a lipophilic weak acid that acts as a protonophore. It easily diffuses across the inner mitochondrial membrane, carrying protons directly down their electrochemical gradient into the matrix.
- (b) This action completely dissipates the proton motive force ( $\Delta p$ ) without directly inhibiting the electron carriers of the ETC.
- (c) Because the proton gradient is destroyed, ATP synthase lacks the driving force to function, causing ATP synthesis rates to drop to zero.
- (d) Deprived of the back-pressure normally exerted by a high proton gradient, the ETC operates at maximum capacity to pump protons out. Consequently, oxygen consumption (the final electron acceptor) rises significantly.

**Final Answer:** ATP synthesis drops to zero while oxygen consumption rises significantly.

**Answer: (B)**

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Q3.

**Solution**

**Concept:** The Münch pressure flow hypothesis states that phloem translocation is driven passively by an osmotically generated hydrostatic pressure gradient between the source (high pressure) and the sink (low pressure).

**Solution:**

Let's evaluate the metabolic requirements of phloem transport along the pathway:

- (a) Metabolic energy (ATP) is strictly required at the source for active phloem loading (e.g., via sucrose- $H^+$  symporters) and at the sink for active unloading.
- (b) In contrast, the movement of phloem sap through the continuous sieve tube matrix between the source and the sink is a passive bulk mass flow driven by a high hydrostatic turgor pressure gradient.
- (c) Injecting a metabolic inhibitor like sodium azide midway down a stem will block local ATP synthesis in that specific area. However, it will not instantly halt translocation, because the physical hydrostatic pressure gradient established at the distant source continues to temporarily drive local sap flow forward.

**Final Answer:**

Local transport continues temporarily driven by the hydrostatic pressure gradient generated at the source.

**Answer: (B)**

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Q4.

**Solution**

**Concept:** The directed, polar transport of auxin is highly dependent on the asymmetric, polarized subcellular distribution of PIN-form (PIN) efflux carrier proteins across the plasma membranes of plant cells.

**Solution:**

Let's examine the consequences of mutating or immobilizing these carriers:

- (a) PIN1 carriers are normally dynamically recycled via vesicle trafficking to maintain their basal positioning, which ensures coordinated downward (acropetal) transport of auxin along the main embryonic and vascular axes.
- (b) If PIN1 carriers become completely immobilized or locked on the basal surfaces, the dynamic reorientation of auxin flow required to adapt to developmental signals is disrupted.
- (c) This continuous, fixed basal accumulation disrupts the normal asymmetric distribution gradients required for patterning, resulting in a complete failure to establish normal embryonic apical-basal polarity and causing highly defective, unorganized vascular venation patterns during organogenesis.

**Final Answer:** Failure to establish apical-basal polarity and defective venation patterns.

**Answer: (B)**

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Q5.

**Solution**

**Concept:** The internal anatomy of a plant root contains distinct concentric cellular rings that regulate the radial movement of water and solutes from the soil toward the central vascular cylinder.

**Solution:**

Let's identify the structural zone described by the cross-sectional layout:

- (a) The target boundary layer shown sits directly between the outer cortical parenchyma cells and the inner vascular core (primary xylem, pericycle, and pith). This positions it precisely at the endodermis ring interface.
- (b) The cell walls of this specialized endodermal ring contain localized bands of hydrophobic suberin and lignin deposits known as Casparian strips.
- (c) These strips block the passive apoplastic movement of water and dissolved minerals, forcing solutes to pass selectively through the plasma membrane into the symplast before entering the xylem.

**Final Answer:** Endodermis Ring Interface

**Answer: (B)**

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Q6.

**Solution**

**Concept:** The Kranz anatomy divides photosynthetic labor between two distinct cell types in  $C_4$  plants: outer mesophyll cells and an inner ring of bundle sheath cells.

**Solution:**

Let's map the specific biochemical compartmentalization of enzymes in the  $C_4$  pathway:

- (a) **Mesophyll Cells:** Atmospheric  $CO_2$  is initially fixed by Phosphoenolpyruvate (PEP) carboxylase into oxaloacetate, which is then converted to malate. Mesophyll cells lack Rubisco and decarboxylating enzymes.
- (b) **Bundle Sheath Cells:** Malate is transported into these cells and decarboxylated to release a high concentration of  $CO_2$  directly around Rubisco. In NADP-malic enzyme type  $C_4$  plants, this decarboxylation is catalyzed by NADP-malic enzyme, which is localized exclusively within the bundle sheath chloroplasts and is absent from mesophyll cells.

**Final Answer:**

**Answer:** (B)

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Q7.

**Solution**

**Concept:** Secondary growth in dicotyledonous stems increases the plant's diameter through the activity of the lateral meristem known as the vascular cambium, which contains two main types of dividing cells: fusiform initials and ray initials.

**Solution:**

Let's analyze the planes of cell division in the vascular cambium:

- (a) **Periclinal Divisions:** Fusiform initials divide primarily along a plane parallel to the surface of the plant organ (periclinal). This division creates new cells directed inward (which differentiate into secondary xylem) and outward (which differentiate into secondary phloem), directly expanding the girth of the stem.
- (b) **Anticlinal Divisions:** Fusiform initials occasionally divide perpendicular to the organ surface (anticlinal) to increase the circumference of the cambial ring itself, keeping pace with the expanding stem diameter.

**Final Answer:**

**Answer:** (A)

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Q8.

**Solution**

**Concept:** The total water potential ( $\Psi_w$ ) of a plant cell is determined by the fundamental thermodynamic relationship combining its internal chemical solute concentration and physical turgor pressure:  $\Psi_w = \Psi_s + \Psi_p$ .

**Solution:**

Let's evaluate the variables when a cell reaches a fully turgid state in pure water:

- (a) Pure water at standard atmospheric pressure has an absolute reference water potential ( $\Psi_w$ ) of 0 MPa.
- (b) When a leaf mesophyll cell is placed in pure water, water enters the cell down its potential gradient, causing the plasma membrane to push outward against the rigid cell wall and generating positive turgor pressure ( $\Psi_p > 0$ ).
- (c) Dissolved cell solutes always depress the water potential, meaning the solute potential ( $\Psi_s$ ) is always a negative value ( $\Psi_s < 0$ ).
- (d) When dynamic equilibrium is achieved, net water movement stops because the internal water potential matches the outside environment ( $\Psi_w = 0$ ). For  $\Psi_w$  to equal 0, the positive turgor pressure must exactly balance the negative solute potential ( $\Psi_s = -\Psi_p$ ).

**Final Answer:**  $\Psi_w = 0$  because  $\Psi_s = -\Psi_p$

**Answer: (B)**

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Q9.

**Solution**

**Concept:** Phototropism is a directional growth response directed by the perception of unilateral blue light at the apex of coleoptiles, governed by the Cholodny-Went hypothesis.

**Solution:**

Let's break down the molecular cascade that drives this bending response:

- Unilateral blue light is captured by phototropin receptors located at the shoot tip, inducing a structural change that triggers their autophosphorylation.
- Active phototropin signaling causes the lateral transport of auxin efflux carriers (PIN proteins), establishing an asymmetric concentration gradient where auxin accumulates on the shaded side of the coleoptile.
- The higher concentration of auxin on the shaded side stimulates active proton extrusion, loosening the cell wall matrix and driving rapid cell elongation on that side, which bends the plant toward the light.

**Final Answer:** Autophosphorylation of phototropin → Lateral gradient formation of auxin towards the shaded side.

**Answer: (B)**

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Q10.

**Solution**

**Concept:** Enzyme inhibitors alter specific kinetic parameters of metabolic reactions, which can be visualized by monitoring changes in the Michaelis-Menten constant ( $K_m$ ) and maximum velocity ( $V_{max}$ ).

**Solution:**

Let's analyze the effects of a competitive inhibitor on enzyme kinetics:

- A competitive inhibitor possesses a structure that mimics the true substrate, allowing it to bind reversibly to the enzyme's active site and compete directly with the substrate.
- Because the inhibitor can be displaced by significantly increasing the concentration of the substrate ( $[S]$ ), the absolute maximum velocity ( $V_{max}$ ) achievable by the enzyme remains completely unchanged.
- However, because the inhibitor blocks a portion of the active sites at lower substrate levels, a higher concentration of substrate is required to reach half of  $V_{max}$ . This shifts the curve to the right, causing a selective increase in the apparent Michaelis constant ( $K_m$ ).

**Final Answer:**  $K_m$  increases;  $V_{max}$  remains unchanged.

**Answer: (A)**

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Q11.

**Solution**

**Concept:** Abscisic acid (ABA) functions as a primary stress hormone that triggers rapid turgor changes in guard cells to close stomata and conserve water during drought conditions.

**Solution:**

Let's trace the secondary messenger signal cascade initiated by ABA:

- ABA binds to its regulatory receptors, stimulating the production of reactive oxygen species (ROS) and nitric oxide, which activates plasma membrane calcium channels.
- This induces a rapid influx and release of free calcium ions ( $\text{Ca}^{2+}$ ) into the cytosol, significantly raising intracellular calcium levels.
- The elevated cytosolic  $\text{Ca}^{2+}$  directly blocks inward-rectifying potassium channels and opens voltage-dependent anion channels (like SLAC1), promoting a massive efflux of anions and potassium ions ( $\text{K}^+$ ) out of the vacuole and cell. The resulting loss of intracellular solutes causes water to exit osmotically, deflating the guard cells and closing the stomatal pore.

**Final Answer:** Elevation of cytosolic free Calcium ( $\text{Ca}^{2+}$ ) levels opening anion channels.

**Answer: (B)**

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Q12.

**Solution**

**Concept:** Photoperiodism in plants is regulated by the relative duration of light and dark periods, sensed by specialized photoreceptor proteins known as phytochromes that switch between an inactive red-absorbing form ( $P_r$ ) and an active far-red-absorbing form ( $P_{fr}$ ).

**Solution:**

Let's analyze the night-break phenomenon in a short-day plant (SDP):

- Short-day plants require a continuous, uninterrupted dark period that exceeds a critical length to induce flowering.
- If a flash of red light is delivered at the midpoint of this extended dark period, it converts  $P_r$  into the active  $P_{fr}$  form, which actively suppresses the transcription of the FT (Florigen) gene and blocks flowering.
- To reverse this suppression and restore the inductive dark signal, the red flash must be followed immediately by a flash of far-red light. This far-red light pulse converts the inhibitory  $P_{fr}$  back into the inactive  $P_r$  form, resetting the phytochrome switch and allowing flowering to proceed.

