UPCATET Biology Sample Paper-6

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 non-cyclic photophosphorylation, the primary electron acceptor of Photosystem II (PS II) transfers its acquired electron to Pheophytin. If an experimental biochemical inhibitor specifically blocks the re-oxidation of Plastohydroquinone (PQH_2) by the Cytochrome b_6f complex, predict the immediate kinetic state of the proton motive force (Δp) across the thylakoid membrane.

(A) Rapid increase due to uncoupled cyclic electron flow.

(B) Complete dissipation because luminal proton accumulation from both photolysis and the Q-cycle terminates.

(C) Stabilization at a higher steady-state value due to structural changes in ATP synthase.

(D) Selective enhancement of the electrical gradient ($\Delta\Psi$) over the chemical gradient (ΔpH).

Q2. A mutant strain of *Arabidopsis thaliana* exhibits a defective protein phosphatase that fails to dephosphorylate the light-harvesting complex II (LHCII) proteins under state transition triggers. When this mutant is shifted abruptly from low-intensity light to sudden high-intensity far-red light, determine the primary physiological consequence observed in its photosynthetic apparatus.

(A) Accelerated excitation energy transfer exclusively to Photosystem I.

(B) Inability to shift back from State 2 to State 1, inducing excitation energy imbalances and severe photoinhibition at PS II.

(C) Spontaneous dissociation of the oxygen-evolving complex (OEC) framework.

(D) Immediate upregulation of non-photochemical quenching (NPQ) via xanthophyll over-activation.

Q3. A continuous gas exchange monitor registers the carbon flux profiles of a mature leaf under a closed glass chamber. If the ambient oxygen concentration is maintained at a high level (30%) while the internal intercellular carbon dioxide concentration (C_i) drops below the compensation point, which biochemical intermediate is generated at the maximum stoichiometric rate within the peroxisomal matrix?

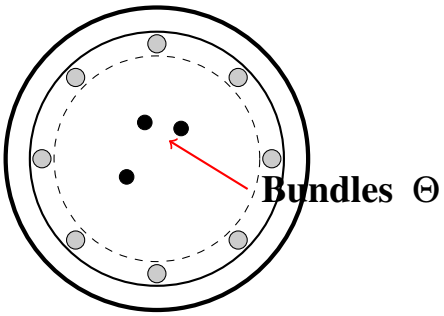
(A) Phosphoglycolate

(B) Glyoxylate

(C) Glycine

(D) Serine

Q4. Examine the high-resolution tissue layer outline representing a transverse section of an anomalous secondary growth configuration inside an angiosperm stem shown below. Identify the structural nature and origins of the isolated interior vascular bundles labeled as Θ:



Transverse Stem Section Framework

(A) Cortical bundles derived from a secondary accessory phellogen ring.

(B) Medullary bundles located permanently in the pith area, showing inverse collateral orientation.

(C) Regular phloem patches generated by anomalous internal pericycle activity.

(D) Included phloem islands trapped inside highly lignified secondary xylem tissues.

Q5. The physiological response of guard cells during stomatal closure induced by Abscisic Acid (ABA) involves an intricate secondary messenger cascade. Which statement accurately chronicles the critical ion-channel coordination that directly causes the dramatic drop in turgor pressure within the guard cell protoplast?

(A) Influx of K^+ via inward-rectifying channels followed by cytosolic acidification.

(B) Activation of slow anion channels (S-type) leading to depolarization, which triggers K^+ efflux through outward-rectifying channels and massive water loss.

(C) Inhibition of voltage-dependent calcium channels causing sudden chloride ion storage inside vacuoles.

(D) Activation of plasma membrane H^+-ATPases causing hyperpolarization and accumulation of malate.

Q6. The asymmetric distribution of auxin across a phototropically stimulated oat coleoptile tip is mediated by PIN-form (PIN) formed efflux carrier proteins. If a coleoptile is treated with N-1-naphthylphthalamic acid (NPA), predict the localized redistribution pattern of auxin when exposed to continuous unilateral blue light coming from the right side.

(A) Massive accumulation of auxin exclusively on the shaded (left) side.

(B) Symmetrical accumulation at the extreme apex due to complete inhibition of polar auxin transport.

(C) Accelerated downward basipetal transport along the epidermal layer facing the light source.

(D) Total destruction of the indole-3-acetic acid pools through oxidation pathways.

Q7. In the citric acid cycle of plant mitochondria, the conversion of succinyl-CoA to

succinate is coupled to substrate-level phosphorylation. Unlike animal tissues which predominantly utilize GDP, the plant mitochondrial isoform of succinyl-CoA synthetase possesses absolute nucleotide specificity for which substrate component?

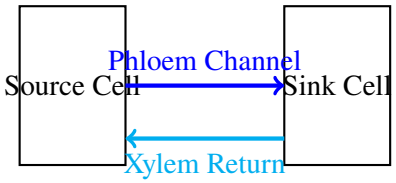
(A) UDP

(B) ADP

(C) CDP

(D) CTP

Q8. The mathematical interpretation of phloem translocation dynamics can be analyzed using a simplified physical pressure flow loop model. Based on the hydraulic network layout shown below, calculate the direction and driving force magnitude of net solution transport when values are changed as: $\Psi_{s(\text{source})} = -1.8$ MPa, $\Psi_{p(\text{source})} = +1.0$ MPa, $\Psi_{s(\text{sink})} = -0.8$ MPa, and $\Psi_{p(\text{sink})} = +0.2$ MPa.



(A) Transport from Sink to Source driven by an overall potential gradient of 0.4 MPa.

(B) Transport from Source to Sink driven by a pressure gradient ($\Delta\Psi_p$) of 0.8 MPa.

(C) Stationary equilibrium where net mass flow drops to exactly zero.

(D) Reverse flow from Source to Sink driven exclusively by the solute potential difference.

Q9. A cell biologist monitors a section of the root apical meristem of *Allium cepa*. During the histogen specification analysis, a continuous cellular lineage tracking experiment establishes that the dermatogen layer gives rise directly and exclusively to which primary anatomical tissue zone?

(A) Cortex layers and endodermis

(B) Central vascular cylinder bundle sheath

(C) Epiblema/Epidermis layer

(D) Root cap protective cells (Calyptrogen)

Q10. During biological nitrogen fixation by the nitrogenase enzyme complex in legumes, the reduction of one molecule of atmospheric N_2 into two molecules of NH_3 requires a specific total stoichiometric consumption of ATP and electrons. Choose the correct balanced energetic input statement.

(A) 8 electrons + 8 protons + 16 ATP

(B) 6 electrons + 6 protons + 12 ATP

(C) 4 electrons + 4 protons + 8 ATP

(D) 12 electrons + 12 protons + 24 ATP

Q11. A physiological assay isolates the aleurone layer from a viable barley grain. If this isolated tissue layer is incubated in a solutions containing an inhibitor of protein synthesis (such as cycloheximide) along with exogenous Gibberellic Acid (GA_3), determine the change in α-amylase secretion kinetics.

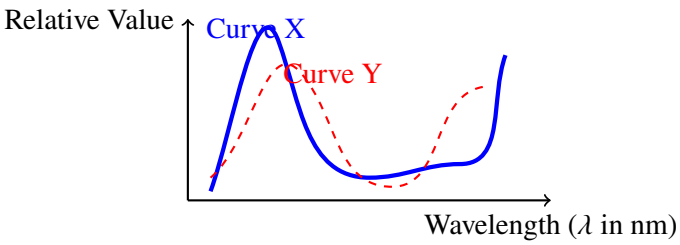
(A) Unaltered high rates of secretion due to pre-existing stored mRNA activation.

(B) Absolute suppression of α-amylase secretion since GA_3-induced *de novo* transcription requires active translation translation machinery.

(C) Enhanced secretion via constitutive exocytosis mechanisms.

(D) Upregulation of protease conversion systems independent of gibberellin signals.

Q12. The graphical curves provided below represent the classic action spectra of photosynthesis versus the absorption spectra of dominant chlorophyll pigments. Identify which curve trajectory represents the true performance profile of chlorophyll *b* across the visible light spectrum:



(A) Curve X exclusively, because its blue peak shifts closer to 480 nm.

(B) Curve Y exclusively, which shows a prominent red peak around 650 nm.

(C) Neither curve, as both track carotenoid conversions.

(D) Both curves combined symmetrically across the green gap.

Q13. The sub-epidermal mechanical support tissue layers of a young dicotyledonous stem are examined. The tissue consists of elongated cells with unevenly thickened primary cell walls rich in pectin and hemicellulose, showing no secondary lignification. Identify this specific cell type.

(A) Sclerenchyma fibers

(B) Angular Collenchyma

(C) Brachysclereids

(D) Aerenchyma blocks

Q14. During the transport of water from the soil solution to the xylem vessel lumen of a root system, the trans-membrane path is physically obstructed at the endodermal interface. Identify the biochemical material composition of this specialized anatomical barrier and its physiological consequence.

(A) Lignified helical rings that accelerate apoplastic flux.

(B) Suberized Casparian strips that force water to cross the selectively permeable plasma membrane via symplastic paths.

(C) Cellulose pads that act as mechanical filters for heavy metal elements.

(D) Chitin deposits that facilitate regular structural changes under water stress.

Q15. Cyanide-resistant respiration is a characteristic metabolic feature of many plant tissues, mediated by the Alternative Oxidase (AOX) pathway. When electron

flow is diverted from the main respiratory chain directly to AOX, calculate the change in ATP yield per molecule of NADH oxidized.

(A) Unchanged yield because the proton gradient is preserved across Complex III and IV.

(B) Drop in yield to exactly zero ATP for that segment, as electrons bypass proton-pumping Complexes III and IV, releasing energy as heat.

(C) Doubling of ATP synthesis via uncoupled matrix phosphorylation.

(D) Increase in yield due to the simultaneous reduction of structural ubiquinone pools.

Q16. A clinical trial monitors a patient with a rare mutation in the gene encoding the enterprise enterokinase enzyme inside the brush border membrane. Analyze the direct physiological defect this creates within the gastrointestinal lumen during protein digestion cascades.

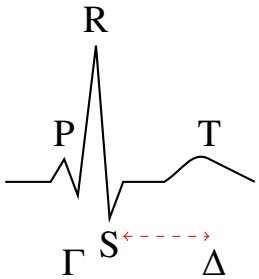
(A) Complete inactivation of gastric pepsin secretion loops.

(B) Failure to convert inactive trypsinogen into active trypsin, preventing the downstream activation of chymotrypsinogen and procarboxypeptidase.

(C) Structural collapse of micelle formation during lipid assimilation.

(D) Selective inhibition of active amino acid co-transport via Na^+ pumps.

Q17. The mechanical cycle of a human heart is mapped out through an advanced electrocardiogram (ECG) sequence synchronized with pressure changes. Study the classic trace vector shown below. Identify the exact physiological phenomenon occurring during the specific segment highlighted between points Γ and Δ:



(A) Isovolumetric ventricular contraction period.

(B) Ventricular ejection phase where intraventricular pressure exceeds aortic pressure.

(C) Isovolumetric ventricular relaxation matching the second heart sound (S_2) profile.

(D) Complete atrial depolarization and contraction sequence.

Q18. An experimental animal is exposed to a gas mixture containing a low level (1%) of Carbon Monoxide (CO). What is the primary biochemical mechanism through which carbon monoxide exerts its extreme, lethal systemic hypoxia response in human vascular networks?

(A) Competitive displacement of bicarbonate transport systems across erythrocyte membranes.

(B) Irreversible binding to the allosteric 2,3-BPG pocket on adult hemoglobin molecules.

(C) Binding to hemoglobin with an affinity 200 times higher than O_2, forming carboxyhemoglobin and shifting the oxygen-hemoglobin dissociation curve to the left, which suppresses oxygen release to tissues.

(D) Immediate structural denaturation of the alpha-globin helical arrays.

Q19. During the generation of an action potential along a myelinated human axon cylinder, the rapid upstroke phase of depolarization is driven by voltage-gated sodium channels. Choose the statement that accurately describes the gating status and structural conformation of these channels at the absolute peak of the action potential graph (+40 mV).

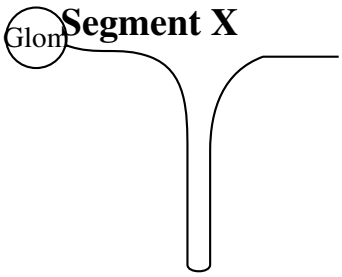
(A) Both activation and inactivation gates remain wide open.

(B) The activation gate is open but the inactivation gate closes, rendering the channel non-conducting and initiating the absolute refractory period.

(C) The activation gate snaps shut while the inactivation gate transitions back to its resting state.

(D) The channel structure undergoes rapid endocytosis into the somatic cytoplasm.

Q20. The structural micro-anatomy of a single human nephron unit is mapped below. If a patient experiences severe acute metabolic acidosis, identify the specific anatomical section segment along the tubule loop where the homeostatic secretion of H^+ ions coupled with the complete reabsorption of filtered HCO_3^- occurs at the maximum rate:



(A) Segment X (Proximal Convoluted Tubule), via the secondary active Na^+/H^+ antiporter system.

(B) Thick Ascending Loop of Henle via the passive structural ion leaks.

(C) Distal Convoluted Tubule using the active calcium-ATPase pumps.

(D) Medullary Collecting Ducts through the aquaporin-2 channel array.

Q21. The endocrine control of systemic calcium homeostasis depends on the balance between Parathyroid Hormone (PTH) and Calcitonin. If a patient develops a benign functional adenoma that constitutively hyper-secretes PTH, analyze the direct physiological outcome on bone and kidney mineral management.

(A) Accelerated osteoblast bone deposition along with severe renal calcium excretion.

(B) Enhanced osteoclast-mediated bone resorption, increased renal tubular calcium reabsorption, and activation of 1,25-dihydroxyvitamin D_3.

(C) Severe systemic hypocalcemia leading to muscle tetany.

(D) Immediate structural inactivation of the intestinal brush border calcium transporters.

Q22. During skeletal muscle contraction via the sliding filament mechanism, the detachment of the cross-bridge head from the actin active binding site requires a specific molecular event. Identify this specific trigger step.

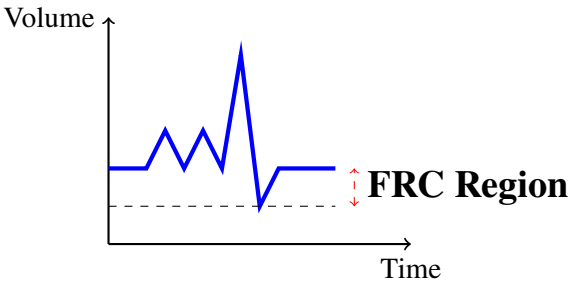
(A) The hydrolysis of ATP into ADP and inorganic phosphate (P_i) inside the sarcoplasm.

(B) The binding of a fresh molecule of ATP to the myosin head domain.

(C) The rapid re-sequestration of calcium ions into the terminal cisternae of the sarcoplasmic reticulum.

(D) The physical displacement of the troponin-T complex across the groove.

Q23. The respiratory volumes of an adult human subject are recorded using a wet spirometer setup, yielding the tracing curve layout shown below. Calculate the mathematical value of the Functional Residual Capacity (FRC) if the Expiratory Reserve Volume (ERV) is measured at 1100 mL and the Residual Volume (RV) is tracked at 1200 mL:



(A) 500 mL

(B) 1600 mL

(C) 2300 mL

(D) 3500 mL

Q24. The physiological phenomenon of the chloride shift (Hamburger phenomenon) occurs as blood moves through systemic capillaries. Choose the statement that accurately describes the directional transport of ions across the erythrocyte membrane interface.

