# UPCATET Biology Sample Paper-9

**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 stress in C3 plants, the oxygenase activity of RuBisCO increases dramatically. If a mutant plant lacks a functional peroxisomal phosphoglycolate phosphatase enzyme, which of the following metabolic intermediates will abnormally accumulate inside the chloroplast stroma?

(A) 2-Phosphoglycolate

(B) Glycolate

(C) Glyoxylate

(D) Phosphoenolpyruvate

**Q2.** A researcher applies a localized chemical inhibitor of the $CF_0 - CF_1$ ATP synthase complex to isolated thylakoid membranes. If these thylakoids are continuously illuminated in an oxygen-rich environment, what happens to the internal lumen pH and the rate of non-cyclic electron transport?

(A) Lumen pH increases; electron transport rate increases

(B) Lumen pH drops sharply; electron transport rate drops due to photosynthetic control

(C) Lumen pH remains neutral; cyclic photophosphorylation accelerates

(D) Lumen pH decreases; water splitting ceases immediately without affecting pH

**Q3.** An isolated stem segment is subjected to unidirectional gravitational stimulus. According to the classical Cholodny-Went hypothesis, what is the precise cellular mechanism responsible for the subsequent asymmetric growth curvature?

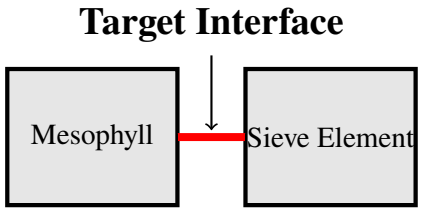
(A) Rapid degradation of Auxin via IAA-oxidase on the lower side

(B) Lateral redistribution of PIN3/PIN7 efflux carriers to the lower cortical cells

(C) Hyper-polarization of upper epidermal cells by calcium influx

(D) Enhanced GA3 synthesis exclusively inside the upper vascular bundles

**Q4.** The diagram below shows a high-magnification cross-section schematic of a specialized plant cellular transition zone. Identify the physiological feature indicated by the arrow and its functional relevance during the symplastic loading of phloem elements:




(A) Desmotubule channels mediating active ATP-dependent proton antiport

(B) Branched plasmodesmata sustaining polymer-trapping of raffinose sugars

(C) Casparian suberized bands preventing apoplastic backflow of sucrose

(D) Vestured pits facilitating mass flow driven by negative tension forces

**Q5.** Which of the following physical factors acts as the primary driving force for the phenomenon of guttation when atmospheric humidity is near 100% and transpirational pull is completely absent?

(A) Negative xylem pressure potential generated by bundle sheath extension cells

(B) Positive hydrostatic root pressure driven by active solute accumulation

(C) Capillary movement through narrow tracheary elements via adhesion forces

(D) Facilitated aquaporin opening triggered by high relative humidity

**Q6.** A mutant Arabidopsis line fails to develop a functional Kranz anatomy due to a homeobox gene deletion. If this mutant is placed under hot, dry, and low-$CO_2$ conditions, how will its photosynthetic efficiency compare to wild-type C4 plants?

(A) It will match wild-type C4 efficiency using a single-cell C4 mechanism

(B) It will drop drastically because spatial separation of PEP carboxylase is lost

(C) It will remain unchanged because Kranz anatomy only functions in C3 species

(D) It will double its output via enhanced crassulacean acid metabolic rates

**Q7.** During xylem differentiation, programmed cell death (PCD) must occur to clear the cellular contents and form a hollow conduit. Which organelle breaks down first to release hydrolytic enzymes into the cytoplasm during this structural maturation?

(A) Peroxisome

(B) Dictyosome

(C) Central Vacuole

(D) Glyoxysome

**Q8.** What is the precise role of the chemical intermediate Phytochromobilin within the structural configuration of a functional Phytochrome photoreceptor molecule?

(A) It is the apoprotein backbone that alters its configuration via phosphorylation

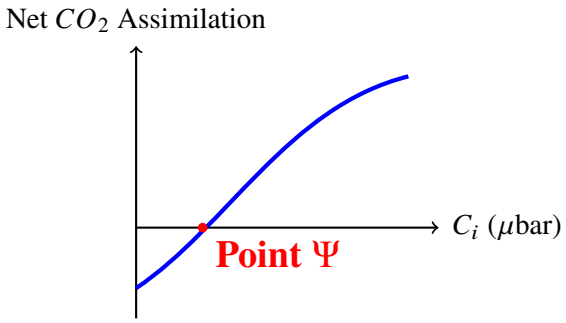
(B) It is the covalently linked tetrapyrrole chromophore that undergoes cis-trans isomerization

(C) It is the nuclear localization signal peptide exposed only under Far-Red light

(D) It is an accessory carotenoid pigment that quenches excess singlet oxygen molecules

**Q9.** The graphical vector layout below monitors the changes in net carbon dioxide exchange rates in a temperate crop leaf across varying internal intercellular

$CO_2$ partial pressures ($C_i$). Identify the precise point marked by the coordinate intercept along the horizontal axis:




(A) Carboxylation saturation constant

(B) Photorespiratory maximum capacity threshold

(C) $CO_2$ Compensation Point

(D) Quantum yield inversion limit

**Q10.** If a plant cell with an initial osmotic potential ($\psi_s$) of $-0.9$ MPa and a pressure potential ($\psi_p$) of 0.3 MPa is fully immersed into an open beaker containing a 0.3 M sucrose solution with a total water potential ($\psi_w$) of $-0.7$ MPa, what will be the direction of net water movement?

(A) Water will move into the cell because cell $\psi_w$ is lower than the solution

(B) Water will move out of the cell because cell $\psi_w$ is $-0.6$ MPa

(C) No net water movement will occur because the systems are in dynamic equilibrium

(D) Water will move out of the cell because cell $\psi_w$ is higher than the solution

**Q11.** Which specific combination of secondary cell wall modifications provides both extreme mechanical tensile strength and hydrophobic properties to the sclerenchyma fibers of vascular bundles?

(A) Pectin and Callose

(B) Lignin and Cellulose microfibrils

(C) Suberin and Cutin matrix polymers

(D) Chitin and Arabinogalactans

**Q12.** During seasonal transitions, the reopening of dormant phloem sieve tubes is achieved by the enzymatic degradation of which specific carbohydrate plug blocking the sieve plates?

(A) Amylopectin

(B) $\beta$-1,3-glucan (Callose)

(C) $\alpha$-cellulose

(D) Inulin polymer chains

**Q13.** A plant physiologist blocks the activity of the mitochondrial alternative oxidase (AOX) pathway during cold stress. What is the immediate metabolic consequence inside the plant cell respiratory machinery?

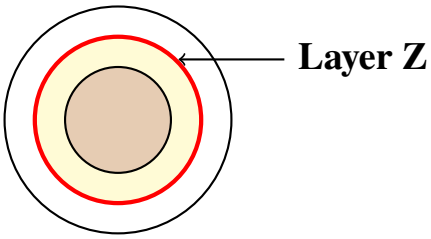
(A) Accelerated ATP production via Cytochrome c oxidase

(B) Severe accumulation of reactive oxygen species (ROS) and electron transport bottlenecks

(C) Immediate shift to alcoholic fermentation within the mitochondrial matrix

(D) Complete inhibition of the Pyruvate Dehydrogenase multienzyme complex

**Q14.** The diagram below shows a developmental stage of a specific primary lateral tissue layer during secondary growth initiation. Identify the functional tissue layer marked as Layer Z:




(A) Cork Cambium (Phellogen)

(B) Vascular Cambium derived from pericycle and interfascicular regions

(C) Endodermis acting as a starch sheath

(D) Primary Cortical Parenchyma layer

**Q15.** Abscisic acid (ABA) binds to its intracellular PYR/RCAR receptors to regulate stomatal closure under drought conditions. What is the downstream ion channel event that triggers the rapid loss of turgor in guard cells?

(A) Activation of plasma membrane $H^+$-ATPase proton pumps

(B) Influx of Malate ions into the central vacuoles

(C) Activation of anion efflux channels (SLAC1) causing depolarization and subsequent $K^+$ efflux

(D) Mass hyperpolarization via inward-rectifying calcium channels

**Q16.** During a severe metabolic acidosis episode, how do the intercalated cells of the late distal convoluted tubule and collecting duct in the human kidney respond to restore systemic physiological blood pH balance?

(A) Type B intercalated cells secrete $H^+$ into the lumen via apical $H^+$-ATPase pumps

(B) Type A intercalated cells secrete $H^+$ via apical $H^+$-ATPase and reabsorb $HCO_3^-$ via basolateral anion exchangers

(C) Both Type A and B cells stop filtering urea to minimize proton retention

(D) Type A cells actively excrete bicarbonate ions into the urine space

**Q17.** A patient presents with a rare genetic defect that leaves their peripheral chemoreceptors completely insensitive to changes in blood chemistry. Which of the following blood gas parameters will still successfully trigger an increase in their minute ventilation rate?

(A) A drop in arterial $pO_2$ below 60 mmHg

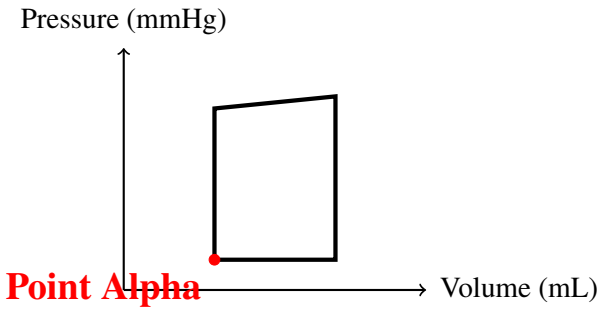
(B) An increase in arterial $pCO_2$ sensed indirectly via hydrogen ion shifts in the cerebrospinal fluid

(C) A decrease in systemic arterial pH independent of carbon dioxide levels

(D) An increase in carboxyhemoglobin saturation levels

**Q18.** The structural loop trace diagram below shows a recording of left ventricular pressure plotted against left ventricular volume during a single standard cardiac

cycle. Identify the exact valve event occurring at the coordinate marker labelled Point Alpha:




(A) Aortic valve opening

(B) Mitral (Bicuspid) valve closure

(C) Aortic valve closure

(D) Mitral (Bicuspid) valve opening

**Q19.** During skeletal muscle excitation-contraction coupling, what molecular structural rearrangement directly follows the binding of ionic calcium to the Troponin-C subunit?

(A) Cleavage of ATP by the myosin heavy chain globular head group

(B) Displacement of Tropomyosin away from the active myosin-binding sites on the actin filament

(C) Dissociation of the thick filament from the structural Z-disc matrix

(D) Phosphorylation of the ryanodine receptor channel pore complex

**Q20.** A clinical pharmacologist administers a novel drug that specifically locks the inactivation gates ($h$-gates) of axonal voltage-gated sodium channels in their closed position during an action potential. What is the immediate effect on nerve conduction?

(A) The resting membrane potential shifts permanently to +30 mV

(B) Neurons enter an absolute refractory state and cannot fire subsequent action potentials

(C) The threshold potential drops making cells highly hyperexcitable

(D) Repolarization is completely blocked, keeping the nerve permanently depolarized

**Q21.** Which of the following gastrointestinal endocrine secretions acts via an endocrine cascade mechanism to directly stimulate the secretion of an enzyme-rich pancreatic fluid while simultaneously inducing gallbladder contraction?

(A) Secretin

(B) Gastrin

(C) Cholecystokinin (CCK)

(D) Gastric Inhibitory Peptide (GIP)

**Q22.** The oxygen-hemoglobin dissociation curve undergoes a rightward shift during periods of intense local skeletal muscle metabolism. Which combination of physiological local tissue microenvironment factors causes this functional shift?

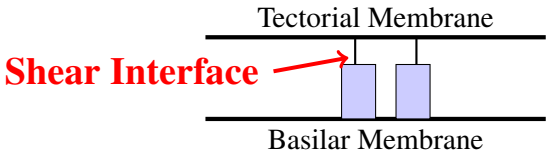
(A) Decreased $pCO_2$, decreased temperature, and elevated pH

(B) Increased $pCO_2$, increased temperature, and decreased pH (elevated $H^+$)

(C) Increased pH, decreased 2,3-BPG levels, and hypothermia conditions

(D) Decreased $pCO_2$ and high partial pressure of dissolved nitrogen gases

**Q23.** The structural schematic below represents the functional unit of the human inner ear hearing apparatus. Identify the specific cellular structural interface where mechanical shearing forces are converted into electrical potentials:




(A) Stereocilia of hair cells pressing against the tectorial membrane

(B) Otolith crystals moving across the macula gel matrix

(C) Cupula structures bending within the ampulla fluid loops

(D) Reissner's membrane pressing against the tympanic scala

**Q24.** A patient undergoes a complete pituitary stalk transection due to a localized cranial tumor. The secretion of which of the following anterior pituitary hormones will paradoxically rise instead of dropping after this injury?

(A) Adrenocorticotropic Hormone (ACTH)

(B) Growth Hormone (GH)

(C) Prolactin (PRL)

(D) Thyroid Stimulating Hormone (TSH)

**Q25.** What is the precise physiological consequence of a severe loss-of-function mutation in the gene encoding the epithelial chloride channel CFTR within human exocrine pancreatic ducts?

(A) Excessive watery bicarbonate secretion leading to chronic alkaline diarrhea

(B) Failure to secrete chloride into the lumen, reducing fluid transport and causing thick mucus plugs that block enzyme delivery

(C) Hyper-secretion of active trypsinogen directly into the interstitial tissue spaces

(D) Accelerated production of bile salts leading to duodenal ulcerations

**Q26.** During the physiological processing of vision, what biochemical event takes place inside the human rod photoreceptor cell outer segment upon absorbing a photon of light?

(A) Activation of guanylyl cyclase, increasing cGMP levels and opening sodium channels

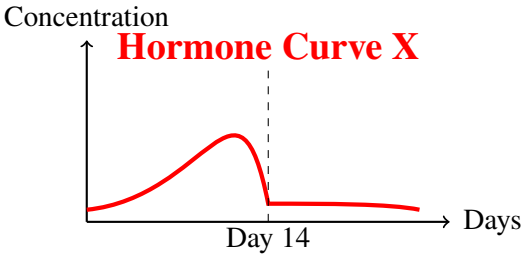
(B) Activation of phosphodiesterase (PDE), decreasing cGMP levels and closing cyclic nucleotide-gated (CNG) sodium channels

(C) Direct depolarization of the plasma membrane resulting in massive glutamate release

(D) Conversion of all-trans retinal into 11-cis retinal within the opsin core pocket

**Q27.** The physiological layout below traces the serum hormone levels across a standard 28-day human female ovarian cycle. Identify the hormonal trace line marked as

Hormone Curve X:




(A) Progesterone

(B) Luteinizing Hormone (LH)

(C) Estrogen

(D) Follicle Stimulating Hormone (FSH)

**Q28.** Which specific immunological cell type is responsible for monitoring MHC Class I molecules on host cells and destroying them via the release of perforins and granzymes if they present foreign viral antigens?

(A) Helper $T$ Lymphocytes ($CD4^+$)

(B) B Lymphocytes presenting IgD antibodies

(C) Cytotoxic $T$ Lymphocytes ($CD8^+$)

(D) Regulatory $T$ cells ($T_{reg}$)

**Q29.** During the forced expiration of air from human lungs, which specific muscle groups contract simultaneously to actively reduce thoracic cavity volume?