**Final Answer:** Far-red light flash delivered precisely during a critical night period break.

**Answer: (C)**

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Q13.

**Solution**

**Concept:** The internal anatomy of primary roots can be differentiated between monocotyledonous and dicotyledonous plants by observing the structural organization and number of their vascular bundles.

**Solution:**

Let's compare the vascular layouts of these roots:

- (a) **Dicotyledonous Roots:** Typically exhibit a small number of xylem lobes alternating with phloem patches, categorized as diarch to tetrarch (usually 2 to 4 vascular bundles), surrounding a minimal or completely absent central pith.
- (b) **Monocotyledonous Roots:** Characterized by a high number of vascular bundles alternating radially in a ring, a condition termed polyarch (typically more than six xylem bundles). Additionally, monocot roots feature a large, prominent, and highly developed central pith tissue.

**Final Answer:** Polyarch xylem condition with a large, highly developed central pith.

**Answer: (B)**

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Q14.

**Solution**

**Concept:** Water transport through a plant is driven by different mechanisms depending on atmospheric conditions, soil moisture levels, and the rate of transpiration from the leaves.

**Solution:**

Let's identify the driving force behind water movement when transpiration is zero:

- (a) During the daytime, active transpiration generates a negative tension or pulling force (transpiration pull) that moves water upward from the soil through the apoplast and symplast.
- (b) At night, under high atmospheric humidity, leaf transpiration stops completely, removing this tension.
- (c) However, root cortical cells continue to actively pump mineral ions from the soil into the central vascular xylem cylinder. This ion accumulation drops the solute potential inside the xylem, drawing water in osmotically.
- (d) Since transpiration is zero, this inward osmotic movement builds up a positive hydrostatic pressure—known as root pressure—which pushes water upward through the stem.

**Final Answer:** Positive root hydrostatic pressure development

**Answer: (B)**

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Q15.

**Solution**

**Concept:** Biological nitrogen fixation by the nitrogenase complex reduces atmospheric dinitrogen into ammonia ( $\text{NH}_3/\text{NH}_4^+$ ), which is highly toxic to plant tissues and must be rapidly assimilated into organic amino acids.

**Solution:**

Let's evaluate the primary pathways for ammonia assimilation in legume root nodules:

- The dominant, highly efficient metabolic route for assimilating ammonia in nodules is the coordinated GS-GOGAT cycle.
- First, the enzyme **Glutamine Synthetase (GS)** combines ammonia with a molecule of glutamate to produce glutamine, consuming one molecule of ATP.
- Next, **Glutamate Synthase (GOGAT)** transfers the amide group from this newly formed glutamine to a molecule of  $\alpha$ -ketoglutarate, producing two molecules of glutamate. One of these glutamates is recycled to sustain the loop, while the other is exported or converted into transport amides or ureides.

**Final Answer:** Glutamine Synthetase (GS) and Glutamate Synthase (GOGAT) cycle.

**Answer: (B)**

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Q16.

**Solution**

**Concept:** Parietal (oxyntic) cells located within the gastric mucosal glands are responsible for secreting hydrochloric acid (HCl) and gastric intrinsic factor into the stomach lumen.

**Solution:**

Let's evaluate the physiological processes dependent on parietal cell secretions:

- Acid Secretion (HCl):** Lowers gastric pH to kill ingested pathogens and cleave inactive pepsinogen into active pepsin. A lack of acid directly impairs pathogen destruction and protein digestion.
- Intrinsic Factor Secretion:** This glycoprotein binds to dietary Vitamin B<sub>12</sub>, protecting it through the digestive tract until it can be absorbed in the terminal ileum. A lack of intrinsic factor leads to pernicious anemia.
- Lipid Emulsification:** Lipid emulsification relies entirely on the secretion of bile salts from the liver and gallbladder into the duodenum, followed by digestion by pancreatic lipases. This process is independent of gastric parietal cell secretions.

**Final Answer:** Emulsification of dietary lipids by pancreatic lipases.

**Answer: (C)**

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Q17.

**Solution**

**Concept:** The oxygen-hemoglobin dissociation curve illustrates how hemoglobin binds and releases oxygen, shifting its affinity in response to changes in allosteric modifiers.

**Solution:**

Let's analyze the physiological adaptations that occur during high-altitude hypoxia:

- At high altitudes (e.g., 5000 meters), the atmospheric partial pressure of oxygen drops, causing arterial hypoxia.
- In response to this low oxygen state, red blood cells increase the synthesis of the allosteric effector 2,3-bisphosphoglycerate (2,3-BPG).
- Elevated 2,3-BPG binds selectively to deoxyhemoglobin, stabilizing its low-affinity T-state configuration. This shifts the oxygen-hemoglobin dissociation curve to the right, reducing hemoglobin's affinity for oxygen and promoting the release of oxygen to oxygen-deprived peripheral tissues.

**Final Answer:** Increased 2,3-BPG levels causing a rightward curve shift.

**Answer: (B)**

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Q18.

**Solution**

**Concept:** The kidneys concentrate urine using a countercurrent multiplier system, which depends on a high osmotic gradient established within the medullary interstitium.

**Solution:**

Let's evaluate the effect of blocking active transport in the loop of Henle:

- The thick ascending limb of the loop of Henle contains  $\text{Na}^+/\text{K}^+/\text{2Cl}^-$  cotransporters that actively pump sodium and chloride ions out of the tubular fluid and into the surrounding medullary interstitium. This segment is impermeable to water.
- This active solute transport is the primary engine that generates and maintains the hyperosmotic medullary interstitial gradient (ranging from 300 mOsm/L up to 1200 mOsm/L).
- If a drug blocks this active transport of sodium (similar to loop diuretics), the hyperosmotic medullary gradient is abolished. Without this high osmotic gradient, the collecting ducts cannot reabsorb water, resulting in the excretion of a large volume of highly dilute urine.

**Final Answer:** Interstitial gradient is abolished; urine becomes highly dilute.

**Answer: (B)**

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Q19.

**Solution**

**Concept:** An electrocardiogram (ECG) records the electrical activity of the heart over time, with distinct waves and segments corresponding to specific depolarization and repolarization events within the myocardium.

**Solution:**

Let's define the electrical events captured by the waves and segments:

- (a) **P Wave:** Reflects atrial depolarization.
- (b) **QRS Complex:** Reflects the rapid depolarization of the ventricles.
- (c) **ST Segment:** Connects the end of the QRS complex to the beginning of the T wave. It represents the period when the entire ventricular myocardium is completely depolarized, corresponding to the prolonged ventricular plateau phase of the cardiac action potential.
- (d) Therefore, a pathological elongation or disturbance of this ST segment directly points to an abnormal alteration in the duration of the ventricular plateau phase of repolarization.

**Final Answer:** Duration of the ventricular plateau phase of repolarization.

**Answer: (C)**

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Q20.

**Solution**

**Concept:** An action potential across an axolemma is characterized by a rapid sequence of voltage changes driven by the opening and closing of specific voltage-gated ion channels.

**Solution:**

Let's break down the sequential channel kinetics during an action potential:

- (a) **Depolarization Phase:** Triggered by a threshold stimulus that rapidly opens voltage-gated  $\text{Na}^+$  channels, causing a massive influx of  $\text{Na}^+$  ions into the axon.
- (b) **Repolarization Phase:** At the peak of the action potential, the voltage-gated  $\text{Na}^+$  channels undergo automatic inactivation (closure). Simultaneously, voltage-gated  $\text{K}^+$  channels open.
- (c) The opening of these voltage-gated  $\text{K}^+$  channels allows  $\text{K}^+$  ions to exit the cell rapidly, carrying positive charge out and restoring the negative resting membrane potential.

**Final Answer:** Closure of voltage-gated  $\text{Na}^+$  channels and opening of voltage-gated  $\text{K}^+$  channels.

**Answer: (B)**

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Q21.

**Solution**

**Concept:** Aldosterone is a mineralocorticoid hormone secreted by the adrenal cortex that acts on the principal cells of the renal distal convoluted tubules and collecting ducts to regulate blood volume and electrolyte balance.

**Solution:**

Let's analyze the effects of pathologically high aldosterone secretion (Conn's syndrome):

- (a) Aldosterone upregulates basolateral  $\text{Na}^+/\text{K}^+$  ATPase pumps and apical epithelial sodium channels (ENaC), driving significant reabsorption of sodium ions ( $\text{Na}^+$ ) from the urine back into the blood plasma. This retention of sodium causes excessive water reabsorption, expanding blood volume and leading to severe hypertension.
- (b) Simultaneously, aldosterone accelerates the secretion and excretion of potassium ions ( $\text{K}^+$ ) into the urine.
- (c) Consequently, a patient with an aldosterone-secreting tumor will display an electrolyte profile marked by elevated plasma sodium (hyponatremia), depleted plasma potassium (hypokalemia), and severe high blood pressure (hypertension).

**Final Answer:** Hyponatremia, Hypokalemia, and Severe Hypertension.

**Answer: (B)**

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Q22.

**Solution**

**Concept:** The sliding filament model details how structural rearrangements and cyclic cross-bridge formations between myosin heads and actin filaments drive skeletal muscle contraction.

**Solution:**

Let's trace the molecular steps of the cross-bridge cycle:

- (a) In the rigid post-power stroke state, the myosin head remains tightly bound to the active site on the actin filament.
- (b) To break this link, a fresh molecule of adenosine triphosphate (ATP) must bind directly to the nucleotide-binding pocket on the myosin head structure.
- (c) Binding of this new ATP alters the conformation of the myosin head, immediately lowering its affinity for actin and causing the cross-bridge to detach. Following detachment, myosin ATPase hydrolyzes the ATP to reset and cock the head for the next cycle.

**Final Answer:** Binding of a fresh molecule of ATP to the myosin head structure.

**Answer: (B)**

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Q23.

**Solution**

**Concept:** The juxtaglomerular apparatus (JGA) acts as an autocrine/endocrine monitoring structure in the kidney cortex, regulating blood pressure and the glomerular filtration rate (GFR).