(A) HCO_3^- moves into the erythrocyte, while Cl^- exits into the plasma.

(B) HCO_3^- exits the erythrocyte into the plasma via an anion exchanger, while Cl^- moves into the erythrocyte to maintain electrical neutrality.

(C) Both HCO_3^- and Cl^- move synchronously out of the cell via active co-transporters.

(D) Cl^- ions bind to hemoglobin, displacing carbon dioxide molecules.

Q25. An injury to the human hypothalamus would most likely result in a profound disruption of which group of regulatory activities and vital homeostatic parameters?

(A) Fine motor coordination and voluntary balance stabilization.

(B) Thermoregulation, osmoregulation via ADH control, and regulation of appetite and satiety levels.

(C) Short-term memory consolidation and processing of complex auditory signals.

(D) Intestinal peristalsis patterns and respiratory rhythm control.

Q26. During visual transduction in a human rod cell, the absorption of a photon of light by the photopigment rhodopsin sets off a biochemical signal cascade. Identify the immediate structural change in the chromophore and the subsequent state of the rod cell's dark current.

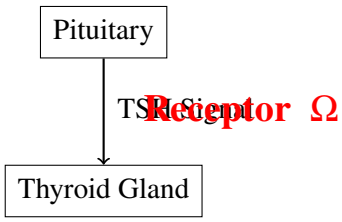
(A) Conversion of 11-cis-retinal to all-trans-retinal, activation of transducin, a decrease in cGMP levels, and hyperpolarization of the rod cell.

(B) Inversion of all-trans-retinal to 11-cis-retinal, causing a massive influx of sodium ions and depolarization.

(C) Activation of adenylyl cyclase, which increases cAMP levels and opens calcium channels.

(D) Dissociation of opsin into individual protein subunits, opening potassium leak channels.

Q27. The endocrine feedback loop governing thyroid hormone synthesis is mapped below. If a patient produces auto-antibodies that act as structural agonists binding to and activating the receptor labeled as Ω, predict the clinical state of the thyroid axis:



(A) Primary Hashimoto's Myxedema with elevated TSH.

(B) Graves' Disease hyperthyroidism characterized by high circulating levels of T_3/T_4 and suppressed endogenous TSH secretion.

(C) Pituitary-driven Cushingoid syndrome.

(D) Iodine deficiency goiter with structural down-regulation of thyroglobulin production.

Q28. The physiological digestion of dietary triacylglycerols within the small intestine requires the activation of pancreatic lipase. Which co-factor is essential for anchoring pancreatic lipase to the surface of lipid droplets coated with bile salts?

(A) Cholecystokinin

(B) Colipase

(C) Secretin

(D) Apolipoprotein C-II

Q29. The primary functional mechanism of the countercurrent multiplier system operating within the mammalian loop of Henle depends on the transport properties of its distinct anatomical limbs. Choose the correct transport profile matching the thick ascending limb.

(A) Highly permeable to water; completely impermeable to NaCl.

(B) Active transport of ions ($Na^+, K^+, 2Cl^-$ co-transporter) out of the tubule lumen; completely impermeable to water.

(C) Passive diffusion of urea into the interstitial spaces.

(D) Rapid active transport of water molecules using ATP-driven aquaporins.

Q30. In a multi-factorial genetic mapping cross involving three autosomal loci (A, B, and C) in Drosophila, a testcross of a trihybrid female ($\frac{\text{AbC}}{\text{aBc}}$) yields the lowest frequency recombinant class corresponding to the genotypes **abc** and **AbC**. Deduce the correct linear sequence alignment of these three genes along the chromosome fabric.

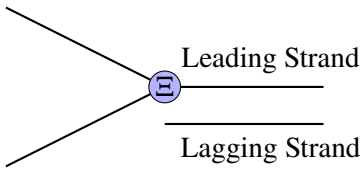
(A) Gene A is located in the middle.

(B) Gene B is located in the middle.

(C) Gene C is located in the middle.

(D) The three loci reside on non-homologous independent chromosomes.

Q31. The complex architecture of a DNA replication fork is illustrated below. Identify the operational enzymatic component labeled as Ξ that synthesizes the short RNA primers required to initiate Okazaki fragment production along the lagging strand template:



(A) DNA Polymerase I

(B) DNA Helicase enzyme

(C) DNA Primase (DnaG)

(D) Topoisomerase II

Q32. A molecular biologist isolates an E. coli mutant displaying an un-induced phenotype for the lac operon system. DNA sequencing reveals a point mutation inside the operator locus (O^c) that prevents the repressor protein from binding. However, the structural genes (*lacZ*, *lacY*, *lacA*) fail to express even in the presence of lactose. Identify the secondary defect causing this phenotype.

(A) A super-repressor mutation (I^s) producing a repressor that cannot bind allolactose.

(B) A mutation in the promoter site preventing RNA Polymerase holoenzyme from recognizing the transcription start site.

(C) Hyperactivation of the cyclic AMP synthesis pathway.

(D) Complete deletion of the CAP-binding locus.

Q33. During eukaryotic mRNA transcription processing, a specific base modification is introduced at the 5′ terminal cap structure. Identify the chemical nature of this protective modification and the precise enzymatic linkage involved.

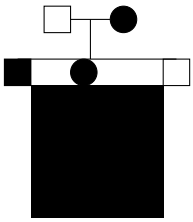
(A) 7-methylguanosine attached via an unusual 5′-to-5′ triphosphate bridge.

(B) 3-methyladenine attached via a conventional phosphodiester linkage.

(C) Pseudouridine attached via a 3′-to-5′ pyrophosphate linkage.

(D) N-acetylcytidine added post-transcriptionally to the poly-A segment.

Q34. The pedigree analysis chart shown below maps a rare metabolic genetic disorder through four human generations. Determine the most likely mode of genetic inheritance driving this disease expression:



*Note: *In this pedigree, every affected male child has an affected mother, and affected mothers pass the trait to all their offspring regardless of sex.*

(A) X-linked recessive inheritance.

(B) Autosomal dominant with variable penetrance.

(C) Mitochondrial/Maternal inheritance.

(D) Y-linked holandric pattern.

Q35. The genetic code exhibits degeneracy, meaning multiple codons can specify a single amino acid. According to Francis Crick's Wobble Hypothesis, which statement accurately defines the permissible base-pairing rules operating at the third position of the mRNA codon?

(A) An Inosine (I) residue at the 5′ end of the tRNA anticodon can form hydrogen bonds with U, C, or A in the codon.

(B) Adenine at the wobble position can pair with any of the four major ribonucleotide bases.

(C) Guanine can only form rigid Watson-Crick pairs with Cytosine at the third base level.

(D) Uracil at the wobble position can pair exclusively with Guanine residues.

Q36. During translation elongation in prokaryotes, the growing polypeptide chain attached to the tRNA in the P-site is transferred to the aminoacyl-tRNA in the A-site. Identify the cellular component that catalyzes this peptide bond formation.

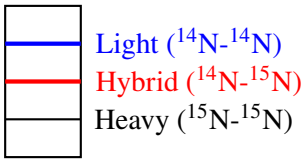
(A) A soluble elongation factor protein named EF-Tu.

(B) The 23S rRNA component of the large (50S) ribosomal subunit acting as a ribozyme.

(C) A specialized ATP-dependent protein kinase within the matrix.

(D) The 16S rRNA component of the small ribosomal subunit.

Q37. The classic Meselson-Stahl experiment used equilibrium density gradient centrifugation with heavy isotope ^{15}N to prove the semi-conservative replication of DNA. If E. coli cells are grown continuously in ^{15}N medium and then transferred to normal ^{14}N medium for exactly three complete rounds of cell division, identify the relative density distribution profile expected in the cesium chloride tube gradient:



(A) 100% Hybrid DNA.

(B) 50% Light DNA and 50% Hybrid DNA.

(C) 75% Light DNA and 25% Hybrid DNA.

(D) 25% Heavy DNA and 75% Hybrid DNA.

Q38. A clinical cytogenetics lab prepares a karyotype from a patient presenting with microcephaly, severe mental retardation, a characteristic high-pitched cat-like cry, and low birth weight. Chromosomal analysis reveals a specific structural aberration. Identify this genetic anomaly.

(A) Trisomy of chromosome 13 (Patau syndrome).

(B) Deletion of the short arm of chromosome 5 (Cri-du-chat syndrome).

(C) Reciprocal translocation between chromosomes 9 and 22 (Philadelphia chromosome).

(D) Inversion inside the long arm of chromosome 21.

Q39. The Ames test evaluates the mutagenic potential of chemical compounds by monitoring reversion events in a specific microorganism. Identify the indicator organism used and the genetic marker tracked in this assay.

(A) Auxotrophic mutants of *Salmonella typhimurium* tracking the reversion from histidine dependence to histidine independence.

(B) Prototrophic strains of *Escherichia coli* checking for ampicillin resistance profiles.

(C) Wild-type *Saccharomyces cerevisiae* monitoring galactose utilization pathways.

(D) *Bacillus subtilis* spores measuring structural heat resistance variations.

Q40. In human genetics, a transition mutation is a type of nucleotide substitution. Choose the option that correctly illustrates a true molecular transition mutation sequence inside a duplex DNA molecule fragment.

(A) Adenine replacing a Thymine residue.

(B) Guanine replacing an Adenine residue (or vice versa, a purine substituted by another purine).

(C) Cytosine replacing an Adenine residue.

(D) Thymine replacing a Guanine residue.

Q41. The phenomenon of genomic imprinting causes genes to be expressed in a parent-of-origin-specific manner. What molecular mechanism is primarily responsible for establishing and maintaining genomic imprinting marks during mammalian gametogenesis?

(A) Histone acetylation at serine positions.

(B) Covalent DNA methylation of cytosine bases within CpG islands by de novo methyltransferases.

(C) Alternative splicing of the primary hnRNA transcript.

(D) Non-reciprocal recombination events during pachytene configurations.

Q42. The fluid mosaic model states that plasma membrane fluidity depends heavily on lipid composition. How does the presence of high concentrations of cholesterol affect membrane fluidity and phase transitions across varying temperatures?

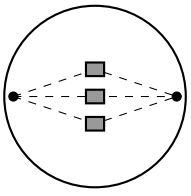
(A) It broadens the phase transition temperature, stabilizing membrane fluidity by preventing hydrocarbon chains from packing tightly at low temperatures and restricting excessive movement at high temperatures.

(B) It continuously hyper-fluidizes the lipid bilayers, inducing spontaneous micelle fragmentation.

(C) It blocks the function of peripheral lipid rafts by irreversibly binding to flip-flop enzymes.

(D) It reduces membrane stability by preventing hydrophobic interactions with integral proteins.

Q43. The diagram below shows the spatial orientation of chromosomes attached to the mitotic spindle framework. Identify the specific phase of cell division shown and the functional status of the spindle assembly checkpoint (SAC):



(A) Prophase; SAC is permanently silenced.

(B) Metaphase; chromosomes are aligned along the equatorial plate, and the SAC remains active until all kinetochores achieve biorientation.

(C) Anaphase; sister chromatids undergo rapid poleward separation.

(D) Telophase; nucleolus reconstruction takes place.

Q44. During the targeting of newly synthesized lysosomal hydrolases from the rough endoplasmic reticulum to the lumen of the lysosome, which specific post-translational carbohydrate modification must be added within the cis-Golgi network for proper sorting?

(A) Glucose-6-phosphate tagging

(B) Mannose-6-phosphate tagging

(C) Galactose-1-phosphate tagging

(D) N-acetylglucosamine-4-phosphate deletion

Q45. The assembly and dynamic instability of eukaryotic microtubules depend on nucleotide binding and hydrolysis. Choose the correct statement regarding the structural state of the tubulin heterodimer during microtubule polymerization.

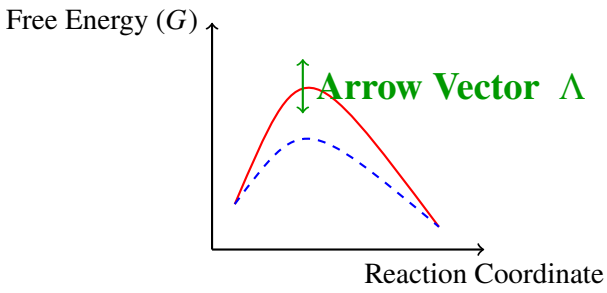
(A) Both α- and β-tubulin subunits must bind active GTP, but only the GTP bound to β-tubulin is hydrolyzed following addition to the protofilament.

(B) α-tubulin hydrolyzes ATP to drive rapid minus-end shortening.

(C) Depolymerization occurs rapidly when the microtubule end retains a stable "GTP cap".

(D) β-tubulin undergoes exchange of bound GDP for cGMP within the centrosome matrix.

Q46. The free energy diagram plotted below maps the enzymatic conversion of substrate S to product P. Identify which variable arrow correctly indicates the exact reduction in activation energy ($\Delta\Delta G^{\ddagger}$) achieved by adding a competitive enzyme catalyst:



(A) Total free energy change (ΔG) of the overall chemical conversion.

(B) Arrow Vector Λ, representing the decrease in activation energy barrier.

(C) Energy of the final ground state product conformation.

(D) Total thermal energy released as heat during the transition state.

Q47. During the pachytene sub-stage of prophase I in meiosis, a multi-protein assembly forms along the length of paired homologous chromosomes. Identify this structure and the enzymatic complex that mediates genetic recombination.

(A) Kinetochore matrix paired with dynein motors.

(B) Synaptonemal complex associated with recombination nodules containing RAD51 and DMC1 recombinases.

(C) Cohesin ring network driven by condensin cleavage enzymes.

(D) Aster rays linked with chromosomal passenger complexes (CPC).

Q48. A biochemical assay analyzes the structure of an unknown structural biomolecule. Complete acid hydrolysis yields equal parts of D-glucosamine and glucuronic acid, with frequent O-sulfation modifications along the polymer chain. Identify this macromolecule.

(A) Glycogen storage core

(B) Heparin (a highly sulfated glycosaminoglycan)

(C) Inulin fructan structure

(D) Peptidoglycan cell wall envelope

Q49. The transition from G2 phase to mitosis (M-phase) in eukaryotic cell cycles is regulated by the activation of the Maturation Promoting Factor (MPF).

Which specific phosphorylation status represents the fully activated form of the Cdk1/Cyclin B complex?

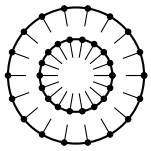
(A) Hyperphosphorylation at Thr14, Tyr15, and Thr161.

(B) Dephosphorylation of inhibitory residues Thr14 and Tyr15 by Cdc25 phosphatase, along with activating phosphorylation at Thr161.

(C) Complete dephosphorylation across all serine and tyrosine positions.

(D) Continuous monoubiquitination of the Cdk1 catalytic pocket interface.

Q50. The geometric structure drawn below represents a specialized lipid aggregation pattern that forms spontaneously inside aqueous physiological systems. Identify this structural layout:



(A) Solid spherical lipid micelle.

(B) Phospholipid bilayer Vesicle (Liposome) containing an aqueous internal core.

(C) Reversed structural soap micelle layer.

(D) Hydrophobic lipid droplet core matrix.

Q51. The structural framework of the plant cell wall consists of cellulose microfibrils embedded in an amorphous matrix. Identify the cellular site where cellulose microfibrils are synthesized and the enzymatic complex responsible.