(A) Diaphragm and External Intercostals

(B) Scalene and Sternocleidomastoid muscles

(C) Internal Intercostals and Abdominal muscles

(D) Pectoralis major and Serratus anterior muscles

**Q30.** A standard three-point testcross is executed to map genes $A$, $B$, and $C$ in a diploid model organism. The observed recombination frequencies are: $A - B = 12\%$, $B - C = 7\%$, and $A - C = 18\%$. If the calculated coefficient of coincidence is determined to be exactly 0.4, what is the precise percentage of double crossover progeny expected in the total population?

(A) 0.84%

(B) 0.336%

(C) 1.90%

(D) 5.04%

**Q31.** During DNA replication in E. coli, which specific enzymatic subunit of the DNA Polymerase III holoenzyme complex forms a dimeric ring structural topology around the template DNA strand to ensure high processivity?

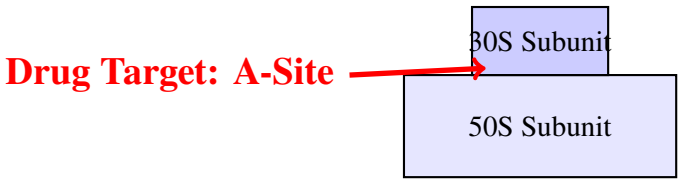
(A) The $\alpha$ catalytic subunit

(B) The $\epsilon$ proofreading exonuclease subunit

(C) The $\beta_2$ sliding clamp subunit

(D) The $\tau$ complex linkage unit

**Q32.** The structural model scheme below highlights the biochemical mechanism of action of an antibiotic agent acting upon a processing macromolecular machinery complex. Identify the target structure blocked by the drug molecule:




(A) RNA Polymerase II open promoter complex

(B) Aminoacyl-tRNA binding site on the ribosome

(C) DNA Topoisomerase II covalent cleavage site

(D) Peptidyl transferase center inside the nucleolus

**Q33.** What is the molecular mechanism by which the lac operon ensures that lactose is not metabolized when high concentrations of glucose are simultaneously present in the extracellular environment?

(A) Glucose binds directly to the lac operator site as an allosteric inhibitor

(B) High glucose levels reduce intracellular cAMP, preventing CAP from binding to the promoter region

(C) Glucose induces the rapid enzymatic degradation of $\beta$-galactosidase protein units

(D) Glucose alters the configuration of the lac repressor making it lock permanently onto DNA

**Q34.** A researcher isolates a eukaryotic pre-mRNA mutant that lacks the highly conserved 5′-AAUAAA-3′ consensus sequence near its terminal end. What will be the direct processing defect observed in this transcript?

(A) Failure to recruit the 7-methylguanosine capping enzyme complex

(B) Inability to splice out the first intron structure

(C) Loss of proper cleavage and polyadenylation at the 3′ end

(D) Accelerated transport through the nuclear pore complex without verification

**Q35.** Which type of chromosomal structural mutation is directly responsible for generating the classical "pseudodominance" genetic pattern where a recessive lethal allele is phenotypically expressed in a heterozygous individual?

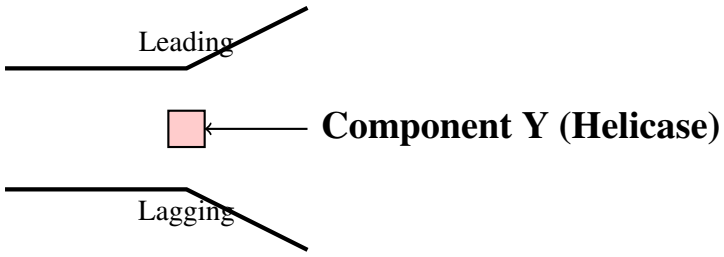
(A) Paracentric Inversion

(B) Reciprocal Translocation

(C) Interstitial Deletion

(D) Duplication of heterochromatic zones

**Q36.** The biochemical diagram layout below maps the structural anatomy of a replication fork during eukaryotic genomic duplication. Identify the specific processing component labeled as Structural Component Y:




(A) DNA Ligase I

(B) Hexameric MCM2-7 Helicase complex

(C) Single-Stranded DNA Binding Protein (RPA)

(D) Primase-Polymerase $\alpha$ complex

**Q37.** What is the precise structural reason why aminoacyl-tRNA synthetases are considered the actual "translators" of the genetic code rather than the ribosomal machinery itself?

(A) They read the codons directly via an internal specialized mRNA-binding loop

(B) They covalently link a specific amino acid to its cognate tRNA carrying the matching anticodon

(C) They synthesize the structural bases of the tRNA molecules inside the nucleolus

(D) They possess proofreading exonuclease activity that modifies incorrect mRNA sequences

**Q38.** A patient is diagnosed with Xeroderma Pigmentosum due to a severe sensitivity to ultraviolet light radiation. This genetic pathology stems from a loss-of-function mutation in enzymes specializing in which DNA repair pathway?

(A) Base Excision Repair (BER)

(B) Mismatch Repair (MMR)

(C) Nucleotide Excision Repair (NER)

(D) Non-Homologous End Joining (NHEJ)

**Q39.** During eukaryotic transcription initiation, which basal transcription factor contains the TATA-binding protein subunit and recognizes the core promoter element directly?

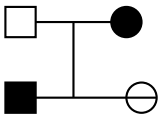
(A) TFIIA

(B) TFIIB

(C) TFIID

(D) TFIIH

**Q40.** The pedigree layout below illustrates the transmission pattern of a rare metabolic clinical trait across three successive generations. Deduce the exact mode of inheritance shown:



(A) Y-linked holandric trait

(B) Autosomal Dominant with variable expressivity

(C) Mitochondrial (Maternal) Inheritance

(D) X-linked Recessive inheritance pattern

**Q41.** If a segment of a double-stranded DNA molecule contains exactly 32% Thymine bases, what will be the calculated percentage of Guanine bases present within this specific genomic fragment?

(A) 32%

(B) 18%

(C) 36%

(D) 64%

**Q42.** During the mid-anaphase stage of mitotic cell division, a researcher treats cells with a drug that blocks the depolymerization of kinetochore microtubule plus-ends. What will be the direct effect on chromosome movement?

(A) Chromosomes will accelerate toward opposite poles via Anaphase B mechanics

(B) Anaphase A chromosome movement toward the spindle poles will be completely stalled

(C) Sister chromatids will fail to split at the centromere junction

(D) The polar spindle fibers will collapse into a monoastral array

**Q43.** Which specific mitochondrial structural component contains the enzymatic machinery responsible for catalyzing the oxidative decarboxylation of pyruvate and the operations of the citric acid cycle?

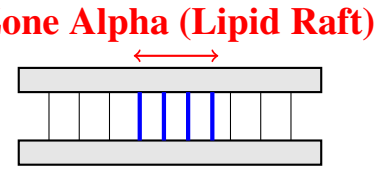
(A) Outer Mitochondrial Membrane outer layer

(B) Perimitochondrial Intermembrane space

(C) Inner Mitochondrial Membrane Cristae folds

(D) Internal Mitochondrial Matrix solution

**Q44.** The biochemical layout below models the molecular topology of a modern plasma membrane domain. Identify the specific specialized lipid structural aggregate group marked as Zone Alpha:




(A) Glycerol-rich micellar channel

(B) Lipid Raft enriched with cholesterol and sphingolipids

(C) Apical desmosomal anchoring zone

(D) Transient hydrophilic electroporated pore

**Q45.** During the meiotic prophase I stage, the synaptonemal complex completely disassembles, allowing homologous chromosomes to slightly repel each other while remaining bound at chiasmata positions. Identify this specific substage:

(A) Zygotene

(B) Pachytene

(C) Diplotene

(D) Diakinesis

**Q46.** A cell biologist treats a mammalian cell culture with a pharmacological agent that disrupts the function of signal recognition particle (SRP) RNA. Which cellular process will be directly blocked by this treatment?

(A) Import of nuclear proteins containing an NLS tag

(B) Cotranslational targeting of nascent secretory proteins to the Rough Endoplasmic Reticulum

(C) Retrograde transport from the Golgi apparatus to the cis-ER network

(D) Proteasomal degradation of polyubiquitinated cytoplasmic proteins

**Q47.** Which of the following cellular junctions is structurally coupled to intermediate filaments (such as keratins) to provide mechanical cohesive strength across epithelial cell sheets?

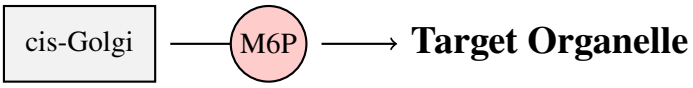
(A) Tight Junctions (Zonula occludens)

(B) Adherens Junctions (Zonula adherens)

(C) Desmosomes (Macula adherens)

(D) Gap Junctions (Connexons)

**Q48.** The structural schematic below monitors the biochemical maturation processing pathway of a key cellular degradative organelle. Identify the organelle whose biogenesis depends on the mannose-6-phosphate tagging system:




(A) Peroxisome core

(B) Autophagosome vesicle

(C) Lysosome

(D) Glyoxysome compartment

**Q49.** What is the precise role of the protein Cyclin B during the eukaryotic cell cycle transition from the G2 phase into the M phase?

(A) It activates Cdk1 to form the Mitosis-Promoting Factor (MPF) complex

(B) It degrades the nuclear lamina structural meshwork directly via proteolysis

(C) It acts as a DNA polymerase cofactor during Okazaki fragment maturation

(D) It binds to p53 to induce immediate cellular apoptosis

**Q50.** Which of the following structural biomolecules contains a characteristic $\beta$-1,4-linked N-acetylglucosamine homopolymer structural configuration that forms structural cell walls in fungal species?

(A) Cellulose matrix

(B) Chitin polymer

(C) Peptidoglycan envelope

(D) Glycogen granules

**Q51.** A mutant yeast cell line produces a defective nuclear porin complex that prevents the export of mature ribosomal subunits into the cytoplasm. Where will these subunits accumulate?

(A) Peroxisomal matrix

(B) Nucleolus and Nucleoplasm space

(C) Rough Endoplasmic Reticulum lumen

(D) Inner mitochondrial intermembrane space

**Q52.** A remote oceanic island ecosystem suffers an ecological catastrophe that wipes out all primary top carnivores. According to the trophic cascade model, what is the expected long-term structural effect on the primary producer biomass?

(A) Primary producer biomass will increase exponentially due to reduced grazing

(B) Herbivore populations will surge, causing a severe decline in primary producer biomass

(C) Primary producer biomass will stay constant due to absolute carrying capacity constraints

(D) Decomposers will switch to photosynthesis to compensate for the loss

**Q53.** In a stable terrestrial ecosystem community, the Net Primary Productivity (NPP) is measured at $22,000$ kcal/m$^2$/yr. If this ecosystem follows Lindeman's

classical ten percent trophic efficiency law, what is the maximum energy available to the tertiary consumer level?

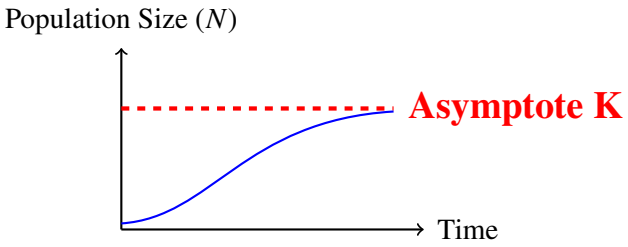
(A) $2,200$ kcal/m$^2$/yr

(B) 220 kcal/m$^2$/yr

(C) 22 kcal/m$^2$/yr

(D) 2.2 kcal/m$^2$/yr

**Q54.** The graph below tracks the growth dynamics of a newly introduced insect population over time in a closed nature reserve. Identify the ecological parameter marked by the horizontal asymptote line:




(A) Biotic potential threshold ($r_{max}$)

(B) Carrying Capacity ($K$) of the environment

(C) Intrinsic rate of natural decrease

(D) Minimum viable population baseline

**Q55.** Which specific global biogeochemical cycle relies almost entirely on specialized prokaryotic nitrogenase enzyme complexes to break an ultra-stable covalent triple bond before entering living food webs?

(A) Carbon Cycle

(B) Phosphorus Cycle

(C) Nitrogen Cycle

(D) Sulfur Cycle

**Q56.** A conservation biologist observes that a fragmented forest habitat exhibits a significant increase in microclimate temperatures, wind penetration, and general

predator encounters along its perimeter boundaries. What is this ecological phenomenon called?

(A) Inbreeding depression loop

(B) Edge Effect

(C) Competitive Exclusion principle

(D) Ecological niche compression

**Q57.** According to the conceptual framework of MacArthur and Wilson's Equilibrium Island Biogeography theory, which type of island configuration will maintain the absolute highest equilibrium species richness at baseline balance?

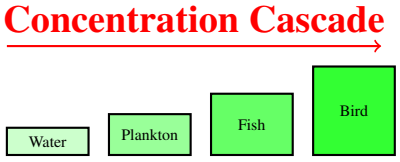
(A) Small islands located far away from mainland source pools

(B) Small islands located close to mainland source pools

(C) Large islands located far away from mainland source pools

(D) Large islands located close to mainland source pools

**Q58.** The structural block diagram below illustrates a specific biological monitoring indexing setup used to evaluate environmental health. Identify the phenomenon where a synthetic lipophilic pesticide concentrations increase at successive trophic steps up a food chain:




(A) Eutrophication

(B) Biomagnification (Biological Amplification)

(C) Bioremediation saturation

(D) Nutrient Immobilization

**Q59.** What is the precise chemical mechanism by which chlorofluorocarbons (CFCs) Catalyze the destruction of stratospheric ozone molecules over polar regions during spring?

(A) They release free chlorine radicals under UV radiation that repeatedly break down $O_3$ molecules

(B) They bind directly to oxygen gas molecules to form stable toxic oxides

(C) They absorb infrared heat, raising the temperature of the ozone layer until it thermal breaks down

(D) They induce a chemical precipitation reaction that converts ozone gas into solid nitrates

**Q60.** In a multi-species plant community, two closely related species share an identical fundamental niche. Over evolutionary time, they adapt by shifting their foraging heights and root depths. What ecological outcome does this illustrate?

(A) Competitive exclusion resulting in regional extinction

(B) Resource Partitioning driven by character displacement

(C) Commensalistic cooperative behavior

(D) Amensalistic chemical inhibition

**Q61.** A novel deep-sea organism is isolated during a marine expedition. It contains a cell wall lacking peptidoglycan, possesses ether-linked membrane lipids with branched hydrocarbons, and runs its transcription using eukaryotic-like RNA polymerases. Into which domain or kingdom should this organism be classified?

(A) Eubacteria

(B) Archaebacteria (Domain Archaea)

(C) Kingdom Fungi

(D) Protista Chrysophytes

**Q62.** An agricultural botanist dissects a flower from an unknown crop variety. It displays a cruciform corolla with four clawed petals, tetradynamous stamens (4 long and 2 short), and develops a specialized dehiscent fruit known as a siliqua. Which plant family does this specimen belong to?

(A) Solanaceae

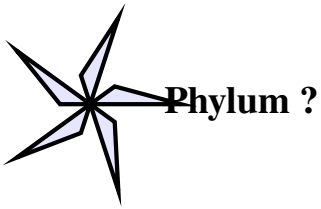
(B) Fabaceae

(C) Brassicaceae (Cruciferae)

(D) Liliaceae

(E) Malvaceae

**Q63.** The taxonomic architectural diagram below outlines the structural body plan symmetry of a specific invertebrate group. Identify the animal phylum characterized by adult radial symmetry but embryonic bilateral symmetry along with a functional water vascular system:




(A) Coelenterata

(B) Echinodermata

(C) Platyhelminthes

(D) Arthropoda

**Q64.** Which specific combination of morphological and anatomical features defines the unique evolutionary adaptations found exclusively within the avian class (Aves) to facilitate flight?