**Solution:**

Let's trace the homeostatic cascade triggered by a drop in renal blood pressure:

- (a) A drop in glomerular hydrostatic pressure decreases the GFR and slows fluid flow through the nephron, reducing sodium chloride delivery to the macula densa cells.
- (b) This signal prompts the juxtaglomerular granular cells to release the proteolytic enzyme renin directly into the bloodstream.
- (c) Renin cleaves circulating angiotensinogen into angiotensin I, which is subsequently converted by angiotensin-converting enzyme (ACE) into angiotensin II. Angiotensin II triggers systemic vasoconstriction and stimulates aldosterone release to elevate blood pressure and restore GFR.

**Final Answer:** Release of Renin to convert angiotensinogen into angiotensin I.

**Answer: (B)**

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Q24.

**Solution**

**Concept:** Cerebrospinal fluid (CSF) is continually produced by the choroid plexuses within the brain ventricles, circulates through the subarachnoid space, and must be reabsorbed back into the systemic venous circulation.

**Solution:**

Let's evaluate the structural consequences of blocking CSF clearance:

- (a) The arachnoid villi (or granulations) act as specialized one-way valves that project through the dura mater into the superior sagittal sinus, serving as the sole pathway for reabsorbing CSF into venous blood.
- (b) If the function of these arachnoid villi is blocked, CSF production in the choroid plexus continues normally, but clearance is halted.
- (c) This imbalance leads to a rapid accumulation of CSF within the subarachnoid spaces and brain ventricles, causing a condition known as hydrocephalus that generates dangerous elevations in intracranial pressure.

**Final Answer:** Accumulation of CSF in the subarachnoid space causing elevated intracranial pressure.

**Answer: (B)**

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Q25.

**Solution**

**Concept:** The Haldane effect describes how changes in oxygen tension ( $PO_2$ ) alter hemoglobin's capacity to transport carbon dioxide ( $CO_2$ ).

**Solution:**

Let's examine the chemical basis of this respiratory mechanism:

- (a) In the capillaries of the lungs, high partial pressures of oxygen drive the binding of oxygen to hemoglobin, converting it into oxyhemoglobin.
- (b) Structurally, oxyhemoglobin acts as a stronger acid than deoxyhemoglobin because oxygen binding alters the conformation of the globin chains, reducing the  $pK_a$  of specific amino acid residues and causing them to release protons ( $H^+$ ).
- (c) These released protons combine with intracellular bicarbonate ions ( $HCO_3^-$ ) to form carbonic acid ( $H_2CO_3$ ), which carbonic anhydrase rapidly breaks down into water and gaseous  $CO_2$ . This shifts the equilibrium to promote the release and exhalation of carbon dioxide.

**Final Answer:**

Oxyhemoglobin is a stronger acid than deoxyhemoglobin, releasing protons that drive bicarbonate toward  $CO_2$  formation.

**Answer: (A)**

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Q26.

**Solution**

**Concept:** Phototransduction is the biochemical process through which retinal photoreceptor cells convert light signals into electrical signals, regulating neurotransmitter release into the visual pathway.

**Solution:**

Let's break down the molecular changes that occur when rod cells transition from dark to bright light:

- (a) In total darkness, rod cells maintain high levels of cyclic guanosine monophosphate (cGMP), which keeps cGMP-gated sodium channels open, allowing a continuous inward "dark current" of  $\text{Na}^+$  that keeps the cell depolarized.
- (b) Exposure to bright light causes photon absorption by rhodopsin, isomerizing 11-cis-retinal into all-trans-retinal and activating the G-protein transducin.
- (c) Active transducin stimulates the enzyme cGMP phosphodiesterase (PDE), which rapidly hydrolyzes and breaks down cytosolic cGMP.
- (d) The depletion of cGMP closes the cGMP-gated sodium channels, halting the dark current. This induces hyperpolarization of the rod cell membrane, reducing the release of the inhibitory neurotransmitter glutamate.

**Final Answer:**

Activation of transducin → Activation of phosphodiesterase → Breakdown of cGMP → Hyperpolarization.

**Answer: (B)**

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Q27.

**Solution**

**Concept:** Epithelial tissues are categorized anatomically based on the number of cell layers (simple vs. stratified) and the shape of the cells on their apical surface, with specialized structural modifications adapting them to specific organ functions.

**Solution:**

Let's decode the three epithelial categories using the provided table:

- (a) **Category X:** Formed by a single layer of cells with specialized apical microvilli (a brush border), located in the proximal convoluted tubules of the kidney cortex to maximize reabsorption. This configuration defines a simple cuboidal epithelium.
- (b) **Category Y:** Consists of multiple cell layers (stratified) that provide mechanical protection, located in high-friction surfaces like the epidermis of the skin and the esophageal lining. This defines a stratified squamous epithelium.
- (c) **Category Z:** Appears multi-layered due to varying nuclear heights but consists of a single layer of cells anchored to the basement membrane. It features motile cilia and is located in the upper respiratory tract to clear mucus. This defines a pseudostratified columnar epithelium.

**Final Answer:**

Simple Cuboidal Epithelium, Stratified Squamous Epithelium, Pseudostratified Columnar Epithelium

**Answer: (A)**[Go Back to Question 27](#)

Q28.

**Solution**

**Concept:** Hormones are categorized by their chemical structures, which dictate whether they act via cell-surface receptors or cross the plasma membrane to interact with intracellular receptors.

**Solution:**

Let's analyze the signaling mechanisms of the listed hormones:

- (a) **Lipophilic Hormones:** Steroids (such as cortisol and testosterone) and thyroid hormones (like thyroxine) are hydrophobic. They easily cross the lipid bilayer of the plasma membrane to bind to intracellular or nuclear receptors, regulating gene transcription directly without generating cyclic AMP (cAMP).
- (b) **Hydrophilic Hormones:** Epinephrine is an amino-acid-derived catecholamine hormone that cannot cross the hydrophobic core of the plasma membrane. Instead, it binds to membrane-bound G-protein coupled receptors ( $\beta$ -adrenergic receptors), activating adenylyl cyclase to convert ATP into the second messenger cAMP.

**Final Answer:** Epinephrine

**Answer: (B)**

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Q29.

**Solution**

**Concept:** Skeletal muscles contain specialized mechanoreceptors that monitor muscle length and tension, protecting the musculoskeletal system from damage during physical workloads.

**Solution:**

Let's differentiate the functions of these muscle sensory structures:

- (a) **Intrafusal Muscle Spindles:** Positioned parallel to extrafusal muscle fibers, these structures monitor changes in muscle \*length\* and velocity, mediating the stretch reflex to prevent over-stretching.
- (b) **Golgi Tendon Organs (GTOs):** Located at the junctions between muscles and tendons, these structures are arranged in series with muscle fibers to monitor muscle \*tension\* or force. When tension becomes excessively high and risks tearing the muscle or tendon, the GTO fires signals that inhibit motor neurons to that muscle, triggering relaxation.

**Final Answer:** Golgi tendon organs

**Answer: (B)**

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Q30.

**Solution**

**Concept:** Gene interactions can alter standard Mendelian dihybrid ratios when two or more independent genes control a single phenotypic trait.

**Solution:**

Let's analyze the allele dynamics behind a 9 : 7 phenotypic ratio in the F<sub>2</sub> generation:

- A standard dihybrid cross ( $AaBb \times AaBb$ ) yields 16 possible genetic combinations in a 9 : 3 : 3 : 1 ratio: 9  $A\_B\_$ , 3  $A\_bb$ , 3  $aaB\_$ , and 1  $aabb$ .
- In duplicate recessive epistasis (also known as complementary gene action), a homozygous recessive condition at \*either\* locus ( $bb$  or  $aa$ ) suppresses the expression of the dominant phenotype.
- Consequently, the groups containing homozygous recessive alleles ( $3 A\_bb + 3 aaB\_ + 1 aabb = 7$ ) produce the same mutant phenotype. Only individuals carrying at least one dominant allele at both loci ( $9 A\_B\_$ ) display the dominant phenotype, creating a classic 9 : 7 ratio.

**Final Answer:** Duplicate Recessive Epistasis (Complementary Gene Action)

**Answer: (C)**

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Q31.

**Solution**

**Concept:** The high replication fidelity of \*Escherichia coli\* DNA Polymerase III relies on its ability to identify and excise mismatched nucleotides immediately after their insertion.

**Solution:**

Let's isolate the specific enzymatic direction of this proofreading activity:

- DNA Polymerase III synthesizes a new DNA strand in the  $5' \rightarrow 3'$  direction by adding deoxyribonucleoside triphosphates to the  $3'$ -OH end of the growing chain.
- If an incorrect, mismatched base is accidentally incorporated, the polymerase pauses, and the newly synthesized  $3'$  end shifts into the proofreading exonuclease active site of the enzyme's  $\epsilon$  (epsilon) subunit.
- This domain cleaves the mismatched base from the  $3'$  terminus moving backward, a catalytic process termed  $3' \rightarrow 5'$  exonuclease proofreading activity. Once the error is removed,  $5' \rightarrow 3'$  synthesis resumes.

**Final Answer:**  $3' \rightarrow 5'$  exonuclease activity

**Answer: (B)**

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Q32.

**Solution**

**Concept:** Eukaryotic transcription initiation requires the sequential assembly of general transcription factors (GTFs) along with RNA Polymerase II at the core promoter to form the pre-initiation complex (PIC).

**Solution:**

Let's identify the functional roles of the listed transcription factors:

- (a) **TFIID:** Binds directly to the TATA box via its TATA-binding protein (TBP) subunit to initiate PIC assembly.
- (b) **TFIIB & TFIIF:** Recruit RNA Polymerase II and help position it accurately over the transcription start site.
- (c) **TFIIH:** A multi-subunit complex that acts as the final factor recruited to the PIC. It contains two subunits with ATP-dependent helicase catalytic activity (XPB and XPD) that unwind the double-stranded promoter DNA near the start site, opening a transcription bubble to allow transcription to begin.

**Final Answer:**

**Answer:** (C)

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Q33.

**Solution**

**Concept:** Pedigree analysis evaluates the phenotypic distribution of a trait across generations to determine its underlying mode of inheritance.

**Solution:**

Let's analyze the inheritance pattern shown in the pedigree chart:

- (a) Look at the affected individual in Generation I: the mother (I-2) expresses the trait, while the father (I-1) does not.
- (b) In Generation II, notice the phenotypes of the offspring: all children inherited the trait directly from their mother, regardless of biological sex. The daughter (II-2) and the son (II-3) are both affected.
- (c) This uniform transmission from an affected mother to all of her offspring is a hallmark of non-Mendelian maternal/mitochondrial inheritance. Because the zygote inherits its cytoplasm and mitochondria almost exclusively from the egg cell, mitochondrial traits are passed from mothers to all offspring, while affected fathers cannot transmit the trait.