(A) Inner cisternal space of the rough Endoplasmic Reticulum using bup-transferases.

(B) The plasma membrane surface, synthesized by hexameric cellulose synthase (CESA) complexes (rosettes) using UDP-glucose.

(C) Golgi secretory vesicles driven by trans-glycosylase cascades.

(D) Plastidial stroma matrix driven by starch phosphorylase complexes.

Q52. According to the island biogeography model proposed by Robert MacArthur and E.O. Wilson, the equilibrium number of species (S) on an island is determined by a dynamic balance between immigration and extinction rates. Choose the island configuration expected to maintain the absolute highest equilibrium species richness.

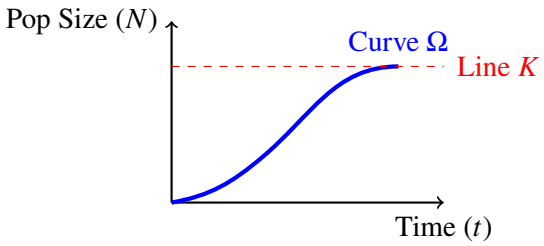
(A) Small islands located far from the mainland source pool.

(B) Large islands located close to the mainland source pool.

(C) Small islands located close to the mainland source pool.

(D) Large islands located far from the mainland source pool.

Q53. The graph below plots species population growth profiles under varying environmental pressures. Identify the mathematical model that matches curve Ω, which approaches a stable plateau, and name the parameter represented by the dashed horizontal line K:



(A) Geometric growth model; Line K is the intrinsic rate of increase (r).

(B) Logistic growth model ($\frac{dN}{dt} = rN\frac{K-N}{K}$); Line K is the environmental Carrying Capacity.

(C) Exponential growth model; Line K is the survival probability threshold.

(D) Stochastic growth model; Line K is the minimal viable population index.

Q54. In an oligotrophic freshwater ecosystem, a chemical spill introduces a persistent organochlorine pesticide. Over time, analytical monitoring registers a massive increase in pesticide concentration at higher trophic levels. Identify this ecological phenomenon and select the trophic level that accumulates the highest concentration.

(A) Eutrophication; highest in primary phytoplankton producers.

(B) Biomagnification; highest in tertiary consumers and top apex predators (e.g., piscivorous birds).

(C) Bioremediation; highest in detritivorous benthic microbes.

(D) Bioaccumulation; distributed evenly across all trophic levels.

Q55. An international conservation group prioritizes regions for biodiversity preservation based on Norman Myers' Biodiversity Hotspot criteria. To qualify as a global biodiversity hotspot, a region must meet which strict set of quantitative biological criteria?

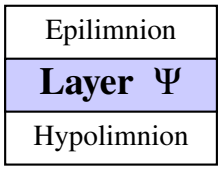
(A) It must contain at least 1500 species of vascular plants as endemics ($> 0.5\%$ of the world's total) and must have lost at least 70% of its original primary native vegetation.

(B) It must span an area larger than $100,000$ square kilometers with 100% pristine climax forest coverage.

(C) It must harbour at least 50 distinct endemic species of large mammalian megafauna.

(D) It must demonstrate complete immunity to invasive species colonization.

Q56. The diagram below shows the spatial stratification profile typical of a deep temperate lake during peak summer stratification. Identify the specific limnetic thermal layer labeled as region Ψ where water temperature drops rapidly with increasing depth:



(A) Littoral Zone

(B) Thermocline (Metalimnion)

(C) Profundal Floor

(D) Benthic Boundary layer

Q57. The competitive exclusion principle formulated by G.F. Gause states that two species competing for the exact same limiting resource cannot stably coexist at constant population values. What evolutionary mechanism enables ecologically similar sympatric species to bypass this constraint and coexist over long periods?

(A) Directional selection toward identical niche dimensions.

(B) Resource partitioning via divergence in structural, behavioral, or physiological traits (character displacement).

(C) Kin selection promoting mutual resource sharing.

(D) Genetic drift driving one species to spontaneous polyploidy.

Q58. During a long-term study of ecological succession on a barren volcanic lava flow, a plant ecologist records a predictable transition in community composition over centuries. Choose the option that correctly lists the typical sequence of plant colonization stages, from pioneer arrivals to the final stable community.

(A) Mosses → Herbs → Lichens → Climax Forest Trees.

(B) Crustose Lichens → Foliose Lichens → Mosses → Herbs → Shrubs → Climax Forest Trees.

(C) Shrubs → Mosses → Herbs → Climax Hardwood Trees.

(D) Annual Grasses → Epiphytic Lichens → Hydrophytic Shrubs.

Q59. The quantitative calculation of species diversity inside an ecological community can be evaluated using the Shannon-Weiner Diversity Index (H'). Choose the community composition profile that will yield the absolute maximum value for H'.

(A) High species richness paired with extremely low species evenness (one dominant species).

(B) Low species richness paired with high species evenness.

(C) High species richness paired with high species evenness (equal abundance distributed across many distinct species).

(D) Total absolute population count irrespective of taxonomic variety.

Q60. The progressive global warming phenomenon is significantly driven by greenhouse gases tracking specific Global Warming Potentials (GWP). Rank the gases CO_2, CH_4, N_2O, and Chlorofluorocarbons (CFCs) in increasing order of their individual molecule-for-molecule radiative forcing efficiency.

(A) CFCs < N_2O < CH_4 < CO_2

(B) CO_2 < CH_4 < N_2O < CFCs

(C) CH_4 < CO_2 < CFCs < N_2O

(D) N_2O < CFCs < CO_2 < CH_4

Q61. A systematic botanist dissects a flower from an unknown agricultural weed species. The dissection reveals a cruciform corolla containing four clawed petals, a tetradynamous stamen configuration (2 short outside and 4 long inside), and a superior ovary that develops a false septum (replum) during maturity. Identify the family of this plant.

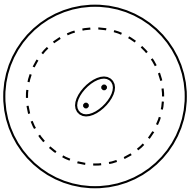
(A) Solanaceae

(B) Brassicaceae (Cruciferae)

(C) Fabaceae

(D) Liliaceae

Q62. The floral diagram drawn below displays the arrangement of organs in an economically important agricultural crop family. Analyze the structures, specifically noting the obliquely placed ovary, swollen placenta, and epipetalous stamens. Identify the plant family mapped by this diagram:



(A) Malvaceae

(B) Solanaceae (e.g., *Solanum nigrum*)

(C) Poaceae

(D) Cucurbitaceae

Q63. In Robert Whittaker's Five Kingdom Classification system, organisms are grouped based on structural and metabolic criteria. Which option correctly identifies the biological traits that separate the Kingdom Fungi from the Kingdom Plantae?

(A) Autotrophic nutrition using starch storage frameworks.

(B) Heterotrophic absorptive nutrition, cell walls composed of chitin, and glycogen acting as the primary storage carbohydrate resource.

(C) Holozoic ingestion mechanisms paired with cellulosic walls.

(D) Chemolithotrophic energy capture profiles lacking true nuclear membranes.

Q64. A deep-sea zoological expedition collects an unsegmented, vermiform marine invertebrate. Structural analysis reveals a triploblastic, coelomate body plan, a distinct proboscis, collar, and trunk region, a stomochord projection in the proboscis area, and pharyngeal gill slits. Identify the phylum of this organism.

(A) Echinodermata

(B) Hemichordata

(C) Urochordata

(D) Nematoda

Q65. The taxonomic categorization of the class Reptilia requires distinguishing among modern lineages based on skull architecture. Identify the specific structural skull modification (number of temporal fossae) that characterizes the evolutionary lineage of modern turtles (*Chelone*).

(A) Diapsid skull condition with two temporal openings.

(B) Synapsid skull condition with a single lower opening.

(C) Anapsid skull condition featuring a complete, solid roof lacking any temporal vacuities.

(D) Parapsid skull layout with a single upper opening loop.

Q66. A comparative analysis of the life cycle of non-vascular embryophytes focuses on the relationship between the gametophyte and sporophyte generations. Choose the statement that accurately describes the lifecycle of the true moss *Funaria*.

(A) Independent, dominant sporophyte alternating with a microscopic, parasitic gametophyte.

(B) Dominant, haploid, photosynthetic gametophyte phase alternating with a physically dependent, diploid sporophyte consisting of a foot, seta, and capsule.

(C) Completely isomorphic lifecycle where both phases are morphologically identical.

(D) Free-living unicellular sporophytic thallus structure lacking tissue specialization.

Q67. A marine biologist studies the canal systems within the phylum Porifera. In the advanced Leuconoid type canal system found in specialized sponges, identify the correct path of water current flux through the sponge body.

(A) Ostia → Spongocoel → Osculum.

(B) Dermal Ostia → Incurrent Canals → Prosopyles → Flagellated Chambers → Apopyles → Excurrent Canals → Osculum.

(C) Osculum → Radial Canals → Apopyles → Spongocoel → Ostia.

(D) Ostia → Spongocoel → Radial Canals → Osculum.

Q68. The systematic classification of the family Fabaceae highlights a unique aestivation pattern of the corolla. Identify this pattern along with the specific nomenclature assigned to its individual petals.

(A) Valvate aestivation; all five petals are identical and fused.

(B) Vexillary (descending imbricate) aestivation; consisting of one large posterior petal (vexillum/standard), two lateral wings (alae), and two fused anterior petals (carina/keel).

(C) Contorted twisted layout; all elements overlap systematically in a clockwise direction.

(D) Ascending imbricate layout; the posterior petal is positioned interior to the lateral wings.

Q69. During megasporogenesis and megagametogenesis in a typical monosporic angiosperm (Polygonum type), a single functional megaspore undergoes successive nuclear divisions to form a mature embryo sac. Identify the exact number and mitotic distribution of these divisions, along with the cellular composition of the resulting structure.

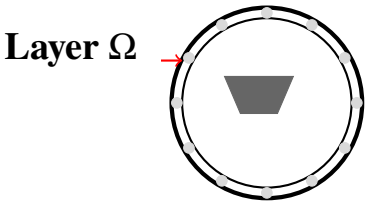
(A) Two rounds of asymmetrical mitosis; forming a 4-cell, 4-nucleate structure.

(B) Three successive rounds of free-nuclear mitosis; producing an 8-nucleate, 7-celled mature embryo sac consisting of an egg apparatus, three antipodal cells, and a central cell containing two polar nuclei.

(C) Four sequential meiotic cycles; creating an 8-cell syncytial mass.

(D) A single asymmetric division; generating a binucleate polar endosperm precursor.

Q70. The structural configuration below shows a mammalian blastocyst during early uterine wall implantation. Identify the specific function of the outer cellular layer labeled as Ω and name the hormone it secretes to maintain the corpus luteum:



(A) Inner Cell Mass; secretes progesterone.

(B) Trophoblast layer Ω; secretes Human Chorionic Gonadotropin (hCG) to prevent luteolysis.

(C) Zona Pellucida envelope; secretes Luteinizing Hormone (LH).

(D) Amniotic membrane wall; secretes Estriol.

Q71. The molecular block mechanism that prevents polyspermy during human fertilization involves a rapid sequence of events. Choose the option that correctly

describes the biochemical mechanism of the slow, permanent block to polyspermy.

(A) Wave of sodium influx that depolarizes the oocyte plasma membrane.

(B) Influx of calcium ions that triggers exocytosis of cortical granules, releasing proteases that cleave ZP2 and cross-link the zona pellucida matrix to destroy sperm receptors.

(C) Immediate degradation of the extracellular hyaluronic acid shell.

(D) Phosphorylation of the acrosin binding core on the sperm head flagellum.

Q72. During embryogenesis, the formation of the primary germ layers occurs through gastrulation cell movements. Which option lists only tissue structures that are derived exclusively from the embryonic ectoderm layer?

(A) Central nervous system (brain and spinal cord), epidermis of skin, and the adrenal medulla.

(B) Dermis of skin, cardiac muscle tissue, and renal tubules.

(C) Epithelial lining of the gastrointestinal tract, liver parenchyma, and thyroid gland follicles.

(D) Notochord rod, skeletal bones, and vascular endothelium.

Q73. An advanced reproductive medicine clinic evaluates a case of female infertility. Hormonal profiling reveals that the growing ovarian follicles fail to transition into mature Graafian follicles due to a lack of cyclical feedback. Which specific hormone surge is required to trigger ovulation and complete the first meiotic division within the primary oocyte?

(A) Progesterone plateau from the adrenal cortex.

(B) A steep surge in Luteinizing Hormone (LH) induced by high threshold levels of estradiol.

(C) Sustained high levels of Inhibin-B from the tunica albuginea.

(D) Deaeration of Follicle Stimulating Hormone (FSH) levels under GnRH block.

Q74. The physiological phenomenon of double fertilization is a defining feature of angiosperm reproduction. If a pollen grain carrying a mutant defective generative cell cannot execute the second syngamy event, predict the structural status of the mature seed.

(A) The embryo will develop normally but the triploid endosperm will fail to form, leading to seed abortion due to a lack of nutrient supply.

(B) A diploid endosperm will form while the embryo duplicates its genome spontaneously.

(C) Polyembryonic twins will form from the synergid nuclei.

(D) Complete conversion of the perisperm into an accessory fruit wall.

Q75. The human placenta serves as a selective barrier and endocrine organ. Identify the structural class of human placenta based on the tissue layers separating maternal blood from the fetal capillary endothelium.

(A) Epitheliochorial type placenta

(B) Syndesmochorial type placenta

(C) Hemochorial type placenta (chorionic villi are bathed directly in maternal blood pools)

(D) Endotheliochorial type placenta

Q76. During a gene cloning experiment, a molecular biologist attempts to insert a foreign DNA fragment into the unique *BamHI* restriction site located within the tetracycline resistance gene (tet^R) of plasmid pBR322. Following transformation of E. coli, what selection protocol distinguishes host cells carrying the recombinant plasmid from those with the non-recombinant vector?

(A) Growth on medium containing both ampicillin and tetracycline.

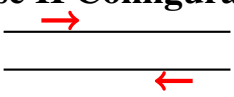
(B) Selection for cells that grow on ampicillin-supplemented medium but fail to grow on medium containing tetracycline (insertional inactivation).

(C) Screen for blue-white colony formation using X-gal substrate analogs.

(D) Direct isolation of non-viable cells from minimal agar plates.

Q77. The molecular steps of a single thermal cycle in the Polymerase Chain Reaction (PCR) are diagrammed below. Identify the correct temperature sequence and operational label for the reaction step marked as phase II:

Phase II Configuration



(A) Denaturation running at 94°C.

(B) Primer Annealing running at 50°C−60°C to allow sequence-specific binding to the single-stranded DNA templates.

(C) Primer Extension running at 72°C using Taq Polymerase.

(D) Ligation stabilization running at 4°C loops.

Q78. The production of transgenic Bt cotton varieties involves inserting cry toxin genes isolated from *Bacillus thuringiensis*. What is the biochemical mechanism through which the Cry1Ac endotoxin kills susceptible lepidopteran insect larvae?

(A) Direct enzymatic cleavage of nervous system acetylcholinesterase receptors.

(B) Solubilization in the highly alkaline midgut environment of the larva, proteolytic activation, and binding to cadherin receptors, which creates lytic pores in the midgut epithelial cell membranes.

(C) Severe cellular dehydration caused by blocking water absorption channels in the hindgut.

(D) Rapid systemic septicemia following entry through tracheolar spiracles.