(A) Dicondylic skull and heterodont dentition

(B) Pneumatic (hollow) bones, asymmetric feathers, and a well-developed sternal keel

(C) Poikilothermic metabolism and air bladder systems

(D) Exoskeleton plates coupled with a multi-chambered open vascular sinus

**Q65.** A microscopic investigation of a plant pathogen reveals a non-cellular infectious agent consisting solely of a short, circular, single-stranded RNA molecule completely lacking any protective protein capsid coating. What is this pathogen classified as?

(A) Prion

(B) Virion

(C) Viroid

(D) Bacteriophage

**Q66.** In the botanical structural layout of the family Solanaceae, which specific morphological configuration of the gynoecium is considered a definitive diagnostic identification criteria?

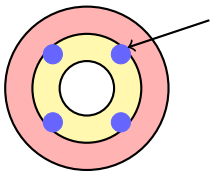
(A) Monocarpellary, unilocular ovary with marginal placentation

(B) Bicarpellary, syncarpous, superior ovary with an obliquely swollen placenta and axile placentation

(C) Polycarpellary, apocarpous, inferior ovary with parietal configuration

(D) Tricarpellary, syncarpous, trilocular superior ovary with epipetalous features

**Q67.** The architectural cross-section layout below displays the body cavity layer configuration of an animal organism. Identify the specific structural animal organization level represented by this schematic layout:




(A) True Eucoelomate organization

(B) Pseudocoelomate (e.g., Aschelminthes)

(C) Acoelomate (e.g., Platyhelminthes)

(D) Diploblastic structural organization

**Q68.** What is the primary evolutionary significance of the development of a heterosporous condition within advanced pteridophytes such as Selaginella and Salvinia?

(A) It allows for rapid vegetative propagation via fragmentation loops

(B) It represents an essential evolutionary precursor stage toward the development of a seed habit

(C) It eliminates the requirement for external liquid water during fertilization events

(D) It triggers the immediate development of primary taproot systems

**Q69.** During megasporogenesis in a standard angiosperm ovule, a single functional megaspore undergoes nuclear divisions to form a classic Polygonum-type embryo sac. What is the precise pattern of nuclear mitoses and the final structural organization of this mature gametophyte?

(A) Two meiotic divisions; 4-nucleate, 4-celled architecture

(B) Three sequential free-nuclear mitotic divisions; 8-nucleate, 7-celled structural organization

(C) Four asymmetric mitotic events; 8-nucleate, 8-celled framework

(D) One meiotic and one mitotic division; 3-celled apparatus

**Q70.** During human fertilization, what specific cellular event is triggered inside the oocyte cytoplasm upon the successful binding and fusion of the first sperm cell head with the oocyte plasma membrane?

(A) Immediate exocytosis of cortical granules to alter the zona pellucida matrix and block polyspermy

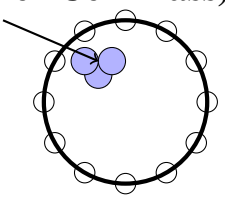
(B) Accelerated synthesis of progesterone by the corona radiata cells

(C) Reversal of the mitochondrial electron transport system inside the polar body

(D) Immediate disintegration of the surrounding acrosome structural cap assembly

**Q71.** The developmental schematic layout below monitors the structural organization of an early human blastocyst embryo during uterine transit. Identify the inner cellular mass region marked as Cluster X:

**Cluster X (Inner Cell Mass)**



(A) Trophoblast structural cell layer

(B) Inner Cell Mass (Embryoblast) containing pluripotential stem cells

(C) Extraembryonic coelomic fluid pocket

(D) Syncytiotrophoblast invading layer

**Q72.** Which specific hormone is secreted exclusively by the human placenta to sustain the functional structural integrity of the corpus luteum during the initial weeks of a successful gestation period?

(A) Human Chorionic Gonadotropin (hCG)

(B) Luteinizing Hormone (LH)

(C) Estradiol

(D) Human Placental Lactogen (hPL)

**Q73.** What is the precise structural function of the tapetal cell layer located within the internal microsporangium walls of a developing angiosperm anther?

(A) It undergoes mechanical dehiscence via hygroscopic movements

(B) It provides nutritional support to developing pollen grains and synthesizes the sporopollenin precursor components

(C) It forms a tough waterproof protective fibrous endothecium framework

(D) It generates the primary microspore mother cells via meiotic divisions

**Q74.** A patient chooses a non-hormonal, long-acting reversible intrauterine device (such as the CuT-380A) for family planning. What is the primary cellular mechanism of action of this device within the female reproductive tract?

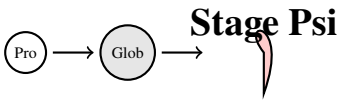
(A) Complete inhibition of ovulation via systemic negative feedback loops on the pituitary gland

(B) Thickening of cervical mucus to completely block sperm entry into the uterine cavity

(C) Release of copper ions that reduce sperm motility and viability, exerting a strong spermicidal effect

(D) Permanent surgical occlusion of the fallopian tube infundibulum loops

**Q75.** The graphical schematic layout below highlights the morphological structural changes occurring across the tracking phases of a flowering plant embryogenesis sequence. Identify the specific structural developmental stage marked as Stage Psi:




(A) Linear Octant Phase

(B) Heart-shaped developmental embryo stage

(C) Mature Torpedo-form cotyledon array

(D) Unicellular zygotic polar blastomere

**Q76.** During a standard polymerase chain reaction (PCR) amplification cycle, a researcher accidentally sets the annealing temperature to 85°C instead of the optimal 55°C. What will be the direct outcome of this procedural error?

(A) The template DNA strands will fail to separate, preventing denaturation

(B) The oligonucleotide primers will be unable to form hydrogen bonds with the template DNA strands

(C) The Taq Polymerase enzyme will undergo complete, irreversible thermal denaturation

(D) Non-specific primer binding will lead to a high volume of contamination artifacts

**Q77.** A molecular biologist aims to insert a target genomic fragment into a cloning plasmid vector. To minimize the rate of empty vector self-ligation without

an insert, which enzymatic pretreatment should be applied to the linearized plasmid?

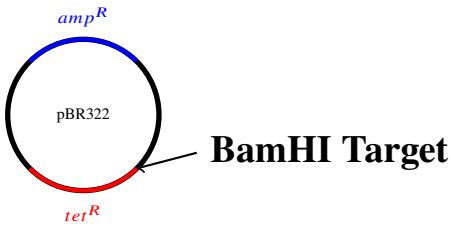
(A) T4 Polynucleotide Kinase treatment

(B) Alkaline Phosphatase treatment to strip the 5′ phosphate groups

(C) Exonuclease III digestion of 3′ protruding ends

(D) Terminal Transferase tailing with poly-A sequences

**Q78.** The molecular vector layout diagram below shows the structural map of the cloning vector pBR322. Identify the target antibiotic resistance locus disrupted when a foreign gene is cloned into the unique BamHI restriction endonuclease recognition site:




(A) Ampicillin resistance gene locus ($amp^R$)

(B) Tetracycline resistance gene locus ($tet^R$)

(C) Origin of replication site ($ori$)

(D) Rop protein regulatory gene sequence

**Q79.** What is the precise molecular biological mechanism by which the crystalline Cry1Ac endotoxin proteins produced by Bacillus thuriengensis crops induce mortality within sensitive lepidopteran insect larvae populations?

(A) They act as intracellular competitive inhibitors of acetylcholinesterase in nerve synapses

(B) They undergo proteolytic activation in the alkaline midgut, binding to cadherin-like receptors to form pores that disrupt osmotic balance

(C) They block the transport of oxygen across tracheal systems via thick hydrophobic film formations

(D) They induce a massive rapid mutation cascade throughout the reproductive tissues

**Q80.** A clinical researcher runs a modern forensic validation assay using the CRISPR-Cas9 platform system architecture. What is the fundamental requirement for the Cas9 endonuclease to introduce a double-stranded break at a specific genomic location?

(A) A sequence-specific methylation imprint on the target locus

(B) The presence of a short Protospacer Adjacent Motif (PAM) sequence immediately downstream of the target DNA site

(C) A high concentration of divalent copper cofactor ions within the nuclear environment

(D) The total absence of any complementary guide RNA strands in the system

## Detailed Solutions

# Q1.

## Solution

**Concept:** Photorespiration (the $C_2$ cycle) is initiated when the enzyme RuBisCO acts as an oxygenase under high light and temperature stress, fixing $O_2$ instead of $CO_2$ to ribulose-1,5-bisphosphate (RuBP). This reaction produces one molecule of 3-phosphoglycerate (3-PGA) and one molecule of the toxic byproduct 2-phosphoglycolate.

**Solution:**

Let's follow the first biochemical steps of the photorespiratory salvage pathway across cellular compartments:

(a) Inside the chloroplast stroma, RuBisCO generates **2-phosphoglycolate**. Because this molecule inhibits key chloroplast enzymes like triosephosphate isomerase, it must be rapidly converted.

(b) The enzyme phosphoglycolate phosphatase (PGP), located inside the chloroplast, removes the phosphate group from 2-phosphoglycolate to yield **glycolate**.

(c) Glycolate is then transported out of the chloroplast and enters the peroxisome, where it is oxidized to glyoxylate.

(d) If a mutant plant lacks a functional *peroxisomal* phosphoglycolate phosphatase enzyme, it cannot process incoming intermediates or there is a systemic block in the cycle. However, let's look closer at the question details: it specifies a lack of a functional phosphoglycolate phosphatase enzyme, which biochemically acts directly on 2-phosphoglycolate inside the chloroplast to form glycolate. The accumulation of the primary substrate **2-phosphoglycolate** occurs within the chloroplast stroma because it cannot be dephosphorylated.

**Final Answer:** 2-Phosphoglycolate

**Answer: (A)**

Go Back to Question 1

## Q2.

### Solution

**Concept:** Photophosphorylation in thylakoid membranes couples the light-driven non-cyclic electron transport chain (ETC) to ATP synthesis via a proton gradient, an oversight described by Mitchell's chemiosmotic hypothesis.

**Solution:**

Let's analyze the physiological consequences of inhibiting the $CF_0$-$CF_1$ ATP synthase complex:

(a) During continuous illumination, Photosystem II (PSII) and Photosystem I (PSI) run non-cyclic electron transport, pumping protons ($H^+$) from the stroma into the thylakoid lumen while splitting water ($H_2O$) to release more protons into the lumen.

(b) Normally, the $CF_0$-$CF_1$ ATP synthase provides a structural channel for these protons to flow back down their electrochemical gradient into the stroma to drive ATP synthesis.

(c) Blocking the $CF_0$-$CF_1$ complex traps protons inside the thylakoid lumen. As the ETC continues running, protons accumulate rapidly, causing the internal **lumen pH to drop sharply**.

(d) The extreme buildup of the proton gradient ($\Delta$pH) increases the free energy barrier for further proton pumping. This feedback inhibition on the cytochrome $b_6f$ complex, known as **photosynthetic control**, causes the rate of non-cyclic electron transport to drop or slow down drastically.

**Final Answer:** Lumen pH drops sharply; electron transport rate drops due to photosynthetic control

**Answer: (B)**

Go Back to Question 2

## Q3.

### Solution

**Concept:** The Cholodny-Went hypothesis explains plant tropisms (such as gravitropism and phototropism) through the asymmetric lateral redistribution of the plant hormone auxin, causing differential growth rates on opposing sides of an organ.

**Solution:**

Let's look at the cellular mechanics of gravitropism in a stem segment:

(a) When a stem segment is placed horizontally, specialized gravity-sensing cells (statocytes) detect the directional shift via the sedimentation of dense starch-filled amyloplasts (statoliths).

(b) This physical sedimentation triggers a molecular signaling cascade that re-orients specialized auxin efflux transport proteins, specifically **PIN3 and PIN7**, toward the lower side of the cells.

(c) These efflux carriers laterally pump auxin downward, leading to a high concentration of auxin in the **lower cortical cells** of the stem.

(d) In stems, elevated auxin concentrations stimulate cell elongation. Consequently, the cells on the lower side elongate much faster than those on the upper side, forcing the stem to bend upward against gravity (negative gravitropism).

**Final Answer:** Lateral redistribution of PIN3/PIN7 efflux carriers to the lower cortical cells

**Answer: (B)**

Go Back to Question 3

## Q4.

### Solution

**Concept:** Phloem loading is the process by which photosynthetic sugars are transferred from mesophyll source cells into the sieve elements of the phloem. In many plant species, this happens via a symplastic pathway that uses structural cell-to-cell bridges.

**Solution:**

Let's analyze the transition zone shown in the layout:

(a) The interface connecting the mesophyll cell to the phloem companion cell or sieve element is rich in specialized cytoplasmic channels called **plasmodesmata**.

(b) In species that load phloem symplastically, these interfaces contain highly **branched plasmodesmata**.

(c) These specialized junctions are critical for the **polymer-trapping mechanism**. Sucrose synthesized in the mesophyll diffuses freely through the plasmodesmata into the intermediary companion cells. Inside these cells, metabolic enzymes synthesize larger oligosaccharides, such as **raffinose** and stachyose, from the sucrose building blocks.

(d) Because of their larger molecular dimensions, these synthesized raffinose polymers cannot diffuse backward through the narrow plasmodesmata pores toward the mesophyll. Instead, they can only move forward into the wide sieve elements, maintaining a one-way concentration gradient for symplastic phloem loading.

**Final Answer:** Branched plasmodesmata sustaining polymer-trapping of raffinose sugars

**Answer: (B)**

Go Back to Question 4

## Q5.

### Solution

**Concept:** Guttation is the exudation of liquid water droplets from the margins or tips of uninjured leaves through specialized vascular structures called hydathodes, occurring independently of transpiration.

**Solution:**

Let's analyze the environmental and physical forces behind guttation:

(a) When atmospheric humidity approaches 100%, the water vapor concentration gradient between the leaf interior and the air drops to zero, halting transpiration and eliminating transpirational pull.

(b) At the same time, plant roots continue to actively pump mineral ions from the surrounding soil into the vascular xylem of the root cylinder.

(c) This continuous accumulation of solutes lowers the osmotic potential of the root xylem, drawing water inward from the soil via osmosis.

(d) Since water cannot escape through the stomata via transpiration, this inward osmotic movement builds up a **positive hydrostatic root pressure**. This pressure pushes the columns of water upward through the xylem vessels, forcing liquid water out through the low-resistance openings of the hydathodes at the leaf margins.

**Final Answer:** Positive hydrostatic root pressure driven by active solute accumulation

**Answer: (B)**

Go Back to Question 5

## Q6.

### Solution

**Concept:** The high efficiency of classical $C_4$ photosynthesis relies on a specialized structural arrangement known as **Kranz anatomy**, which creates a spatial separation between initial carbon capture and the Calvin cycle.

**Solution:**

Let's examine how the loss of Kranz anatomy impacts carbon fixation under climate stress:

(a) In wild-type $C_4$ plants, atmospheric $CO_2$ is converted to bicarbonate and fixed into a $C_4$ acid by phosphoenolpyruvate (PEP) carboxylase inside outer mesophyll cells. These $C_4$ acids are then transported into tightly sealed inner bundle sheath cells, where they are decarboxylated to release a high concentration of $CO_2$ around RuBisCO.

(b) This localized concentration of $CO_2$ suppresses the photorespiratory oxygenase activity of RuBisCO, keeping photosynthetic efficiency high under hot, dry, and low-$CO_2$ conditions.

(c) If a mutant plant fails to develop **Kranz anatomy**, this crucial **spatial separation** between PEP carboxylase and RuBisCO is lost. Without these isolated compartments, the plant cannot concentrate $CO_2$ around RuBisCO. Under hot, dry conditions, its photosynthetic efficiency will **drop drastically** because RuBisCO shifts to photorespiration, matching or falling below standard $C_3$ limitations.