**Final Answer:**

**Answer:** (C)

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Q34.

**Solution**

**Concept:** The genetic code is read non-overlappingly in triplets of nucleotides known as codons during translation by the ribosome.

**Solution:**

Let's evaluate the structural impact of inserting a single nucleotide base into an mRNA reading frame:

- (a) The ribosome reads the mRNA sequence sequentially three bases at a time.
- (b) Inserting or deleting a single nucleotide base (a number not divisible by three) disrupts this triplet reading frame.
- (c) This disruption triggers a frameshift mutation, completely altering the codon composition downstream from the point of insertion. As a result, an entirely different sequence of amino acids is incorporated into the growing polypeptide chain, often leading to a premature stop codon and a non-functional protein.

**Final Answer:** Frame-shift mutation completely altering all downstream codons.

**Answer: (B)**

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Q35.

**Solution**

**Concept:** The tryptophan (\*trp\*) operon of \*E. coli\* uses attenuation as a secondary regulatory mechanism, relying on the structural dynamics of a leader mRNA sequence containing four distinct regions capable of forming alternative stem-loop hairpins.

**Solution:**

Let's analyze the structural folding under high tryptophan conditions:

- (a) The leader sequence contains a small open reading frame encoding a leader peptide that includes two adjacent tryptophan codons, translated by a ribosome concurrently with ongoing transcription by RNA polymerase.
- (b) When cytosolic levels of charged tRNA-Trp are high, the translating ribosome moves quickly past the tryptophan codons, covering region 1 and stalling briefly at the stop codon in region 2.
- (c) Because the ribosome covers region 2, region 2 cannot pair with region 3. This leaves region 3 free to pair with region 4, forming a stable 3-4 stem-loop structure. This 3-4 structure acts as a Rho-independent terminator, causing RNA polymerase to dissociate and prematurely terminating transcription before the structural genes can be transcribed.

**Final Answer:**

Formation of the 3-4 terminator stem-loop structure causing premature transcription termination.

**Answer: (B)**

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Q36.

**Solution**

**Concept:** Chargaff's rules state that in any double-stranded DNA molecule, the total abundance of purines equals the total abundance of pyrimidines. Specifically, the molar ratio of Adenine (A) equals Thymine (T), and the molar ratio of Guanine (G) equals Cytosine (C).

**Solution:**

Let's calculate the exact percentage of Cytosine step by step:

- (a) According to Chargaff's rules, the percentage of Adenine is equal to the percentage of Thymine:

$$A = T = 34\%$$

- (b) Summing the percentages of Adenine and Thymine gives:

$$A + T = 34\% + 34\% = 68\%$$

- (c) The remaining percentage of the genome must consist of Guanine and Cytosine bases:

$$G + C = 100\% - 68\% = 32\%$$

- (d) Since the amount of Guanine is equal to the amount of Cytosine ( $G = C$ ), we divide this remainder equally by two:

$$C = \frac{32\%}{2} = 16\%$$

**Final Answer:**

**Answer:** (C)

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Q37.

**Solution**

**Concept:** The structural organization of eukaryotic chromatin is regulated dynamically by post-translational modifications (PTMs) occurring on the amino-terminal tails of core histone proteins. These modifications alter the interaction between histones and DNA, dictating whether chromatin transitions into a tightly packed, inactive state (heterochromatin) or an open, transcriptionally active state (euchromatin).

**Solution:**

Let's analyze the physiological outcomes of the listed histone modifications:

- (a) **Histone Acetylation:** Catalyzed by Histone Acetyltransferases (HATs), this process attaches negatively charged acetyl groups to highly conserved lysine residues on histone tails. This modification neutralizes the positive charges on the histones, disrupting their electrostatic attraction to the negatively charged DNA backbone. The resulting structural relaxation unwinds the nucleosomes, transforming dense chromatin into accessible euchromatin, which allows transcription factors and RNA polymerase to bind and initiate gene expression.
- (b) **Histone Deacetylation:** Catalyzed by Histone Deacetylases (HDACs), this removes acetyl groups, restoring the positive charges on histones and promoting tight chromatin condensation into transcriptionally silent heterochromatin.
- (c) **H3K9 Methylation:** Generally recruits heterochromatin protein 1 (HP1), promoting chromatin compaction and gene silencing.

**Final Answer:** Acetylation of core histone amino-terminal tails by HATs

**Answer: (B)**

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Q38.

**Solution**

**Concept:** The landmark Meselson-Stahl experiment definitively demonstrated that DNA replication in living cells follows a semi-conservative mechanism, meaning that each newly synthesized double helix preserves one intact parental template strand paired with one newly synthesized daughter strand.

**Solution:**

Let's track the molecular distribution of isotopes across generations starting from heavy parental DNA ( $^{15}\text{N}/^{15}\text{N}$ ):

- (a) **Generation 0:** The initial population contains exclusively heavy double-stranded DNA molecules ( $^{15}\text{N}/^{15}\text{N}$ ).
- (b) **Generation 1 (1st Cycle in Light Media):** The two heavy strands separate to serve as templates. Synthesis incorporates light isotope ( $^{14}\text{N}$ ) nucleotides, resulting in 100% intermediate hybrid DNA molecules ( $^{14}\text{N}/^{15}\text{N}$ ).
- (c) **Generation 2 (2nd Cycle in Light Media):** The hybrid molecules separate, yielding two heavy strands and two light strands to serve as templates. Synthesis in light media ( $^{14}\text{N}$ ) produces a total of four double-stranded molecules: two completely light molecules ( $^{14}\text{N}/^{14}\text{N}$ ) and two hybrid molecules ( $^{14}\text{N}/^{15}\text{N}$ ).
- (d) This produces an absolute ratio of 2 Light : 2 Hybrid, which simplifies to a precise 1 : 1 molecular ratio.

**Final Answer:**

**Answer:** (A)

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Q39.

**Solution**

**Concept:** Huntington's disease is a progressive, autosomal dominant neurodegenerative disorder belonging to a group of genetic conditions caused by dynamic trinucleotide repeat expansion mutations within a specific coding exon.

**Solution:**

Let's identify the specific triplet expansion and its translation product:

- (a) The molecular basis of Huntington's disease is the abnormal, unstable expansion of a tandemly repeated **CAG** trinucleotide sequence located within exon 1 of the \*huntingtin\* (\*HTT\*) gene on chromosome 4.
- (b) The triplet codon 5'-CAG-3' directs the translation machinery to incorporate the amino acid glutamine.
- (c) Consequently, this nucleotide repeat expansion results in a pathologically elongated polyglutamine (polyQ) tract within the mutant huntingtin protein. This alteration causes protein misfolding, accumulation of toxic intracellular aggregates, and targeted neurodegeneration in the striatum and cerebral cortex.

**Final Answer:** CAG tract encoding Poly-Glutamine

**Answer: (B)**

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Q40.

**Solution**

**Concept:** Nascent pre-mRNA transcripts produced by RNA Polymerase II must undergo three major co-transcriptional processing modifications: 5' capping, splicing, and 3' polyadenylation. The 5' capping event occurs shortly after transcription initiation to protect the transcript from exonucleolytic degradation and facilitate nuclear export and translation.

**Solution:**

Let's analyze the chemical configuration of the 5' cap structure:

- (a) The capping enzyme complex removes the  $\gamma$ -phosphate from the 5' end of the nascent pre-mRNA chain.
- (b) Next, it transfers a guanylyl residue from a GTP molecule, creating a unique linkage between the 5' carbon of the modified guanosine and the 5' carbon of the initial nucleotide of the pre-mRNA transcript.
- (c) This results in an atypical 5'  $\rightarrow$  5' triphosphate linkage. This unconventional bond cannot be recognized or hydrolyzed by standard cellular 5' exoribonucleases, providing vital chemical protection to the transcript. Subsequently, methyltransferase enzymes add a methyl group to position 7 of the guanine base to form a functional mature 7-methylguanosine ( $m^7G$ ) cap.

**Final Answer:** 5'  $\rightarrow$  5' triphosphate linkage

**Answer: (B)**

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Q41.

**Solution**

**Concept:** Transposable elements (transposons) are mobile genetic sequences that move to different positions within a host genome. They are broadly categorized into two major classes based on their distinct transposition intermediate structures and catalytic mechanisms.

**Solution:**

Let's compare the operational mechanisms of both classes:

- (a) **Class II Transposons (DNA Transposons):** Move directly via a physical "cut-and-paste" mechanism. The encoded transposase enzyme binds to inverted terminal repeats, cleaves the element out of its original locus, and inserts it into a new target site without creating an RNA intermediate.
- (b) **Class I Transposons (Retrotransposons):** Move via a "copy-and-paste" mechanism. The DNA element is first transcribed into a single-stranded RNA intermediate. This RNA transcript is then reverse-transcribed back into a complementary DNA (cDNA) molecule by an element-encoded reverse transcriptase enzyme, and this new copy is integrated elsewhere in the genome, leaving the original sequence intact.

**Final Answer:** Retrotransposons duplicate via a "copy-and-paste" mechanism using an RNA intermediate.

**Answer: (C)**

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Q42.

**Solution**

**Concept:** Lysosomes serve as the primary hydrolytic degradation compartments within eukaryotic cells, containing acidic hydrolase enzymes that require a low internal pH environment (pH ~ 4.5 to 5.0) to operate optimally.

**Solution:**

Let's isolate the molecular mechanism responsible for maintaining this proton gradient:

- (a) To maintain an internal proton concentration up to 100 times higher than that of the neutral cytosol, the lysosomal membrane contains specialized electrogenic transport proteins.
- (b) This protein is a vacuolar-type  $H^+$ -ATPase (V-type proton pump).
- (c) The V-type pump uses the chemical energy derived from ATP hydrolysis to actively translocate protons ( $H^+$ ) across the membrane against their steep electrochemical gradient into the lysosomal lumen, maintaining the acidic environment needed for continuous macromolecular degradation.

**Final Answer:** V-type  $H^+$ -ATPase proton pump powered by ATP hydrolysis

**Answer: (B)**

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Q43.

**Solution**

**Concept:** The key molecular checkpoint regulating entry from the G<sub>2</sub> phase into the mitotic M phase of the cell cycle is the activation of the maturation-promoting factor (MPF), a heterodimeric complex composed of Cyclin-Dependent Kinase 1 (CDK1) and Cyclin B.