Q79. The genome editing platform CRISPR-Cas9 utilizes a dual-component system to introduce targeted double-stranded breaks in genomic DNA. Identify the specific structural element within the single guide RNA (sgRNA) complex that specifies target site selection and direct cleavage activity.

(A) A random poly-A track that binds non-specifically to promoter elements.

(B) A 20-nucleotide spacer sequence complementary to the target DNA protospacer site, located adjacent to a 5′-NGG-3′ Protospacer Adjacent Motif (PAM).

(C) A hydrophobic loop that anchors Cas9 to nuclear envelope importins.

(D) A ribozyme core that directly hydrolyzes the target DNA phosphodiester backbone.

Q80. In the commercial production of human insulin (Humulin) using recombinant DNA technology, Eli Lilly scientists bypassed the technical challenge of handling the complex eukaryotic post-translational splicing of pro-insulin. Identify the strategy they implemented.

(A) Cloning and expressing the entire preproinsulin cDNA sequence directly inside E. coli cells.

(B) Synthesizing separate nucleotide sequences for DNA coding for insulin chain A and chain B, expressing them in independent E. coli cultures, purifying the proteins, and assembling them *in vitro* via disulfide bond linkage.

(C) Utilizing transgenic goat mammary excretion profiles to isolate functional pro-insulin.

(D) Co-injecting synthetic human peptidase enzymes into the fermentation tank during culture.

Detailed Solutions

Q1.

Solution

Concept: The proton motive force (Δp) across the thylakoid membrane is composed of an electrical potential gradient ($\Delta\Psi$) and a chemical pH gradient (ΔpH). It is generated by proton translocation during electron transport along the photosynthetic chain (including the Q-cycle at the Cytochrome b_6f complex) and the release of protons in the lumen during water photolysis at Photosystem II.

Solution:

Let's analyze the consequence of blocking the re-oxidation of Plastohydroquinone (PQH_2):

(a) When an inhibitor selectively blocks the re-oxidation of PQH_2 by the Cytochrome b_6f complex, electron flow downstream of plastoquinone is completely halted.

(b) Because electrons can no longer move down the transport chain, the primary electron acceptor of PS II quickly becomes completely reduced. This feedback loop stops the photolysis of water at the oxygen-evolving complex, terminating luminal proton accumulation from water splitting.

(c) Concurrently, halting Cytochrome b_6f activity shuts down the Q-cycle mechanism, stopping active proton pumping from the stroma into the lumen. As a result, the existing proton gradient is rapidly spent through ATP synthase with zero replenishment, causing a complete dissipation of the proton motive force.

Final Answer: Complete dissipation because luminal proton accumulation from both photolysis and the Q-cycle terminates.

Answer: (B)

Go Back to Question 1

Q2.

Solution

Concept: State transitions manage excitation balance between Photosystem II (PS II) and Photosystem I (PS I). Over-excitation of PS II activates a kinase that phosphorylates Light-Harvesting Complex II (LHCII), causing it to migrate to PS I (State 2). Under far-red light (which excites PS I), a specific phosphatase dephosphorylates LHCII, causing it to return to PS II (State 1).

Solution:

Let's analyze the physiological failure in this mutant strain:

(a) The mutant *Arabidopsis thaliana* lacks a functional protein phosphatase and cannot dephosphorylate LHCII. Therefore, once LHCII is phosphorylated and shifted to PS I, it is permanently locked in State 2.

(b) When shifted to high-intensity far-red light, a normal plant would shift back to State 1 to direct more energy toward PS II. The mutant cannot do this, creating severe excitation energy imbalances.

(c) Because the light-harvesting antenna remains locked onto PS I, PS II becomes highly susceptible to photoinhibitory damage due to unregulated excitation delivery and systemic downstream stress under sudden intensity spikes.

Final Answer: Inability to shift back from State 2 to State 1, inducing excitation energy imbalances and severe photoinhibition at PS II.

Answer: (B)

Go Back to Question 2

Q3.

Solution

Concept: Under high oxygen (30%) and low intercellular carbon dioxide (C_i) conditions below the compensation point, RuBisCO undergoes maximum oxygenase activity instead of carboxylase activity, triggering the photorespiratory carbon oxidation cycle (C_2 cycle).

Solution:

Let's trace the metabolic pathway of the photorespiratory cycle across compartments:

(a) In the chloroplast, RuBisCO oxygenates ribulose-1,5-bisphosphate to form one molecule of 3-phosphoglycerate and one molecule of phosphoglycolate. Phosphoglycolate is quickly dephosphorylated to glycolate.

(b) Glycolate is exported from the chloroplast and enters the peroxisome.

(c) Inside the peroxisomal matrix, glycolate oxidase converts glycolate into glyoxylate, producing H_2O_2. This glyoxylate is immediately transaminated to form glycine. Because this pathway runs at its maximum rate under these extreme conditions, glycine is produced at the highest stoichiometric rate within the peroxisome before being exported to the mitochondria to form serine.

Final Answer: Glycine

Answer: (C)

Go Back to Question 3

Q4.

Solution

Concept: Anomalous secondary growth patterns can introduce unusual configurations, such as cortical bundles, medullary bundles, or included phloem, depending on the plant family. Bundles located deep within the central pith are defined as medullary vascular bundles.

Solution:

Let's analyze the transverse anatomical section framework:

(a) The outermost rings represent the epidermis, cortex, and the regular primary/secondary ring of vascular bundles positioned normally around the perimeter.

(b) The internal regions labeled as Θ are located entirely inside the core pith boundary of the stem tissue.

(c) These are medullary bundles, characteristic of anomalous secondary growth configurations found in specific angiosperm families (such as *Amaranthaceae* and *Nyctaginaceae*). They often display an inverse collateral orientation where xylem and phloem arrangements are flipped relative to the normal ring.

Final Answer: Medullary bundles located permanently in the pith area, showing inverse collateral orientation.

Answer: (B)

Go Back to Question 4

Q5.

Solution

Concept: Abscisic acid (ABA)-induced stomatal closure is mediated by a signaling cascade that triggers cytosolic calcium spikes, cellular depolarization, and massive solute efflux from the guard cells, leading to water loss and a drop in turgor.

Solution:

Let's review the step-by-step channel mechanics of the ABA pathway:

(a) ABA binding activates reactive oxygen species (ROS) and calcium channels, increasing intracellular Ca^{2+} concentrations.

(b) The rise in cytosolic calcium and downstream signaling cascades directly activates slow-type (S-type) and rapid-type (R-type) anion channels in the plasma membrane.

(c) The resulting efflux of anions (such as Cl^- and malate^{2-}) causes a strong depolarization of the guard cell membrane. This depolarization turns off inward-rectifying potassium channels and activates outward-rectifying potassium channels (GORK), forcing rapid K^+ efflux. Water follows osmotically, collapsing the turgor pressure.

Final Answer: Activation of slow anion channels (S-type) leading to depolarization, which triggers K^+ efflux through outward-rectifying channels and massive water loss.

Answer: (B)

Go Back to Question 5

Q6.

Solution

Concept: Unilateral blue light creates an asymmetric distribution of auxin in coleoptile tips by stimulating phototropin receptors, which rearrange PIN-form (PIN) efflux carriers to direct auxin laterally toward the shaded side.

Solution:

Let's analyze the effect of adding N-1-naphthylphthalamic acid (NPA):

(a) NPA is a highly specific, potent inhibitor of polar auxin transport (PAT) that works by blocking PIN efflux carrier proteins.

(b) Under normal conditions, unilateral blue light coming from the right would cause auxin to relocate laterally from right to left, leading to an accumulation on the shaded (left) side.

(c) When PIN activity is blocked by NPA, lateral relocation and downward basipetal transport are completely disabled. Consequently, auxin synthesis continues at the extreme coleoptile tip, but the hormone cannot move, resulting in a symmetrical accumulation confined entirely to the apex.

Final Answer: Symmetrical accumulation at the extreme apex due to complete inhibition of polar auxin transport.

Answer: (B)

Go Back to Question 6

Q7.

Solution

Concept: Substrate-level phosphorylation in the Krebs/Citric Acid Cycle occurs during the conversion of succinyl-CoA to succinate by the enzyme succinyl-CoA synthetase.

Solution:

Let's highlight the evolutionary divergence between animal and plant mitochondrial isoforms:

(a) In animal tissues (especially specialized mammalian organs), succinyl-CoA synthetase is typically coupled to the phosphorylation of guanosine diphosphate (GDP) to synthesize GTP.

(b) In plants, fungi, and many bacterial systems, the mitochondrial isoform of succinyl-CoA synthetase is structurally distinct and displays an absolute nucleotide specificity for adenosine diphosphate (ADP).

(c) Therefore, in plants, this substrate-level phosphorylation step directly yields ATP from ADP and inorganic phosphate (P_i) without requiring a nucleoside diphosphate kinase intermediate.

Final Answer: ADP

Answer: (B)

Go Back to Question 7

Q8.

Solution

Concept: Phloem translocation operates via Ernst Münch's pressure-flow hypothesis, where long-distance transport is driven by a hydrostatic pressure gradient ($\Delta\Psi_p$) between the source and sink regions, rather than the total water potential gradient ($\Delta\Psi_w$).

Solution:

Let's analyze the driving parameters given for the source and sink cells:

(a) The total water potential equation is $\Psi_w = \Psi_s + \Psi_p$. Let's compute the hydrostatic pressure values directly:

$$\text{Source Turgor Pressure } (\Psi_{p(\text{source})}) = +1.0 \text{ MPa}$$

$$\text{Sink Turgor Pressure } (\Psi_{p(\text{sink})}) = +0.2 \text{ MPa}$$

(b) The physical driving force for bulk flow inside the sieve tube channel is the pressure gradient ($\Delta\Psi_p$) between the source and the sink:

$$\Delta\Psi_p = \Psi_{p(\text{source})} - \Psi_{p(\text{sink})} = 1.0 \text{ MPa} - 0.2 \text{ MPa} = 0.8 \text{ MPa}$$

(c) Because the pressure is higher at the source than at the sink (+1.0 MPa > +0.2 MPa), bulk flow moves from Source to Sink driven by this 0.8 MPa gradient.

Final Answer: Transport from Source to Sink driven by a pressure gradient ($\Delta\Psi_p$) of 0.8 MPa.

Answer: (B)

Go Back to Question 8

Q9.

Solution

Concept: According to Hanstein's Histogen Theory, the root and shoot apical meristems are organized into three primary tissue histogen zones: the dermatogen, the periblem, and the plerome.

Solution:

Let's review the developmental fates of these individual histogen layers:

(a) **Plerome:** Gives rise to the central core tissue, including the primary vascular cylinder (xylem, phloem) and the pith.

(b) **Periblem:** Gives rise to the inner ground tissues, forming the cortex layers and the endodermis.

(c) **Dermatogen:** Represents the outermost single-cell layer of the meristem. Lineage tracking shows that it differentiates directly and exclusively into the primary outer protective covering, which corresponds to the epidermis in stems and the epiblema/rhizodermis layer in roots.

Final Answer: Epiblema/Epidermis layer

Answer: (C)

Go Back to Question 9

Q10.

Solution

Concept: Biological nitrogen fixation by the nitrogenase enzyme complex is an energy-intensive process. It requires electrons, protons, and ATP to reduce inert atmospheric dinitrogen (N_2) into bioavailable ammonia (NH_3).

Solution:

Let's look at the stoichiometry of the overall balanced equation for nitrogenase:

(a) The nitrogenase reduction catalysis requires an obligatory synthesis of one molecule of hydrogen gas (H_2) for every molecule of N_2 reduced.

(b) The full balanced biochemical equation is:

$$N_2 + 8e^- + 8H^+ + 16ATP \rightarrow 2NH_3 + H_2 + 16ADP + 16P_i$$

(c) This shows that reducing 1 molecule of N_2 requires a total stoichiometric input of exactly 8 electrons, 8 protons, and 16 ATP molecules.

Final Answer: 8 electrons + 8 protons + 16 ATP

Answer: (A)

Go Back to Question 10

Q11.

Solution

Concept: During cereal grain germination, Gibberellic Acid (GA_3) released from the embryo signals the aleurone layer to produce and secrete hydrolases, like α-amylase, to break down stored starch in the endosperm.

Solution:

Let's analyze the cellular response in the presence of a translation inhibitor:

(a) GA_3 activates a signaling cascade that leads to the degradation of DELLA repressor proteins, allowing transcription factors to induce the *de novo* transcription of the α-amylase gene.

(b) However, because the incubation solution contains cycloheximide, a potent protein synthesis inhibitor, any newly transcribed α-amylase mRNA cannot be translated into functional enzymes.

(c) Since there are no significant pre-existing pools of stored α-amylase inside resting aleurone cells, blocking translation leads to an absolute suppression of α-amylase secretion.

Final Answer: Absolute suppression of α-amylase secretion since GA_3-induced *de novo* transcription requires active translation machinery.

Answer: (B)

Go Back to Question 11

Q12.

Solution

Concept: Chlorophyll *a* and chlorophyll *b* are the primary photosynthetic pigments in higher plants. They have distinct, non-overlapping absorption spectra that optimize light harvesting in the blue and red regions of the visible spectrum.

Solution:

Let's identify the absorption characteristics of chlorophyll *b* relative to chlorophyll *a*:

(a) Chlorophyll *a* exhibits its primary blue absorption peak around 430 nm and its red absorption peak near 660 nm.

(b) Chlorophyll *b* features structural modifications (a formyl group instead of a methyl group) that shift its absorption spectrum. Its blue absorbance peak is shifted to the right, near 450-480 nm (Curve X), and its red absorbance peak is shifted to the left, peaking prominently around 640-650 nm (Curve Y).

(c) Looking at the provided graph, Curve Y clearly illustrates this prominent left-shifted red peak characteristic of chlorophyll *b*.

Final Answer: Curve Y exclusively, which shows a prominent red peak around 650 nm.

Answer: (B)

Go Back to Question 12

Q13.

Solution

Concept: Plant ground tissues are divided into parenchyma, collenchyma, and sclerenchyma based on wall morphology, cell shape, and composition.

Solution:

Let's match the structural features to the correct tissue type:

(a) **Sclerenchyma:** Characterized by thick, rigid secondary cell walls heavily impregnated with hydrophobic lignin. These cells are typically dead at maturity.

(b) **Collenchyma:** Composed of living, elongated cells with unevenly thickened primary cell walls. The walls are rich in hydrophilic pectin and hemicellulose, allowing for flexible mechanical support without secondary lignification.

(c) Because the question specifies unevenly thickened primary cell walls rich in pectin, no secondary lignification, and a sub-epidermal location in young dicot stems, this matches collenchyma (specifically angular collenchyma).

Final Answer: Angular Collenchyma

Answer: (B)

Go Back to Question 13

Q14.

Solution

Concept: Water moves through the root cortex via three pathways: the apoplastic path (through cell walls), the symplastic path (through plasmodesmata), and the transmembrane path. At the endodermal interface, the apoplastic route is physically blocked.

Solution:

Let's analyze the composition and role of this endodermal barrier:

(a) The radial and transverse walls of endodermal cells contain localized bands of suberin, a waxy, hydrophobic biochemical material. These bands are known as Casparian strips.

(b) Because suberin is completely impermeable to water and dissolved ions, the Casparian strip acts as a physical barrier that stops apoplastic fluid movement through the cell walls.

(c) This forces water and minerals to leave the wall space and cross the selectively permeable plasma membrane into the living cytoplasm, switching to a symplastic pathway. This allows the plant to actively filter and regulate solute entry into the vascular cylinder.