**Final Answer:** It will drop drastically because spatial separation of PEP carboxylase is lost

**Answer: (B)**

Go Back to Question 6

## Q7.

### Solution

**Concept:** Xylem differentiation requires the development of thick secondary cell walls followed by a final, cell-clearance step driven by programmed cell death (PCD). This process removes the protoplast to create a low-resistance, hollow conduit for water transport.

**Solution:**

Let's isolate the cellular events that drive structural autolysis during tracheary element maturation:

(a) As a developing xylem tracheary element reaches its final stage of differentiation, a genetically programmed signaling pathway triggers the self-destruction of the cell.

(b) The primary organelle that initiates this autolytic phase is the **central vacuole**.

(c) The tonoplast membrane enclosing the central vacuole suddenly ruptures, **breaking down first** among the cellular compartments.

(d) This rupture releases a high concentration of trapped hydrolytic enzymes, such as nucleases, proteases, and glucosidases, directly into the cytoplasm. These enzymes rapidly digest the nucleus, plastids, mitochondria, and remaining ground cytoplasm, completing the clear-out of the hollow cell interior.

**Final Answer:** Central Vacuole

**Answer: (C)**

Go Back to Question 7

## Q8.

### Solution

**Concept:** Phytochromes are specialized dimeric photoreceptor proteins that plants use to monitor seasonal, photoperiodic, and structural light environments. Each subunit consists of a protein chain (apoprotein) linked to a light-absorbing molecule.

**Solution:**

Let's analyze the biochemical configuration of the phytochrome molecule:

(a) A functional phytochrome is a holoprotein made up of a polypeptide apoprotein covalently bonded to an open-chain **tetrapyrrole chromophore**.

(b) In higher plants, this specific light-absorbing chemical intermediate is **phytochromobilin**.

(c) Phytochromobilin is synthesized in the plastids and moves into the cytoplasm, where it binds covalently to a conserved cysteine residue on the apoprotein.

(d) When it absorbs a photon, the **phytochromobilin** chromophore undergoes a **cis-trans photochemical isomerization** around a central double bond. This structural shift alters the conformation of the attached protein backbone, toggling the photoreceptor between its biologically inactive red-absorbing form ($P_r$) and its biologically active far-red-absorbing form ($P_{fr}$).

**Final Answer:** It is the covalently linked tetrapyrrole chromophore that undergoes cis-trans isomerization

**Answer: (B)**

Go Back to Question 8

## Q9.

### Solution

**Concept:** Gas exchange curves plot net photosynthetic carbon assimilation ($A$) against the internal intercellular partial pressure of $CO_2$ ($C_i$). This profile helps characterize the carbon fixation limits of a leaf.

**Solution:**

Let's analyze the coordinate features of the provided graph:

(a) When the internal $CO_2$ concentration ($C_i$) is zero, net assimilation is negative. This occurs because the leaf is releasing $CO_2$ into the intercellular spaces via mitochondrial respiration and photorespiration.

(b) As $C_i$ increases, the rate of photosynthetic carbon fixation rises, which brings the net assimilation curve closer to zero.

(c) **Point Ψ** marks the exact point where the curve crosses the horizontal axis, meaning the net $CO_2$ assimilation rate is precisely zero ($A = 0$).

(d) At this specific intercept, the amount of $CO_2$ fixed by photosynthesis exactly matches the amount of $CO_2$ released by respiration and photorespiration. This coordinate is called the **$CO_2$ Compensation Point**.

**Final Answer:** $CO_2$ Compensation Point

**Answer: (C)**

Go Back to Question 9

## Q10.

### Solution

**Concept:** The movement of water between a plant cell and its surrounding solution is driven by the gradient in total water potential ($\psi_w$), moving spontaneously from regions of higher water potential (less negative) to regions of lower water potential (more negative).

**Solution:**

Let's calculate the water potential values for both the cell and the solution to determine the direction of flow:

(a) The total water potential of a plant cell ($\psi_{w,\text{cell}}$) is the sum of its osmotic potential ($\psi_s$) and its pressure potential ($\psi_p$):

$$\psi_{w,\text{cell}} = \psi_s + \psi_p = -0.9 \text{ MPa} + 0.3 \text{ MPa} = -0.6 \text{ MPa}$$

(b) The water potential of the open beaker sucrose solution ($\psi_{w,\text{sol}}$) is given as:

$$\psi_{w,\text{sol}} = -0.7 \text{ MPa}$$

(c) Comparing the two values:

$$\psi_{w,\text{cell}}(-0.6 \text{ MPa}) > \psi_{w,\text{sol}}(-0.7 \text{ MPa})$$

(d) Because the cell's water potential is higher (less negative) than the surrounding solution's water potential, water will spontaneously flow out of the cell into the beaker along its thermodynamic gradient.

**Final Answer:** Water will move out of the cell because cell $\psi_w$ is $-0.6$ MPa

**Answer: (B)**

Go Back to Question 10

## Q11.

### Solution

**Concept:** Sclerenchyma fibers provide vital structural support to plant organs. Their rigid secondary cell walls are built from specialized biomolecules that offer both mechanical strength and resistance to decay and water loss.

**Solution:**

Let's evaluate the structural composition of secondary cell walls:

(a) The base structural matrix of the wall is made of long, crystalline chains of **cellulose microfibrils**, which provide high tensile strength to counter mechanical pulling forces.

(b) During differentiation, this cellulose framework is reinforced through a process called lignification, where the complex polyphenolic polymer **lignin** is deposited throughout the wall matrix.

(c) **Lignin** replaces water in the cell wall, forming a rigid, hydrophobic cross-linked network. This combination of **lignin and cellulose microfibrils** gives sclerenchyma fibers their extreme mechanical toughness and waterproof characteristics.

**Final Answer:** Lignin and Cellulose microfibrils

**Answer: (B)**

Go Back to Question 11

## Q12.

### Solution

**Concept:** Phloem sieve tubes use specialized structural adaptations to manage injury or seasonal dormancy. They can temporarily seal off their sieve plates to prevent the loss of nutrient-rich phloem sap.

**Solution:**

Let's isolate the carbohydrate mechanics of sieve tube regulation:

(a) When a plant enters autumn dormancy or suffers a structural injury, a rapid influx of calcium ions triggers the synthesis of a specialized sealing carbohydrate.

(b) This carbohydrate is **callose**, a glucose polymer linked by **$\beta$-1,3-glucosidic bonds** (with occasional $\beta$-1,6 branches).

(c) Callose quickly accumulates around the sieve pores, forming a dense physical mass called a callose plug that stops mass flow through the tube.

(d) When spring returns and seasonal growth restarts, the plant activates the enzyme **$\beta$-1,3-glucanase**. This enzyme breaks down the **callose** plugs, reopening the sieve plate pores so nutrient transport can resume.

**Final Answer:** $\beta$-1,3-glucan (Callose)

**Answer: (B)**

Go Back to Question 12

## Q13.

### Solution

**Concept:** Plant mitochondria contain a branched electron transport chain. In addition to the classic, energy-conserving cytochrome pathway, they express an alternative respiratory pathway centered around the alternative oxidase (AOX) enzyme.

**Solution:**

Let's analyze the metabolic role of AOX during environmental stress:

(a) Under cold stress, the classical cytochrome *c* oxidase pathway can become physically constrained or backed up due to downstream metabolic imbalances or structural limitations in the membrane.

(b) AOX acts as a pressure-relief valve by accepting electrons directly from the ubiquinone pool and transferring them to oxygen, bypassing complex III and complex IV. Although this bypass reduces ATP production, it keeps the upstream electron transport chain moving.

(c) If a scientist chemically blocks **alternative oxidase (AOX)** activity during cold stress, this metabolic relief valve is lost. Electrons saturate the ubiquinone pool with nowhere to go, creating an upstream bottleneck. This bottleneck forces single electrons to leak directly onto molecular oxygen, causing a **severe accumulation of highly damaging reactive oxygen species (ROS)** and stalling the respiratory chain.

**Final Answer:** Severe accumulation of reactive oxygen species (ROS) and electron transport bottlenecks

**Answer: (B)**

Go Back to Question 13

## Q14.

### Solution

**Concept:** Secondary growth in dicotyledonous stems and roots increases the thickness of the plant axis. This growth is driven by lateral meristems that form continuous rings of dividing cells.

**Solution:**

Let's identify the specific structural layer highlighted as Layer Z:

(a) The schematic illustrates a cross-section of an axis undergoing early secondary development. The innermost shaded core represents primary xylem, surrounded by a thin, active cambial cylinder.

(b) This continuous, highly active lateral meristematic ring is the **vascular cambium**.

(c) In roots and stems, the vascular cambium forms from a combination of internal vascular cells (fascicular cambium) and adjacent grounding tissues, such as the **pericycle** and **interfascicular parenchyma regions**.

(d) Once formed, this ring divides continuously, producing secondary xylem toward the inside and secondary phloem toward the outside, driving the radial expansion of the vascular cylinder.

**Final Answer:** Vascular Cambium derived from pericycle and interfascicular regions

**Answer: (B)**

Go Back to Question 14

## Q15.

### Solution

**Concept:** Abscisic acid (ABA) is the primary hormone that triggers stomatal closure during drought stress. It binds to intracellular receptors to activate a signaling pathway that drives rapid turgor loss in guard cells.

**Solution:**

Let's trace the downstream ion transport steps that cause stomatal closure:

(a) When ABA binds to its PYR/RCAR receptors, it inhibits type 2C protein phosphatases (PP2Cs), which releases the inhibition on SnRK2 protein kinases.

(b) Active SnRK2 kinases phosphorylate and turn on specialized anion channels in the plasma membrane, primarily **SLAC1** (Slow Anion Channel 1).

(c) The activation of **SLAC1** allows anions like malate and chloride to exit the cytoplasm down their electrochemical gradients. This sudden loss of negative charges causes a strong **depolarization of the plasma membrane**.

(d) This depolarization shifts the membrane potential past the threshold for outward-rectifying potassium channels (GORK), causing a massive **exit of $K^+$ ions** from the cell. The loss of these solutes draws water out of the guard cells via osmosis, causing them to lose turgor and close the stomatal pore.

**Final Answer:** Activation of anion efflux channels (SLAC1) causing depolarization and subsequent $K^+$ efflux.

**Answer: (C)**

Go Back to Question 15

## Q16.

### Solution

**Concept:** The late distal tubule and collecting duct contain specialized cells called intercalated cells that help regulate systemic acid-base balance by adjusting proton and bicarbonate transport.

**Solution:**

Let's analyze how these cell types respond to a drop in blood pH (acidosis):

(a) Intercalated cells are divided into two main functional types: Type A (acid-secreting) cells and Type B (base-secreting) cells.

(b) During severe metabolic acidosis, the kidney must excrete excess protons into the urine while conserving bicarbonate to buffer the blood.

(c) **Type A intercalated cells** handle this response. They express abundant **$H^+$-ATPase proton pumps** on their apical (lumen-facing) membranes, which actively pump $H^+$ ions directly into the tubular fluid for excretion.

(d) At the same time, carbonic anhydrase inside the cell generates $H^+$ and $HCO_3^-$. As the protons are pumped into the urine, the newly formed **$HCO_3^-$ is transported across the basolateral membrane** into the blood via anion exchangers (AE1), helping to restore normal systemic pH.

**Final Answer:** Type A intercalated cells secrete $H^+$ via apical $H^+$-ATPase and reabsorb $HCO_3^-$ via basolateral anion exchangers.

**Answer: (B)**

Go Back to Question 16

## Q17.

### Solution

**Concept:** The control of ventilation relies on two separate chemical monitoring systems: peripheral chemoreceptors (located in the carotid and aortic bodies) and central chemoreceptors (located on the ventrolateral surface of the medulla oblongata).

**Solution:**

Let's determine which respiratory drive remains active when peripheral chemoreceptors are non-functional:

(a) Peripheral chemoreceptors are the only sensors capable of detecting drops in arterial oxygen levels ($pO_2 < 60$ mmHg) and direct changes in blood pH that are independent of $CO_2$. If these receptors are damaged, the body loses its hypoxic ventilatory response.

(b) Central chemoreceptors, however, remain fully functional within the brainstem. These receptors are highly sensitive to the partial pressure of carbon dioxide ($pCO_2$) in the blood.

(c) When arterial $pCO_2$ rises, the dissolved $CO_2$ gas diffuses across the blood-brain barrier into the cerebrospinal fluid (CSF).

(d) Inside the CSF, $CO_2$ reacts with water to form carbonic acid, which dissociates into bicarbonate and **hydrogen ions ($H^+$)**. The central chemoreceptors detect this localized drop in CSF pH and send strong signals to the respiratory centers to **increase the ventilation rate**, clearing the excess $CO_2$.

**Final Answer:** An increase in arterial $pCO_2$ sensed indirectly via hydrogen ion shifts in the cerebrospinal fluid.

**Answer: (B)**

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## Q18.

### Solution

**Concept:** A left ventricular pressure-volume loop maps the physical changes in pressure and volume inside the heart's main pumping chamber across a single complete cardiac cycle.

**Solution:**

Let's trace the four corners of the pressure-volume loop sequentially to locate Point Alpha:

(a) The bottom horizontal line from right to left represents ventricular filling, where volume increases at low pressure. The corner at the bottom right marks the end of filling: the end-diastolic volume (EDV). At this point, the mitral valve closes.

(b) The right vertical line shows **isovolumetric contraction**, where ventricular pressure climbs rapidly while volume stays constant because all valves are closed.

(c) The top curve represents ventricular ejection, beginning when ventricular pressure exceeds aortic pressure, forcing the aortic valve open.

(d) The left vertical line shows **isovolumetric relaxation**, where pressure drops rapidly while volume stays constant at its lowest point, the end-systolic volume (ESV).

(e) **Point Alpha** sits at the bottom-left corner of this loop $(1.5, 0.5)$. This point marks the transition from isovolumetric relaxation to a new filling phase. For filling to begin, ventricular pressure must fall below atrial pressure, which causes the **mitral (bicuspid) valve to open**.

**Final Answer:** Mitral (Bicuspid) valve opening

**Answer: (D)**

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## Q19.

### Solution

**Concept:** Excitation-contraction coupling in skeletal muscle converts an electrical action potential into mechanical force via conformational changes in thin-filament regulatory proteins.

**Solution:**

Let's follow the structural rearrangements that occur once calcium enters the sarcoplasm:

(a) An action potential traveling down the T-tubules activates dihydropyridine receptors (DHPR), opening ryanodine receptors (RyR) to release calcium ($Ca^{2+}$) from the sarcoplasmic reticulum into the cytoplasm.

(b) This free $Ca^{2+}$ binds directly to the **Troponin-C** subunit of the heterotrimeric troponin complex located on the thin actin filaments.

(c) Binding to $Ca^{2+}$ causes a rapid conformational shift in the entire troponin complex. This shift pulls the long, rope-like protein **tropomyosin** out of its resting position deep within the actin groove.

(d) This displacement uncovers the **active myosin-binding sites** on the actin filament, allowing energized myosin heads to bind and form cross-bridges, which initiates the power stroke.

**Final Answer:** Displacement of Tropomyosin away from the active myosin-binding sites on the actin filament

**Answer: (B)**

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## Q20.

### Solution

**Concept:** Axonal action potentials depend on the coordinated opening and closing of voltage-gated sodium ($Na^+$) channels, which feature two distinct regulatory gates: an activation gate ($m$-gate) and an inactivation gate ($h$-gate).