**Solution:**

Let's trace the precise regulatory phosphorylation events that control CDK1 activation:

- (a) As Cyclin B accumulates, it binds to CDK1. To prevent premature activation during G<sub>2</sub>, the protein kinase Wee1 phosphorylates CDK1 at two inhibitory residues: Threonine-14 (Thr14) and Tyrosine-15 (Tyr15).
- (b) Concurrently, the CDK-activating kinase (CAK) phosphorylates CDK1 at an essential activating site, Threonine-161 (Thr161). However, the complex remains inactive as long as the inhibitory phosphate groups are present.
- (c) Entry into mitosis is triggered when the Cdc25 phosphatase removes the inhibitory phosphate groups from the Thr14 and Tyr15 positions. This dephosphorylation, paired with the activating phosphorylation at Thr161, induces a structural shift that activates the CDK1-Cyclin B complex, driving the cell into mitosis.

**Final Answer:** Dephosphorylation at Thr14 and Tyr15 paired with phosphorylation at Thr161.

**Answer: (B)**

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Q44.

**Solution**

**Concept:** Prophase I of Meiosis I is a prolonged, structurally complex stage where homologous chromosomes pair, undergo genetic recombination, and begin to segregate. It is divided into five distinct sub-stages: leptotene, zygotene, pachytene, diplotene, and diakinesis.

**Solution:**

Let's review the physical events that characterize each sub-stage:

- (a) **Leptotene:** Chromatin threads condense into visible chromosomes.
- (b) **Zygotene:** Synaptonemal complexes assemble to pair homologous chromosomes (synapsis).
- (c) **Pachytene:** Homologous strands align tightly, and crossing over takes place between non-sister chromatids.
- (d) **Diplotene:** Recombination concludes, and the synaptonemal complex degrades, allowing homologous chromosomes to separate slightly. This separation is resisted at sites where crossing over occurred, revealing characteristic X-shaped intersection points known as chiasmata. These chiasmata structures remain clearly visible as pull forces are exerted between the homologues.

**Final Answer:**

**Answer:** (C)

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Q45.

**Solution**

**Concept:** Biological membranes must maintain a fluid state to function properly. Cholesterol acts as a bidirectional membrane fluidity buffer, modulating physical state changes across varying temperature extremes.

**Solution:**

Let's analyze the physical effects of high cholesterol concentrations at elevated ambient temperatures:

- (a) At low temperatures, cholesterol prevents phospholipids from packing tightly together, interfering with crystallization and maintaining membrane fluidity.
- (b) At high ambient temperatures, the increased thermal energy causes phospholipids to move rapidly, which can destabilize the bilayer and make it excessively fluid or leaky.
- (c) Under these high-temperature conditions, the rigid steroid ring structure of cholesterol inserts between the fatty acid tails of neighboring phospholipids. This structural arrangement restricts their lateral movement and rotation, decreasing membrane fluidity and stabilizing the core bilayer structure.

**Final Answer:**

Stabilizes the membrane and decreases fluidity by restricting phospholipid lateral movement.

**Answer: (B)**[Go Back to Question 45](#)

Q46.

**Solution**

**Concept:** Eukaryotic cells contain specialized membrane-bound organelles that partition biochemical pathways to optimize metabolic efficiency.

**Solution:**

Let's isolate the primary metabolic functions of the listed organelles:

- (a) **Rough Endoplasmic Reticulum (RER):** Primarily responsible for the synthesis, folding, and post-translational modification of membrane-bound, lysosomal, and secreted proteins.
- (b) **Smooth Endoplasmic Reticulum (SER):** Lacks attached ribosomes and serves as the primary site for lipid metabolism, including the synthesis of membrane phospholipids, fatty acids, and steroid hormones from cholesterol. Additionally, the SER contains the cytochrome P450 enzyme superfamily, which catalyzes reactions to detoxify hydrophobic drugs and xenobiotic compounds.
- (c) **Peroxisomes:** Specialized for long-chain fatty acid  $\beta$ -oxidation and the neutralization of hydrogen peroxide via catalase.

**Final Answer:** Smooth Endoplasmic Reticulum

**Answer: (B)**

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Q47.

**Solution**

**Concept:** Nuclear-encoded mitochondrial matrix proteins are synthesized on cytosolic ribosomes and must be actively imported post-translationally across the outer and inner mitochondrial membranes via specialized TOM and TIM translocase complexes. This selective targeting is directed by an N-terminal signal sequence (or presequence).

**Solution:**

Let's evaluate the structural features of this signal peptide:

- (a) The mitochondrial matrix targeting signal is situated at the amino (N) terminus of the newly synthesized polypeptide chain and typically spans 15 to 50 amino acid residues.
- (b) This sequence lacks a continuous stretch of purely hydrophobic residues; instead, it is enriched with positively charged basic amino acids (such as arginine and lysine) and hydroxylated residues (such as serine and threonine).
- (c) Structurally, this signal peptide folds into an amphipathic  $\alpha$ -helix. In this conformation, the positively charged residues cluster on one face of the helix, while uncharged hydrophobic residues align on the opposite face. This specific amphipathic arrangement is recognized by import receptors on the outer mitochondrial membrane.

**Final Answer:** Amphipathic alpha-helix containing positively charged residues clustered on one side.

**Answer: (B)**

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Q48.

**Solution**

**Concept:** Polysaccharides are large carbohydrate polymers constructed from repeating monosaccharide units linked by glycosidic bonds. The stereochemical orientation ( $\alpha$  vs.  $\beta$ ) of these glycosidic linkages determines the three-dimensional geometry and biological properties of the macromolecule.

**Solution:**

Let's analyze the glycosidic linkages shown in the schematic:

- The diagram depicts hexose sugar rings joined via a  $\beta(1 \rightarrow 4)$  glycosidic bond, where the oxygen atom bridging the C1 carbon of one glucose unit sits above the plane of the ring relative to the C4 carbon of the adjacent unit.
- This structural configuration is the repeating arrangement of **cellulose**, a linear homopolymer of D-glucose that aggregates into high-tensile-strength microfibrils to form plant cell walls.
- Human digestive enzymes, such as salivary and pancreatic  $\alpha$ -amylase, are stereospecific for  $\alpha(1 \rightarrow 4)$  glycosidic linkages (found in amylose and glycogen). They cannot bind or hydrolyze the rigid  $\beta(1 \rightarrow 4)$  linkages of cellulose, making it indigestible as dietary fiber.

**Final Answer:** Cellulose microfibrils

**Answer: (B)**

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Q49.

**Solution**

**Concept:** The intrinsic (mitochondrial) apoptotic pathway is triggered by cellular stress signals that alter the permeability of the outer mitochondrial membrane, causing the release of pro-apoptotic proteins into the cytosol.

**Solution:**

Let's trace the molecular interactions that form the apoptosome:

- (a) Pro-apoptotic proteins like Bax and Bak form channels in the outer mitochondrial membrane, allowing cytochrome \*c\* to escape from the intermembrane space into the cytosol.
- (b) Once in the cytosol, cytochrome \*c\* binds directly to the adaptor protein **Apoptotic Protease Activating Factor-1 (Apaf-1)**.
- (c) This binding triggers an ATP-dependent conformational change that causes Apaf-1 to oligomerize into a wheel-like heptameric structure known as the **apoptosome**. The apoptosome then recruits and activates the initiator caspase, procaspase-9, which downstream activates executioner caspases like caspase-3 to complete apoptosis.

**Final Answer:** Apoptotic Protease Activating Factor-1 (Apaf-1)

**Answer: (B)**

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Q50.

**Solution**

**Concept:** Nucleocytoplasmic transport through the nuclear pore complex (NPC) is highly regulated. Small molecules can pass through the NPC via passive diffusion, whereas larger macromolecular cargoes (exceeding ~ 40 kDa) require active, receptor-mediated transport driven by a Ran-GTPase concentration gradient.

**Solution:**

Let's break down the active nuclear import pathway:

- (a) Proteins destined for the nucleus display a specific amino acid sequence known as a Nuclear Localization Signal (NLS).
- (b) This NLS is recognized in the cytoplasm by a soluble heterodimeric receptor complex called the **importin  $\alpha/\beta$  heterodimer**.
- (c) Within this complex, the importin  $\alpha$  subunit acts as an adaptor that binds directly to the cargo's NLS, while the importin  $\beta$  subunit interacts with the phenylalanine-glycine (FG) repeats lining the nuclear pore channel, facilitating transport across the NPC into the nucleoplasm.

**Final Answer:**

**Answer: (B)**

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Q51.

**Solution**

**Concept:** The extracellular matrix (ECM) of animal tissues contains a dense network of fibrous proteins and glycosaminoglycans that provide mechanical support and mediate cellular signaling.

**Solution:**

Let's match the structural description with the correct ECM protein:

- (a) The description highlights a structural protein with a triple-helix conformation composed of three intertwined polypeptide chains ( $\alpha$ -chains).
- (b) Biochemically, this protein features a repeating amino acid motif,  $(\text{Gly-X-Y})_n$ , where glycine is required at every third position to allow the tight packing of the triple helix. The X and Y positions are frequently occupied by proline and hydroxyproline residues, which stabilize the helical structure.
- (c) This specific triple-helical, hydroxyproline-rich organization is the defining structural hallmark of **collagen** matrix elements, the most abundant structural protein family in the animal extracellular matrix.

**Final Answer:**

**Answer: (C)**

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Q52.

**Solution**

**Concept:** Ecosystem energy flow is governed by Lindeman's ten percent law of trophic efficiency, which states that during the transfer of organic energy from one trophic level to the next, approximately 90% of the energy is lost as metabolic heat, respiration, and waste. Consequently, only about 10% of the net energy is fixed into biomass and made available to the next consumer level.

**Solution:**

Let's calculate the available energy sequentially across trophic levels starting from the primary producers:

(a) **Trophic Level 1 (Primary Producers):** Fixed energy content = 10,000 Joules.

(b) **Trophic Level 2 (Primary Consumers / Herbivores):** Receives 10% of producer energy:

$$\text{Energy} = 10,000 \times 0.10 = 1,000 \text{ Joules}$$

(c) **Trophic Level 3 (Secondary Consumers / Carnivores):** Receives 10% of herbivore energy:

$$\text{Energy} = 1,000 \times 0.10 = 100 \text{ Joules}$$

(d) **Trophic Level 4 (Tertiary Consumers / Apex Predators):** Receives 10% of secondary consumer energy:

$$\text{Energy} = 100 \times 0.10 = 1 \text{ Joule}$$

**Final Answer:** 1 Joule

**Answer: (D)**

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Q53.