Final Answer: Suberized Casparian strips that force water to cross the selectively permeable plasma membrane via symplastic paths.

Answer: (B)

Go Back to Question 14

Q15.

Solution

Concept: Plant mitochondria contain an alternative respiratory pathway mediated by Alternative Oxidase (AOX). This pathway branches off from the main electron transport chain at the ubiquinone pool, transferring electrons directly to oxygen.

Solution:

Let's calculate the impact on proton pumping and ATP yield:

(a) In the standard respiratory chain, electrons from NADH pass through Complex I, Complex III, and Complex IV, driving proton pumping across all three sites to generate a large ATP yield.

(b) When electron flow is diverted to the AOX pathway, electrons bypass Complex III and Complex IV entirely.

(c) Because Complex III and Complex IV are bypassed, no protons are pumped along this segment. The energy stored in the electrons is instead released directly as heat. Consequently, the ATP yield for this bypassed segment drops to exactly zero.

Final Answer: Drop in yield to exactly zero ATP for that segment, as electrons bypass proton-pumping Complexes III and IV, releasing energy as heat.

Answer: (B)

Go Back to Question 15

Q16.

Solution

Concept: Protein digestion in the small intestine relies on a proteolytic cascade. Inactive zymogens secreted by the pancreas must be sequentially cleaved into their active enzyme forms within the intestinal lumen.

Solution:

Let's track the effect of an enterokinase mutation:

(a) Enterokinase (also called enteropeptidase) is a brush-border enzyme that specifically cleaves a hexapeptide from inactive trypsinogen to convert it into active trypsin.

(b) Active trypsin acts as the master activator for the entire downstream pancreatic cascade. It cleaves and activates more trypsinogen, chymotrypsinogen (to chymotrypsin), and procarboxypeptidase (to carboxypeptidase).

(c) If a mutation inactivates enterokinase, trypsinogen cannot be converted to trypsin. This breaks the activation chain, preventing protein digestion within the gastrointestinal lumen.

Final Answer: Failure to convert inactive trypsinogen into active trypsin, preventing the downstream activation of chymotrypsinogen and procarboxypeptidase.

Answer: (B)

Go Back to Question 16

Q17.

Solution

Concept: The electrical segments of an electrocardiogram (ECG) trace correspond to specific mechanical events in the cardiac cycle. The QRS complex represents ventricular depolarization, while the T wave represents ventricular repolarization.

Solution:

Let's analyze the highlighted interval between points Γ and Δ:

(a) Point Γ begins at the end of the S wave, and point Δ terminates near the peak of the T wave. This interval covers the ST segment and the upstroke of the T wave.

(b) Mechanically, ventricular depolarization triggers ventricular contraction. During this phase, intraventricular pressure rises sharply. Once it exceeds the pressure within the aorta and pulmonary artery, the semilunar valves open.

(c) This initiates the ventricular ejection phase, where blood is actively pumped out into the systemic and pulmonary circulations. This phase continues until ventricular repolarization (the T wave) begins to lower intraventricular pressure.

Final Answer: Ventricular ejection phase where intraventricular pressure exceeds aortic pressure.

Answer: (B)

Go Back to Question 17

Q18.

Solution

Concept: Carbon monoxide (CO) poisoning causes severe tissue hypoxia because CO competes directly with oxygen for heme binding sites on hemoglobin.

Solution:

Let's examine the biochemical properties of carboxyhemoglobin formation:

(a) Hemoglobin's binding affinity for carbon monoxide is roughly 200 to 250 times higher than its affinity for O_2, allowing trace levels of CO to readily form carboxyhemoglobin.

(b) When CO binds to one of the four heme sites, it alters the quaternary structure of the hemoglobin tetramer, increasing the oxygen affinity of the remaining unoccupied sites.

(c) This cooperative structural shift locks hemoglobin into its high-affinity R-state, shifting the oxygen-hemoglobin dissociation curve sharply to the left. This prevents hemoglobin from releasing oxygen to peripheral tissues, causing severe systemic hypoxia.

Final Answer: Binding to hemoglobin with an affinity 200 times higher than O_2, forming carboxyhemoglobin and shifting the oxygen–hemoglobin dissociation curve to the left, which suppresses oxygen release to tissues.

Answer: (C)

Go Back to Question 18

Q19.

Solution

Concept: Voltage-gated sodium channels control the depolarization phase of an action potential using two separate physical gates: a voltage-dependent activation gate and a time-dependent inactivation gate.

Solution:

Let's analyze the state of these gates at the action potential peak (+40 mV):

(a) At the resting membrane potential, the activation gate is closed and the inactivation gate is open. Threshold depolarization causes the activation gate to open rapidly, driving the Na^+ influx that powers the upstroke phase.

(b) At the absolute peak of the action potential (+40 mV), the channel reaches its peak depolarization. At this point, the time-dependent inactivation gate snaps shut (inactivates), blocking further sodium entry.

(c) Even though the membrane potential keeps the activation gate open, the closure of the inactivation gate renders the channel non-conducting. This stops depolarization and initiates the absolute refractory period.

Final Answer: The activation gate is open but the inactivation gate closes, rendering the channel non-conducting and initiating the absolute refractory period.

Answer: (B)

Go Back to Question 19

Q20.

Solution

Concept: The kidneys maintain blood pH through acid-base regulation, primarily by secreting excess H^+ ions into the tubular lumen and reabsorbing filtered bicarbonate (HCO_3^-) back into the bloodstream.

Solution:

Let's identify where the bulk of this acid-base transport takes place along the nephron:

(a) Under normal conditions or during metabolic acidosis, the vast majority (approximately 80-85%) of filtered bicarbonate reabsorption and proton secretion occurs in Segment X, the Proximal Convoluted Tubule (PCT).

(b) This massive transport is driven by secondary active transport via the apical Na^+/H^+ antiporter (NHE3) system, which pumps protons into the lumen in exchange for sodium ions.

(c) In the lumen, secreted protons react with filtered bicarbonate to form carbonic acid, which is broken down by carbonic anhydrase to facilitate reabsorption, helping buffer systemic acidosis.

Final Answer: Segment X (Proximal Convoluted Tubule), via the secondary active Na^+/H^+ antiporter system.

Answer: (A)

Go Back to Question 20

Q21.

Solution

Concept: Parathyroid Hormone (PTH) is the primary endocrine regulator of systemic calcium levels, acting on bone, kidneys, and the intestines to increase blood calcium concentrations.

Solution:

Let's trace the homeostatic physiological mechanisms activated by excess PTH:

(a) A functional parathyroid adenoma hyper-secretes PTH, continuously stimulating osteoblasts to release RANKL. This increases osteoclast differentiation and drives bone resorption, releasing calcium into the blood.

(b) In the kidneys, PTH directly increases calcium reabsorption in the distal convoluted tubule while reducing phosphate reabsorption.

(c) Additionally, PTH upregulates the renal enzyme 1-α-hydroxylase, converting inactive vitamin D into its active form, 1,25-dihydroxyvitamin D_3. This active hormone goes on to increase calcium absorption within the intestinal tract.

Final Answer: Enhanced osteoclast-mediated bone resorption, increased renal tubular calcium reabsorption, and activation of 1,25-dihydroxyvitamin D_3.

Answer: (B)

Go Back to Question 21

Q22.

Solution

Concept: The sliding filament mechanism of muscle contraction relies on the cyclic interaction of actin and myosin filaments, driven by ATP binding, hydrolysis, and release.

Solution:

Let's break down the cross-bridge cycle to isolate the detachment step:

(a) During the power stroke, the myosin head releases ADP and inorganic phosphate, pulling the actin filament toward the center of the sarcomere. At the end of the stroke, myosin remains tightly bound to actin in a "rigor" state.

(b) To break this bond and detach from the actin filament, the myosin head must bind a fresh molecule of ATP.

(c) The binding of a new ATP molecule lowers myosin's affinity for actin, causing the cross-bridge head to detach. Subsequent hydrolysis of this ATP re-cocks the myosin head for the next cycle.

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

Answer: (B)

Go Back to Question 22

Q23.

Solution

Concept: Functional Residual Capacity (FRC) is the volume of air remaining in the lungs after a normal, passive tidal expiration. It is calculated as the sum of the Expiratory Reserve Volume (ERV) and the Residual Volume (RV).

Solution:

Let's calculate the value using the provided lung volume measurements:

(a) Identify the measured respiratory volumes from the spirometer assay:

$$\text{Expiratory Reserve Volume (ERV)} = 1100 \text{ mL}$$

$$\text{Residual Volume (RV)} = 1200 \text{ mL}$$

(b) Apply the standard formula for Functional Residual Capacity:

$$\text{FRC} = \text{ERV} + \text{RV}$$

$$\text{FRC} = 1100 \text{ mL} + 1200 \text{ mL} = 2300 \text{ mL}$$

Final Answer: 2300 mL

Answer: (C)

Go Back to Question 23

Q24.

Solution

Concept: The chloride shift (Hamburger phenomenon) is a passive transport mechanism that maintains electrical neutrality across erythrocyte membranes during carbon dioxide transport in systemic tissues.

Solution:

Let's trace ion movement at the systemic capillary interface:

(a) Tissues release CO_2 into the blood, where it enters erythrocytes and is converted into carbonic acid by carbonic anhydrase. This acid dissociates into hydrogen ions (H^+) and bicarbonate ions (HCO_3^-).

(b) As HCO_3^- accumulates inside the cell, it is exported into the plasma along its concentration gradient using the Band 3 anion exchanger protein.

(c) To balance the loss of negative charges and maintain electrical neutrality, chloride ions (Cl^-) move from the plasma into the erythrocyte through the same exchanger.

Final Answer: HCO_3^- exits the erythrocyte into the plasma via an anion exchanger, while Cl^- moves into the erythrocyte to maintain electrical neutrality.

Answer: (B)

Go Back to Question 24

Q25.

Solution

Concept: The hypothalamus is a master homeostatic control center in the mammalian brain, connecting the nervous system to the endocrine system to regulate vital physiological parameters.

Solution:

Let's match regulatory roles to the correct brain structures:

(a) Fine motor coordination and balance are managed primarily by the cerebellum. Memory consolidation is centered in the hippocampus.

(b) Intestinal peristalsis and basic respiratory rhythms are controlled by the medulla oblongata and pons.

(c) The hypothalamus contains specialized nuclei that manage thermoregulation (body temperature), osmoregulation (via osmoreceptors and antidiuretic hormone secretion), and metabolic energy balance (through hunger and satiety centers in the arcuate nucleus). An injury here would disrupt these core homeostatic parameters.

Final Answer: Thermoregulation, osmoregulation via ADH control, and regulation of appetite and satiety levels.

Answer: (B)

Go Back to Question 25

Q26.

Solution

Concept: Visual phototransduction in rod photoreceptors translates light signals into electrical changes through a G-protein-coupled signaling cascade that modulates ion channel gating.

Solution:

Let's break down the biochemical steps of the activation cascade:

(a) In the dark, high cGMP levels keep cyclic nucleotide-gated sodium channels open, generating a continuous inward sodium flux known as the "dark current."

(b) When rhodopsin absorbs a photon, its chromophore isomerization converts 11-cis-retinal into all-trans-retinal. This conformational shift activates the G-protein transducin.

(c) Activated transducin stimulates cGMP phosphodiesterase (PDE), which rapidly hydrolyzes and lowers intracellular cGMP levels. The drop in cGMP closes the sodium channels, shutting down the dark current and causing the rod cell to hyperpolarize, which reduces neurotransmitter release.

Final Answer: Conversion of 11-cis-retinal to all-trans-retinal, activation of transducin, a decrease in cGMP levels, and hyperpolarization of the rod cell.

Answer: (A)

Go Back to Question 26

Q27.

Solution

Concept: Graves' disease is an autoimmune endocrine disorder caused by auto-antibodies called thyroid-stimulating immunoglobulins (TSIs) that act as agonists on the thyroid axis.

Solution:

Let's analyze the physiological impact of these auto-antibodies binding to receptor Ω:

(a) The receptor labeled Ω on the thyroid gland is the TSH receptor. TSIs bind to and continuously activate this receptor, mimicking the action of thyroid-stimulating hormone (TSH).

(b) This continuous activation drives the constitutive synthesis and hyper-secretion of thyroid hormones (T_3 and T_4), causing clinical hyperthyroidism (Graves' disease).

(c) High levels of circulating T_3/T_4 act on the pituitary and hypothalamus via negative feedback loops, strongly suppressing the secretion of endogenous TSH.

Final Answer: Graves' Disease hyperthyroidism characterized by high circulating levels of T_3/T_4 and suppressed endogenous TSH secretion.

Answer: (B)

Go Back to Question 27

Q28.

Solution

Concept: Dietary lipids are hydrophobic aggregates that must be emulsified by bile salts in the small intestine before they can be enzymatically cleaved by water-soluble pancreatic lipase.

Solution:

Let's look at the roles of the listed gastrointestinal factors:

(a) Bile salts coat lipid droplets to emulsify them, but this coating creates a steric barrier that blocks pancreatic lipase from binding to its substrate.

(b) To overcome this barrier, the pancreas secretes colipase as an inactive procolipase, which is activated by trypsin in the intestinal lumen.

(c) Active colipase binds directly to the hydrophobic lipid surface and anchors pancreatic lipase to the droplet, allowing the enzyme to break down triacylglycerols into monoglycerides and free fatty acids.

Final Answer: Colipase

Answer: (B)

Go Back to Question 28

Q29.

Solution

Concept: The loop of Henle acts as a countercurrent multiplier to establish a hyperosmotic medullary gradient, relying on distinct permeability and transport properties along its parallel limbs.

Solution:

Let's review the transport profile of the thick ascending limb:

(a) The descending limb is highly permeable to water but impermeable to solutes, concentrating the tubular fluid as it moves downward.

(b) In contrast, the thick ascending limb is completely impermeable to water due to a lack of aquaporin channels.

(c) Its epithelial cells actively pump solutes out of the lumen into the surrounding interstitium using the $Na^+/K^+/2Cl^-$ cotransporter (NKCC2). This active solute transport lowers the concentration of the tubular fluid while generating the hyperosmotic medullary gradient needed for water reabsorption in the collecting ducts.

Final Answer: Active transport of ions (Na^+, K^+, and the $Na^+ - K^+ - 2Cl^-$ co-transporter) out of the tubule lumen; completely impermeable to water.

Answer: (B)

Go Back to Question 29

Q30.

Solution

Concept: In genetic mapping crosses, double crossover (DCO) events occur at the lowest frequency. Comparing the parental chromosomes with the DCO recombinant classes allows you to determine the gene order by isolating which allele switches position.

Solution:

Let's deduce the gene order step-by-step:

(a) Identify the parental alleles from the trihybrid female genotype ($\frac{\text{AbC}}{\text{aBc}}$):

Parental Chromosome 1: **A b C**, Parental Chromosome 2: **a B c**

(b) Identify the lowest frequency recombinant classes, which represent the double crossovers:

DCO Class 1: **a b c**, DCO Class 2: **A b C**

(Note: There is a typographical mismatch in the problem's option list phrasing for Class 2, but we can determine the switched marker directly). Let's compare a true DCO class like **a b c** to the parental strands: **a B c** and **A b C**.

(c) Notice that alleles **A**/**a** and **C**/**c** remain in their original combinations, while the **B**/**b** locus switches its alignment relative to the other two. This indicates that a double crossover swapped the middle gene, confirming that gene B is located in the middle.

Final Answer: Gene B is located in the middle.