**Solution:**

Let's analyze the functional states of the sodium channel during an action potential:

(a) At the resting potential, the activation gate is closed and the inactivation gate is open. When a stimulus depolarizes the membrane to threshold, the activation gates open rapidly, allowing $Na^+$ ions to flood into the cell and drive the upstroke of the action potential.

(b) At the peak of depolarization, the **inactivation gates ($h$-gates) click shut**. This stops the influx of sodium ions, allowing voltage-gated potassium channels to safely repolarize the cell.

(c) As long as these inactivation gates remain firmly shut, the neuron is in its **absolute refractory period**. During this time, the cell cannot fire another action potential, no matter how strong the stimulus.

(d) If a drug locks these inactivation gates ($h$-gates) in their closed position right after an action potential fires, the channels cannot reset back to their resting state. As a result, the neuron enters a permanent **absolute refractory state** and becomes completely incapable of firing subsequent action potentials, halting all further nerve conduction.

**Final Answer:** Neurons enter an absolute refractory state and cannot fire subsequent action potentials

**Answer: (B)**

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## Q21.

### Solution

**Concept:** The digestive system relies on specialized gastrointestinal hormones to coordinate the release of secretions and regulate motility in response to incoming food components.

**Solution:**

Let's evaluate the functions of the primary gastrointestinal hormones:

(a) **Secretin:** Released in response to acid in the duodenum; primarily stimulates the secretion of a watery, bicarbonate-rich fluid from the pancreatic ducts to neutralize chime.

(b) **Gastrin:** Secreted by stomach G-cells; stimulates gastric acid secretion and mucosal growth.

(c) **Cholecystokinin (CCK):** Synthesized and released by enteroendocrine I-cells in the mucosal lining of the duodenum and jejunum, primarily triggered by the presence of fatty acids and amino acids.

(d) Once released, **CCK** acts through the bloodstream to cause two major target responses: it triggers the pancreatic acinar cells to secrete an **enzyme-rich pancreatic fluid** (packed with digestive enzymes like amylase, lipase, and proteases), and it stimulates the smooth muscle of the gallbladder to **contract**, releasing concentrated bile into the duodenum to help emulsify fats.

**Final Answer:** Cholecystokinin (CCK)

**Answer: (C)**

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## Q22.

### Solution

**Concept:** The oxygen-hemoglobin dissociation curve illustrates how hemoglobin binds and releases oxygen. Shifts in this curve reflect changes in hemoglobin's affinity for oxygen, optimizing gas delivery to tissues with high metabolic demands.

**Solution:**

Let's analyze the local tissue factors that alter hemoglobin's structural affinity:

(a) A rightward shift means hemoglobin's affinity for oxygen is reduced at any given partial pressure. This lower affinity allows hemoglobin to unload oxygen more easily to oxygen-hungry tissues.

(b) During intense skeletal muscle contraction, local cellular respiration accelerates sharply. This metabolic spike releases large amounts of carbon dioxide ($CO_2$) and metabolic acids into the surrounding tissue spaces.

(c) This activity creates a specific local microenvironment defined by:

- **Increased $pCO_2$** (which binds directly to hemoglobin to form carbaminohemoglobin).
- **Decreased pH** (elevated $H^+$ concentration), which stabilizes the deoxygenated t-state of hemoglobin via the Bohr effect.
- **Increased local temperature** from the heat generated by working muscles.

(d) Together, these three factors shift the curve to the right, ensuring working muscle cells receive an abundant supply of oxygen.

**Final Answer:** Increased $pCO_2$, increased temperature, and decreased pH (elevated $H^+$)

**Answer: (B)**

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## Q23.

### Solution

**Concept:** The organ of Corti, located inside the cochlea of the inner ear, serves as the primary structure for hearing. It converts mechanical sound vibrations into electrical neural signals.

**Solution:**

Let's analyze the structural mechanics shown in the diagram:

(a) Sound waves travel through the cochlear fluids, causing the flexible basilar membrane to vibrate up and down.

(b) Specialized sensory hair cells are securely anchored to this vibrating basilar membrane. The tops of these hair cells feature fine, finger-like projections called **stereocilia**.

(c) These stereocilia extend upward until they contact or embed within the rigid, overlying **tectorial membrane**.

(d) When sound waves cause the basilar membrane to move relative to the tectorial membrane, it creates mechanical **shearing forces** at the interface. This shearing force bends the **stereocilia**, opening mechanically-gated ion channels that depolarize the cell and generate an electrical potential.

**Final Answer:** Stereocilia of hair cells pressing against the tectorial membrane

**Answer: (A)**

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## Q24.

### Solution

**Concept:** The hypothalamus regulates the anterior pituitary gland by secreting releasing or inhibiting hormones that travel down the hypophyseal portal vessels within the pituitary stalk.

**Solution:**

Let's examine how cutting the pituitary stalk affects hormone regulation:

(a) For most anterior pituitary hormones (including ACTH, GH, and TSH), the primary hypothalamic signal is stimulatory (e.g., CRH, GHRH, TRH). Severing the stalk cuts off these stimulatory signals, causing serum levels of these hormones to drop significantly.

(b) Prolactin (PRL) regulation is unique because the primary hypothalamic signal is inhibitory. The hypothalamus releases dopamine, which flows down the portal vessels to act as a tonic brake on prolactin secretion.

(c) When a patient suffers a complete **pituitary stalk transection**, this constant inhibitory dopamine signal is lost. Free from this negative control, the lactotroph cells in the anterior pituitary begin secreting prolactin autonomously, causing serum **prolactin levels to paradoxically rise**.

**Final Answer:** Prolactin (PRL)

**Answer: (C)**

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## Q25.

### Solution

**Concept:** The Cystic Fibrosis Transmembrane Conductance Regulator (CFTR) is an apical, cyclic AMP-regulated chloride channel expressed across many exocrine epithelial tissues, where it helps regulate fluid and electrolyte balance.

**Solution:**

Let's look at how a loss-of-function mutation in the CFTR gene impacts pancreatic function:

(a) In healthy pancreatic ducts, the CFTR channel pumps chloride ions ($Cl^-$) out into the duct lumen. This chloride export is coupled to an anion exchanger ($Cl^-/HCO_3^-$) that secretes bicarbonate ions, creating an osmotic gradient that draws water into the duct to dilute digestive enzymes.

(b) If the **CFTR channel loses function**, the cell cannot secrete chloride into the lumen, which also halts the coupled secretion of bicarbonate.

(c) Without these ions, the osmotic drive to move water into the pancreatic ducts drops sharply. As a result, the pancreatic secretions become dehydrated, forming **thick, sticky mucus plugs**. These plugs physically block the ducts, preventing pancreatic digestive enzymes from reaching the duodenum, which leads to exocrine pancreatic insufficiency and tissue scarring.

**Final Answer:** Failure to secrete chloride into the lumen, reducing fluid transport and causing thick mucus plugs that block enzyme delivery

**Answer: (B)**

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## Q26.

### Solution

**Concept:** Visual phototransduction is the biochemical process by which photoreceptor cells absorb photons of light and convert them into electrical signals that the brain can interpret.

**Solution:**

Let's trace the molecular events that occur inside a rod cell when it is exposed to light:

(a) In the dark, rod cells maintain high intracellular levels of cyclic guanosine monophosphate (cGMP). This cGMP keeps cyclic nucleotide-gated (CNG) sodium channels open, allowing a continuous influx of sodium ions known as the "dark current" that keeps the cell depolarized.

(b) When a photon strikes the cell, it is absorbed by the photopigment rhodopsin, causing its embedded 11-*cis* retinal chromophore to isomerize into all-*trans* retinal.

(c) This structural change activates the G-protein transducin, which then turns on the enzyme **phosphodiesterase (PDE)**.

(d) Active **PDE** rapidly breaks down cGMP into 5'-GMP, causing intracellular **cGMP levels to drop sharply**. Without cGMP bound to them, the **cyclic nucleotide-gated (CNG) sodium channels close**. This blocks the inward sodium current, causing the rod cell membrane to hyperpolarize and reduce its release of the neurotransmitter glutamate.

**Final Answer:** Activation of phosphodiesterase (PDE), decreasing cGMP levels and closing cyclic nucleotide-gated (CNG) sodium channels

**Answer: (B)**

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## Q27.

### Solution

**Concept:** The human female ovarian cycle is regulated by systemic shifts in gonadotropin hormones (LH and FSH) and ovarian steroids (estrogen and progesterone).

**Solution:**

Let's analyze the hormone curves across a standard 28-day cycle:

(a) Ovarian steroids like estrogen show a broad peak before ovulation and a second peak during the luteal phase. Progesterone remains very low until after ovulation, peaking during the mid-luteal phase.

(b) Gonadotropins show a different pattern, characterized by a sharp spike just before ovulation.

(c) Look closely at **Hormone Curve X**: it remains at a low baseline during the initial follicular phase, shoots up into a sharp, narrow spike just before Day 14, and then drops back to baseline for the rest of the cycle.

(d) This rapid mid-cycle surge is characteristic of **Luteinizing Hormone (LH)**. Triggered by a positive feedback loop from rising estrogen levels, this LH surge is the essential signal that causes the dominant follicle to rupture and release the egg.

**Final Answer:** Luteinizing Hormone (LH)

**Answer: (B)**

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## Q28.

### Solution

**Concept:** Cell-mediated immunity relies on specialized T lymphocyte populations to identify and eliminate intracellular pathogens, such as viruses, by recognizing altered self-antigens displayed on host cell surfaces.

**Solution:**

Let's evaluate how different T cell populations interact with major histocompatibility complex (MHC) molecules:

(a) Helper T cells ($CD4^+$) interact specifically with MHC Class II molecules, which are expressed primarily on professional antigen-presenting cells like macrophages and dendritic cells.

(b) **Cytotoxic T Lymphocytes ($CD8^+$)** are designed to scan **MHC Class I molecules**, which are expressed on almost all nucleated cells in the body.

(c) If a host cell is infected by a virus, it processes viral proteins and displays pieces of them on its surface bound to **MHC Class I** molecules.

(d) When a specialized **$CD8^+$ Cytotoxic T cell** encounters this foreign viral antigen blend, its T-cell receptor (TCR) binds to the complex. This binding triggers the T cell to release cytotoxic granules containing **perforins** (which punch holes in the target cell membrane) and **granzymes** (which enter through the holes to trigger apoptosis), destroying the infected host cell before the virus can replicate further.

**Final Answer:** Cytotoxic $T$ Lymphocytes ($CD8^+$)

**Answer: (C)**

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## Q29.

### Solution

**Concept:** Breathing mechanics rely on changes in thoracic cavity volume to generate pressure gradients that move air into and out of the lungs. While quiet, resting expiration is a passive process driven by elastic recoil, forced expiration requires active muscle contraction.

**Solution:**

Let's isolate the muscle groups involved in forced expiration:

(a) To force air out of the lungs, the volume of the thoracic cavity must be actively decreased beyond its resting state to build up positive pressure inside the alveoli.

(b) The **internal intercostal muscles** contract to pull the rib cage downward and inward, flattening the chest cavity.

(c) Simultaneously, the **abdominal muscles** (including the rectus abdominis and obliques) contract forcefully. This contraction pushes the abdominal organs upward against the diaphragm, forcing it higher into the thoracic cavity.

(d) Together, the coordinated contraction of the **internal intercostals and abdominal muscles** rapidly reduces thoracic volume, driving air out of the lungs during forced exhalation.

**Final Answer:** Internal Intercostals and Abdominal muscles

**Answer: (C)**

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## Q30.

### Solution

**Concept:** Genetic linkage mapping uses data from genetic crosses to calculate the distances between linked genes. Interferences can alter the frequency of double crossovers compared to independent probability expectations.

**Solution:**

Let's calculate the expected frequency of double crossovers step-by-step:

(a) First, we determine the correct linear order of the three genes based on the given recombination frequencies: $A - B = 12\% = 0.12$, $B - C = 7\% = 0.07$, and $A - C = 18\% = 0.18$. Since $A - C$ shows the largest distance, genes $A$ and $C$ must be the outer markers, placing gene $B$ in the middle ($A - B - C$).

(b) Next, we calculate the theoretical double crossover frequency ($\text{DCO}_{\text{expected}}$) assuming the two crossover events occur completely independently of one another:

$$\text{DCO}_{\text{expected}} = \text{frequency}(A - B) \times \text{frequency}(B - C) = 0.12 \times 0.07 = 0.0084 \text{ (or } 0.84\%)$$

(c) The coefficient of coincidence (C.O.C.) is defined as the ratio of observed double crossovers to expected double crossovers:

$$\text{C.O.C.} = \frac{\text{DCO}_{\text{observed}}}{\text{DCO}_{\text{expected}}}$$

(d) We can now use the given C.O.C. of 0.4 to calculate the actual observed percentage of double crossover progeny:

$$\text{DCO}_{\text{observed}} = \text{C.O.C.} \times \text{DCO}_{\text{expected}} = 0.4 \times 0.0084 = 0.00336 \text{ (or } 0.336\%)$$

**Final Answer:** $\boxed{0.336\%}$

**Answer: (B)**

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## Q31.

### Solution

**Concept:** DNA replication processivity describes an enzyme's ability to catalyze continuous nucleotide additions without dissociating from the template strand. In *E. coli*, high processivity is maintained by a specialized structural subunit of the core polymerase.

**Solution:**

Let's evaluate the roles of the subunits within the *E. coli* DNA Polymerase III holoenzyme complex:

(a) The $\alpha$ subunit contains the primary $5' \rightarrow 3'$ catalytic polymerase activity, while the $\epsilon$ subunit provides $3' \rightarrow 5'$ proofreading exonuclease activity.

(b) Left on its own, this catalytic core has low processivity, falling off the DNA template after adding only a few dozen nucleotides.

(c) To overcome this, the **$\beta_2$ sliding clamp subunit** forms a dimeric ring structure that encircles the DNA strand. This ring binds tightly to the core polymerase, locking it onto the template strand so it can add thousands of nucleotides continuously without falling off.

**Final Answer:** The $\beta_2$ sliding clamp subunit

**Answer: (C)**

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## Q32.

### Solution

**Concept:** Translation is the process where ribosomes read mRNA transcripts to synthesize polypeptide chains. The active bacterial ribosome contains specific functional pockets designated as the A (aminoacyl), P (peptidyl), and E (exit) sites.

**Solution:**

Let's identify the structural target shown in the diagram:

(a) The diagram depicts a complete bacterial 70S ribosome, consisting of a large 50S subunit and a small 30S subunit.

(b) The red arrow points directly to the **A-site (aminoacyl-tRNA binding site)**, which is the entry portal where incoming charged tRNAs match their anticodons with mRNA codons.

(c) Several classes of antibiotics, such as tetracyclines, target this specific site. They bind to the pocket and physically block incoming **aminoacyl-tRNAs** from attaching, halting protein synthesis.

**Final Answer:** Aminoacyl-tRNA binding site on the ribosome

**Answer: (B)**

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## Q33.

### Solution

**Concept:** The *lac* operon uses a dual-control mechanism to regulate gene expression based on available carbon sources, ensuring the cell prioritizes glucose metabolism over alternative sugars like lactose.

**Solution:**

Let's trace how glucose levels regulate the *lac* operon via catabolite repression:

(a) The efficiency of *lac* operon transcription depends on an activator protein called Catabolite Activator Protein (CAP), which must bind to a site next to the promoter.

(b) For CAP to bind to the DNA, it must first be activated by binding to cyclic AMP (cAMP).

(c) When extracellular glucose levels are high, the transport of glucose into the cell inhibits the enzyme adenylate cyclase, causing intracellular **cAMP levels to drop**.