**Solution**

**Concept:** Gause's competitive exclusion principle states that two distinct species competing for the exact same limiting resource cannot coexist indefinitely in a stable environment; the more efficient competitor will eventually drive the other to local extinction.

**Solution:**

Let's identify the ecological mechanism that enables coexistence:

- (a) In natural ecosystems, species with overlapping resource needs often avoid direct competition and achieve stable coexistence through evolutionary adaptations.
- (b) This is accomplished via **resource partitioning** and niche differentiation, where natural selection drives species to utilize different parts of a resource, distinct food items, or different microhabitats.
- (c) By shifting their ecological niches (e.g., foraging at different heights in a canopy or feeding at different times of day), species reduce the intensity of competition, allowing them to coexist within the same habitat.

**Final Answer:** Resource partitioning and niche differentiation

**Answer: (B)**

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Q54.

**Solution**

**Concept:** Survivorship curves graphically display the number of individuals within a cohort that survive at different ages across their maximum lifespan potential. They are classified into three major categories based on the timing of mortality.

**Solution:**

Let's analyze the three types of survivorship strategies:

- (a) **Type I Curve:** Characterized by low initial mortality, high juvenile survival, and a sharp increase in mortality later in life (typical of large mammals like humans and elephants).
- (b) **Type II Curve:** Displays a constant mortality rate throughout the organism's lifespan, appearing as a straight line with a constant negative slope (typical of passerine songbirds and hydras).
- (c) **Type III Curve:** Characterized by a steep initial drop, indicating extremely high juvenile mortality. However, the individuals that survive this early bottleneck exhibit high survival rates later in life. This r-selection strategy is characteristic of marine pelagic fish, oysters, and many invertebrates that produce thousands of offspring but provide little to no parental care.

**Final Answer:** Marine pelagic fish and oysters

**Answer: (B)**

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Q55.

**Solution**

**Concept:** The MacArthur-Wilson equilibrium model of island biogeography predicts species richness on an island based on a dynamic equilibrium balance between two physical rates: the rate of new species immigration and the rate of established species extinction.

**Solution:**

Let's analyze how island size and isolation affect these rates:

- (a) **Immigration Rate:** Highly dependent on the island's isolation. Islands located **close to the mainland** exhibit significantly higher immigration rates because they are easier for dispersing organisms to locate and reach.
- (b) **Extinction Rate:** Highly dependent on the island's size. **Large islands** support larger total population sizes, which reduces the probability of random extinctions. They also provide greater habitat diversity and more resources.
- (c) Therefore, an island that is both **large** and **close** to the mainland will experience high immigration and low extinction rates, supporting the highest equilibrium number of species at steady state.

**Final Answer:** Large islands located close to the mainland continent.

**Answer: (B)**

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Q56.

**Solution**

**Concept:** The introduction of untreated organic sewage into an aquatic ecosystem disrupts its chemical and biological balance. This impact can be tracked by measuring the opposing kinetic relationship between dissolved oxygen (DO) and biochemical oxygen demand (BOD).

**Solution:**

Let's analyze the chemical trends that follow an organic sewage discharge:

- (a) Untreated organic sewage provides a massive influx of biodegradable organic matter into the river water.
- (b) This abundance of nutrients triggers exponential growth of aerobic decomposers, such as heterotrophic bacteria. This rapid increase in bacterial respiration consumes oxygen at an accelerated rate, causing the **Biochemical Oxygen Demand (BOD)** to surge upward.
- (c) Because the decomposers consume oxygen faster than it can dissolve into the water from the atmosphere or via photosynthesis, the level of **Dissolved Oxygen (DO)** drops precipitously, creating an "oxygen sag curve" that can lead to widespread hypoxia in aquatic organisms.

**Final Answer:** DO drops precipitously while BOD values surge upwards.

**Answer: (C)**

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Q57.

**Solution**

**Concept:** Ecological succession describes the predictable, sequential shifts in species composition over time within an ecological community. Primary succession begins on newly exposed, barren terrains (such as volcanic flows) that lack organic soil.

**Solution:**

Let's evaluate the life-history traits of a pioneer species colonizing a barren environment:

- (a) Pioneer species are classic opportunistic r-strategists adapted to exploit open, unstable habitats with minimal competition.
- (b) These species allocate a high proportion of their energy budget toward reproduction rather than growth or competitive structures.
- (c) Consequently, they possess life-history traits such as small seed size (produced in vast quantities), rapid growth and development, early sexual maturity, and highly efficient, long-distance wind or water dispersal mechanisms to effectively colonize distant, open terrains.

**Final Answer:**

Small seed size, rapid development, early reproduction, and wide dispersal capacity.

**Answer: (B)**

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Q58.

**Solution**

**Concept:** Biomagnification (or bioamplification) describes the process by which persistent, lipophilic, non-biodegradable toxins (such as DDT or heavy metals) increase in concentration inside tissue layers at progressively higher levels of a food chain.

**Solution:**

Let's trace the toxin concentration across the ecosystem nodes:

- (a) When a chemical like DDT enters an aquatic habitat, it is absorbed at low baseline levels by primary producers at the base of the food web (the \*Phyto\* node).
- (b) Because the toxin is fat-soluble and resistant to metabolic breakdown, it accumulates within the organisms' tissues over time (bioaccumulation).
- (c) As primary consumers (\*Zoo\*) consume large quantities of phytoplankton, they ingest and store the accumulated toxins. This concentration increases at each successive step up the food chain (from \*Phyto\* → \*Zoo\* → \*Fish\* → \*Apex\*).
- (d) Consequently, the top predator at the highest trophic level (the \*Apex\* consumer node) will exhibit the highest concentration of the toxin in its tissues.

**Final Answer:**

**Answer: (D)**

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Q59.

**Solution**

**Concept:** Ecologists quantify community biodiversity using index equations that evaluate different aspects of species distribution rather than counting absolute population sizes alone.

**Solution:**

Let's look at the mathematical components of the Shannon-Wiener Index ( $H'$ ):

- (a) The mathematical expression for the Shannon-Wiener Index is:

$$H' = - \sum_{i=1}^S p_i \ln p_i$$

- (b) Inside this equation, the variable  $S$  represents **species richness**, which is the total count of distinct species present within the sampled community.
- (c) The variable  $p_i$  represents the proportion of individuals belonging to the  $i^{\text{th}}$  species relative to the total number of individuals ( $n/N$ ). This accounts for **species evenness**, which measures the equitability or relative abundance of each species' population distribution. A community where species have similar abundances has a higher evenness and a higher overall  $H'$  value.

**Final Answer:** Species richness and species evenness (relative abundance).

**Answer: (B)**

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Q60.

**Solution**

**Concept:** Global environmental treaties are international agreements designed to coordinate regulatory efforts to mitigate anthropogenic damage to the biosphere.

**Solution:**

Let's identify the core objective of the listed international treaties:

- (a) **Kyoto Protocol:** Focuses on reducing greenhouse gas emissions to mitigate anthropogenic climate change.
- (b) **Montreal Protocol (1987):** A highly successful global treaty explicitly designed to protect the stratospheric ozone layer. It regulates the global production and industrial consumption of ozone-depleting substances (ODS), establishing a phased reduction and complete ban on compounds like chlorofluorocarbons (CFCs) and halons.
- (c) **Nagoya & Cartagena Protocols:** Sub-agreements under the Convention on Biological Diversity focusing on genetic resources and biosafety, respectively.

**Final Answer:**

**Answer: (B)**

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Q61.

**Solution**

**Concept:** The five-kingdom system of biological classification (Monera, Protista, Fungi, Plantae, and Animalia) group organisms based on structural properties, cellular organization, and their primary mode of nutrition.

**Solution:**

Let's analyze the criteria used to separate Kingdom Fungi from Kingdom Plantae:

- (a) Historically, fungi were grouped with plants because both possess rigid cell walls and are non-motile.
- (b) However, Whittaker separated them based on fundamental differences in their cellular chemistry and nutrition. Plants are autotrophic organisms that synthesize sugars via photosynthesis using cellulose-based cell walls.
- (c) In contrast, fungi are completely achlorophyllous and heterotrophic. They obtain nutrients via an absorptive mode of nutrition, secreting extracellular digestive enzymes to break down organic matter before absorbing it. Additionally, their cell walls are composed of chitin rather than cellulose.

**Final Answer:** Cell wall composition (chitin vs. cellulose) and heterotrophic absorptive mode of nutrition.

**Answer: (B)**

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Q62.

**Solution**

**Concept:** Taxonomic families within the angiosperms are classified based on specific combinations of vegetative, floral, and reproductive characters.

**Solution:**

Let's identify the definitive floral characters of the family Solanaceae (the nightshade family):

- (a) Flowers are typically radially symmetrical (**actinomorphic**) and bisexual.
- (b) The androecium features five stamens that are **epipetalous**, meaning the filaments are fused directly to the inner surface of the corolla petals.
- (c) The definitive anatomical trait of this family lies in the gynoecium: a bicarpellary, syncarpous superior ovary characterized by an **obliquely placed** septum and a noticeably **\*\*swollen placenta\*\*** bearing numerous ovules arranged via axile placentation.

**Final Answer:** Actinomorphic symmetry, epipetalous stamens, and an obliquely placed ovary with swollen placenta.

**Answer: (B)**

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Q63.

**Solution**

**Concept:** Archaeobacteria are distinct from Eubacteria and Eukaryotes, possessing specialized molecular adaptations that allow them to thrive in extreme environments such as hydrothermal vents, hypersaline lakes, and highly acidic hot springs.

**Solution:**

Let's analyze the molecular structure of the archaeobacterial plasma membrane:

- (a) Unlike eubacterial and eukaryotic membranes, which consist of straight-chain fatty acids linked to glycerol via ester bonds, archaeobacterial membranes contain long, **branched-chain hydrocarbons** (isoprenoids).
- (b) These branched hydrocarbon chains are linked to glycerol molecules by highly stable **ether linkages**. Ether bonds are significantly more resistant to chemical cleavage and thermal hydrolysis than ester bonds.
- (c) In many hyperthermophilic archaeobacteria, these lipid tails fuse to form a continuous lipid **monolayer**. This monolayer configuration prevents the membrane from melting or separating at extreme temperatures exceeding 100°C, maintaining its structural integrity.