Answer: (B)

Go Back to Question 30

Q31.

Solution

Concept: DNA replication requires an initial primer because DNA polymerases can only elongate an existing polynucleotide chain. They cannot initiate synthesis *de novo*.

Solution:

Let's analyze the roles of the enzymes at the replication fork:

(a) **DNA Helicase:** Unwinds the double-stranded DNA template at the fork.

(b) **DNA Polymerase I:** Removes RNA primers and replaces them with DNA.

(c) **DNA Primase (Ξ):** This specialized RNA polymerase binds near the replication fork. It synthesizes short RNA primers (around 10-12 nucleotides long) on the lagging strand template, providing the free 3′-OH group needed for DNA Polymerase III to synthesize Okazaki fragments.

Final Answer: DNA Primase (DnaG)

Answer: (C)

Go Back to Question 31

Q32.

Solution

Concept: Transcription of the *lac* operon requires both the removal of the *lac* repressor from the operator site and the binding of the cAMP-CAP activator complex to the promoter site to recruit RNA polymerase.

Solution:

Let's isolate the reason for this un-induced phenotype:

(a) The operator mutation (O^c) prevents the repressor from binding, which normally leads to constitutive expression of the structural genes (*lacZ*, *lacY*, *lacA*).

(b) However, because these genes fail to express even when lactose is present, there must be a defect that blocks transcription initiation.

(c) If a second mutation alters the core promoter site, the RNA Polymerase holoenzyme cannot recognize or bind to the DNA. Without RNA polymerase binding, transcription cannot initiate, completely preventing operon expression regardless of repressor or activator dynamics.

Final Answer: A mutation in the promoter site preventing RNA Polymerase holoenzyme from recognizing the transcription start site.

Answer: (B)

Go Back to Question 32

Q33.

Solution

Concept: Eukaryotic pre-mRNA undergoes several post-transcriptional modifications, including the addition of a 5′ cap, capping, polyadenylation, and splicing, to protect the transcript from exonuclease degradation and facilitate translation.

Solution:

Let's examine the chemical structure of the 5′ cap:

(a) During early transcription elongation, a capping enzyme complex modifies the 5′ end of the pre-mRNA transcript.

(b) A guanylyltransferase adds a guanine nucleotide, which is then methylated at the 7-position by a methyltransferase, forming a 7-methylguanosine (m^7G) residue.

(c) This 7-methylguanosine is linked to the first encoded nucleotide of the mRNA transcript via an unusual 5′-to-5′ triphosphate bridge. This unique linkage protects the mRNA from degradation by 5′ → 3′ exonucleases and plays a key role in ribosome binding.

Final Answer: 7-methylguanosine attached via an unusual 5′-to-5′ triphosphate bridge.

Answer: (A)

Go Back to Question 33

Q34.

Solution

Concept: Pedigree analysis tracks the inheritance patterns of genetic traits across generations based on typical phenotypic distribution rules.

Solution:

Let's evaluate the inheritance clues provided for this pedigree:

(a) The key observation states that every affected male child has an affected mother, and affected mothers pass the trait to all of their offspring, regardless of sex.

(b) This strict transmission pattern from mothers to 100% of their children is characteristic of mitochondrial (maternal) inheritance.

(c) Because the mitochondria inside a zygote are derived almost exclusively from the egg cytoplasm rather than the sperm, paternal transmission does not occur. This matches the maternal inheritance profile perfectly.

Final Answer: Mitochondrial/Maternal inheritance.

Answer: (C)

Go Back to Question 34

Q35.

Solution

Concept: Francis Crick's Wobble Hypothesis explains how a single tRNA anticodon can recognize multiple mRNA codons, owing to non-standard, flexible base-pairing rules at the third codon position.

Solution:

Let's review the permitted wobble base-pairing rules:

(a) Non-standard base-pairing is restricted to the 3′ base of the mRNA codon and the matching 5′ base (position 34) of the tRNA anticodon.

(b) When the modified purine base Inosine (I) is present at the 5′ wobble position of the tRNA anticodon, it can form stable hydrogen bonds with three different bases at the 3′ position of the mRNA codon: Uracil (U), Cytosine (C), or Adenine (A).

(c) This flexibility allows a single tRNA molecule to decode up to three distinct degenerate codons specifying the same amino acid.

Final Answer: An Inosine (I) residue at the 5′ end of the tRNA anticodon can form hydrogen bonds with U, C, or A in the codon.

Answer: (A)

Go Back to Question 35

Q36.

Solution

Concept: Peptide bond formation during translation elongation is a fundamental catalytic event that occurs within the peptidyl transferase center (PTC) of the large ribosomal subunit.

Solution:

Let's analyze the catalytic component responsible for this reaction:

(a) During elongation, the growing polypeptide chain attached to the tRNA in the P-site is joined via a peptide bond to the incoming aminoacyl-tRNA in the A-site.

(b) Biochemical and structural studies have established that this reaction is not catalyzed by a protein enzyme. Instead, it is catalyzed directly by the highly conserved 23S rRNA molecule of the large (50S) ribosomal subunit in prokaryotes.

(c) The 23S rRNA positions the substrates properly and stabilizes the transition state, acting as a true RNA catalyst or ribozyme.

Final Answer: The 23S rRNA component of the large (50S) ribosomal subunit acting as a ribozyme.

Answer: (B)

Go Back to Question 36

Q37.

Solution

Concept: The Meselson-Stahl experiment demonstrated that DNA replication follows a semi-conservative mechanism, where each strand of a parent DNA duplex serves as a template for the synthesis of a new complementary strand.

Solution:

Let's track the distribution of nitrogen isotopes (^{15}N and ^{14}N) through three generations of replication:

(a) **Generation 0:** All DNA molecules are fully heavy (^{15}N-^{15}N).

(b) **Generation 1 (Round 1 in ^{14}N):** Each heavy strand template pairs with a newly synthesized light strand, producing 100% hybrid molecules (^{14}N-^{15}N).

(c) **Generation 2 (Round 2 in ^{14}N):** The strands separate again. The two hybrid strands give rise to two new hybrid molecules, while the two light template strands form two fully light molecules (^{14}N-^{14}N). This yields a 1:1 ratio (50% light and 50% hybrid).

(d) **Generation 3 (Round 3 in ^{14}N):** Total strands equal 8 duplexes (16 strands). The 2 original heavy strands remain locked inside 2 hybrid duplexes, while the remaining 6 duplexes are completely light (^{14}N-^{14}N). The proportion is:

$$\text{Hybrid DNA} = \frac{2}{8} = 25\%, \quad \text{Light DNA} = \frac{6}{8} = 75\%$$

Final Answer: 75% Light DNA and 25% Hybrid DNA.

Answer: (C)

Go Back to Question 37

Q38.

Solution

Concept: Specific phenotypic abnormalities and clinical symptoms are tied to distinct structural or numerical chromosomal aberrations in human cytogenetics.

Solution:

Let's analyze the symptoms presented by the patient:

(a) Clinical indicators such as microcephaly (abnormally small head), severe intellectual disability, low birth weight, and a highly distinctive high-pitched, mewing cat-like infant cry point to a well-documented genetic disorder.

(b) This clinical profile describes Cri-du-chat (cat's cry) syndrome.

(c) Karyotypic analysis of individuals with Cri-du-chat syndrome reveals a specific terminal or interstitial structural deletion affecting the short arm (p arm) of chromosome 5.

Final Answer: Deletion of the short arm of chromosome 5 (Cri-du-chat syndrome).

Answer: (B)

Go Back to Question 38

Q39.

Solution

Concept: The Ames test is a widely utilized biological assay designed to screen chemical compounds for potential mutagenicity and carcinogenicity by measuring genetic reversion rates in bacteria.

Solution:

Let's outline the tracking mechanics and indicator strains used in the assay:

(a) The test utilizes specially engineered auxotrophic mutant strains of the bacterium *Salmonella typhimurium*.

(b) These specific strains carry a loss-of-function mutation in genes involved in the biosynthesis pathway of the essential amino acid histidine, rendering them histidine-dependent (auxotrophic).

(c) When exposed to a mutagenic chemical substance, back-mutations or reversion events occur that repair the defective gene. This enables the bacteria to synthesize histidine independently (reverting to prototrophy) and form visible colonies on histidine-deficient minimal agar plates.

Final Answer: Auxotrophic mutants of Salmonella typhimurium tracking the reversion from histidine dependence to histidine independence.

Answer: (A)

Go Back to Question 39

Q40.

Solution

Concept: Point mutations involving nucleotide substitutions inside a double-stranded DNA duplex are classified into two distinct structural mechanisms: transitions and transversions.

Solution:

Let's differentiate between transition and transversion substitution pathways:

(a) **Transversion:** Occurs when a double-ring purine base (A or G) is substituted by a single-ring pyrimidine base (C or T), or vice versa.

(b) **Transition:** Occurs when a purine base is replaced by another alternative purine (A $\longleftrightarrow$ G), or a pyrimidine base is replaced by another pyrimidine (C $\longleftrightarrow$ T).

(c) Therefore, a mutation where a Guanine residue replaces an Adenine residue represents a true molecular transition pathway.

Final Answer: Guanine replacing an Adenine residue (or vice versa, a purine substituted by another purine).

Answer: (B)

Go Back to Question 40

Q41.

Solution

Concept: Genomic imprinting is an epigenetic phenomenon that leads to monoallelic expression, where a gene is expressed exclusively from either the maternal or paternal allele.

Solution:

Let's trace the molecular mechanism behind the establishment of genomic imprinting:

(a) During gametogenesis, pre-existing epigenetic marks are erased and reset based on the sex of the individual.

(b) The biochemical mechanism responsible for setting these parent-of-origin marks involves the targeted, covalent addition of methyl groups to the 5th carbon position of cytosine residues.

(c) This process occurs within dense cytosine-guanine dinucleotide regions (CpG islands) near gene promoters, and is mediated by *de novo* DNA methyltransferases (DNMT3a and DNMT3b). This stable methylation silences the imprinted gene allele, and the pattern is preserved across subsequent mitotic divisions.

Final Answer: Covalent DNA methylation of cytosine bases within CpG islands by de novo methyltransferases.

Answer: (B)

Go Back to Question 41

Q42.

Solution

Concept: According to the fluid mosaic model, cholesterol functions as a critical biophysical buffer that modulates membrane fluidity and stabilizes lipid bilayers across fluctuating thermal states.

Solution:

Let's analyze cholesterol's regulatory effects at different temperature ranges:

(a) At elevated temperatures, the rigid steroid ring structure of cholesterol interferes with the movement of fatty acid hydrocarbon chains, restricting excessive lateral mobility and preventing the membrane from becoming overly fluid or leaky.

(b) At low temperatures, cholesterol breaks up the regular, tightly packed crystalline arrangement of phospholipid tails, preventing the membrane from freezing or solidifying.

(c) By exerting these dual protective actions, cholesterol prevents sharp transitions between gel and fluid states, widening the overall phase transition temperature range to maintain homeostatic membrane fluidity.

Final Answer: It broadens the phase transition temperature, stabilizing membrane fluidity by preventing hydrocarbon chains from packing tightly at low temperatures and restricting excessive movement at high temperatures.

Answer: (A)

Go Back to Question 42

Q43.

Solution

Concept: The spindle assembly checkpoint (SAC) is a strict quality-control mechanism that delays the transition from metaphase to anaphase until all chromosomes are properly attached to the mitotic spindle.

Solution:

Let's analyze the cell division status shown in the provided diagram:

(a) The diagram depicts condensed chromosomes lined up end-to-end along a central equatorial plate between two opposing centrosome poles, which is characteristic of metaphase.

(b) The spindle assembly checkpoint remains actively signaling to inhibit the anaphase-promoting complex/cyclosome (APC/C) as long as unattached kinetochores are present.

(c) The SAC is silenced only after every single kinetochore achieves proper amphitelic (bioriented) microtubule attachment and experiences mechanical tension from the opposing poles, clearing the cell to proceed to anaphase.

Final Answer: Metaphase; chromosomes are aligned along the equatorial plate, and the SAC remains active until all kinetochores achieve biorientation.

Answer: (B)

Go Back to Question 43

Q44.

Solution

Concept: Protein sorting and trafficking from the Golgi network depend on specific carbohydrate modifications that act as chemical zip codes to route newly synthesized proteins to their correct cellular destinations.

Solution:

Let's trace the trafficking pathway of lysosomal proteins:

(a) Soluble lysosomal hydrolases are synthesized in the rough endoplasmic reticulum and travel to the *cis*-Golgi network.

(b) Inside the *cis*-Golgi, an enzyme recognizes a specific signal patch on the hydrolase and adds an N-acetylglucosamine-1-phosphate group to terminal mannose residues. A second enzyme removes the N-acetylglucosamine, exposing a mannose-6-phosphate (M6P) tag.

(c) In the *trans*-Golgi network, specific M6P receptors recognize this tag and package the hydrolases into clathrin-coated vesicles bound for late endosomes and lysosomes.

Final Answer: Mannose-6-phosphate tagging

Answer: (B)

Go Back to Question 44

Q45.

Solution

Concept: Microtubule dynamics, including polymerization and structural stability, are regulated by the binding and hydrolysis of guanosine triphosphate (GTP) within α- and β-tubulin heterodimers.

Solution:

Let's evaluate the nucleotide dynamics of tubulin subunits during assembly:

(a) Each tubulin heterodimer contains two distinct GTP-binding sites. The site on α-tubulin is trapped at the subunit interface and cannot be hydrolyzed or exchanged.

(b) The binding site on the β-tubulin subunit is exposed and can exchange GDP for a fresh molecule of GTP. Both subunits must bind active GTP to form an assembly-competent heterodimer.

(c) Shortly after the heterodimer is added to the growing plus-end of a protofilament, the GTP bound to the β-tubulin subunit is hydrolyzed to GDP. This conformational shift weakens the subunit bonds, predisposing the microtubule to catastrophic depolymerization if the protective, stabilizing "GTP cap" is lost.

Final Answer: Both α- and β-tubulin subunits must bind active GTP, but only the GTP bound to β-tubulin is hydrolyzed following addition to the protofilament.

Answer: (A)

Go Back to Question 45

Q46.

Solution

Concept: Enzymes serve as biological catalysts that accelerate chemical reactions by lowering the activation energy barrier ($\Delta G^{\ddagger}$) required to reach the high-energy transition state, without altering the overall net thermodynamic free energy change (ΔG).

Solution:

Let's analyze the energy changes plotted in the diagram:

(a) The solid red line represents the uncatalyzed reaction, which requires a substantial input of activation energy to reach its transition state peak.

(b) The dashed blue line tracks the enzyme-catalyzed reaction pathway, which proceeds through an alternative mechanism with a significantly lower transition state peak.

(c) The vertical green vector labeled Λ measures the distance between these two peaks. This directly quantifies the exact reduction in activation energy ($\Delta\Delta G^{\ddagger}$) brought about by adding the enzyme catalyst.

Final Answer: Arrow Vector Λ, representing the decrease in activation energy barrier.

Answer: (B)

Go Back to Question 46

Q47.

Solution

Concept: Meiosis I features prolonged prophase sub-stages that facilitate homologous chromosome pairing and reciprocal genetic recombination to promote genetic diversity.

Solution:

Let's focus on the structural and enzymatic mechanisms of the pachytene stage:

(a) During the zygotene and pachytene stages, homologous chromosomes pair tightly along their lengths. This pairing is stabilized by a protein structure known as the synaptonemal complex.