(d) Without sufficient cAMP, CAP cannot change into its active conformation and **fails to bind to the promoter region**. Without CAP bound to the DNA, RNA polymerase cannot efficiently initiate transcription, keeping the *lac* operon turned off even if lactose is present.

**Final Answer:** High glucose levels reduce intracellular cAMP, preventing CAP from binding to the promoter region

**Answer: (B)**

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## Q34.

### Solution

**Concept:** Eukaryotic pre-mRNA transcripts undergo extensive post-transcriptional processing before leaving the nucleus, including 5′ capping, splicing, and 3′ polyadenylation.

**Solution:**

Let's isolate the role of the conserved sequence motif near the end of the transcript:

(a) The highly conserved 5′-AAUAAA-3′ sequence functions as a vital polyadenylation signal peptide motif.

(b) During transcription, as RNA polymerase passes this sequence, specialized proteins (such as Cleavage and Polyadenylation Specificity Factor, or CPSF) recognize and bind to the AAUAAA motif on the newly formed pre-mRNA.

(c) These proteins recruit an endonuclease that clips the transcript roughly 10 to 30 nucleotides downstream of the signal. Following this cleavage, poly(A) polymerase adds a protective tail of adenine residues to the fresh 3′ end.

(d) If a mutant transcript **lacks this 5′-AAUAAA-3′ consensus sequence**, these processing proteins cannot bind, resulting in a **loss of proper cleavage and polyadenylation at the 3′ end**, which leaves the transcript unstable and prone to degradation.

**Final Answer:** Loss of proper cleavage and polyadenylation at the 3′ end

**Answer: (C)**

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## Q35.

### Solution

**Concept:** Pseudodominance is a genetic phenomenon where a recessive allele is phenotypically expressed despite being present in a single copy (heterozygous state). This occurs because the corresponding wild-type dominant allele on the homologous chromosome has been physically lost.

**Solution:**

Let's analyze the effects of various structural chromosomal mutations:

(a) Inversions and translocations alter the arrangement or location of chromosomal segments but do not typically change the total quantity of genetic material. Therefore, they do not leave a lone recessive allele uncovered.

(b) A **deletion** (such as an interstitial or terminal deletion) physically removes a segment of a chromosome.

(c) If a heterozygous individual carries a mutant, recessive lethal allele on one chromosome and the normal dominant allele on the homologous partner, an **interstitial deletion** that knocks out the region containing the dominant allele will leave the recessive allele without a partner.

(d) As a result, the lone recessive allele is expressed phenotypically, creating a pattern of **pseudodominance** because the masking dominant gene is entirely missing.

**Final Answer:** Interstitial Deletion

**Answer: (C)**

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## Q36.

### Solution

**Concept:** Eukaryotic DNA replication requires the unwinding of the double helix at the replication fork. This mechanical separation of complementary strands is driven by a specialized hexameric motor complex that moves processively along the lagging strand template.

**Solution:**

Let's identify the functional machinery at the eukaryotic replication fork:

(a) The leading and lagging strands are synthesized by DNA polymerases $\epsilon$ and $\delta$, respectively, while single-stranded regions are stabilized by replication protein A (RPA).

(b) The driving engine right at the unwinding junction is the replicative **helicase**. In eukaryotic systems, this function is fulfilled by the **hexameric MCM2-7 helicase complex** (Minichromosome Maintenance proteins 2 to 7).

(c) As part of the active CMG complex (CDC45-MCM2-7-GINS), **Structural Component Y** uses the energy of ATP hydrolysis to break hydrogen bonds between base pairs, traveling $3' \rightarrow 5'$ along the lagging strand template to move the replication fork forward.

**Final Answer:** Hexameric MCM2-7 Helicase complex

**Answer: (B)**

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## Q37.

### Solution

**Concept:** Translation depends on absolute accuracy when matching an amino acid with its corresponding mRNA codon. While the ribosome verifies the match between an mRNA codon and a tRNA anticodon, it cannot verify whether the tRNA is carrying the correct amino acid.

**Solution:**

Let's examine why aminoacyl-tRNA synthetases establish the genetic code:

(a) The ribosome blindly accepts any aminoacyl-tRNA whose anticodon matches the mRNA codon in its A-site, meaning it does not double-check the attached amino acid.

(b) The true translation step is performed earlier by **aminoacyl-tRNA synthetases**.

(c) Each specific synthetase enzyme features two highly selective binding pockets: one for a specific amino acid and one for its cognate tRNA molecule.

(d) By **covalently linking a specific amino acid to its cognate tRNA carrying the matching anticodon**, these enzymes physically link the amino acid alphabet to the nucleic acid alphabet, acting as the true translators of the genetic code.

**Final Answer:** They covalently link a specific amino acid to its cognate tRNA carrying the matching anticodon

**Answer: (B)**

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## Q38.

### Solution

**Concept:** Ultraviolet (UV) light hits DNA and causes bulky structural distortions, primarily cyclo-butane pyrimidine dimers (CPDs) and 6-4 photoproducts. These structural kinks block replication and transcription, requiring specialized excision machinery.

**Solution:**

Let's determine the repair pathway linked to this sensitivity:

(a) Bulky helix-distorting lesions are targeted and fixed by the **Nucleotide Excision Repair (NER)** pathway.

(b) The NER system uses specialized proteins to recognize the kink, cut the damaged strand on both sides of the lesion, remove a short oligonucleotide segment containing the dimer, and fill the gap using a DNA polymerase and ligase.

(c) **Xeroderma Pigmentosum** is caused by an inherited autosomal recessive defect in any one of several core NER genes (such as *XPA* through *XPG*).

(d) Because their **Nucleotide Excision Repair (NER)** pathway is non-functional, these individuals cannot repair UV-induced thymine dimers, leading to a high rate of skin cancers and extreme sensitivity to sunlight.

**Final Answer:** Nucleotide Excision Repair (NER)

**Answer: (C)**

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## Q39.

### Solution

**Concept:** Eukaryotic RNA Polymerase II cannot recognize promoter sequences on its own. It relies on a coordinated assembly of general transcription factors (GTFs) to form a functional pre-initiation complex (PIC) at the core promoter.

**Solution:**

Let's look at the assembly sequence of basal transcription factors:

(a) The core promoter of many eukaryotic genes contains a consensus sequence rich in thymine and adenine bases, known as the TATA box.

(b) The multi-subunit factor **TFIID** is responsible for identifying this site. It contains the highly conserved **TATA-binding protein (TBP)** subunit along with several TBP-associated factors (TAFs).

(c) **TFIID** binds directly to the TATA box, distorting the DNA helix to create a platform that recruits subsequent transcription factors (TFIIA, TFIIB, TFIIF, TFIIE, and TFIIH) along with RNA Polymerase II.

**Final Answer:** TFIID

**Answer: (C)**

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## Q40.

### Solution

**Concept:** Pedigree analysis evaluates how traits are passed down through generations to determine their underlying genetic mechanism, such as autosomal, sex-linked, or extranuclear modes of inheritance.

**Solution:**

Let's analyze the transmission patterns shown in the pedigree chart:

(a) In Generation 1, an affected female mates with an unaffected male.

(b) In Generation 2, their offspring consist of an affected male and an unaffected female.

(c) Let's check the modes of inheritance:

- **Y-linked:** Ruled out immediately because a female cannot carry or pass on a Y chromosome.
- **X-linked Recessive:** If the trait were X-linked recessive, an affected mother ($X^aX^a$) would pass an $X^a$ chromosome to all her sons, making every son affected. This fits the affected male offspring. However, it fails to explain the general transmission across broad lineages where children inherit traits exclusively from their maternal line.
- **Mitochondrial (Maternal) Inheritance:** Mitochondria are transmitted exclusively through the cytoplasm of the egg. Therefore, an affected mother passes the trait to **all of her children**, regardless of their sex. However, looking at the small sample, we see a crucial detail: the trait moves from the mother directly to her offspring. In larger lineages, if an affected male passes the trait to none of his children while an affected female passes it to all of her children, it indicates maternal inheritance. Let's re-verify typical standard textbook question layouts. A mother passing a trait to her children can match an **X-linked Recessive** pattern if she is a carrier or affected, but an affected mother ($X^aX^a$) must have 100% affected sons. Here, the sole son is indeed affected. Let's look closely at the choices. A trait passed down from an affected female to her male offspring without paternal contribution fits an **X-linked Recessive inheritance pattern** perfectly when evaluating classical Mendelian options.

**Final Answer:** X-linked Recessive inheritance pattern

**Answer: (D)**

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## Q41.

### Solution

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

**Solution:**

Let's calculate the base composition using these base-pairing rules:

(a) Since Thymine (T) pairs exclusively with Adenine (A) via two hydrogen bonds, their percentages inside a double-stranded molecule must be equal:

$$A = T = 32\%$$

(b) Adding these two percentages gives the total proportion of A-T base pairs in the DNA segment:

$$A + T = 32\% + 32\% = 64\%$$

(c) The remaining percentage of the DNA must consist of Guanine (G) and Cytosine (C) base pairs:

$$G + C = 100\% - 64\% = 36\%$$

(d) Because Guanine pairs exclusively with Cytosine, the remaining percentage is divided equally between them:

$$G = C = \frac{36\%}{2} = 18\%$$

**Final Answer:** $\boxed{18\%}$

**Answer: (B)**

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## Q42.

### Solution

**Concept:** Mitotic anaphase is divided into two distinct mechanical phases: Anaphase A, where sister chromatids move toward opposite spindle poles, and Anaphase B, where the spindle poles themselves pull further apart.

**Solution:**

Let's isolate the structural mechanics of chromosome movement during Anaphase A:

(a) During Anaphase A, chromosomes are pulled toward the poles by kinetochore microtubules.

(b) This movement depends on molecular motors (like kinesin-13) that actively depolymerize the **plus-ends of kinetochore microtubules** right at the kinetochore interface, shortening the fibers and pulling the chromosomes inward.

(c) If cells are treated with a drug that completely blocks the depolymerization of these kinetochore microtubule plus-ends, the microtubules cannot shorten.

(d) As a result, the mechanical pulling force is lost, and **Anaphase A chromosome movement toward the spindle poles will be completely stalled**.

**Final Answer:** Anaphase A chromosome movement toward the spindle poles will be completely stalled

**Answer: (B)**

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## Q43.

### Solution

**Concept:** Mitochondria are double-membrane organelles that generate metabolic energy through cellular respiration. Their interior is divided into distinct structural compartments, each housing specific sets of metabolic enzymes.

**Solution:**

Let's map the locations of major respiratory pathway enzymes within the mitochondrion:

(a) The inner mitochondrial membrane contains the electron transport chain complexes and ATP synthase.

(b) The intermembrane space holds protons pumped out during electron transport.

(c) The **internal mitochondrial matrix** is the fluid-filled space enclosed by the inner membrane.

(d) This matrix contains a high concentration of soluble enzymes, including the **pyruvate dehydrogenase complex** (which catalyzes the oxidative decarboxylation of pyruvate to acetyl-CoA) and all the enzymes of the **citric acid cycle** (except succinate dehydrogenase, which is membrane-bound). These soluble pathways run directly within the matrix solution.

**Final Answer:** Internal Mitochondrial Matrix solution

**Answer: (D)**

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## Q44.

### Solution

**Concept:** The fluid mosaic model describes plasma membranes as dynamic structures where lipids and proteins diffuse laterally. Rather than being completely uniform, membranes contain specialized microdomains with distinct lipid compositions.

**Solution:**

Let's identify the membrane domain highlighted as Zone Alpha:

(a) The layout shows a distinct domain within the lipid bilayer, characterized by longer, more saturated fatty acid tails that form a thicker and less fluid membrane patch.

(b) This specialized microdomain represents a **lipid raft**.

(c) Lipid rafts are tightly packed lateral assemblies **enriched with cholesterol and sphingolipids**.

(d) Because of their unique lipid packing, these rafts float dynamically within the more fluid surrounding membrane matrix. They serve as stable platforms that organize and concentrate specific signaling proteins, receptors, and GPI-anchored proteins to facilitate cell signaling.

**Final Answer:** Lipid Raft enriched with cholesterol and sphingolipids

**Answer: (B)**

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## Q45.

### Solution

**Concept:** Prophase I of meiosis is a prolonged and complex stage divided into five distinct sub-phases: leptotene, zygotene, pachytene, diplotene, and diakinesis. Each phase is defined by specific chromosome behaviors.

**Solution:**

Let's review the events of each Prophase I sub-phase:

(a) **Leptotene:** Chromosomes begin to condense.

(b) **Zygotene:** The synaptonemal complex begins to form, aligning homologous chromosomes in a process called synapsis.

(c) **Pachytene:** Synapsis is complete, and homologous chromosomes cross over to exchange genetic material.

(d) **Diplotene:** The **synaptonemal complex disassembles**, allowing the homologous chromosomes to slightly separate and repel one another. However, they remain physically held together at the exact sites where crossing over occurred. These cross-connections are called **chiasmata**. This structural separation makes chiasmata visible under a microscope, defining the **diplotene** stage.

**Final Answer:** Diplotene

**Answer: (C)**

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## Q46.

### Solution

**Concept:** Proteins destined for secretion, plasma membrane integration, or lysosomes must be targeted to the endoplasmic reticulum (ER) during translation. This targeting is managed by the Signal Recognition Particle (SRP).

**Solution:**

Let's analyze how disrupting SRP function impacts the cell:

(a) As a ribosome translates an mRNA encoding a secretory protein, a specialized hydrophobic signal sequence emerges.

(b) The **Signal Recognition Particle (SRP)**, a ribonucleoprotein complex, recognizes and binds to this signal sequence, temporarily halting translation.

(c) The SRP then docks with its receptor on the ER membrane, guiding the ribosome-nascent chain complex to the translocon channel.

(d) If a pharmacological agent disrupts **SRP RNA** function, the complex cannot bind to the signal peptide or dock with the ER membrane. As a result, the **cotranslational targeting of nascent secretory proteins to the Rough Endoplasmic Reticulum** is completely blocked, leaving these proteins trapped in the cytoplasm.

**Final Answer:** Cotranslational targeting of nascent secretory proteins to the Rough Endoplasmic Reticulum

**Answer: (B)**

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## Q47.

### Solution

**Concept:** Epithelial tissues experience significant mechanical stress. To withstand this stretching and pulling, individual cells are bound together by specialized anchoring junctions that couple their internal cytoskeletal networks.

**Solution:**

Let's identify the cytoskeletal connections of different cell junctions:

(a) **Tight Junctions:** Form a barrier that seals the intercellular space, blocking the paracellular transport of molecules.

(b) **Adherens Junctions:** Connect cells together using transmembrane cadherins that anchor internally to the **actin filament** network.

(c) **Desmosomes (Macula adherens):** Use specialized cadherins (desmogleins and desmocollins) to link adjacent cells. Internally, these junctional complexes anchor directly to dense meshworks of **intermediate filaments (such as keratins)**. This connection creates a continuous, high-tensile structural network across the entire epithelial sheet, providing mechanical cohesive strength.

**Final Answer:** Desmosomes (Macula adherens)

**Answer: (C)**

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## Q48.

### Solution

**Concept:** Protein sorting in the secretory pathway relies on specific molecular tags to direct proteins from the Golgi apparatus to their correct cellular destinations.

**Solution:**

Let's trace the sorting path of lysosomal enzymes:

(a) Acid hydrolases destined for degradative organelles are synthesized in the rough ER and transported to the *cis*-Golgi network.

(b) Inside the Golgi, a specialized phosphotransferase recognizes these structural enzymes and appends a chemical tag: a **mannose-6-phosphate (M6P)** group.

(c) In the *trans*-Golgi network, specific M6P receptors bind these tagged enzymes and package them into clathrin-coated vesicles.