**Final Answer:**

Branched-chain hydrocarbons linked to glycerol by chemically stable ether linkages forming a monolayer.

**Answer: (B)**

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Q64.

**Solution**

**Concept:** A floral formula is a standardized shorthand notation that summarizes the structural arrangement, symmetry, and numerical distribution of organs within a flower.

**Solution:**

Let's decode the provided floral formula step by step:

- (a)  $\oplus$ : Represents a radially symmetrical (**actinomorphic**) flower.
- (b)  $\phi$ : Indicates a bisexual (hermaphrodite) flower structure.
- (c)  $K_{2+2}$ : The calyx consists of four sepals arranged in two distinct concentric rings of two (2 + 2).
- (d)  $C_4$ : The corolla contains four distinct petals arranged diagonally in the shape of a cross (cruciform corolla).
- (e)  $A_{2+4}$ : The androecium contains six stamens in a **tetradynamous** arrangement: two shorter outer stamens and four longer inner stamens (2 + 4).
- (f)  $G_{(2)}$ : The gynoecium features a bicarpellary, syncarpous (fused) superior ovary.
- (g) This specific structural combination (cruciform petals and tetradynamous stamens) is the definitive identifier for the **Brassicaceae** (Cruciferae or mustard) family.

**Final Answer:** Family Brassicaceae (Cruciferae)

**Answer: (B)**

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Q65.

**Solution**

**Concept:** The evolutionary history of the plant kingdom records major structural adaptations as lineages transitioned from aquatic environments onto land, optimizing survival and reproductive efficiency.

**Solution:**

Let's evaluate the primary transition between bryophytes and pteridophytes:

- (a) **Bryophytes (Mosses/Liverworts):** Characterized by a dominant, independent haploid gametophyte phase. Their sporophyte generation is physically dependent on the gametophyte, and they lack true vascular tissues (xylem and phloem) to transport water and nutrients.
- (b) **Pteridophytes (Ferns):** Mark a major evolutionary milestone by establishing a dominant, independent diploid **sporophyte phase** in their life cycle.
- (c) Concurrently, pteridophytes evolved **true vascular tissues** (conducting elements), allowing them to grow larger and adapt more effectively to terrestrial environments compared to non-vascular bryophytes.

**Final Answer:**

Transition from a dominant gametophyte phase to a dominant sporophyte phase with true vascular tissues.

**Answer: (B)**[Go Back to Question 65](#)

Q66.

**Solution**

**Concept:** Animal phyla are classified based on body symmetry, embryonic tissue layers, coelom configurations, and unique physiological organ systems.

**Solution:**

Let's evaluate the structural features of the isolated organism:

- (a) The organism displays bilateral symmetry during its free-swimming larval stage but develops radial pentamerous (five-part) symmetry as an adult. This transformation is a classic metamorphic characteristic.
- (b) It possesses a calcareous endoskeleton made of protective ossicles embedded within the body wall.
- (c) The definitive physiological feature is the presence of a **water vascular system** (coelomic origin) connected to tube feet, which functions in locomotion, respiration, and food capture.
- (d) This combination of traits is unique to members of the phylum **Echinodermata** (such as sea stars and sea urchins).

**Final Answer:**

**Answer:**

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Q67.

**Solution**

**Concept:** Comparative anatomy tracks evolutionary changes in physiological systems—such as the circulatory and excretory systems—across chordate lineages to reconstruct evolutionary relationships.

**Solution:**

Let's analyze the character matrix to identify Group Gamma:

- (a) **Group Alpha:** Features a two-chambered heart (one atrium, one ventricle) with single systemic circulation, excreting waste as ammonia. This configuration characterizes aquatic fish classes.
- (b) **Group Beta:** Features a three-chambered heart with a double aortic arch system, excreting waste primarily as urea. This matches Class Amphibia and most reptiles.
- (c) **Group Gamma:** Features a completely partitioned four-chambered heart that separates oxygenated and deoxygenated blood. It retains a **single right aortic arch** (the left arch is lost) and excretes nitrogenous waste as water-insoluble **uric acid** (uricotelism) to conserve water. This precise combination is the anatomical blueprint of Class **Aves** (birds). (Class Mammalia also possesses a four-chambered heart but retains a single left aortic arch and excretes urea).

**Final Answer:**

**Answer:** (C)

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Q68.

**Solution**

**Concept:** The common liver fluke (*Fasciola hepatica*) is a parasitic trematode with a complex, indirect life cycle that requires multiple developmental shifts across primary (sheep/cattle) and intermediate (snail) hosts.

**Solution:**

Let's trace the sequential progression of larval stages:

- (a) **Miracidium:** Eggs passed in host feces hatch in water to release this free-swimming, ciliated larva, which infects an intermediate snail host (e.g., *Lymnaea*).
- (b) **Sporocyst:** Inside the snail tissue, the miracidium loses its cilia and transforms into an elongated sac-like sporocyst.
- (c) **Redia:** Germ cells inside the sporocyst divide to produce the next larval stage, the redia, which migrates to the snail's digestive gland.
- (d) **Cercaria:** Rediae give rise to tadpole-like cercariae, which emerge from the snail and swim through aquatic vegetation.
- (e) **Metacercaria:** The cercaria loses its tail and encysts on aquatic plants as a resilient metacercaria, the infective stage ingested by the primary mammalian host.

**Final Answer:** Miracidium → Sporocyst → Redia → Cercaria → Metacercaria

**Answer: (B)**

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Q69.

**Solution**

**Concept:** The development of the female gametophyte (megagametogenesis) in the majority of angiosperm species follows the \*Polygonum\*-type pathway, a monosporic pattern that forms a functional mature embryo sac.

**Solution:**

Let's trace the nuclear divisions that form the embryo sac:

- (a) A single functional haploid megaspore undergoes three successive, uncoupled mitotic nuclear divisions without immediate cytokinesis, producing an elongated cell containing eight haploid nuclei ( $2 \rightarrow 4 \rightarrow 8$ ).
- (b) These eight nuclei organize into specific positions within the gametophyte: three migrate to the chalazal end, three to the micropylar end, and two remain in the center.
- (c) Cell walls then form around these nuclei:
  - Three cells form at the chalazal end (antipodal cells).
  - Three cells form at the micropylar end, comprising the egg apparatus (one egg cell and two flanking synergids).
  - The remaining two polar nuclei share a single, large **central cell**.
- (d) This spatial organization results in a mature embryo sac that is structurally **7-celled** but contains **8 nuclei**.

**Final Answer:** 7-celled and 8-nucleate structure

**Answer: (B)**

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Q70.

**Solution**

**Concept:** Fertilization requires a series of coordinated molecular interactions between human spermatozoa and the extracellular coats surrounding the oocyte.

**Solution:**

Let's isolate the specific glycoprotein responsible for triggering the acrosome reaction:

- (a) The oocyte is surrounded by an outer investment layer of follicular cells (corona radiata) and an inner translucent extracellular matrix ring known as the zona pellucida.
- (b) The human zona pellucida is composed of major structural sulfated glycoproteins, including ZP1, ZP2, ZP3, and ZP4.
- (c) **Zona Pellucida Glycoprotein 3 (ZP3)** functions as the primary species-specific receptor for sperm binding. Binding of complementary proteins on the sperm head to ZP3 triggers an influx of calcium ions into the sperm, initiating the exocytotic acrosome reaction. This releases lytic enzymes (such as acrosin) that digest a path through the matrix, allowing the sperm to reach the oocyte plasma membrane.

**Final Answer:**

**Answer:** (A)

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Q71.

**Solution**

**Concept:** The human female ovarian and menstrual cycles are tightly regulated by a complex endocrine feedback loop involving the hypothalamus, anterior pituitary, and ovaries. The timing of ovulation is determined by a critical shift from negative to positive feedback regulation within this axis.

**Solution:**

Let's analyze the hormonal cascade leading up to ovulation:

- (a) During the follicular phase of the ovarian cycle, developing ovarian follicles secrete increasing amounts of estrogen.
- (b) When estrogen levels rise above a critical threshold and remain elevated for approximately 36 to 48 hours near the middle of the cycle (around day 12-13), a regulatory switch occurs. Instead of suppressing gonadotropin secretion, high estrogen levels exert a strong positive feedback effect on both the hypothalamus and the anterior pituitary.
- (c) This positive feedback triggers a rapid, high-amplitude release of gonadotropins, culminating in a massive surge of **Luteinizing Hormone (LH)**. This LH surge, which peaks roughly 12 to 36 hours prior to ovulation, stimulates the primary oocyte to complete meiosis I, activates proteolytic enzymes to weaken the follicular wall, and induces the physical rupture of the dominant mature Graafian follicle to release the oocyte on exactly day 14.

**Final Answer:**

A rapid, high-amplitude surge of Luteinizing Hormone (LH) induced by positive feedback of estrogen.

**Answer: (B)**

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Q72.

**Solution**

**Concept:** Double fertilization is a unique and defining reproductive characteristic of angiosperms (flowering plants) that occurs within the embryo sac (female gametophyte) following the landing of a compatible pollen grain on the stigma.

**Solution:**

Let's trace the pathways of the two separate male gametes involved in this dual fusion mechanism:

- (a) A pollen tube grows down the style and enters the micropyle of the ovule, releasing two haploid ( $n$ ) male gamete nuclei directly into the cytoplasm of a synergid cell within the embryo sac.
- (b) **First Fusion Event (Syngamy):** One haploid male gamete migrates to and fuses with the haploid ( $n$ ) egg cell nucleus. This fusion creates a diploid ( $2n$ ) zygote, which subsequently undergoes mitotic divisions to develop into the functional plant embryo.
- (c) **Second Fusion Event (Triple Fusion):** The second haploid male gamete migrates to the center of the embryo sac and fuses simultaneously with the two haploid polar nuclei (or the single fused diploid secondary nucleus) contained within the large central cell. This fusion of three haploid nuclei produces a triploid ( $3n$ ) nucleus known as the **\*\*Primary Endosperm Nucleus (PEN)\*\***, which develops into the nutrient-rich endosperm tissue that nourishes the embryo.

**Final Answer:** Diploid Zygote and Triploid Primary Endosperm Nucleus.

**Answer:** (C)

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Q73.

**Solution**

**Concept:** During early human embryonic development, the blastocyst differentiates into two primary cellular components before implantation: the inner cell mass (embryoblast), which forms the embryo proper, and the surrounding outer cell layer, known as the trophoblast, which gives rise to the embryonic contributions of the placenta.