(b) Interspaced along this synaptonemal complex are large protein assemblies called recombination nodules.

(c) These nodules contain specialized recombinase enzymes, including RAD51 and the meiosis-specific DMC1. These enzymes catalyze strand invasion, DNA break repair, and reciprocal crossing-over events to swap genetic material between non-sister chromatids.

Final Answer: Synaptonemal complex associated with recombination nodules containing RAD51 and DMC1 recombinases.

Answer: (B)

Go Back to Question 47

Q48.

Solution

Concept: Glycosaminoglycans (GAGs) are long, unbranched polysaccharides consisting of repeating disaccharide units, typically composed of an amino sugar and a uronic acid, often modified with sulfate groups.

Solution:

Let's analyze the composition profile obtained from acid hydrolysis:

(a) The hydrolysis of this structural biomolecule yields alternating units of D-glucosamine (an amino sugar) and glucuronic acid (a sugar acid).

(b) The polymer chain also displays a high degree of O-sulfation modifications, giving it a dense negative charge.

(c) Among the choices, this specific chemical composition—repeating units of sulfated glucosamine and glucuronic acid—defines the structure of Heparin, a highly sulfated glycosaminoglycan.

Final Answer: Heparin (a highly sulfated glycosaminoglycan)

Answer: (B)

Go Back to Question 48

Q49.

Solution

Concept: The transition from G2 phase to mitosis is driven by the activation of Maturation Promoting Factor (MPF), a heterodimeric complex composed of the catalytic subunit Cdk1 (Cdc2) and the regulatory subunit Cyclin B.

Solution:

Let's examine the phosphorylation events that regulate MPF activation:

(a) As Cyclin B accumulates during G2, it binds to Cdk1. The complex is then phosphorylated at two inhibitory positions, Thr14 and Tyr15, by the kinase Wee1, which keeps the complex inactive.

(b) Simultaneously, the CAK kinase phosphorylates an activating residue at position Thr161 within the T-loop of Cdk1.

(c) To fully activate MPF and drive the cell into mitosis, the Cdc25 phosphatase must remove the inhibitory phosphate groups from Thr14 and Tyr15. This leaves Cdk1 phosphorylated only at its activating Thr161 site, triggering a rapid feedback loop that activates the entire pool of MPF.

Final Answer: Dephosphorylation of inhibitory residues Thr14 and Tyr15 by Cdc25 phosphatase, along with activating phosphorylation at Thr161.

Answer: (B)

Go Back to Question 49

Q50.

Solution

Concept: Amphipathic lipid molecules, such as phospholipids, spontaneously self-assemble into organized structural aggregates when placed in an aqueous environment to satisfy hydrophobic interactions.

Solution:

Let's interpret the concentric structural layout illustrated in the diagram:

(a) The diagram depicts two concentric rings of lipid molecules. Each molecule is represented by a hydrophilic head group (the black circle) and a hydrophobic tail (the straight line).

(b) In this configuration, the outer layer has its hydrophilic heads facing outward toward the bulk solution, while the inner layer has its heads facing inward toward a central cavity. The hydrophobic tails point toward each other, forming a continuous lipid bilayer.

(c) This specific spherical bilayer structure enclosing an aqueous core is called a liposome or phospholipid vesicle. This contrasts with a solid micelle, which has a hydrophobic interior core filled with lipid tails.

Final Answer: Phospholipid bilayer Vesicle (Liposome) containing an aqueous internal core.

Answer: (B)

Go Back to Question 50

Q51.

Solution

Concept: The plant cell wall provides mechanical support and protection. Its primary structural framework is made of cellulose microfibrils, which are synthesized by specialized enzyme complexes embedded in the cell membrane.

Solution:

Let's identify the cellular site and enzyme complexes involved in cellulose synthesis:

(a) While matrix polysaccharides like pectin and hemicellulose are synthesized in the Golgi apparatus and transported via vesicles, cellulose is synthesized directly at the cell surface.

(b) This synthesis is carried out by hexameric protein arrays embedded in the plasma membrane, known as cellulose synthase (CESA) complexes or rosettes.

(c) These rosettes take UDP-glucose substrates from the cytoplasm, polymerize them into long β-$(1 \rightarrow 4)$-glucan chains, and extrude them into the extracellular space. There, the chains self-assemble via hydrogen bonding into rigid cellulose microfibrils.

Final Answer: The plasma membrane surface, synthesized by hexameric cellulose synthase (CESA) complexes (rosettes) using UDP-glucose.

Answer: (B)

Go Back to Question 51

Q52.

Solution

Concept: The equilibrium model of island biogeography states that the species richness (S) of an isolated island represents a dynamic balance between the rate of new species immigration (I) and the rate of existing species extinction (E).

Solution:

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

(a) **Immigration Rate (I):** Is determined primarily by an island's distance from the mainland source pool. Islands located closer to the mainland have a higher probability of receiving new dispersing individuals ($I_{near} > I_{far}$).

(b) **Extinction Rate (E):** Is determined primarily by island size. Large islands support larger populations, which are less vulnerable to stochastic extinction events ($E_{large} < E_{small}$).

(c) Therefore, a **large** island located **close** to the mainland source pool will maximize immigration while minimizing extinction, supporting the absolute highest equilibrium species richness.

Final Answer: Large islands located close to the mainland source pool.

Answer: (B)

Go Back to Question 52

Q53.

Solution

Concept: Population growth models describe how a population's size changes over time under varying environmental constraints.

Solution:

Let's interpret the growth trajectory shown in the graph:

(a) Curve Ω displays a sigmoidal (S-shaped) growth trajectory. The population grows slowly at first, then accelerates exponentially, and finally slows down as it approaches a stable plateau.

(b) This trajectory is described by the logistic growth model, expressed by the differential equation:

$$\frac{dN}{dt} = rN\left(\frac{K-N}{K}\right)$$

(c) The dashed horizontal line labeled K represents the maximum population size that the environment's resources can sustainably support over time, known as the Carrying Capacity.

Final Answer: Logistic growth model $\left(\frac{dN}{dt} = rN\frac{K-N}{K}\right)$; Line K is the environmental carrying capacity.

Answer: (B)

Go Back to Question 53

Q54.

Solution

Concept: Persistent, lipophilic chemical pollutants that enter an ecosystem cannot be easily metabolized or excreted by organisms. Instead, they accumulate within tissues and concentrate as they move up the food chain.

Solution:

Let's define the ecological mechanism and trace its concentration across trophic levels:

(a) This progressive increase in pollutant concentration at successive steps of the food chain is called biomagnification.

(b) While organisms at lower trophic levels (like phytoplankton) absorb the pesticide directly from the water, consumers must ingest large numbers of contaminated prey.

(c) Because energy decreases but toxin burden is retained at each trophic transfer, the highest pollutant concentrations accumulate within top apex predators, such as tertiary consumers and piscivorous birds.

Final Answer: Biomagnification; highest in tertiary consumers and top apex predators (e.g., piscivorous birds).

Answer: (B)

Go Back to Question 54

Q55.

Solution

Concept: Norman Myers' biodiversity hotspot framework helps conservation groups identify and prioritize regions around the world where exceptional concentrations of endemic species are facing severe habitat loss.

Solution:

Let's list the two strict quantitative criteria required to qualify as a global biodiversity hotspot:

(a) **Endemism:** The region must contain at least 1,500 species of vascular plants as endemics, meaning these plants are found nowhere else on Earth. This accounts for roughly 0.5% of the world's total plant diversity.

(b) **Threat Level:** The ecosystem must be under severe threat, having lost at least 70% of its original primary, native vegetation.

Final Answer: It must contain at least 1500 species of vascular plants as endemics and must have lost at least 70% of its original primary native vegetation.

Answer: (A)

Go Back to Question 55

Q56.

Solution

Concept: Deep lakes in temperate regions undergo thermal stratification during the summer, dividing the water column into three distinct layers based on temperature and density differences.

Solution:

Let's review the three layers of a stratified lake:

(a) **Epilimnion:** The warm, less dense upper layer that is well-oxygenated and exposed to sunlight.

(b) **Hypolimnion:** The cold, dense bottom layer that is insulated from the surface.

(c) **Region Ψ:** The middle layer, situated between the epilimnion and hypolimnion, where temperature drops rapidly with increasing depth. This zone of rapid temperature change is called the thermocline or metalimnion.

Final Answer: Thermocline (Metalimnion)

Answer: (B)

Go Back to Question 56

Q57.

Solution

Concept: Gause's competitive exclusion principle states that two species competing for the exact same limiting resource cannot stably coexist if their ecological niches overlap completely; the more efficient competitor will eventually eliminate the other.

Solution:

Let's analyze how ecologically similar species coexist in nature:

(a) To avoid extinction from competitive exclusion, sympatric species shift their resource use to minimize niche overlap.

(b) This niche shift is known as resource partitioning, where species divide resources by feeding at different times, occupying slightly different microhabitats, or targeting different prey sizes.

(c) Over evolutionary time, this behavioral partitioning drives directional selection, leading to divergent morphological variations in competing species. This evolutionary divergence is called character displacement.

Final Answer: Resource partitioning via divergence in structural, behavioral, or physiological traits (character displacement).

Answer: (B)

Go Back to Question 57

Q58.

Solution

Concept: Primary ecological succession describes the predictable process of plant community development over time on newly formed, barren substrates that lack pre-existing soil, such as a cooled volcanic lava flow.

Solution:

Let's trace the typical stages of primary plant succession:

(a) **Pioneers:** The first organisms to colonize the bare rock are crustose lichens, which can survive extreme conditions and slowly weather the rock surface. They are followed by more complex foliose lichens and mosses, which trap organic matter and begin forming a thin layer of soil.

(b) **Intermediate Stages:** As the soil deepens, herbaceous plants (herbs) and annual grasses take root. Over decades, these are replaced by woody shrubs that shade out the shorter vegetation.

(c) **Climax Community:** Eventually, slow-growing, shade-tolerant trees establish themselves, forming a stable climax forest community that remains dominant unless disrupted by a major disturbance.

Final Answer: Crustose Lichens → Foliose Lichens → Mosses → Herbs → Shrubs → Climax Forest Trees.

Answer: (B)

Go Back to Question 58

Q59.

Solution

Concept: The Shannon-Weiner Diversity Index (H') measures species diversity within an ecological community by accounting for both species richness and species evenness.

Solution:

Let's analyze the mathematical parameters that maximize the index:

(a) **Species Richness:** Represents the total number of distinct species present in the community. Higher richness increases the range of the summation.

(b) **Species Evenness:** Reflects how equally individuals are distributed among those species. If a community is dominated by a single species while others are rare, evenness is low, which reduces the index value.

(c) Therefore, the index value reaches its absolute maximum (H'_{max}) when a community combines high species richness with high species evenness, meaning individuals are distributed equally across a large variety of distinct species.

Final Answer: High species richness paired with high species evenness (equal abundance distributed across many distinct species).

Answer: (C)

Go Back to Question 59

Q60.

Solution

Concept: The Global Warming Potential (GWP) of a greenhouse gas measures its individual molecule-for-molecule radiative forcing efficiency and atmospheric lifetime relative to carbon dioxide (CO_2).

Solution:

Let's rank the common greenhouse gases based on their radiative forcing efficiency:

(a) CO_2 is the most abundant greenhouse gas, but it serves as the baseline reference unit (GWP = 1) because it has the lowest radiative efficiency per molecule.

(b) Methane (CH_4) is significantly more efficient at trapping infrared radiation than CO_2, with a GWP roughly 28–36 times higher over a 100-year timescale.

(c) Nitrous Oxide (N_2O) has an even greater radiative warming impact, with a molecule-for-molecule GWP roughly 265–298 times that of CO_2.

(d) Halocarbon compounds, such as Chlorofluorocarbons (CFCs), possess an extraordinary radiative forcing capacity, with GWPs thousands of times higher than CO_2 due to their specific infrared absorption bands and long atmospheric lifetimes.

Final Answer: $\boxed{CO_2 < CH_4 < N_2O < CFCs}$

Answer: (B)

Go Back to Question 60

Q61.

Solution

Concept: Plant families are characterized by unique combinations of floral and anatomical traits, including petal orientation, stamen arrangement, and ovary structure.

Solution:

Let's match the observed diagnostic features to the correct family:

(a) The presence of a cruciform corolla consisting of four clawed petals arranged in a cross is a classic identifying feature of the mustard family.

(b) The flower also contains a tetradynamous stamen configuration, which is a specific arrangement of six stamens where two short outer stamens surround four long inner stamens.

(c) Finally, the superior ovary contains a false internal septum known as a replum that splits the chamber during seed development. These combined traits are diagnostic of the Brassicaceae (Cruciferae) family.

Final Answer: Brassicaceae (Cruciferae)

Answer: (B)

Go Back to Question 61

Q62.

Solution

Concept: Floral diagrams illustrate the structural arrangement, symmetry, and fusion of reproductive organs within a flower, serving as a diagnostic tool for plant identification.

Solution:

Let's evaluate the specific anatomical markers described:

(a) **Epipetalous Stamens:** Stamens that are physically fused to the inner petals of the corolla whorl.

(b) **Ovary Anatomy:** The diagram shows a syncarpous, superior ovary containing a swollen central placenta with numerous ovules.

(c) A key diagnostic feature of this family is that the entire carpel/ovary assembly is oriented obliquely at a 45-degree angle relative to the median plane of the flower. These traits combined are diagnostic of the Solanaceae (nightshade) family, which includes species like *Solanum nigrum*.

Final Answer: Solanaceae (e.g., *Solanum nigrum*)

Answer: (B)

Go Back to Question 62

Q63.

Solution

Concept: Whittaker's Five Kingdom Classification system groups organisms based on cellular structure, body organization, and their primary mode of nutrition.

Solution:

Let's highlight the physiological and structural traits that separate Fungi from Plantae:

(a) **Plantae:** Consists of autotrophic organisms that synthesize energy via photosynthesis, have cellulose-based cell walls, and store excess carbohydrates as starch.

(b) **Fungi:** Consists of heterotrophic organisms that acquire nutrients via absorptive mechanisms, secreting extracellular digestive enzymes into their surroundings to break down organic matter before absorbing it.

(c) Additionally, fungal cell walls are composed of chitin (a polymer of N-acetylglucosamine) rather than cellulose, and they store excess carbohydrates as glycogen, similar to animal cells.

Final Answer: Heterotrophic absorptive nutrition, cell walls composed of chitin, and glycogen acting as the primary storage carbohydrate resource.

Answer: (B)

Go Back to Question 63

Q64.

Solution

Concept: Invertebrate taxa are classified based on key morphological features, such as body segmentation, coelom architecture, and developmental structures.

Solution:

Let's analyze the structural traits of the collected marine specimen:

(a) The organism is unsegmented, triploblastic, and coelomate, which rules out simpler phyla like Nematoda or Platyhelminthes.

(b) The body is divided into three distinct anatomical regions: an anterior proboscis, a middle collar, and a long posterior trunk.

(c) The presence of pharyngeal gill slits and a stomochord (an anterior outpocketing of the gut that was historically misidentified as a notochord) are diagnostic traits of the phylum Hemichordata, which includes acorn worms like *Balanoglossus*.

Final Answer: Hemichordata

Answer: (B)

Go Back to Question 64

Q65.

Solution

Concept: The classification of amniotes, including reptiles, is based on temporal fenestration—the number and arrangement of structural openings (temporal fossae) in the post-orbital region of the skull.

Solution:

Let's review the main skull types within amniote lineages:

(a) **Synapsid:** Features a single lower temporal opening on each side of the skull (the evolutionary lineage that led to mammals).