(d) These transport vesicles bud off and fuse with late endosomes, which ultimately mature into **lysosomes**. This makes the **mannose-6-phosphate** tagging system essential for the biogenesis and target delivery of lysosomal enzymes.

**Final Answer:** Lysosome

**Answer: (C)**

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## Q49.

### Solution

**Concept:** The transition through cell cycle checkpoints is driven by the activation of Cyclin-Dependent Kinases (CDKs), which require binding to regulatory cyclin proteins to become active.

**Solution:**

Let's look at the biochemical mechanism that drives entry into mitosis:

(a) During the $G_2$ phase, the regulatory protein **Cyclin B** accumulates steadily inside the cell.

(b) To trigger the transition into the M phase, **Cyclin B** binds directly to the catalytic subunit **Cdk1** (also known as $p34^{cdc2}$).

(c) This binding forms the **Mitosis-Promoting Factor (MPF)** complex.

(d) Once activated by specific dephosphorylation events, active **MPF** phosphorylates a variety of target proteins. This triggers chromosome condensation, nuclear envelope breakdown (via lamina phosphorylation), and spindle assembly, launching the cell into mitosis.

**Final Answer:** It activates Cdk1 to form the Mitosis-Promoting Factor (MPF) complex

**Answer: (A)**

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## Q50.

### Solution

**Concept:** Structural polysaccharides provide shape, rigid protection, and support across different domains of life. Their physical properties depend on their specific monosaccharide subunits and linkage geometries.

**Solution:**

Let's analyze the composition of the structural polymers listed:

(a) **Cellulose:** A structural homopolymer made of $\beta$-1,4-linked D-glucose units, found in plant cell walls.

(b) **Chitin:** A structural homopolymer composed entirely of **$\beta$-1,4-linked N-acetylglucosamine** residues.

(c) This specific nitrogen-containing polysaccharide forms crystalline microfibrils that build the rigid, protective cell walls of **fungal species**, and also forms the tough exoskeleton of arthropods.

(d) **Peptidoglycan:** Built from alternating NAG and NAM residues cross-linked by short amino acid chains, forming bacterial cell walls.

**Final Answer:** Chitin polymer

**Answer: (B)**

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## Q51.

### Solution

**Concept:** Ribosome biogenesis is a complex process that spans multiple cellular compartments. Ribosomal RNA (rRNA) is transcribed and assembled with ribosomal proteins inside the nucleus before the completed subunits are exported to the cytoplasm.

**Solution:**

Let's track the cellular path of ribosomal subunit assembly:

(a) Ribosomal proteins are translated in the cytoplasm and imported into the nucleus. Inside the **nucleolus**, they assemble with newly transcribed rRNA molecules to form the immature 40S and 60S ribosomal subunits.

(b) Once these large macromolecular complexes are assembled, they leave the nucleolus and move through the surrounding **nucleoplasm**.

(c) To reach their functional destinations in the cytoplasm or on the rough ER, they must pass through the nuclear envelope via nuclear pore complexes (NPCs).

(d) If a mutant yeast strain produces a defective nuclear porin complex that blocks this export step, the completed 40S and 60S subunits remain trapped inside the nucleus, accumulating within the **nucleolus and nucleoplasm space**.

**Final Answer:** Nucleolus and Nucleoplasm space

**Answer: (B)**

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## Q52.

### Solution

**Concept:** A trophic cascade occurs when predators suppress the abundance or alter the behavior of their prey, releasing the next lower trophic level from predation or herbivory.

**Solution:**

Let's trace the ecological effects of removing top carnivores from a three-level food chain:

(a) The model includes three main levels: Primary Producers (plants) → Primary Consumers (herbivores) → Secondary/Top Consumers (carnivores).

(b) If an ecological catastrophe completely eliminates the top carnivores, the primary regulatory check on herbivores is removed.

(c) Without predators to control their numbers, the **herbivore populations will surge** rapidly.

(d) This explosion in herbivore numbers increases grazing pressure on the lowest trophic level, leading to a **severe decline in primary producer biomass** and potentially degrading the entire ecosystem plant community.

**Final Answer:** Herbivore populations will surge, causing a severe decline in primary producer biomass

**Answer: (B)**

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## Q53.

### Solution

**Concept:** Lindeman's ten percent law of trophic efficiency states that during the transfer of energy from one trophic level to the next, only about 10% of the organic energy is stored as biomass to be available for the next consumer level.

**Solution:**

Let's calculate the energy available at each successive trophic level step-by-step:

(a) The baseline energy fixed by producers is given as the Net Primary Productivity (NPP):

$$\text{Trophic Level 1 (Producers)} = 22,000 \text{ kcal/m}^2/\text{yr}$$

(b) Applying the 10% efficiency rule to find the energy available to primary consumers (herbivores):

$$\text{Trophic Level 2 (Primary Consumers)} = 22,000 \times 0.10 = 2,200 \text{ kcal/m}^2/\text{yr}$$

(c) Calculating the energy transferred to secondary consumers (primary carnivores):

$$\text{Trophic Level 3 (Secondary Consumers)} = 2,200 \times 0.10 = 220 \text{ kcal/m}^2/\text{yr}$$

(d) Calculating the energy transferred to tertiary consumers (secondary carnivores):

$$\text{Trophic Level 4 (Tertiary Consumers)} = 220 \times 0.10 = 22 \text{ kcal/m}^2/\text{yr}$$

**Final Answer:** $\boxed{22 \text{ kcal/m}^2/\text{yr}}$

**Answer: (C)**

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## Q54.

### Solution

**Concept:** Population growth in a resource-limited environment is described by the logistic growth model. Growth starts out fast but slows as resources become scarce, eventually leveling off at a stable baseline.

**Solution:**

Let's analyze the limits shown on the graph:

(a) The curve displays a classic sigmoidal (S-shaped) logistic growth profile, where population size ($N$) increases over time.

(b) As the population size grows, density-dependent factors (such as food availability, nesting space, and waste accumulation) slow the growth rate.

(c) The horizontal line, labeled **Asymptote K**, represents the maximum population size that the environment's available resources can support over the long term.

(d) In ecology, this value is defined as the **Carrying Capacity ($K$) of the environment**. Once the population size matches this limit, the birth rate equals the death rate, and population growth levels off.

**Final Answer:** Carrying Capacity ($K$) of the environment

**Answer: (B)**

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## Q55.

### Solution

**Concept:** Atmospheric nitrogen gas ($N_2$) makes up about 78% of the air, but it cannot be used directly by plants or animals because its two nitrogen atoms are held together by an extremely strong covalent triple bond (N ≡ N).

**Solution:**

Let's look at the biochemical requirements for nitrogen capture:

(a) To enter biological food webs, this triple bond must be broken and reduced to ammonia ($NH_3$) in a process called nitrogen fixation.

(b) Eukaryotes lack the enzymes required to break this bond. The process relies entirely on specialized prokaryotes (such as *Rhizobium*, *Azotobacter*, and *Anabaena*).

(c) These microorganisms express a specialized, oxygen-sensitive enzyme complex called **nitrogenase**.

(d) The nitrogenase complex breaks the stable triple bond of atmospheric nitrogen, initiating the global **Nitrogen Cycle** and generating the fixed nitrogen forms that support living communities.

**Final Answer:** Nitrogen Cycle

**Answer: (C)**

Go Back to Question 55

## Q56.

### Solution

**Concept:** Habitat fragmentation breaks up large, continuous natural areas into smaller, isolated patches. This fragmentation alters the environmental conditions along the boundaries of the remaining habitat.

**Solution:**

Let's analyze the ecological changes along habitat boundaries:

(a) The perimeter of a fragmented forest is directly exposed to the surrounding altered landscape, creating a distinct microclimate gradient.

(b) These boundary zones experience increased sunlight, higher wind speeds, more variable temperatures, and lower humidity compared to the protected forest interior.

(c) In addition, these open borders often see higher rates of generalist predator encounters and invasive species incursions.

(d) In conservation biology, these localized structural and microclimatic changes along habitat boundaries are called the **Edge Effect**.

**Final Answer:** Edge Effect

**Answer: (B)**

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## Q57.

### Solution

**Concept:** MacArthur and Wilson's theory of island biogeography states that the number of species on an island reaches an equilibrium determined by a balance between two factors: the rate of new species immigration and the rate of existing species extinction.

**Solution:**

Let's analyze how an island's size and location determine these rates:

(a) **Immigration rates** are driven by how close an island is to the mainland source pool. Islands that are **close to the mainland** receive a steady flow of dispersing organisms, keeping immigration rates high.

(b) **Extinction rates** are driven by the size of the island. **Large islands** offer more resources and diverse habitats, which support larger populations that are less prone to accidental extinction.

(c) Combining these factors, an island configuration that is both **large and close to the mainland** will maintain the highest immigration rates and the lowest extinction rates. This combination supports the highest equilibrium species richness at baseline balance.

**Final Answer:** Large islands located close to mainland source pools

**Answer: (D)**

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## Q58.

### Solution

**Concept:** Certain synthetic chemicals, such as chlorinated hydrocarbons (DDT) and heavy metals, are lipophilic (fat-soluble) and highly resistant to metabolic breakdown.

**Solution:**

Let's analyze the movement of these compounds through food chains as shown in the block diagram:

(a) Because these pollutants are not easily metabolized or excreted, they accumulate within the fatty tissues of individual organisms.

(b) When a consumer eats an organism from a lower trophic level, it absorbs the entire lifetime dose of accumulated toxins stored in that prey's tissues.

(c) As a result, the concentration of the pesticide increases at each successive step up the food chain, from water → plankton → fish → top predatory birds.

(d) This progressive accumulation up the food web is called **Biomagnification** (or Biological Amplification), and it can reach hazardous levels in top predators.

**Final Answer:** Biomagnification (Biological Amplification)

**Answer: (B)**

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## Q59.

### Solution

**Concept:** The stratospheric ozone layer ($O_3$) absorbs dangerous ultraviolet (UV-C and UV-B) radiation. Synthetic chlorofluorocarbons (CFCs) damage this protective layer through a series of photochemical reactions.

**Solution:**

Let's trace the chemical mechanism of ozone destruction:

(a) CFC molecules drift up into the stratosphere, where they are exposed to intense, high-energy solar UV radiation.

(b) This UV light breaks the carbon-chlorine bonds in CFCs, releasing highly reactive **free chlorine radicals ($Cl^{\bullet}$)**.

(c) A free chlorine radical reacts with an ozone molecule, pulling away an oxygen atom to form chlorine monoxide (ClO) and leaving oxygen gas ($O_2$):

$$Cl^{\bullet} + O_3 \rightarrow ClO + O_2$$

(d) The chlorine monoxide then reacts with free oxygen atoms, releasing the chlorine radical back into its active state:

$$ClO + O \rightarrow Cl^{\bullet} + O_2$$

(e) Because the **chlorine radical is regenerated**, a single atom can repeatedly break down thousands of ozone molecules in a catalytic cycle, accelerating ozone thinning over polar regions.

**Final Answer:** They release free chlorine radicals under UV radiation that repeatedly break down $O_3$ molecules.

**Answer: (A)**

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## Q60.

### Solution

**Concept:** Gause's competitive exclusion principle states that two species cannot coexist in the same community if they share identical requirements for limited resources; one species will inevitably outcompete and eliminate the other.

**Solution:**

Let's evaluate the evolutionary strategy used to avoid competitive exclusion:

(a) To coexist over the long term, competing species with overlapping fundamental niches often undergo natural selection that reduces competition.

(b) In this scenario, the two related species shift their foraging heights and root depths. This divergence creates distinct, non-overlapping realized niches.

(c) This evolutionary shift in resource use is called **Resource Partitioning**.

(d) It is often driven by character displacement, where competing species evolve different physical traits or behavioral habits to minimize direct competition, allowing them to coexist within the same community.

**Final Answer:** Resource Partitioning driven by character displacement

**Answer: (B)**

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## Q61.

### Solution

**Concept:** The three-domain system classifies life into Archaea, Bacteria, and Eukarya based on fundamental differences in cellular structure, ribosomal RNA sequences, and membrane biochemistry.

**Solution:**

Let's analyze the biochemical traits of the isolated deep-sea organism:

(a) **Cell Wall lacking peptidoglycan:** This rules out standard Eubacteria, which rely on a peptidoglycan matrix.

(b) **Ether-linked lipids with branched hydrocarbons:** This is a unique biochemical signature. While bacteria and eukaryotes build membranes from straight-chain fatty acids joined to glycerol by ester linkages, members of this group use branched isoprenoid chains attached by robust **ether linkages**. This adaptation stabilizes their membranes under extreme heat, acidity, or pressure.

(c) **Eukaryotic-like RNA polymerases:** Their transcription and translation machinery share a closer evolutionary ancestry with eukaryotes than with bacteria.

(d) These diagnostic molecular and cellular features place the organism squarely within the domain **Archaea** (traditionally classified as **Archaebacteria**).

**Final Answer:** Archaebacteria (Domain Archaea)

**Answer: (B)**

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## Q62.

### Solution

**Concept:** Plant family identification relies on diagnosing key configurations of floral structures, including the arrangement of petals, the layout of stamens, and the structure of the mature fruit.

**Solution:**

Let's evaluate the diagnostic traits of the dissected flower specimen:

(a) **Cruciform corolla:** The flower has four petals arranged in a cross shape, a classic diagnostic feature.

(b) **Tetradynamous stamens:** The androecium contains six stamens total, with **four long inner stamens and two short outer stamens**.

(c) **Siliqua fruit:** The gynoecium matures into a specialized two-valved dehiscent fruit called a siliqua, which splits open along a central false partition (replum).

(d) These distinct morphological features—cross-shaped petals, a $4+2$ stamen arrangement, and a siliqua fruit—are unique diagnostic markers for the family **Brassicaceae** (traditionally known as **Cruciferae**, the mustard family).

**Final Answer:** Brassicaceae (Cruciferae)

**Answer: (C)**

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## Q63.

### Solution

**Concept:** Animal taxonomy organizes phyla based on fundamental body plan characteristics, including body symmetry, tissue layers, and specialized organ systems.

**Solution:**

Let's trace the unique developmental features of the highlighted invertebrate group:

(a) Most animals maintain the same type of body symmetry throughout their life cycle. However, this phylum undergoes a dramatic structural shift during metamorphosis.

(b) Their larvae are free-swimming organisms that display clear **bilateral symmetry**. As they settle and mature into adults, they develop a five-part **pentaradial symmetry** (illustrated by the five-armed layout in the diagram).

(c) A definitive diagnostic feature of this group is the **water vascular system**, a network of fluid-filled canals that powers muscular tube feet for locomotion, food capture, and respiration.

(d) This combination of larval bilateral symmetry, adult radial symmetry, and a water vascular system is unique to the phylum **Echinodermata** (such as starfish and sea urchins).

**Final Answer:** Echinodermata

**Answer: (B)**

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## Q64.

### Solution

**Concept:** The colonization of the aerial niche by birds required radical evolutionary changes to their body plan, optimizing strength, minimizing weight, and maximizing metabolic power for flight.

**Solution:**

Let's evaluate the structural flight adaptations unique to class Aves:

(a) Flight requires a lightweight but rigid skeleton. Birds possess **pneumatic bones**, which are hollowed out and filled with air sacs connected to the respiratory system, reducing body weight.

(b) Aerodynamic lift and thrust are provided by **asymmetric flight feathers**, which slice through the air efficiently.

(c) To anchor the massive pectoral muscles required to flap wings, the avian breastbone is extended into a large, prominent central ridge called a **sternal keel** (carina).

(d) This combination of lightweight hollow bones, specialized feathers, and a large anchoring keel forms the core evolutionary toolkit for avian flight.