**Solution:**

Let's look at the differentiation and invasive mechanisms of the trophoblast layer during implantation:

- (a) Upon making physical contact with the maternal endometrium, the outer **trophoblast layer** proliferates rapidly and differentiates into two morphologically distinct layers.
- (b) The inner layer remains cellular and is called the cytotrophoblast. The outer layer fuses to form a multinucleated protoplasmic mass without distinct cell boundaries, known as the **syncytiotrophoblast**.
- (c) The syncytiotrophoblast secretes proteolytic enzymes that degrade the extracellular matrix of the maternal endometrium. This allows the blastocyst to embed deep within the uterine wall and erode maternal capillaries, creating lacunae that establish the primitive maternal-fetal circulatory interface.

**Final Answer:**

**Answer: (B)**

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Q74.

**Solution**

**Concept:** During amniote embryogenesis, four distinct extraembryonic membranes develop outside the embryo proper to support gas exchange, nutrient absorption, waste storage, and physical protection: the amnion, yolk sac, allantois, and chorion.

**Solution:**

Let's identify the specific membrane layer responsible for forming the fetal placenta:

- (a) **Amnion:** Direct innermost fluid-filled sac that encloses and cushions the developing embryo against mechanical shock.
- (b) **Yolk Sac and Allantois:** Serve early vascular and respiratory roles, eventually contributing to the structural components of the umbilical cord.
- (c) **Chorion:** The outermost extraembryonic membrane layer that completely encloses the embryo and all other extraembryonic compartments. The chorion proliferates and develops highly vascularized finger-like projections called chorionic villi. These villi invade the vascularized maternal endometrium (decidua basalis), directly participating in forming the structural fetal component of the mature **placenta** to facilitate nutrient, gas, and waste exchange.

**Final Answer:**

**Answer:** (C)

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Q75.

**Solution**

**Concept:** Emergency oral contraceptive pills (such as morning-after pills containing high doses of the synthetic progestin Levonorgestrel) are designed to prevent pregnancy following unprotected intercourse or contraceptive failure. Their primary clinical objective is to stop fertilization before it occurs.

**Solution:**

Let's break down the physiological mechanism of action of Levonorgestrel:

- (a) Levonorgestrel is a potent synthetic progestin. When administered in a high dose within 72 hours of unprotected intercourse, it mimics high systemic progesterone levels, which exerts strong negative feedback on the hypothalamic-pituitary axis.
- (b) This negative feedback suppresses the secretion of Gonadotropin-Releasing Hormone (GnRH) and slows the pulse frequency of Follicle-Stimulating Hormone (FSH) and Luteinizing Hormone (LH).
- (c) Consequently, it prevents the mid-cycle LH surge. By blocking or delaying this surge, it **delays or inhibits ovulation**, ensuring that no mature egg is released from the ovary while viable sperm are present. Additionally, it increases the thickness and density of cervical mucus, creating a physical barrier that impedes sperm migration through the reproductive tract. It does not act as an abortifacient and does not disrupt an already established pregnancy.

**Final Answer:**

Delays or inhibits ovulation by disrupting the LH surge pattern, or alters cervical mucus density.

**Answer: (B)**

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Q76.

**Solution**

**Concept:** Plasmid vectors like pBR322 carry selectable marker genes encoding resistance to specific antibiotics (such as ampicillin, Amp<sup>R</sup>, and tetracycline, Tet<sup>R</sup>). These markers enable researchers to distinguish between non-transformed host cells, non-recombinant plasmids, and successful recombinant clones through a process known as insertional inactivation.

**Solution:**

Let's trace the molecular consequences of cloning into the *Bam*HI restriction site:

- (a) The classic cloning vector pBR322 contains two primary antibiotic resistance genes: the ampicillin resistance gene (amp<sup>r</sup>) and the tetracycline resistance gene (tet<sup>r</sup>).
- (b) The unique restriction endonuclease recognition site for *Bam*HI is located directly within the coding sequence of the tet<sup>r</sup> gene.
- (c) When a genetic engineer cleaves the plasmid with *Bam*HI and ligates a foreign target gene into this site, the open reading frame of the tetracycline resistance gene is disrupted and broken apart. This disruption causes **\*\*insertional inactivation\*\*** of the tetracycline gene.
- (d) Because the amp<sup>r</sup> gene remains intact, host bacterial cells transformed with this recombinant plasmid will express functional  $\beta$ -lactamase. Consequently, the recombinant colonies will display a phenotype of being **resistant to Ampicillin but sensitive to Tetracycline**.

**Final Answer:** Resistance to Ampicillin but sensitivity to Tetracycline.

**Answer: (C)**

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Q77.

**Solution**

**Concept:** The Polymerase Chain Reaction (PCR) is an automated *in vitro* technology used to amplify specific target DNA sequences through repeated cycles of thermal denaturation, primer annealing, and enzymatic extension.

**Solution:**

Let's analyze why human DNA Polymerase I cannot be used in this process:

- (a) A single PCR cycle requires raising the reaction temperature to approximately 94°C to 95°C during the denaturation step to break the hydrogen bonds between complementary strands, separating double-stranded DNA templates into single strands.
- (b) Standard human DNA Polymerase I is an enzyme adapted to function at normal physiological body temperature (37°C).
- (c) When exposed to the high temperatures (94°C) of the denaturation step, human DNA Polymerase I undergoes immediate, irreversible **thermal denaturation**. Its tertiary structure unfolds, destroying its catalytic active site. This would require adding fresh enzyme at every cycle, making automated amplification impossible. PCR instead relies on thermostable DNA polymerases, such as *Taq* polymerase isolated from the thermophilic bacterium *Thermus aquaticus*.

**Final Answer:**

It undergoes immediate thermal denaturation at the high temperatures (94°C) required for DNA strand denaturation.

**Answer: (B)**

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Q78.

**Solution**

**Concept:** Engineered DNA cloning vectors are specialized plasmids designed to carry foreign genetic material into a host cell. To function as an effective vehicle, a cloning plasmid must contain three essential components: an origin of replication (ori), a multiple cloning site (MCS), and at least one selectable marker gene.

**Solution:**

Let's evaluate the functional roles of these plasmid components:

- (a) **Origin of Replication (ori):** Essential for initiating autonomous, high-copy-number replication of the plasmid circle within the host cell.
- (b) **Selectable Marker Gene:** Transformation is an inefficient process; only a small fraction of host bacterial cells successfully take up a plasmid vector from the surrounding medium. To identify these rare transformants, a selectable marker gene (typically an antibiotic resistance gene like Amp<sup>R</sup> or Kan<sup>R</sup>) is included. This marker allows researchers to kill off non-transformed cells using selective media, permitting only the host cells that have successfully taken up the plasmid vector to survive and form colonies.

**Final Answer:**

To permit identification and selective survival of host cells that have successfully taken up the plasmid vector.

**Answer: (C)**

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Q79.

**Solution**

**Concept:** Agricultural biotechnology uses genetic engineering to introduce endogenous insect-resistance traits into economic crop cultivars, such as \*Bt\* corn and \*Bt\* cotton, to minimize chemical pesticide applications.

**Solution:**

Let's trace the physiological mechanism of action of \*Bt\* delta-endotoxins:

- (a) Transgenic \*Bt\* corn expressions contain genes derived from the soil bacterium \*Bacillus thuringiensis\* that encode crystalline protoxin proteins (Cry endotoxins).
- (b) When a target insect pest ingests the transgenic plant tissue, the inactive crystalline protoxins enter its digestive tract. Inside the highly **alkaline midgut** environment of the insect, specific proteases cleave the protoxin, converting it into an active, toxic polypeptide fragment.
- (c) This activated toxin binds specifically to cadherin-like receptor proteins located on the surface of the midgut epithelial cells. Upon binding, the toxin oligomerizes and inserts into the cell membrane, forming lytic pores. These pores disrupt osmotic regulation, causing an influx of water that leads to **osmotic lysis** of the midgut cells. The gut wall ruptures, causing the insect to stop feeding and die from starvation or septicemia. Mammals are unaffected because their stomach environment is highly acidic and lacks the specific receptors required for toxin binding.

**Final Answer:**

Binding to specific receptors in the alkaline midgut epithelial cells, creating pores that cause osmotic lysis.

**Answer: (B)**

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Q80.

**Solution**

**Concept:** RNA interference (RNAi) is a conserved post-transcriptional gene silencing (PTGS) mechanism found in eukaryotic cells that regulates gene expression and protects against viral pathogens and transposable elements.

**Solution:**

Let's break down the molecular steps of the RNAi pathway:

- (a) The RNAi pathway is initiated by the presence of double-stranded RNA (dsRNA) molecules inside the cell. An endoribonuclease enzyme called Dicer cleaves these long dsRNAs into short fragments called small interfering RNAs (siRNAs), which are typically 21 to 23 base pairs long.
- (b) These short double-stranded siRNA fragments are then loaded into a multi-protein catalytic complex called the **RNA-Induced Silencing Complex (RISC)**.
- (c) Within RISC, the passenger strand of the siRNA is degraded, while the remaining single-stranded guide RNA molecule guides the complex to its target. The RISC complex uses this guide RNA to locate and bind to complementary single-stranded messenger RNA (mRNA) transcripts through base pairing. Once bound, the catalytic subunit of RISC (Argonaute) cleaves the target mRNA molecule, preventing it from being translated into a functional protein product.

**Final Answer:**

Degradation of specific target single-stranded mRNA molecules by the RISC complex using complementary double-stranded RNA guides.

**Answer: (B)**

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## Answer Key

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	B	2	B	3	B	4	B	5	B
6	B	7	A	8	B	9	B	10	A
11	B	12	C	13	B	14	B	15	B
16	C	17	B	18	B	19	C	20	B
21	B	22	B	23	B	24	B	25	A
26	B	27	A	28	B	29	B	30	C
31	B	32	C	33	C	34	B	35	B
36	C	37	B	38	A	39	B	40	B
41	C	42	B	43	B	44	C	45	B
46	B	47	B	48	B	49	B	50	B
51	C	52	D	53	B	54	B	55	B
56	C	57	B	58	D	59	B	60	B
61	B	62	B	63	B	64	B	65	B
66	C	67	C	68	B	69	B	70	A
71	B	72	C	73	B	74	C	75	B
76	C	77	B	78	C	79	B	80	B