(b) **Diapsid:** Features two temporal openings on each side of the skull (found in birds, crocodilians, lizards, and snakes).

(c) **Anapsid:** Characterized by a solid bone roof behind the eye orbits that completely lacks temporal openings. This primitive skull architecture is the defining evolutionary feature of modern turtles (*Chelone*) and their ancestors.

Final Answer: Anapsid skull condition featuring a complete, solid roof lacking any temporal vacuities.

Answer: (C)

Go Back to Question 65

Q66.

Solution

Concept: Non-vascular bryophytes follow a heteromorphic alternation of generations, where the haploid gametophyte and diploid sporophyte phases have distinct life histories and morphologies.

Solution:

Let's trace the life cycle phases of the true moss *Funaria*:

(a) The dominant, conspicuous, long-lived phase of the life cycle is the haploid gametophyte. This stage is green, photosynthetic, and independent, developing from a filamentous protonema into a leafy shoot that produces gametes.

(b) Following fertilization, the zygote develops into the diploid sporophyte generation.

(c) This sporophyte phase is physically dependent on the maternal gametophyte for water and nutrients. It remains attached throughout its lifespan and is composed of three anatomical structures: a anchoring foot, an elongated stalk (seta), and a terminal capsule where haploid spores are produced via meiosis.

Final Answer: Dominant, haploid, photosynthetic gametophyte phase alternating with a physically dependent, diploid sporophyte consisting of a foot, seta, and capsule.

Answer: (B)

Go Back to Question 66

Q67.

Solution

Concept: Sponges rely on a water canal system to circulate water through their bodies, driving filter feeding, gas exchange, and excretion. The complexity of this system varies among structural types (asconoid, syconoid, and leuconoid).

Solution:

Let's map the water transport pathway through an advanced leuconoid canal system:

(a) Water enters the sponge through small intake pores on the outer surface called dermal ostia, moving into incurrent canals.

(b) From these canals, water passes through tiny openings called prosopyles to enter distinct, rounded flagellated chambers lined with choanocytes.

(c) The beating flagella pump water out of the chambers through exit openings called apopyles, directing it into excurrent canals. These canals merge into larger channels that carry the water out of the sponge through a main exit opening called the osculum.

Final Answer: Dermal Ostia → Incurrent Canals → Prosopyles → Flagellated Chambers → Apopyles → Excurrent Canals → Osculum.

Answer: (B)

Go Back to Question 67

Q68.

Solution

Concept: Aestivation describes the spatial arrangement and overlapping pattern of calyx or corolla segments within a flower bud before it opens.

Solution:

Let's examine the characteristic corolla arrangement of the Fabaceae (pea) family:

(a) Flowers in the Fabaceae family display a unique arrangement known as vexillary or descending-imbricate aestivation.

(b) The corolla is composed of five distinct petals with specialized roles and structures.

(c) The largest, outermost posterior petal is called the vexillum or standard. It overlaps two smaller lateral petals known as wings (alae). These wings, in turn, enclose two anterior petals that are fused along their lower edge to form a boat-shaped structure called the keel (carina), which protects the reproductive organs.

Final Answer: Vexillary (descending imbricate) aestivation; consisting of one large posterior petal (vexillum/standard), two lateral wings (alae), and two fused anterior petals (carina/keel).

Answer: (B)

Go Back to Question 68

Q69.

Solution

Concept: The development of the female gametophyte (embryo sac) in angiosperms involves megasporogenesis followed by megagametogenesis within the ovule.

Solution:

Let's trace the nuclear divisions that form a standard monosporic (*Polygonum*-type) embryo sac:

(a) Meiosis produces four haploid megaspores, but three degenerate, leaving a single functional megaspore.

(b) This remaining functional megaspore undergoes three successive rounds of free-nuclear mitotic divisions ($1 \rightarrow 2 \rightarrow 4 \rightarrow 8$ nuclei), producing an elongated cell containing eight haploid nuclei.

(c) Cytokinesis then seals these nuclei into separate cells, forming a mature gametophyte structure composed of seven cells and eight nuclei: an egg apparatus (one egg cell and two flanking synergids) at the micropylar pole, three antipodal cells at the chalazal pole, and a large central cell containing the remaining two polar nuclei.

Final Answer: Three successive rounds of free-nuclear mitosis; producing an 8-nucleate, 7-celled mature embryo sac consisting of an egg apparatus, three antipodal cells, and a central cell containing two polar nuclei.

Answer: (B)

Go Back to Question 69

Q70.

Solution

Concept: During early mammalian development, the blastocyst differentiates into two distinct cellular lineages: an inner cell mass that forms the embryo proper, and an outer cell layer involved in implantation and placental development.

Solution:

Let's analyze the role and endocrine secretions of the outer cell layer labeled Ω:

(a) The outer single-cell layer highlighted by the vector arrow is the trophoblast layer. Its primary role is to anchor the blastocyst and invade the uterine endometrium during implantation.

(b) Following successful implantation, the trophoblast synthesizes and secretes the peptide hormone Human Chorionic Gonadotropin (hCG).

(c) This hormone enters the maternal bloodstream and acts on the ovaries to sustain the corpus luteum, preventing luteolysis. This ensures a steady supply of progesterone to maintain the uterine lining and support the pregnancy.

Final Answer: Trophoblast layer Ω; secretes Human Chorionic Gonadotropin (hCG) to prevent luteolysis.

Answer: (B)

Go Back to Question 70

Q71.

Solution

Concept: Human fertilization involves mechanisms to prevent polyspermy, ensuring only a single sperm fertilizes the egg. This is achieved via a fast, transient membrane depolarization followed by a slow, permanent physical block.

Solution:

Let's trace the biochemical cascade of the permanent block:

(a) Binding of the first successful sperm triggers a signaling cascade that causes a wave of calcium ion (Ca^{2+}) influx from internal stores across the oocyte cytoplasm.

(b) This elevation of intracellular calcium triggers the exocytosis of cortical granules located just beneath the plasma membrane, releasing their enzymatic contents into the perivitelline space.

(c) These released proteases cleave the glycoproteins ZP2 and modify ZP3 within the extracellular zona pellucida matrix. This structural alteration cross-links the matrix and permanently destroys the sperm-binding receptors, preventing any further sperm penetration.

Final Answer: Influx of calcium ions that triggers exocytosis of cortical granules, releasing proteases that cleave ZP2 and cross-link the zona pellucida matrix to destroy sperm receptors.

Answer: (B)

Go Back to Question 71

Q72.

Solution

Concept: Gastrulation establishes three primary embryonic germ layers (ectoderm, mesoderm, and endoderm), each giving rise to specific, highly specialized tissue lineages during organogenesis.

Solution:

Let's analyze the developmental derivations of the listed tissues:

(a) **Ectoderm:** Gives rise to the central and peripheral nervous systems (via the neural tube and neural crest), the epidermis of the skin and its appendages, and neural crest derivatives like the adrenal medulla.

(b) **Mesoderm:** Gives rise to deeper structural elements such as the dermis of the skin, bone tissue, skeletal and cardiac muscle, the cardiovascular system (vascular endothelium), and the urinary system (renal tubules).

(c) **Endoderm:** Forms the inner epithelial linings of the respiratory and digestive tracts, along with parenchymal organs like the liver and thyroid.

(d) Therefore, the central nervous system, skin epidermis, and adrenal medulla are derived exclusively from the ectoderm.

Final Answer: Central nervous system (brain and spinal cord), epidermis of skin, and the adrenal medulla.

Answer: (A)

Go Back to Question 72

Q73.

Solution

Concept: The mammalian ovarian cycle is regulated by complex neuroendocrine feedback loops along the hypothalamus-pituitary-ovarian axis.

Solution:

Let's trace the hormonal changes that trigger ovulation:

(a) During the follicular phase, developing ovarian follicles secrete increasing amounts of estradiol.

(b) When circulating estradiol levels surpass a high threshold concentration and remain elevated for a sustained period, they exert positive feedback on the anterior pituitary and hypothalamus.

(c) This positive feedback triggers a sharp, dramatic surge in Luteinizing Hormone (LH). This LH surge is the vital physiological signal that forces the primary oocyte to resume and complete its first meiotic division (arresting at metaphase II) and prompts rupture of the mature Graafian follicle to release the egg.

Final Answer: A steep surge in Luteinizing Hormone (LH) induced by high threshold levels of estradiol.

Answer: (B)

Go Back to Question 73

Q74.

Solution

Concept: Angiosperm reproduction features a unique mechanism called double fertilization, where two distinct syngamy events occur within the female embryo sac.

Solution:

Let's evaluate the structural consequences of a defective second fertilization event:

(a) A normal pollen grain delivers two haploid male gametes (sperm cells) generated by the division of the generative cell into the embryo sac.

(b) **First Fertilization:** One sperm cell fuses with the haploid egg cell to form the diploid ($2n$) zygote, which develops into the embryo.

(c) **Second Fertilization:** The second sperm cell must fuse with the binucleate central cell (containing two polar nuclei) to form the triploid ($3n$) primary endosperm nucleus, which develops into the nutrient-rich endosperm tissue.

(d) If the generative cell is defective and the second fertilization fails, the zygote may form normally, but the crucial triploid endosperm tissue will not develop. Lacking this essential nutrient source, the seed will ultimately abort.

Final Answer: The embryo will develop normally but the triploid endosperm will fail to form, leading to seed abortion due to a lack of nutrient supply.

Answer: (A)

Go Back to Question 74

Q75.

Solution

Concept: Placental structures are classified anatomically based on the specific tissue layers that separate the maternal bloodstream from the fetal capillary endothelium.

Solution:

Let's identify the structural class of the human placenta:

(a) In the human placenta, the maternal uterine tissue layers—including the maternal vascular endothelium, connective tissue, and uterine epithelium—are broken down during early trophoblast invasion.

(b) As a result, the chorionic villi containing fetal capillaries project directly into open, blood-filled spaces (maternal lacunae).

(c) Because the fetal chorionic epithelium is bathed directly in pools of maternal blood, the human placenta is classified structurally as a hemochorial type placenta.

Final Answer: Hemochorial type placenta (chorionic villi are bathed directly in maternal blood pools)

Answer: (C)

Go Back to Question 75

Q76.

Solution

Concept: Plasmid vectors like pBR322 carry selectable marker genes, such as ampicillin resistance (amp^R) and tetracycline resistance (tet^R), to identify transformed cells and screen for recombinant plasmids.

Solution:

Let's evaluate the process of insertional inactivation:

(a) The unique *BamHI* restriction enzyme recognition site lies directly within the coding sequence of the tet^R gene.

(b) When a foreign DNA fragment is successfully ligated into this *BamHI* site, it disrupts the open reading frame of the gene, rendering the resulting recombinant plasmid incapable of conferring tetracycline resistance. The amp^R gene remains intact and functional.

(c) To screen for these recombinants, transformed *E. coli* cells are replica-plated. Host cells carrying the recombinant plasmid will survive and grow on medium supplemented with ampicillin, but will fail to grow on medium containing tetracycline. This allows them to be differentiated from cells with non-recombinant vectors that resist both antibiotics.

Final Answer: Selection for cells that grow on ampicillin-supplemented medium but fail to grow on medium containing tetracycline (insertional inactivation).

Answer: (B)

Go Back to Question 76

Q77.

Solution

Concept: The Polymerase Chain Reaction (PCR) uses a repeated sequence of three temperature-dependent steps to amplify a targeted segment of DNA *in vitro*.

Solution:

Let's evaluate the three operational phases of a PCR cycle:

(a) **Phase I (Denaturation):** The reaction mix is heated to 94°C – 95°C to melt the double-stranded DNA template into separate single strands by breaking hydrogen bonds.

(b) **Phase II (Annealing):** The temperature is lowered to 50°C – 60°C. As shown in the diagram, this cooler temperature allows short forward and reverse single-stranded oligonucleotide primers to bind to their complementary sequences on the single-stranded DNA templates.

(c) **Phase III (Extension):** The temperature is raised to approximately 72°C, the optimal operating condition for a thermostable DNA polymerase (like *Taq* polymerase) to synthesize a new complementary strand from 5′ to 3′.

Final Answer: Primer annealing occurs at 50°C–60°C to allow sequence-specific binding to the single-stranded DNA templates.

Answer: (B)

Go Back to Question 77

Q78.

Solution

Concept: Transgenic Bt crops exploit the crystalline delta-endotoxins produced by the soil bacterium *Bacillus thuringiensis* to provide targeted resistance against specific insect pests.

Solution:

Let's trace the biochemical mechanism of action of the Cry1Ac endotoxin:

(a) An insect larva ingests the crystalline protoxins from the plant tissue. Once inside the insect, the highly alkaline environment of the larval midgut ($pH > 9.0$) solubilizes the crystals.

(b) Midgut proteases then cleave the inactive protoxin, converting it into a smaller, biologically active toxin fragment.

(c) This active endotoxin binds to specific cadherin-like receptors on the surface of the midgut epithelial cells. Upon binding, the toxins oligomerize and insert themselves into the membrane, creating lytic pores. This disrupts osmotic balance, causing cell lysis, midgut paralysis, and eventual death of the larva.

Final Answer: Solubilization in the highly alkaline midgut environment of the larva, proteolytic activation and binding to cadherin receptors, which creates lytic pores in the midgut epithelial cell membranes.

Answer: (B)

Go Back to Question 78

Q79.

Solution

Concept: The CRISPR-Cas9 system uses a programmable single guide RNA (sgRNA) complex combined with the Cas9 endonuclease to introduce precise double-stranded breaks into a target genome.

Solution:

Let's analyze target site selection and cleavage by the CRISPR-Cas9 platform:

(a) The target specificity of the Cas9 protein is directed by a customizable 20-nucleotide spacer sequence located at the 5′ end of the guide RNA.

(b) This spacer sequence scans genomic DNA and binds via complementary base-pairing to the matching genomic protospacer site.

(c) For successful binding and subsequent cleavage by the Cas9 nuclease domains (HNH and RuvC), the target genomic site must be located directly adjacent to a short, conserved sequence known as the Protospacer Adjacent Motif (PAM), which typically reads 5′-NGG-3′ in the case of *Streptococcus pyogenes* Cas9.

Final Answer: A 20-nucleotide spacer sequence complementary to the target DNA protospacer site, located adjacent to a 5′-NGG-3′ Protospacer Adjacent Motif (PAM).

Answer: (B)

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Q80.

Solution

Concept: Human insulin is synthesized as a preprohormone that requires complex post-translational modifications, including the removal of a signal peptide and the excision of an internal C-peptide chain, to link the functional A and B chains.

Solution:

Let's review the recombinant DNA strategy used to produce commercial Humulin:

(a) Prokaryotic hosts like *E. coli* lack the necessary eukaryotic enzymatic machinery to splice out the non-functional C-peptide from a proinsulin precursor.

(b) To bypass this limitation, scientists synthesized two separate, distinct artificial DNA nucleotide sequences: one coding for insulin chain A and another for insulin chain B.

(c) These separate genes were inserted into plasmids and expressed in independent *E. coli* cultures. The isolated chain A and chain B proteins were then purified and mixed together *in vitro*, where they were chemically joined via disulfide bonds to form functional, mature human insulin.

Final Answer: Synthesizing separate nucleotide sequences for DNA coding for insulin chain A and chain B, expressing them in independent *E. coli* cultures, purifying the proteins, and assembling them *in vitro* via disulfide bond linkage.

Answer: (B)

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Answer Key

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