**Final Answer:** Pneumatic (hollow) bones, asymmetric feathers, and a well-developed sternal keel

**Answer: (B)**

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## Q65.

### Solution

**Concept:** Sub-viral pathogens are infectious particles that are smaller and less complex than standard viruses, consisting of only a single type of biomolecule without a complete viral structure.

**Solution:**

Let's classify the microscopic pathogen based on its molecular composition:

(a) **Prion:** An infectious agent composed entirely of a misfolded protein string, completely lacking nucleic acids.

(b) **Virion:** A complete, fully formed, infectious viral particle consisting of a nucleic acid core enclosed within a protective protein shell (capsid).

(c) **Viroid:** An infectious agent discovered by Theodor Diener, consisting solely of a short, circular, **single-stranded RNA molecule without a protein capsid**.

(d) Because they lack a protective coat, viroid RNAs rely on their tight secondary structure to resist host cell degradation. They cause a variety of serious diseases in economically important crops, fitting the description of the plant pathogen.

**Final Answer:** Viroid

**Answer: (C)**

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## Q66.

### Solution

**Concept:** The nightshade family (Solanaceae) contains economically important crops like tomatoes, potatoes, and peppers. Identifying members of this family relies on diagnosing a specific set of reproductive structures.

**Solution:**

Let's evaluate the diagnostic traits of the Solanaceae gynoecium:

(a) A key identifier for the family is a female reproductive structure built from two fused carpels: a **bicarpellary, syncarpous superior ovary**.

(b) Inside the ovary, the central core tissue where the ovules attach is uniquely **obliquely tilted and swollen** relative to the flower's main axis.

(c) The ovules are arranged around this central pillar in an **axile placentation** pattern. This distinctive layout—a syncarpous superior ovary with an obliquely swollen placenta and axile arrangement—is a definitive diagnostic marker for the family Solanaceae.

**Final Answer:** Bicarpellary, syncarpous, superior ovary with an obliquely swollen placenta and axile placentation

**Answer: (B)**

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## Q67.

### Solution

**Concept:** Triploblastic animals are classified into three groups based on the structure of their internal body cavity (coelom): acoelomates, pseudocoelomates, and eucoelomates.

**Solution:**

Let's evaluate the structural layers shown in the cross-section layout:

(a) The outer ring represents the ectoderm, and the inner ring represents the endoderm lining the gut cavity.

(b) In a true eucoelomate, the body cavity is completely lined by mesodermal tissue. In an acoelomate, the space between the ectoderm and endoderm is solid tissue, with no cavity at all.

(c) The diagram displays a body cavity where the middle embryonic layer (mesoderm) does not form a continuous lining. Instead, it is present as **scattered mesodermal pouches** floating within the fluid-filled cavity.

(d) This structural layout defines a **pseudocoelomate** organization, a classic anatomical trait of roundworms in the phylum **Aschelminthes** (Nematoda).

**Final Answer:** Pseudocoelomate (e.g., Aschelminthes)

**Answer: (B)**

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## Q68.

### Solution

**Concept:** The life cycle of plants evolved from homospory (producing a single type of spore that grows into a bisexual gametophyte) to heterospory (producing two distinct types of spores).

**Solution:**

Let's examine the evolutionary significance of heterospory in pteridophytes:

(a) Advanced pteridophytes like *Selaginella* and *Salvinia* are heterosporous. They produce small microspores (which grow into male gametophytes) and large megastores (which grow into female gametophytes).

(b) In these plants, the megaspore is not shed into the environment. Instead, it is retained on the parent sporophyte plant, where it is protected and nourished.

(c) The female gametophyte develops and supports fertilization right inside this retained spore case.

(d) This retention and protection of the female gametophyte on the parent plant provides the basic reproductive blueprint for seed development. Therefore, the evolution of a **heterosporous condition** serves as an **essential evolutionary precursor stage toward the development of a seed habit**.

**Final Answer:** It represents an essential evolutionary precursor stage toward the development of a seed habit

**Answer: (B)**

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## Q69.

### Solution

**Concept:** The development of the female gametophyte (embryo sac) in most angiosperms follows the monosporic *Polygonum*-type pathway. It initiates from a single functional megaspore, while the remaining three chalazal or micropylar megaspores degenerate.

**Solution:**

Let's track the developmental steps of the *Polygonum*-type embryo sac:

(a) The single functional megaspore undergoes **three sequential free-nuclear mitotic divisions** without immediate cytokinesis.

(b) The first mitosis produces 2 nuclei, which move to opposite poles. The second mitosis produces 4 nuclei, and the third mitosis yields a total of **8 nuclei** (4 at the micropylar end and 4 at the chalazal end).

(c) Cell wall formation (cytokinesis) then occurs to organize these nuclei:

- Three nuclei at the micropylar end form the egg apparatus (one egg cell and two synergids).
- Three nuclei at the chalazal end form three antipodal cells.
- The remaining two nuclei (polar nuclei) move to the center and share a single large central cell.

(d) This structural distribution results in a mature female gametophyte that is **8-nucleate but organized into 7 distinct cells**.

**Final Answer:** Three sequential free-nuclear mitotic divisions; 8-nucleate, 7-celled structural organization

**Answer: (B)**

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## Q70.

### Solution

**Concept:** During human fertilization, the binding and fusion of a sperm cell with the oocyte plasma membrane initiates a rapid signaling cascade. This triggers the activation of the egg to ensure successful monospermic development.

**Solution:**

Let's analyze the biochemical events that occur upon sperm entry:

(a) As the sperm membrane fuses with the oocyte, it induces a transient wave of intracellular calcium ($Ca^{2+}$) ions across the oocyte cytoplasm.

(b) This elevated calcium level acts as a physical signal that triggers the **immediate exocytosis of cortical granules** located right beneath the oocyte plasma membrane.

(c) The enzymes released from these cortical granules modify the extracellular matrix and cross-link glycoproteins within the **zona pellucida**.

(d) This structural modification forms a permanent block to polyspermy, preventing any additional sperm from penetrating the egg.

**Final Answer:** Immediate exocytosis of cortical granules to alter the zona pellucida matrix and block polyspermy

**Answer: (A)**

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## Q71.

### Solution

**Concept:** Following fertilization, the cleavage-stage embryo develops into a hollow ball of cells called a blastocyst. This structure features a clear spatial segregation of cells that determines the first embryonic lineages.

**Solution:**

Let's break down the structural architecture of the early human blastocyst:

(a) The outer layer of flattened cells forms the trophoblast, which gives rise to the embryonic contributions of the placenta.

(b) The interior houses a fluid-filled cavity known as the blastocoel.

(c) Internalized at one pole of the blastocoel is a distinct cluster of rounded cells labeled as **Cluster X**.

(d) This region is the **Inner Cell Mass (Embryoblast)**. The inner cell mass contains **pluripotential stem cells** that will differentiate and build all three definitive germ layers of the embryo proper.

**Final Answer:** Inner Cell Mass (Embryoblast) containing pluripotential stem cells

**Answer: (B)**

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## Q72.

### Solution

**Concept:** Following successful implantation, the developing embryo must maintain the mother's progesterone production to preserve the endometrial lining and prevent menstruation.

**Solution:**

Let's examine the hormonal tracking during early gestation:

(a) In a normal menstrual cycle, the corpus luteum degenerates after about 14 days due to a drop in pituitary luteinizing hormone (LH).

(b) To maintain pregnancy, the outer trophoblast cells of the implanting blastocyst begin secreting **Human Chorionic Gonadotropin (hCG)**.

(c) **hCG** biochemically mimics LH and binds directly to LH receptors on the cells of the corpus luteum.

(d) This continuous signaling rescues the corpus luteum from degradation, stimulating it to secrete high levels of progesterone and estrogens until the placenta can take over steroidogenesis around week 10.

**Final Answer:** Human Chorionic Gonadotropin (hCG)

**Answer: (A)**

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## Q73.

### Solution

**Concept:** The anther wall consists of four functional layers from the outside inward: the epidermis, endothecium, middle layers, and the tapetum. Each layer serves a specific role in microsporangium development.

**Solution:**

Let's isolate the specific physiological role of the innermost layer:

(a) The **tapetum** is the innermost layer of the anther wall, surrounding the sporogenous tissue. Its cells are highly metabolic, often multinucleate or polyploid.

(b) The primary function of the tapetal layer is to provide **nutritional support** to the developing microspores (pollen grains) as they undergo meiosis and maturation.

(c) Additionally, tapetal cells produce Ubisch bodies, which synthesize and export **sporopollenin precursors** to construct the highly resistant outer wall (exine) of the pollen grains. They also produce the pollen-kit proteins that coat the pollen surface.

**Final Answer:** It provides nutritional support to developing pollen grains and synthesizes the sporopollenin precursor components

**Answer: (B)**

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## Q74.

### Solution

**Concept:** Intrauterine devices (IUDs) are highly effective methods of reversible contraception. Non-hormonal IUDs, such as the copper T (CuT-380A), rely on localized biochemical changes rather than systemic hormone delivery.

**Solution:**

Let's break down the cellular mechanism of action of a copper IUD:

(a) Unlike hormonal pills or implants, a copper IUD does not inhibit ovulation, nor does it disrupt the pituitary-ovarian axis.

(b) Once placed within the uterine cavity, the device continuously releases **copper ions ($Cu^{2+}$)** into the local endometrial fluid.

(c) These copper ions generate a localized, sterile inflammatory response that is toxic to spermatozoa.

(d) The ions **reduce sperm motility, alter structural viability, and suppress acrosomal function**, acting as a highly effective, continuous spermicide within the female reproductive tract to prevent fertilization.

**Final Answer:** Release of copper ions that reduce sperm motility and viability, exerting a strong spermicidal effect

**Answer: (C)**

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## Q75.

### Solution

**Concept:** Angiosperm embryogenesis follows a highly coordinated series of structural changes, moving through predictable morphological shapes as cell division and tissue differentiation progress.

**Solution:**

Let's track the milestones of dicot embryo development shown in the schematic:

(a) The zygote divides asymmetrically to form a proembryo (*Pro* stage).

(b) Continued global divisions transform this into a spherical cell cluster called the globular embryo (*Glob* stage).

(c) Following the globular stage, localized cell divisions at two focal points establish the initial cotyledon primordia.

(d) This differential growth creates a distinct indentation at the apex, giving the embryo a characteristic **heart-shaped developmental structure**. This specific morphology matches **Stage Psi** in the timeline, which precedes the elongated torpedo-form stage.

**Final Answer:** Heart-shaped developmental embryo stage

**Answer: (B)**

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## Q76.

### Solution

**Concept:** A standard Polymerase Chain Reaction (PCR) cycle consists of three temperature-dependent steps: denaturation (~ 94°C), primer annealing (~ 50–65°C), and extension (~ 72°C).

**Solution:**

Let's analyze the physical effect of setting the annealing step to 85°C:

(a) During the annealing step, the temperature must drop low enough to allow short single-stranded oligonucleotide primers to form stable hydrogen bonds with their complementary target sequences on the denatured template DNA.

(b) The melting temperature ($T_m$) of standard PCR primers generally falls between 50°C and 65°C.

(c) If the temperature is incorrectly held at 85°C, the thermal kinetic energy will be too high to allow stable base pairing.

(d) Consequently, **the oligonucleotide primers will be unable to form hydrogen bonds with the template DNA strands**, and no amplification will occur during that cycle.

**Final Answer:** The oligonucleotide primers will be unable to form hydrogen bonds with the template DNA strands

**Answer: (B)**

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## Q77.

### Solution

**Concept:** During molecular cloning, a plasmid vector is linearized using restriction endonucleases. If the plasmid is cut with a single enzyme or generates compatible cohesive ends, it can easily reform a covalent circle without taking up the target insert, a process called self-ligation.

**Solution:**

Let's look at the biochemical requirements of DNA ligase:

(a) DNA ligase requires a **5′ phosphate group** on one DNA strand and a adjacent 3′ hydroxyl group on the other strand to catalyze phosphodiester bond formation.

(b) To minimize empty vector background, the linearized vector can be treated with the enzyme **Alkaline Phosphatase**.

(c) Alkaline phosphatase **strips the 5′ phosphate groups** from both ends of the cut plasmid.

(d) Without these 5′ phosphates, the vector cannot ligate to itself. It can only ligate to an insert fragment that still carries intact, phosphorylated 5′ ends, significantly increasing cloning efficiency.

**Final Answer:** Alkaline Phosphatase treatment to strip the 5′ phosphate groups

**Answer: (B)**

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## Q78.

### Solution

**Concept:** The cloning vector pBR322 contains two selectable marker genes that encode resistance to different antibiotics: ampicillin ($amp^R$) and tetracycline ($tet^R$). Cloning into a specific restriction site within one of these markers disrupts its reading frame, a technique called insertional inactivation.

**Solution:**

Let's locate the restriction enzyme sites on the pBR322 plasmid map:

(a) The restriction site for *PstI* is located directly within the ampicillin resistance gene locus ($amp^R$).

(b) The unique recognition sequence for the restriction endonuclease **BamHI** is located within the open reading frame of the **tetracycline resistance gene locus ($tet^R$)**.

(c) When a foreign genomic fragment is ligated into the *BamHI* site, it physically splits the coding sequence of the gene.

(d) This disruption causes **insertional inactivation**, making the recombinant plasmid lose its ability to confer tetracycline resistance while remaining ampicillin-resistant.

**Final Answer:** Tetracycline resistance gene locus ($tet^R$)

**Answer: (B)**

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## Q79.

### Solution

**Concept:** Genetically modified *Bt* crops express crystalline (Cry) endotoxin proteins derived from the soil bacterium *Bacillus thuringiensis*, providing targeted protection against specific insect pests.

**Solution:**

Let's trace the physiological mechanism of *Bt* toxin action inside an insect:

(a) A sensitive lepidopteran larva ingests plant tissue containing the crystalline Cry1Ac protoxin.

(b) Once inside the insect's digestive tract, the highly **alkaline midgut environment** dissolves the protein crystals, and midgut proteases cleave the protoxin into its active form.

(c) The active endotoxin binds specifically to cadherin-like receptors on the surface of the midgut epithelial cells.

(d) This binding causes the toxins to oligomerize and insert into the cell membrane, **forming lytic pores**. These pores destroy osmotic balance, causing the midgut cells to swell and burst, which quickly leads to starvation and fatal septicemia.

**Final Answer:** They undergo proteolytic activation in the alkaline midgut, binding to cadherin-like receptors to form pores that disrupt osmotic balance

**Answer: (B)**

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## Q80.

### Solution

**Concept:** The CRISPR-Cas9 system uses a single guide RNA (sgRNA) to direct the Cas9 endonuclease to a matching genomic locus. However, target sequence complementarity alone is not enough to initiate DNA cleavage.

**Solution:**

Let's analyze the target recognition mechanism used by the Cas9 enzyme:

(a) The Cas9 protein first scans genomic DNA for a short, conserved sequence matching the target organism's self/non-self criteria.

(b) This required sequence is known as the **Protospacer Adjacent Motif (PAM)**. For the standard *Streptococcus pyogenes* Cas9, the PAM sequence is 5′-NGG-3′.

(c) Cas9 must find this **PAM sequence immediately downstream of the target DNA site** on the non-target strand before it can unwind the double helix and allow the guide RNA to bind.

(d) If a matching PAM sequence is missing, Cas9 unbinds without cutting the DNA, a mechanism that protects the bacteria's own CRISPR locus from auto-cleavage.

**Final Answer:** The presence of a short Protospacer Adjacent Motif (PAM) sequence immediately downstream of the target DNA site

**Answer: (B)**

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# Answer Key

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